UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

GERMPLASM CONSERVATION OF NATIVE SAVANNA TREES THROUGH BIOLOGICAL AND SOCIAL RESILIENCE SYSTEMS IN NORTHERN GHANA

ABDUL-AZIZ ADAM

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BY

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THESIS SUBMITTED TO THE DEPARTMENT OF ENVIRONMENT AND SUSTAINABILITY SCIENCES FACULTY OF NATURAL RESOURCES AND ENVIRONMENT, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DOCTOR OF PHILOSOPHY DEGREE IN ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY

MARCH 2026

DECLARATION

I hereby declare that this thesis is the result of my original research work, except for citations and quotations which have been duly acknowledged. I also declare that no part of it has been previously and concurrently presented for another degree in this University or elsewhere.

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ABSTRACT

Native multipurpose trees such as *Adansonia digitata*, *Parkia biglobosa*, *Lannea microcarpa*, and *Bombax costatum* are ecologically and socio-economically vital to rural livelihoods in the Guinean Savanna zone of Ghana, providing food, medicine, income, and environmental services. However, their populations are increasingly threatened due to limited propagation efforts, seed dormancy, slow growth and overharvesting, resulting in significant germplasm erosion. This study employed an integrated approach, comprising ethnobotanical surveys, seed pretreatment experiments, and vegetative propagation trials, to identify socially and biologically resilient strategies for their conservation and domestication. Data from 260 informants revealed a strong age and location-based variation in indigenous propagation knowledge, with seed propagation predominating but vegetative methods largely unused. Experimental results under open nursery conditions demonstrated that scarification significantly enhanced seed germination and seedling growth in *A. digitata*, *P. biglobosa*, and *L. microcarpa*, while hot water pretreatment was optimal for *B. costatum*. Pretreatment duration and seed provenance within the Guinean Savanna agro-ecological zone significantly influenced germination performance, with seeds from the Kassena-Nankana location consistently outperforming those from other locations. Additionally, grafting trials under uncontrolled environmental conditions indicated low overall success (6.67%), with limited compatibility observed only in *A. digitata* using top cleft grafting. These findings underscore the need for integration of local knowledge into conservation practices, species-specific pretreatment protocols and refinement of vegetative propagation methods to support community-based restoration and agroforestry programs. The study provides practical, scalable insights to enhance native tree propagation and germplasm conservation across dryland ecosystems in West Africa.

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DEDICATION

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Trees are central to rural livelihoods, providing essential goods such as fuelwood, edible fruits, medicinal resources, and income-generating products (FAO, 2022). Apart from their direct benefits, trees also regulate many ecosystem processes that contribute to people's safety and well-being (e.g., climate, water supply and quality, flood mitigation, pest and disease control, soil fertility, and protection from soil erosion (Castro-Díez *et al*., 2026). The multipurpose nature of trees is of particular interest due to their intrinsic potential to supply the diverse products and/or services that can support enhanced household resilience to both natural and socio-economic shocks (Nyamukuru *et al*., 2014). Unlike many annual crops, most native fruit trees provide nutrient-rich products that are ready for consumption with little or no processing, making them critical for food and nutrition security (Zaca *et al*., 2025). In sub-Saharan Africa, growing evidence links tree cover to improved dietary diversity and micronutrient intake, underscoring the importance of native fruit trees in food and nutrition security (Ickowitz *et al*., 2014; FAO, 2022). Collectively, these highlight the strategic role of tree-based systems in sustainable rural development under conditions of climate variability and land degradation.

Indigenous or native tree species are trees that have evolved and adapted to local ecological conditions over long periods and are typically genetically well-suited to their environments (Wilkinson *et al*., 2014). These tree species form a vital component of rural livelihoods by supplying medicine, income, food and materials such as fiber, mulch, lumber, sap, and resin (Awodoyin *et al*., 2015; Leakey, 2012). Some of the important indigenous trees in northern Ghana, include *Adansonia digitata* (baobab), *Vitellaria paradoxa* (shea), *Parkia biglobosa* (locust bean), *Bombax costatum* (bombax), *Lannea microcarpa* (African grapes), *Diospyros ebenum* (ebony), and *Sclerocarya birrea* (marula). These trees are usually preserved during land preparation and remain integral to agricultural landscapes across Sub-Saharan Africa (Bayala *et al*., 2011), playing a significant role in sustaining biodiversity (Schroth *et al*., 2004; Atangana *et al*., 2014).

Despite their ecological and socio-economic importance, most indigenous trees are still harvested from wild populations and remain largely undomesticated or semi-domesticated (Ræbild *et al*., 2011; Muok, 2019). This lag in domestication reflects structural and biological constraints rather than a lack of value. Many indigenous species exhibit long juvenile phases, resulting in delayed returns on investment compared to annual crops or fast-growing exotics, thereby weakening short-term economic incentives (Akinnifesi *et al*., 2006; Boffa, 2015). In addition, domestication efforts are further limited by weak germplasm supply systems and restricted access to quality planting materials (Gregorio *et al*., 2015), alongside technical challenges such as seed dormancy, irregular germination, and limited dissemination of reliable vegetative propagation protocols (Dadlani & Yadava, 2023).

Adansonia digitata, for instance, is regarded as one of the most important African fruit trees that needs to be domesticated because of its diminishing natural populations and growing human pressures like land-use changes, infrastructure development, and agricultural expansion (Duvall, 2007; Gebauer *et al*., 2016). Both asexual and sexual approaches, including cuttings, grafting, and in vitro procedures, have been used in reproductive efforts (N'doye *et al*., 2012; Anjarwalla *et al.,* 2016; Egbadzor & Akuaku, 2022). Similarly, *P. biglobosa* is a highly valued native species with ecological functions such as nutrient cycling and social uses, including its seeds as cooking condiments (Gbadamosi, 2005). Although propagation through seeds is common, vegetative techniques like root cuttings, air layering, and tissue culture also offer potential (Lamien *et al*., 2011). *Lannea microcarpa*, restricted to the Sudanian zone, is a multipurpose species integrated into agroforestry systems and harvested for various products including food, fuel, and medicinal substances (Neya *et al*., 2008; Sinsin & Kampmann, 2010). *B. costatum*, a widely used wild vegetable, is propagated both sexually and vegetatively (Mertz *et al*., 2001; Belem *et al.*, 2008).

Domestication of these trees will facilitate the multiplication of superior phenotypes found in wild populations and contributes to the conservation of their germplasm, which is under threat from deforestation, agricultural expansion, and urbanization (Pye-Smith, 2010). Germplasm conservation ensures the long-term availability of genetic resources through systematic collection, propagation, and storage practices (Gosal *et al*., 2010).

1.2 Problem Statement and Justification

Despite their importance, native tree populations in Ghana and across Sub-Saharan Africa face significant threats, including habitat loss from agricultural expansion, overexploitation, inadequate regeneration, and climate change (Sina, 2006; Ouédraogo *et al*., 2006; Belem *et al*., 2008; Wickens & Lowe, 2008; Helm & Witkowski, 2012; Lykke *et al*., 2025). In response to these pressures, many tree-planting programs have expanded across the region, though well-intentioned, many of these initiatives focus predominantly on fast-growing exotic species, often ignoring native trees and thereby diminishing their genetic diversity and undermining local development options (Okech, 2016; Mensah, 2022). Yet, indigenous trees are typically well adapted to local environmental conditions, culturally valued, and integral to traditional land-use systems, indicating their appropriateness for restoration and domestication efforts when supported by suitable management approaches (Wilkinson *et al*., 2014).

Although domestication efforts for native species have been undertaken in the region, particularly through farmer-managed natural regeneration and enrichment planting, these initiatives have often remained limited in scale due to biological and institutional constraints (Lovett & Haq, 2000; Bayala *et al*., 2014). Notably, their limited impact appears less related to a lack of local interest or knowledge and more to the predominance of technically driven, top-down approaches that insufficiently incorporate local management systems and livelihood priorities (Ayantunde et al., 2008; Brancalion & Holl, 2020). Given that local communities possess a deep understanding of their environments, derived from generations of interaction with them (Brook & McLachlan, 2008), integrating indigenous knowledge systems into domestication strategies can enhance community acceptance and ensure the long-term sustainability of conservation efforts (Joshi *et al*., 2001; Gouwakinnou *et al*., 2011).

Natural regeneration of native trees such as *A. digitata, P. biglobosa, L. microcarpa* and *B. costatum* remains low across much of Africa (Venter & Witkowski, 2010; Chirwa *et al*., 2006; Lykke *et al*., 2025), due to the combined effects of intrinsic biological constraints (including seed dormancy) and extrinsic anthropogenic pressures such as agricultural intensification, fire, grazing, herbicide use, and over-exploitation. Physical dormancy, caused by impermeable seed coats, limits water and oxygen absorption, thereby hindering germination and seedling emergence (Assogbadjo *et al*., 2011; Lennart *et al*., 2021). Without pretreatment, germination rates may fall below 20% (Danthu *et al*., 1995; Egbadzor, 2020). However, naturally fluctuating temperatures, fires, or biological actions such as seed passage through animal guts or micro-organism feeding, and pretreatment methods including physical or acid scarification, hot water, and combinations of these approaches can significantly enhance germination by overcoming dormancy (Baskin & Baskin, 1998; Kumar *et al*., 2015).

Furthermore, native trees generally have slow growth and late maturity when propagated from seeds, which discourages farmers from planting them. Vegetative propagation such as grafting, offers an alternative by enabling the preservation of desirable traits and reducing the juvenile period (Tchoundjeu *et al*., 2006). Grafting techniques have been effective under controlled conditions, though rural communities may lack access to such environments (Jenya *et al*., 2018; Anjarwalla *et al*., 2016). Understanding how these techniques perform under non-controlled environments typical of rural settings is crucial for scaling up domestication efforts.

To address these challenges, there is a need for empirical evidence that integrates indigenous knowledge with scientific evaluation of seed pretreatment methods and assesses the viability of vegetative propagation under local environmental conditions. Such integrated approaches are essential for developing effective and locally applicable domestication strategies for native tree species in the Guinean Savanna.

1.3 Main objective

The main objective of the study is to identify the socially and biologically resilient strategies for the propagation and domestication of four native trees, including *Adansonia digitata, Parkia biglobosa, Lannea microcarpa* and *Bombax costatum* to support their conservation and sustainable use in the Guinean Savanna Agro-ecological zone of Ghana.

1.3.1 Specific Objectives

1. To assess indigenous knowledge on the propagation of four native tree species in the Guinean Savanna agro-ecological zone of Ghana.

2. To evaluate the effect of seed pretreatment methods and seed source (location) on the germination and early growth of *Adansonia digitata* seeds within the Guinean Savanna zone.

3. To determine the effects of seed pretreatment methods and seed source (location) on the germination and early seedling growth of *Parkia biglobosa, Lannea microcarpa,* and *Bombax costatum* within the Guinean Savanna agro-ecological zone.

4. To assess the amenability of the selected native tree species to grafting under uncontrolled environmental conditions typical of rural areas.

1.4 Research Questions

1. What indigenous knowledge exists regarding the propagation of *Adansonia digitata, Parkia biglobosa, Lannea microcarpa,* and *Bombax costatum* in the Guinean Savanna zone?

2. How do different seed pretreatment methods affect germination and early growth of *Adansonia digitata* from different locations within the Guinean Savanna Agro-ecological zone?

3. What are the germination and growth responses of *Parkia biglobosa, Lannea microcarpa*, and *Bombax costatum* to various pretreatment methods?

4. To what extent are the selected native tree species amenable to grafting under uncontrolled rural environmental conditions?

1.5 Significance of the Study

1. It provides scientifically validated propagation protocols for underutilized native savanna species.
2. It bridges indigenous knowledge with experimental seed biology.
3. It supports community-based domestication efforts.
4. It contributes to germplasm conservation strategies under climate change.
5. It offers scalable, practical recommendations for agroforestry interventions in dryland ecosystems.

1.6 Structure of the Thesis

This thesis is organized into seven chapters, structured to systematically address the research objectives and questions.

Chapter One: Introduction

This chapter presents the background to the study, highlighting the ecological and socio-economic importance of native savanna tree species in northern Ghana. It outlines the problem statement, justification, research objectives, research questions, significance of the study, and provides an overview of the thesis structure.

Chapter Two: Literature Review

This chapter reviews relevant theoretical and empirical literature underpinning the study. It covers:

- Domestication of indigenous trees
- Germplasm conservation (in situ and ex situ strategies)
- Propagation methods (sexual and asexual)
- Seed dormancy and dormancy-breaking techniques
- Grafting biology and compatibility
- Biological characteristics of the four selected species:
    - *Adansonia digitata*
    - *Parkia biglobosa*
    - *Lannea microcarpa*
    - *Bombax costatum*

This chapter establishes the scientific and conceptual foundation for the study.

Chapter Three: Assessment of Indigenous Knowledge on Propagation of Native Trees

This chapter presents findings from ethnobotanical surveys conducted across selected communities in the Guinean Savanna agro-ecological zone. It examines:

- Knowledge of propagation experience and methods
- Knowledge of fruit maturations
- Perceptions of tree population trends
- Age-related variation in ecological knowledge
- Constraints to seedling survival

This chapter addresses the social resilience component of the research.

Chapter Four: Effects of Seed Pretreatment on Germination and Early Growth of *Adansonia digitata*

This experimental chapter evaluates:

- The effects of different pretreatment methods
- The influence of pretreatment duration
- Variation across seed collection locations

It provides species-specific dormancy-breaking protocols for *A. digitata*.

Chapter Five: Effects of Pretreatment on Germination and Early Growth of *Parkia biglobosa*, *Lannea microcarpa*, and *Bombax costatum*

This chapter extends the experimental framework to three additional species. It assesses:

- Comparative germination responses
- Growth performance under nursery conditions
- Influence of seed origin

It contributes to biological resilience through optimized propagation protocols.

Chapter Six: Amenability of Selected Native Trees to Grafting Under Uncontrolled Conditions

This chapter evaluates the feasibility of vegetative propagation through grafting under rural, non-controlled environmental conditions. It examines:

- Graft success rates across species
- Effect of grafting methods
- Influence of scion source

The findings inform practical domestication strategies for community application.

Chapter Seven: General Conclusions, and Recommendations

This final chapter synthesizes the key findings of the study, integrates biological and social resilience perspectives, and presents:

- Overall conclusions
- Policy implications
- Practical recommendations
- Areas for further research

It highlights how integrated propagation strategies can enhance germplasm conservation and sustainable livelihoods in the Guinean Savanna zone.

CHAPTER TWO

LITERATURE REVIEW

2.1 Domestication of indigenous trees

Indigenous trees are essential in rural sustenance and ecosystem sustainability in tropical regions, particularly in Sub-Saharan Africa. They offer crucial resources such as fruits, oils, medicines, timber, and fodder while also contributing to ecological stability through carbon sequestration, soil conservation, and biodiversity support (Leakey, 2012; Gyau *et al*., 2012). Nevertheless, these species often remain undomesticated and are harvested directly from wild populations, making them exposed to overexploitation and habitat loss (Jamnadass *et al*., 2011; Muok, 2019).

The domestication of indigenous trees refers to the process of bringing native tree species under human cultivation and selective breeding, with the aim of enhancing desirable traits for human use while maintaining the species' viability (Leakey & Simons, 1998). Tree domestication has gained importance as a strategy for both rural development and conservation in tropical regions, including the savanna ecosystems of Africa (Akinnifesi *et al*., 2008; Dawson *et al*., 2014). Among the native species of significant ecological, socio-economic, and cultural importance are *A. digitata*, *P. biglobosa*, *L. microcarpa*, and *B. costatum*. These multipurpose species, traditionally harvested from wild populations, are increasingly recognized for their potential in agroforestry systems and community-led domestication initiatives (Lovett & Haq, 2000). Despite their value, wild populations are under threat due to deforestation, overexploitation, and land-use change, necessitating urgent domestication efforts to ensure both their survival and their continued contribution to sustainable development in savanna landscapes (Assogbadjo *et al.,* 2006).

Domesticating these species, will secure sustainable livelihoods, simultaneously conserve the genetic resources ("germplasm") and improve yields and quality of tree products, of these trees in the face of environmental change (Jamnadass *et al*., 2011; Dawson *et al*., 2014). The domestication of these trees holds transformative potential for rural economies, because they all provide high-value non-timber forest products (NTFPs) that are integral to food security, nutrition, and income generation in the Guinean Savanna. *Adansonia digitata* leaves and fruit pulp are rich in micronutrients, particularly vitamin C, calcium, and iron, making them critical components of household diets and nutrition interventions (Gebauer *et al*., 2002). *Parkia biglobosa* seeds are processed into "dawadawa," a widely consumed fermented condiment with high protein content and substantial market demand across West Africa (Codjia *et al*., 2001). Likewise, *L. microcarpa* produces edible fruits that are consumed fresh or processed into juice and preserves, while its bark and roots are used in traditional medicine (Yunus *et al*., 2013). *Bombax costatum*, though less commercialized, yields medicinal bark and edible calyces that support seasonal food availability (Lykke *et al*., 2002). Their domestication will therefore contribute to livelihood resilience by reducing dependence on volatile rain-fed crops and integrating perennials into farming systems (Lovett & Haq, 2000).

Additionally, these species have co-evolved with traditional agroforestry practices in northern Ghana, where they are often protected and managed on farms and fallows. This indicates a long-standing interaction between local communities and their woody landscapes (Nair *et al*., 2012). As such, their domestication not only aligns with ecological conservation goals but also builds upon existing indigenous knowledge systems and land management traditions. They further play a key role in the functioning of ecosystems through their deep taproot system and extensive canopy, which contribute to microclimate regulation, soil moisture retention, carbon sequestration, soil fertility improvement, nutrient cycling and erosion control (Boffa, 1999), thereby enhancing land productivity and ecosystem resilience.

The genetic erosion of these key species poses a serious threat to their long-term utility and adaptability, thus their domestication on farms offers a pathway to maintain and utilize their genetic diversity while addressing pressures on wild populations.

2.2 Germplasm conservation

Germplasm is the genetic material that determines the phenotypic expression (inheritance) of characters in plant or animal bodies and can be transferred from one generation to another via sexual and asexual ways (Offord, 2017). For trees, germplasm consists of seeds, seedlings, wildlings, and clonal planting stock (cuttings, grafts, marcots) used in plant breeding and as the basis for conservation and research (Akinnifesi *et al*., 2008; Kuyah *et al*., 2023). The germplasm conservation of trees includes the systematic gathering, management, and in some cases, the long-term storage of genetic resources from different taxa with the objective that these remain available for us and future generations (Gosal *et al*., 2010). This is essential for continued ecological restoration, and rural livelihoods derived from these indigenous trees such as *A. digitata, P. biglobosa, L. microcarpa,* and *B. costatum,* which are being further threatened by human activities and climatic change.

Conservation of germplasm, therefore, must be based on the twin goals of conservation of genetic diversity and sustainable use.

Plant improvement and enhancement programs essential for increasing agricultural productivity frequently contribute to accelerating the loss of genetic diversity by favoring a limited number of high-yielding genotypes. These selection pressures narrow the genetic base of the cultivated species, making them potentially susceptible to pests, diseases, and environmental changes (Priyanka *et al.*, 2021). This phenomenon is called genetic erosion, the progressive decrease of individual genes, or gene combinations unique to locally adapted landraces and ecotypes (Guarino, 2003).

The key drivers of genetic erosion are the overutilization of a species; the replacement of local variants with exotics; changing agricultural landscapes and a reduction of fallows; environmental degradation; climate change; overgrazing; altered policy; and pests and diseases that make plant resources more vulnerable to extinction (Brodie *et al*., 2014).

2.3 Methods of Germplasm Conservation

Two major methods are used for conserving germplasm: the in situ and ex situ methods. Although these methods do not conflict, they work best when used in tandem as parts of a comprehensive conservation plan (Brütting *et al*., 2012).

2.3.1 In situ conservation

In situ conservation refers to the preservation of genetic resources in their natural surroundings, enabling them to continue their ecological functions and evolutionary processes (FAO *et al.,* 2001). This approach focuses on the restoration and maintenance of healthy populations of species in the ecosystems in which they have evolved. Principal strategies of application are the establishment of set-aside areas like national/game parks and forestry reserves and gene sanctuaries, in which human influence has been minimized or is specifically managed (FAO, 2014b).

The in situ conservation of tree genetic resources consists of a variety of activities, including those aimed at identifying priority species and habitats for protection, the development and implementation of species-specific management plans, the restoration and reinforcement of degraded populations, as well as long-term ecological monitoring and public awareness (Dawson *et al.*, 2013). More importantly, it effectively shifts along environmental gradients, and thus, it is evolutionarily robust when compared to static conservation strategies because it adapts to the changing environment (Rajora & Mosseler, 2001).

In situ conservation is especially beneficial for preserving the ecological, social, and aesthetic values of tree species because it allows for the simultaneous conservation of multiple taxa within landscape mosaics (FAO, 2014b). Although it involves costs associated with habitat management and population monitoring, in some instances, it can be more economical in the long run relative to ex situ storage (Ledig *et al*., 1998).

Despite the benefits of in situ conservation, there are significant barriers to its effectiveness, including high deforestation rates in some regions, climate change from which the effects can be uncertain, insufficient knowledge of the importance of genetic diversity and genetic processes, and the poor enforcement of laws and regulations for forest genetic resource conservation (FAO, 2014b). Therefore, supplementary conservation strategies (e.g., ex situ methods) may have to be applied.

2.3.2 Ex situ conservation

Alternatively, ex situ conservation is the conservation of the genetic resources of species outside their habitats, or in galleries, gardens, or on farms. It is a useful complement to in situ approaches, particularly for rare, endangered, or nearly extinct species threatened in the wild (Given, 1994; Dawson *et al*., 2013). Ex situ approaches include seed banks, pollen and tissue storage facilities, clonal orchards, field gene banks, arboreta, and botanical gardens (Maunder *et al*., 2004; Cavender *et al*., 2015).

Seed banking is one of the most efficient and widely used ex situ techniques (and their cost-effectiveness), particularly for species with orthodox seeds (Li & Pritchard, 2009; Oldfield & Newton, 2012) that can be desiccated and stored cold for long periods. After efficient drying and at low storage temperature, vast amounts of genetic material may be effectively stored at a lower cost and higher genetic diversity/unit sample.

For species with recalcitrant seeds or even non-seed setting trees (as is the case with many native trees in savannas), ex situ conservation can be more complicated. In these cases, other techniques such as vegetative propagation, cryopreservation, and the use of field gene banks are needed (Fant *et al*., 2016). Furthermore, ex situ collections are important for propagation activities and for educational outreach, serving both conservation and utilitarian purposes.

However, ex situ approaches also suffer some significant drawbacks, such as the inability to indefinitely maintain natural selection as well as adaptive evolution outside the range of the species, typically leading to the loss of genetic variation across the time scale (Yanchuk & Lester, 1996). Moreover, global ex situ collections suffer from a lack of unified approach, lack of funding, and lack of long-term vision (Cavender *et al*., 2015).

Unlike in situ strategies aimed at preserving wild species as they exist in their natural habitat, ex situ strategies are more broadly applied to both domesticated species and species housed in managed settings (Dar *et al*., 2015). Both are critically important and interact in the wider conservation of tree genetic resources. In a broader context, when included as part of a broader framework, they help to improve the resilience of forest landscapes that are largely based on adaptation, maintain some level of evolutionary potential, and support ecosystem resilience.

2.4 Propagation

The ability of plants to regenerate, reproduce and colonize a new habitat is essential for their survival and adaptability in both natural and managed environments (Fenner & Thompson, 2005). The process by which plants are produced (developed), ensuring the continuity of their genetic material across generations, is referred to as plant propagation. Propagation involves both natural and artificial methods used to increase the numbers of plants and disperse them (Hartmann *et al*., 2011). It is a key factor in agriculture, horticulture, forestry, and biodiversity conservation (Awotedu *et al*., 2021). In general, there are two types of plant propagation: sexual propagation and asexual (or vegetative) propagation. There are diverse advantages, limitations, and applications for each method, depending on the species and the objective of the propagation (Hartmann *et al*., 2011).

2.4.1 Sexual propagation

For most plant species, sexual propagation is the primary mode of reproduction, and the mechanism is essential for genetic diversity and adaptive evolution (Toogood, 1999). This technique allows for plants to be reproduced by seeds, which are produced by the fusion of male and female gametes (Awotedu *et al*., 2021). The genetic material from the male and female parents combines in the seed or spore, which then produces a new plant from the seed embryo that may look very much like the parents but is genetically different from either (Toogood, 1999). This genetic diversity is essential for evolution and adaptation in the presence of environmental stresses such as climate variation, pests, or diseases (Fenner, 2004).

Sexual propagation is often used in crop production, forestry, and conservation because it is simple, inexpensive, and enables the production of numerous propagules. It is especially suitable for new cultivars and hybrids development, and preserving genetic diversity in the gene banks and field gene banks (Awotedu *et al*., 2021).

Seeds are typically composed of three main parts: an embryo, which is the precursor to the new plant; an endosperm, which acts as a repository of nutrients necessary for the germination and establishment of the new seedling; and the seed coat, which acts as a protective barrier against physical damage, desiccation, and other biological challenges such as bacterial or insect attack (Beltrati & Paoli, 2003).

In addition, sexual propagation might be useful in breaking disease cycles that frequently occur during vegetative propagation and is the preferred method in some plant health management scenarios (Hartmann *et al*., 2011). Nevertheless, it may be restricted by challenges such as seed dormancy, low viability, or recalcitrance in some species; in particular, in numerous tropical trees (Berjak & Pammenter, 2008; Fenner & Thompson, 2005).

2.4.1.1 Seed Dormancy

Seed dormancy is the innate, natural inhibition (either physical or physiological) to germination of a viable seed under specific conditions that are normally favorable to germination, such as the presence of water, light, oxygen, and favorable temperatures for germination (Baskin & Baskin, 2004). Such a dormancy strategy has arisen across species through adaptation to different situations, indicative of evolutionary responses to ecological limitations (Bhatla & Lal, 2023).

Dormancy is not simply the absence of germination, but a set of traits which have evolved to ensure the timing of germination is under the control of favorable ecological conditions (Fenner & Thompson, 2005). Differentiation can be based on various types of dormancy regulation, of which the two main types are: (a) physical dormancy (or seed coat-imposed dormancy) and (b) embryonic, internal (endogenous) dormancy. In contrast, seeds can have both types of dormancies simultaneously (Ceccato *et al*., 2015).

There are at least a few mechanisms for physical dormancy, which is frequently imposed by the seed coat. These can include preventing water uptake by the seed coat due to impermeable layers, such as waxy cuticles, suberized layers, or lignified sclereids; gas exchange restriction due to impermeable seed coats through inhibition of oxygen availability to the embryo; mechanical restriction to radicle protrusion; retention or production of germination-inhibiting compounds; and the seed coat filtering out of specific light wavelengths necessary for germination (Debeaujon *et al*., 2007; Bhatla & Lal, 2023).

Besides the structural system of classification, seed dormancy is divided temporally into primary and secondary dormancies. Primary dormancy is commonly induced in the mother plant during seed development and persists with seeds remaining attached to the plant. One of the effects of maturation drying is to increase the content of abscisic acid (ABA) in seeds such that imbibition of newly harvested seeds does not result in germination (Bhatla & Lal, 2023). This type of dormancy can be broken by a treatment with some environmental signals (either by cold or warm stratification, light, exogenous application of gibberellins, or other chemical treatments). On the other hand, secondary dormancy is imposed post-dispersal as a result of adverse environmental conditions. Such a form of physiological dormancy is reversible and permits the seeds to postpone germination until the suitable environmental conditions, usually in response to seasonal environmental changes (Bhatla & Lal, 2023).

2.4.1.2 Techniques for Breaking Seed Dormancy

Seed dormancy can be broken in nature by several ecological and physiological means including: a) degradation or loosening of a hard seed coat by soil-borne microorganisms, b) digestion effect of fruit-eating birds, c) mechanical wear of soil grains, d) percolation of inhibitory substances due to rainfall or irrigation, and e) mutation or physiological change within the embryo. Furthermore, dormancy can be counteracted by the production of germination-enhancing hormones or by the inactivation of growth inhibitors during severe temperatures (Bhatla & Lal, 2023).

2.4.1.3 Seed Scarification

Physical dormancy, which is a hard, impermeable seed coat, may be removed by scarification (either by some aspect of the environment or intentionally by man). Scarification also occurs as a result of microbial degradation, fire, prolonged rain, or passage through the digestive system of animals. Mechanical or manual scarification can be achieved by rubbing seeds with sandpaper, manually removing a portion of the seed coat, or chemical scarification using concentrated acids (Bhatla & Lal, 2023).

Scarification facilitates water and oxygen absorption of seeds as it makes a break into the seed coat to initiate germination (Awetodu *et al*., 2021). The success of the method relies on the nature of the seed coat (thickness and hardness) of the target species. Special care has to be taken to not cause injury to the internal structures like the endosperm, cotyledons, or embryo by scarification.

Many plants have phenolics (trans-cinnamic acid, coumaric acid, and coumarin) in the seed coat to avoid predation. Most of these phenolics are water soluble and soaking of the seed in water can facilitate release from dormancy (Bhatla & Lal, 2023). When the seed is soaked in cold water before sowing, the seed swells, bursting the coat and leaching out the substances that delay germination. Seeds soaking in water below 40 °C enhance germination when the water permeates the seeds. This dormancy-breaking technique is mainly carried out with tropical species (Kaul & Manohar, 1996).

Soaking seeds in 100 °C boiling water can help remove the hard coat of the seed, leaving a softer covering that sprouts more easily by removing the cuticle and part of the palisade layer of the seed coat (Awetodu *et al*., 2021). The heat causes a split to form in the seed coat. To avoid damaging seeds, this treatment needs to be monitored closely. This must be checked often to prevent seeds from being scorched.

2.4.1.4 Seed stratification

Stratification is a pre-germination treatment that mimics the environmental conditions seeds naturally experience in their native habitat. It involves subjecting seeds to controlled temperature regimes over a specified period to break physiological dormancy. Many species, especially those from temperate climates, require seasonal temperature fluctuations to trigger germination (Bhatla & Lal, 2023).

The degree of seed dormancy can be inferred from the temperature range required for germination. Seeds with narrow germination temperature ranges often exhibit deeper dormancy (Bhatla & Lal, 2023). Exposure to alternating warm and cold cycles, similar to summer and winter, can be critical in overcoming dormancy in such seeds.

2.4.1.5 Germination

Germination is the emergence of the embryonic root (radicle) from the seed coat. This process is controlled by a sequence of catalytic anabolic events in the seed, initiated by seed hydration (Awetodu *et al*., 2021; Bhatla & Lal, 2023). Successful germination requires a specific set of environmental conditions, including adequate water for tissue hydration, sufficient oxygen for aerobic respiration, appropriate temperature ranges, and, in some species, the presence or absence of light (Bhatla & Lal, 2023).

Seed germination is regulated by both intrinsic and extrinsic factors. Among these are seed size, which has been reported to influence time to germination, germination percentage, and seedling performance in natural habitats (Murali, 1997; He *et al*., 2007, Silveira *et al.,* 2012). Additionally, the mechanical strength of the seed coat and the duration of seed storage play significant roles in the germination rate of different species (Awetodu *et al*., 2021).

Seed storage behavior is also critical in understanding germination performance. According to the susceptibility to desiccation and storage conditions, the seeds have been generally classified into three categories: recalcitrant, intermediate, and orthodox.

Recalcitrant seeds, having high water content, are extremely sensitive to desiccation and low temperatures. They typically do not store well and must be freshly sown to obtain good germination. Intermediate seeds have only moderate tolerance to desiccation and can be maintained for shorter periods under controlled conditions. Orthodox seeds, on the other hand, have low moisture content and can tolerate desiccation, making them suitable for long-term storage without significant loss in germination potential (Berjak & Pammenter, 2004; McDonald, 2004).

2.4.2 Asexual Propagation

Asexual propagation, also known as vegetative propagation, is the reproduction of plants using vegetative parts such as stems, roots, leaves, or shoots rather than seeds (Awetodu *et al*., 2021). This method uses several techniques such as budding, grafting, cuttings, suckering, and layering (Gubbuk *et al*., 2011).

Vegetative propagation offers numerous advantages in tree domestication and genetic conservation, particularly in the context of indigenous and underutilized tree species. Compared to sexual (seed-based) propagation, vegetative methods often result in an earlier onset of fruiting, which significantly reduces the juvenile phase of many perennial species (Agbohessou *et al*., 2020). One of the key advantages of vegetative propagation is its ability to facilitate the clonal transfer of desirable genetic traits from the parent tree to its progeny, thereby ensuring the preservation and continuity of elite genotypes, particularly those preferred by local communities and end-users (Tchoundjeu *et al*., 2006). Additionally, vegetative propagation enables consistent production independent of fruiting seasons, providing better control over planting schedules (Assogbadjo *et al*., 2009).

In domestication and conservation of wild tree species, vegetative propagation is a fundamental method to make use of the existing large genetic variation among and within natural populations. Grafting, budding, and air-layering techniques are particularly suitable for propagating mature tissues that are able to flower and fruit, and hence for expediting breeding and conservation programmes on-station and on-farm (Leakey *et al*., 2005; Tchoundjeu *et al*., 2006).

2.4.2.1 Grafting

Grafting is a horticultural technique that involves the union of two living plant parts, typically a shoot (scion) from one plant and the stem or root system (rootstock) of another, such that they grow together and function as a single plant (Chander *et al*., 2016; Feng *et al*., 2024). The most important thing in grafting is to match up the cambium layers with the pith of the scion and pith of the rootstock so that the two grow together and form a successful vascular connection. After union, growth from the rootstock is inhibited and the scion becomes the aerial portion of the plant (Lewis & Alexander, 2008).

Grafting is the most widely used asexual propagation method for many horticultural and fruit trees. It allows for the retention of all desirable traits of the scion variety, such as high yield and fruit quality, attractive form, foliage, and increased resistance to pests and diseases (Lewis & Alexander, 2008; Bhandari, 2021). The process is also advantageous for species with long juvenile phases, as grafting can significantly reduce the time to fruiting (precocity) and enable the multiplication of selected elite genotypes (Akinnifesi *et al*., 2006).

In the multiplication of indigenous fruit trees, grafting has been found to be instrumental in overcoming problems of delayed maturation and promoted a widespread of trees with desirable attributes. Grafting success and the ease of grafting depend on three concepts of plant age: (1) chronological age, which is the time since planting; (2) physiological age, based on the maturity of the tissues in terms of cell differentiation and lignification; and (3) ontogenetic age, which is the plant's reproductive maturity (Akinnifesi *et al*., 2006).

Even if scion performance, including vigor, drought tolerance, or disease resistance, can be affected by the rootstock, there is no cellular or genetic fusion between the two parts. Each retains its distinct genetic identity, and tissue characteristics above and below the graft union remain true to either the scion or the rootstock (Toogood, 1999). Cross-species graft compatibility is generally limited to those among or very near genetically related species. Rootstocks of the same species as the scion are mostly preferable to guarantee successful graft union and better-growing performance (Lewis & Alexander, 2008).

The success of grafting depends on several essential factors. These include the physiological condition of the rootstock, the quality of the scion material, the selection of an appropriate grafting technique (e.g., cleft, whip-and-tongue, or budding) and the time of grafting and aftercare. The role of post-graft management is particularly important, as vigorous shoot growth from the rootstock must be consistently suppressed to prevent it from outcompeting the scion. The optimal formation of a callus and the best vascular contact generally occur at temperatures ranging from 15°C to 30°C. However, temperatures outside this range, particularly those below 10°C or above 30°C, can inhibit graft success or delay development. Also, a balanced water and nutrient supply are essential for maintaining healthy vegetative growth during the establishment phase (Lewis & Alexander, 2008).

2.4.2.2 Scion

The scion is a shoot section including one or more dormant buds, which is grafted to a rootstock to form the upper parts of a new plant (Hartmann *et al*., 2002). It represents the aerial component of the plant and determines the morphological and productive properties of the grafted individual. Scion wood may be collected from either dormant or actively growing (green) shoots, although dormant scions are most commonly used due to their stability and ease of handling during grafting procedures (Lewis & Alexander, 2008).

Scion selection is a critical factor influencing graft success and long-term plant performance. Desirable scions are chosen for their fruit yield, quality, disease resistance, and growth habit (Rasool *et al*., 2020). Scions should be healthy, vigorous, and well-exposed to sunlight, preferably collected from the most recent flush of mature growth. The recommended scion wood length is 50 to 100 mm with at least one viable bud. Scion wood should be the same in thickness as the rootstock to attain uniform cambia alignment during grafting (Lewis & Alexander, 2008).

For optimal results, scion wood should be collected and used on the same day. If not used immediately, scions can be kept in sealed plastic bags in an ordinary refrigerator for a few weeks (Lewis & Alexander, 2008).

2.4.2.3 Rootstock

The rootstock constitutes the lower portion of a grafted plant, including the root system and, in some cases, a short section of the lower trunk. It forms the base onto which the scion is grafted and is an important determinant of food and water uptake, general plant health, and response to environmental stresses (Hartmann *et al*., 2002; Lewis & Alexander, 2008). Rootstocks can be seedlings, rooted cuttings, micro propagated plants, or even mature trees depending on the species and on the propagation objectives. The selection of rootstock can significantly affect scion performance especially in terms of growth vigor, water relations, stress tolerance, and disease resistance (Rasool *et al*., 2020). A good rootstock should exhibit ease of propagation, robust root development, high resistance to pests and diseases, and compatibility with the scion, as well as good adaptation to local soil and climate (Gupta *et al*., 2022).

For a successful graft, rootstocks must attain a minimum stem diameter of approximately 5 mm (pencil thickness) at the intended grafting point, which is typically located 10–15 cm above the root system. During all grafting procedures, the rootstock should be prepared before the scion to avoid prolonged delays between cutting and union in order to maximize viability and callusing of the graft (Lewis & Alexander, 2008).

2.4.2.4 Grafting techniques

Grafting is a general propagation technique with a diversity of grafting methods adopted for various plant species, tissue development, and propagation purposes. The choice of grafting method depends on the compatibility between scion and rootstock, the age of the mother plant, and environmental conditions (LeBude & Blazich, 2022). Grafting can be classified based on the genetic relationship between the grafted components: autografting refers to grafts within the same plant; homografting involves two individuals of the same species; and heterografting refers to grafting between different species. Heterografting often results in incompatibility, where either the scion, the rootstock, or both may eventually die (Awotedu *et al*., 2021).

Several widely used grafting techniques include cleft, side veneer, whip and tongue, bridge, bark, and splice grafting (Rasool *et al*., 2020). Each technique has specific applications depending on the plant type, compatibility of tissue and desired outcome.

2.4.2.5 Cleft Grafting

Cleft grafting, also known as wedge grafting, is one of the oldest and widely used techniques in horticulture, especially for top-working fruit trees. It is particularly beneficial when the rootstock is significantly larger in diameter than the scion. In this method, the base of the scion is shaped into a wedge, and a vertical cleft is made in the horizontally sliced top of the rootstock. The scion is then inserted into the cleft in such a way that the cambial layers of both scion and rootstock align as closely as possible to promote a successful union (Wang, 2011; Rasool *et al*., 2020). This method is valued for its simplicity and effectiveness in woody perennial species.

2.4.2.6 Side Veneer Grafting

Side veneer grafting is a precise technique often employed in the propagation of ornamental and coniferous species. It involves making two angled cuts, one small and one large, on the scion, and creating a matching flap-like cut on the side of the rootstock. The larger cut on the scion is brought into contact with the exposed sapwood of the rootstock, leaving the smaller cut facing the bark. Proper cambial contact is essential for vascular integration and graft success. This method is commonly used for grafting potted or container-grown rootstocks, and it is particularly advantageous in controlled nursery conditions (Agbohessou *et al*., 2018).

2.4.2.7 Whip and Tongue Grafting

The whip and tongue grafting is a precision technique commonly employed when the scion and the stock are nearly equal in diameter (approximately a pencil in size to 10–15 mm). The procedure begins with a long, sloping cut on each component, followed by a secondary vertical incision (tongue) on both the scion and the rootstock. These tongues interlock, enhancing the physical stability of the graft and ensuring close cambial contact, which is critical for vascular continuity and graft success (MasterClass, 2021). This method is particularly advantageous for species that graft readily and is applicable for root, stem, or top grafting.

2.4.2.8 Bridge grafting

Bridge grafting is a restorative grafting technique used to repair damage to the lower stem or root collar of woody perennials, often caused by mechanical injury, girdling by rodents, or disease. The procedure involves the removal of damaged or necrotic tissues, followed by the insertion of scions that are long enough to span the injured area. Small vertical incisions, or bark flaps, are made above and below the damaged section of the trunk, and the ends of the scions are inserted beneath these flaps to re-establish vascular continuity. The primary function of this method is to bridge the gap in the cambium and re-enable the translocation of water and nutrients from the roots to the canopy (MasterClass, 2021). Bridge grafting is particularly useful in high-value or heritage trees where replacement is not desirable.

2.4.2.9 Splice grafting

Splice grafting is a basic means of grafting that is generally successful with small, herbaceous, or softwood material, and when the scion is about the same diameter as the rootstock. In this technique, similar angled cuts are made on the scion and rootstock (approximately 30-45 degrees). The two parts are then joined so that their cut surfaces match perfectly, allowing direct cambial contact. Because no interlocking tongue is created, as in whip-and-tongue grafting, splice grafts typically require external support such as grafting tape to maintain alignment and ensure callus formation during the healing process. It is commonly used in greenhouse conditions or in environments with controlled humidity and temperature (MasterClass, 2021).

2.4.2.10 Graft success

The most important requirement for successful grafting is the exact fusion of the vascular cambial layers and the attached tissues in the rootstock and scion. Proper cambial alignment ensures that the wound-healing process can effectively join the two partners: once the cut surfaces are juxtaposed, a series of events ensues, including the formation of a callus bridge and the regeneration of a new vascular cambium at the graft interface, ultimately leading to continuous xylem and phloem connections between the stock and scion (Mudge *et al*., 2009; Hartmann *et al*., 2011).

In addition to precise physical alignment, successful grafting requires that the scion and rootstock be physiologically and genetically compatible. Grafting is usually successful among closely related taxa, such as those belonging to the same species or genus, whereas grafts between distantly related species or genera often display signs of incompatibility (Mudge *et al*., 2009; Rasool *et al*., 2020). Indeed, genetic relatedness is considered a key determinant of long-term graft survival, as incompatible combinations can elicit adverse physiological responses at the graft interface (Goldschmidt, 2014; Rasool *et al*., 2020). Graft incompatibility may manifest immediately or emerge later, despite an initially successful union, a phenomenon commonly referred to as delayed incompatibility. This may be due to the complex biochemical and physiological differences of the graft partners, and it is frequently associated with signs of tissue necrosis, impaired vascular continuity, or abnormal swelling at the graft junction (Hartmann *et al*., 2011; Rasool *et al*., 2020).

Besides compatibility between stock and scion, grafting strongly depends on the physiological status of the grafting material and the conditions during the operation and the healing period. Optimal grafting outcomes require that both the scion and rootstock be in a healthy, disease-free state and at an appropriate physiological stage of development. Environmental conditions, particularly temperature, play a crucial role in graft union formation. Moderate temperatures, typically in the range of 25–28 °C, are known to promote active callus formation and vascular differentiation, which are essential for graft success in woody perennials. In contrast, excessively low temperatures slow metabolic processes, while high temperatures may induce stress responses or result in weak callus development, both of which can compromise graft integrity (Hartmann *et al*., 2011).

2.5 Native trees

Native trees, or indigenous trees, have long occupied an area naturally before the influence of humans or before anthropogenic changes. These species are ecologically adapted, genetically suited, and evolutionarily aligned with their environments (Wilkinson *et al*., 2014). Native trees are the keystone of ecosystem stability and productivity, providing vital ecological functions, including nutrient recycling, water filtration, carbon capture, wildlife support, and maintaining biodiversity.

Native tree species in the Guinean Savanna of northern Ghana play a vital ecological, cultural, and socio-economic role. Among the notable ones are *Adansonia digitata* (baobab), *Parkia biglobosa* (locust bean), *Lannea microcarpa*, and *Bombax costatum* (bombax). Yet these species contribute to food security, provide the means for livelihoods in rural areas, and constitute potential anchorage points for sustainable land use, agroforestry, and genetic resource conservation. Therefore, their preservation and cultivation are essential for the maintenance of biodiversity and the socio-ecological resilience of the communities.

2.5.1 *Adansonia digitata*

The baobab, *Adansonia digitata*, is a massive, stem-succulent tree that is native to the arid and semi-arid regions of tropical Africa. The species has been spread by human activity and is now found in parts of Madagascar and Australia (N'doye *et al*., 2012). The Baobab is a tree with a very large trunk and wide-spreading branches; it can grow to 25m high and live for several hundred years (Gebauer *et al*., 2002). It is usually a low-altitude species, inhabiting areas where the number of dry months is 4–10 out of twelve months, and it is observed primarily as isolated individuals, with small aggregations depending on soil type (Salim *et al*., 2012).

The baobab is characterized by a thick, fluted trunk with girths exceeding 10 to 14 meters. The form of the trunk changes with age, from being conical in young individuals to being cylindrical, tapering or bottle-shaped in older trees (Gebauer *et al*., 2002). It is intolerant to waterlogging, frost, and does not grow well on deep sands but prefers free-draining soils in arid areas (Salim *et al*., 2012).

The genus Adansonia was named in honour of Michel Adanson, who studied the species during his research in Senegal in the 18th century and introduced its seeds to Paris (Esterhuyse *et al*., 2001; Kamatou *et al.,* 2011). The vernacular name "baobab" is believed to have been derived from the Arabic term "buhibab," meaning "fruit with many seeds" (Diop *et al*., 2005; Kamatou *et al*., 2011). Baobabs are drought-resistant and yield nutritious fruit and leaves. The naturally acidic and dry fruit pulp has prebiotic and antioxidant qualities and is high in vitamin C, calcium, potassium, and dietary fiber (Gebauer *et al*., 2002; Simbo *et al*., 2013; Stadlmayr *et al*., 2013; Kabore *et al*., 2011).

Apart from their nutritional value, the baobab tree has been valued for multiple non-food uses such as medicine, fibre, tannins, fodder, and oil (Sidibé & Williams, 2002; Gebauer *et al*., 2016). Since 2008, baobab fruit pulp has been accepted as a novel food in the EU and US and is commercially available in these markets as a 'superfood' (European Commission, 2008; FDA, 2009). The pulp is locally utilized in the production of sweets, snacks, and beverages (Gebauer *et al*., 2014).

The leaves, whether fresh or dried, represent an important source of protein and are highly consumed as vegetables in West Africa (Sidibé & Williams, 2002). They are also high in minerals and vitamins A and C (Chadare *et al*., 2008, Chadare *et al*., 2014). It also has nutritious seeds rich in vitamins A, D, and E, which can be extracted to produce edible oil used in cosmetics and massage (Besco *et al.,* 2007). The bark is used for ropes, baskets, and craftwork (Gebauer *et al*., 2016). Medicinally, various parts of the tree are used for the treatment of inflammation, fever, diarrhoea, dysentery, and other diseases (Kabore *et al*., 2011).

Baobab trees start flowering at 8-23 years of their life (Diop *et al*., 2005). The flowers are single or paired in the leaf axils, big, pendant and perfect (hermaphroditic). Flowering is not seasonally fixed and can occur at any point in the year other than during the peak of the dry season. Primary pollinators are bats (e.g., *Eidolon helvum*, *Epomophorus gambiensis, Rousettus aegyptiacus*); nocturnal insects and wind can play an additional role (Assogbadjo *et al*., 2005).

2.5.1.1 Domestication of *Adansonia digitata*

Adansonia digitata is one of the most significant indigenous fruit trees selected for domestication in Africa (Gebauer *et al*., 2016). Nevertheless, its use is mostly supplied from the wild, which is increasingly under pressure from overharvesting, habitat conversion, and agricultural intensification (Duvall, 2007). Domestication is a must for the sustenance of this resource for the future and can play a role in poverty reduction, food security, and biodiversity conservation (Egbadzor & Akuaku, 2022).

Propagation of baobab can be achieved through both sexual (seed-based) and asexual (vegetative) methods (Ourèye *et al*., 2012). Vegetative methods include grafting, cuttings, and in vitro propagation (Agbohessou *et al*., 2020). Achievements include in vitro cloning (N'doye *et al*., 2012), testing of grafting techniques (Anjarwalla *et al.*, 2016), or reports of fruiting within only two years with grafted stock (Egbadzor & Akuaku, 2022).

Vegetative propagation is of great advantage as it imparts true-to-type plants and maintains characters, e.g., high vitamin C fruit (Sidibé *et al.*, 1996). Nonetheless, success rates vary. For instance, cutting propagation has low success, typically not exceeding 30% even with hormonal stimulation, and falling as low as 2% without indole-3- butyric acid IBA (Assogbadjo *et al*., 2009). Grafting, particularly top and side grafting, has shown promise with success rates up to 85% (Kalinganire *et al*., 2007). Young rootstocks (3 months to 2 years) grafted with mature scions yield better results, and scions can be stored in moist, ambient conditions for up to two weeks, though younger scions exhibit higher success (Cuni Sanchez *et al*., 2011). Grafted baobabs can fruit in as short as 3 years after planting, whereas regular seedling trees may take 8–23 years till fruiting (Sidibé *et al*., 1996; Sidibé & Williams, 2002).

2.5.2 *Parkia biglobosa*

Parkia biglobosa is a perennial, deciduous leguminous tree in the family Fabaceae and subfamily Mimosoideae. Its height usually does not exceed 20 meters and forms a wide spreading crown. This species is well adapted to different ecological factors, such as regions with an average annual rainfall of between 600-1500 mm and a dry season that spans between five to seven months (Abbas *et al*., 2018). Commonly referred to as "néré" in Francophone West Africa and "locust bean tree" in Anglophone regions, it is highly valued for its ecological resilience and multipurpose value (Hopkins, 1983).

Parkia biglobosa trees have a long life cycle, taking 30–50 years to reach full height, and and surviving for more than a century. The species is nitrogen-fixing and exhibits tolerance to drought and fire, making it particularly suited to the savanna environment (Sina & Traoré, 2002). They normally flower at the end of the dry season (December – April), although this may vary with latitude and local environmental moisture factors (Janick & Paull, 2008). Flowering coincides with leaf senescence, and new leaves develop following the peak of flowering. The flowering period typically lasts 3 to 8 weeks. Fruiting is from the late dry to early rainy season (April/May), but sometimes shows bimodal flowering and fruiting behavior (Sina & Traoré 2002).

Ecologically, *P. biglobosa* also plays a vital role in nutrient cycling and land stabilization (Gbadamosi, 2005; Udobi et al., 2010). It offers important ecosystem services and products such as traditional medicines, forage, fuel, charcoal, and glaze for ceramics (Olorunmaiye *et al*., 2011). It also plays a crucial role in food security, especially through its seeds, which are widely used as seasoning (Oluwafemi *et al*., 2014). The fruit pulps are high in sucrose, and the seeds contain a lot of carbohydrates, protein, and lipids, which supply necessary energy and nutrition (Djakpo, 2005). Several plant parts such as seeds, bark, roots, fruits, and flowers have been reported to be used in curing over 80 diseases in traditional West African medicine (Dedehou *et al*., 2016).

The seeds are fermented and used as a protein condiment, called "dawadawa" or "soumbala," and are also valued for their antihypertensive properties (Ognatan *et al*., 2011). Furthermore, the sweet fruit pulp is a good source of nutrients as it contributes glucids, proteins, carotenoids, vitamins A, B, and C, and certain minerals in trace amounts (Omojola *et al*., 2011; Dahouenon-Ahoussi *et al*., 2012; Ijarotimi & Keshinro, 2012). The entire tree contributes to rural livelihoods, offering timber, firewood, fodder, green manure, and reclamation of soil fertility (Koura *et al*., 2011; Nyadanu *et al*., 2017).

2.5.2.1 Domestication of *Parkia biglobosa*

Despite the significant socio-economic and ecological value of *P. biglobosa*, the species remains largely undomesticated and vulnerable to human activities within its natural range in West Africa (Lamien *et al*., 2011). Its natural populations are increasingly threatened by land-use change, overharvesting, deforestation and unsustainable management practices. Field observations have shown a significant decrease in population densities, mainly due to low recruitment of seedlings, low seedling germination rates under natural conditions and the ageing of existing stands (Abubakar & Maimuna, 2013; Abbas *et al*., 2018). These challenges have resulted in fragmented and declining populations within traditional agroforestry systems, thereby exacerbating the species' vulnerability (Sina, 2006).

Although *P. biglobosa* is mainly propagated through seeds, this method is hampered by physiological dormancy and extended juvenile phases, which delay fruit production. Consequently, vegetative propagation techniques, such as root cuttings, air layering, and tissue culture, have been tested as alternative options to the efforts of domestication (Lamien *et al*., 2011).

2.5.3 *Lannea microcarpa*

Lannea microcarpa is a dioecious tree species naturally distributed in the Sudanian belt of sub-Saharan Africa and usually associated with agroforestry systems and cultivated crops (Sinsin & Kampmann, 2010). This species reaches a mean height of 16 m and its crown is dense and semi-spherical (Marquet & Jansen, 2005). The species is distributed across a wide geographical range, including Benin, Cameroon, Côte d'Ivoire, Gambia, Ghana, Guinea, Mali, Niger, Nigeria, Senegal, and Togo (Maroyi, 2018). It is well-suited for rocky and friable soils in the Sahel and Sudanian savannas and has been widely reported throughout the broader savanna biome (Marquet & Jansen, 2005).

The fruit of *L. microcarpa* is characterized by a dark-red color epicarp, which contains anthocyanin pigments of interest as natural food colorants (Sereme *et al*., 2014). Young leaves are eaten as green leafy vegetables, contributing to household nutrition (Marquet & Jansen, 2005). The seeds are a rich source of edible oil, with applications in biodiesel production, animal feed, and the cosmetic industry (Yunus *et al*., 2013; Bazongo *et al*., 2014). Also, leaf powders have promising applications for cosmetic, food, and nutraceutical formulations (Sansone *et al.*, 2014).

The traditional use of *L. microcarpa* is extensive; it is applied for at least 46 human and three animal diseases. Aerial parts, bark, roots, fruits, seeds, gum, and ash are used for treating multiple health disorders in indigenous ethnomedical practices (Maroyi, 2018). However, extensive bark stripping and unsustainable harvesting practices have led to increased pressure on wild populations (Sereme *et al*., 2014).

2.5.3.1 Domestication of *Lannea microcarpa*

Despite its multiple uses and cultural significance, *Lannea microcarpa* remains largely undomesticated. It continues to be collected from the wild for food, fuel, medicine, fibre, dye, handicrafts, and woodcarving purposes (Marquet & Jansen, 2005). As a result, the species is confronted with threats such as overexploitation, habitat loss, and population decrease in some parts of West Africa (Leßmeister *et al*., 2015; Ouédraogo *et al*., 2017; Agbani *et al*., 2018b; Abubakar *et al*., 2018).

Initial domestication efforts have focused on characterizing the species' seed biology and potential for vegetative propagation. Its natural regeneration and opportunity for propagation through horticultural cuttings have been studied (Agbogan *et al*., 2014, 2017). However, vegetative propagation has yielded limited success, with poor rooting responses reported in early experiments (Loada, 2004; Sereme *et al*., 2008).

Physiological dormancy of the seeds and high lipid levels of approximately 35% is one of the main challenges in the propagation of *L. microcarpa*, since the high lipid content of the seeds leads to rapid loss of viability (Neya, 2006; Sacande, 2007). Also, low natural regeneration recruitment rates in situ are a limitation to regeneration (Ouédraogo *et al*., 2006). Such restriction underlines the necessity for better propagation procedures and germplasm conservation methods.

2.5.4 *Bombax costatum*

Bombax costatum is a deciduous tree in the family Malvaceae, native to the West African Sudanian and Sahelian zones, where it readily grows in savannas and dry woodlands (Arbonnier, 2002; Ouédraogo *et al*., 2014). The species is generally found on stony and gravelly lateritic soils, such as in croplands and lands adjacent to human settlements, and it does well under rainfall regimes of 800 to 1,500 mm (Belem, 2009; Oyen, 2011). It exhibits a straight, thorny bole and can attain a height of 10 to 25 meters, with tuberous roots, used as the storage organ for water and sugar, and helps the tree to withstand drought (Orwa *et al*., 2009).

Bombax costatum flowers during the dry season before leaves develop. The fruits are capsules, ellipsoidal in shape, brown to black in color, dehiscent by five valves, and contain silky white or cream-colored floss surrounding the black seeds (Zerbo *et al*., 2022). This floss has important economic value, being widely used to stuff mattresses, cushions, and pillows (Oyen, 2011).

The species holds great ethnobotanical and economic importance. Its leaves and succulent calyces are consumed as vegetables, while young fruits are harvested and dried for meal preparation or beverage production (Lykke *et al*., 2002; Orwa *et al*., 2009). The seed oil is edible and used in cooking, while the bark and roots are used in traditional medicine for treating ailments such as fever, skin diseases, headaches, epilepsy, and yellow fever (Belem *et al*., 2008; Oyen, 2011). The powdered root is consumed with sauces or used in therapeutic baths.

In addition, *B. costatum* is a valuable resource for timber and fuelwood. It is used for making domestic articles, door and window frames, matchsticks, and by virtue of its acoustic characteristics, it is used in making traditional musical instruments (Oyen 2011). Its flowers and leaves are important forage for livestock, and the tree is important for its shade in grazing lands. The species is also important as a forage plant for honeybees (Orwa *et al*., 2009).

Despite its importance, the regeneration of *B. costatum* in natural habitats is limited. The species is subject to intense harvesting pressure, particularly of its flowers for food and commercial use, which contributes to its declining population (Belem *et al*., 2008; Ouédraogo *et al*., 2006).

2.5.4.1 Domestication of *Bombax costatum*

Domestication of *Bombax costatum* is increasingly receiving attention because of its ecological robustness and multiple uses. However, the species remains largely undomesticated, with regeneration in natural ecosystems primarily reliant on seed germination and vegetative reproduction. The principal constraint to its natural regeneration is the overexploitation of its flowers and bark, coupled with low seedling survival under field conditions (Belem, 2009; Zerbo *et al*., 2022).

Efforts to propagate *B. costatum* have focused on both sexual and asexual methods. While seed propagation is possible, seedling establishment is often poor, particularly under degraded field conditions where moisture and soil fertility are limiting. Furthermore, the recalcitrant nature of its seeds poses challenges for long-term conservation and large-scale seedling production (Ouédraogo *et al*., 2014).

Vegetative propagation, especially by root suckering and root pruning methods, has shown encouraging results. Studies by Belem *et al*. (2008) demonstrated that root wounding methods induce suckering in mature plants, thus providing a possible route to clonal propagation. These methods, when applied in agroforestry systems, can provide a means of contributing to the goals of conservation and domestication, by allowing farmers to multiply elite and favorable genotypes.

CHAPTER THREE

ASSESSMENT OF INDIGENOUS KNOWLEDGE ON PROPAGATION OF NATIVE TREES IN THE GUINEAN SAVANNA AGRO-ECOLOGICAL ZONE OF GHANA

Abstract

Despite the ecological and socio-economic importance of indigenous trees to rural livelihoods in West Africa, there is little documentation of traditional knowledge and scientific evidence of their propagation, especially in northern Ghana. The study was conducted to assess local knowledge on the propagation of four priority multipurpose indigenous tree species, *Adansonia digitata, Parkia biglobosa, Lannea microcarpa* and *Bombax costatum,* for effective domestication in the Guinean savanna agro-ecological zone of Ghana. We conducted fieldwork in 13 communities across the Kassena Nankana municipality, Kumbungu District, and Nandom municipality between September and October 2022. We conducted semi-structured interviews with 260 respondents (138 males and 122 females) purposefully selected through local leaders using questionnaires. Our results revealed significant variations in propagation knowledge, fruiting perceptions, and perceived tree population trends across locations and age groups. Most respondents relied on seed-based propagation, while few used vegetative techniques. Elderly participants, especially those aged 50–69, demonstrated greater propagation knowledge, particularly for *P. biglobosa,* Communities reported perceived differences in fruit maturation between locations and seasons. Livestock herbivory emerged as the main constraint to seedling survival, alongside cultural taboos and ecological barriers such as seed dormancy. These

results underscored the need to incorporate indigenous knowledge into tree domestication and conservation programs. If this knowledge is incorporated into policy and reforestation programs, it will encourage more culturally appropriate, ecologically responsible, and socially inclusive methods of landscape restoration and rural development.

Keywords: Indigenous knowledge, native trees, ethnobotanical, propagation, domestication

3.1 Introduction

Trees are of great ecological importance, filling an indispensable ecological niche in terrestrial ecosystems. They play an important role in biogeochemical cycling, including nutrient supply and carbon sequestration, as well as influencing soil formation, hydrological function, and climate regulation (Sjöman *et al*., 2024). Indigenous tree species, which have evolved over time in particular regions, are highly adapted to local environmental conditions and are closely bound to native fauna, including birds and pollinating insects (Wilkinson *et al*., 2014). They provide various ecosystem goods and services such as food, nutrition, medicine, income and raw material for housing, fuel, fibre and resin to the rural communities (Awodoyin *et al.*, 2015; Leakey, 2012).

In agricultural landscapes, indigenous trees play multifunctional roles that enhance environmental sustainability, as well as supporting livelihoods, particularly through agroforestry systems (Gouwakinnou *et al*., 2011). In northern Ghana, important native tree species including *Vitellaria paradoxa*, *Parkia biglobosa*, *Adansonia digitata*, *Bombax costatum*, and *Lannea macrocarpa*, have been valued for their socio-economic and ecological contributions (Lovett & Haq 2000, Assogbadjo *et al*., 2012, Amoako 2012, Haarmeyer *et al*., 2013, Zerbo *et al*., 2022).

Adansonia digitata (baobab) is one of Africa's most important indigenous fruit trees targeted for domestication (Gebauer *et al*., 2016). However, natural populations are under increasing pressure due to agricultural expansion, infrastructure development, and land use change (Duvall, 2007). Propagation methods include sexual reproduction via seeds and asexual methods such as grafting, cuttings, and in vitro techniques (Agbohessou *et al*., 2020; N'doye *et al.*, 2012; Anjarwalla *et al*., 2016; Egbadzor & Akuaku, 2022).

Parkia biglobosa thrives under diverse environmental conditions, with annual rainfall ranging from 600 to 1,500 mm and a dry season that lasts five to seven months (Abbas *et al*., 2018). While seed propagation is the most widely used method, vegetative approaches such as root cuttings, air layering, and tissue culture are also reported (Lamien *et al*., 2011).

Lannea microcarpa is a dioecious species confined to the Sudanian zone and is commonly integrated into agroforestry systems. It prefers areas with annual rainfall between 500 and 1,100 mm and is primarily propagated by seed (Sinsin & Kampmann, 2010; Haarmeyer *et al*., 2013; Neya, 2006).

Bombax costatum occurs in areas receiving 800 to 1,500 mm of annual rainfall. It is typically propagated through seeds and vegetatively via root cuttings, air layering, grafting, and sucker stimulation (Belem, 2009; Oyen, 2011).

Despite their ecological and socio-economic values, many native trees are increasingly threatened and suffer from habitat destruction, over-exploitation, and low or lack of conservation efforts, resulting in decline of their population in several areas across West Africa (Belem *et al.,* 2008; Ræbild *et al*., 2012; Lykke *et al*., 2025). Recent reforestation policies in Ghana, including the Green Ghana Project and the Youth in Afforestation

Programme are dominated by fast-growing exotic species (Forestry Commission, 2022). Sadly, however, these programs commonly ignore the use of native trees, which are more appropriate ecologically, traditionally culturally significant and have the potential to adapt because they have existed these territories (Wilkinson *et al*., 2014). As a result, such preference contributes to the erosion of indigenous genetic resources and threaten long-term ecosystem resilience (Okunlola *et al*., 2011).

In addition, many tree planting interventions are largely informed by technical beliefs and external knowledge regimes, frequently neglecting practical knowledge and local needs (Brancalion & Holl, 2020), an omission often found to be associated with project failure (Ayantunde *et al*., 2008). Rural farmers, on the other hand, have a wealth of experience based on generations of interaction with the environment and traditional resource management technology (Brook & McLachlan, 2008). Indigenous knowledge systems have come to be increasingly appreciated as invaluable tools for the conservation of biodiversity, sustainable management of natural resources, and for the successful domestication of native plants (Berkes *et al*., 2000; Uprety *et al*., 2011).

In contrast with related earlier studies that have largely addressed the economic importance, cultural value, or ecological roles played by particular indigenous tree species (Gouwakinnou *et al.,* 2011, Houehanou *et al.,* 2011), emphasis of the present study is given to aspects of traditional propagation knowledge. Although some of the ethnobotanical studies conducted in Ghana focused on the ecological and/or economic importance of some native tree species to the local communities, such as *Vitellaria paradoxa* and *Parkia biglobosa* (Lovett & Haq, 2000, Elias & Carney, 2007), very few have explored how propagation knowledge of native trees varies across demographic groups within an ecological zone. Even fewer have studied this knowledge across multiple species and among culturally diverse areas. Such an absence of specific and local investigation on propagation methods, especially age, site, and phenological knowledge, represents a critical knowledge gap that this study attempts to bridge.

This study investigates indigenous propagation knowledge across three socio-culturally distinct districts: Kassena Nankana, Kumbungu, and Nandom, located in the Guinean savanna agro-ecological zone of northern Ghana. These districts were purposively selected as they heavily depend on indigenous tree species for their livelihoods, they exhibit differences in customary land management systems and have varying levels of exposure to conservation and afforestation projects. They also vary in farming structure, and in cultural beliefs toward tree use and planting (GSS 2021, Backes, 2001, Amoako, 2012, Asare *et al.,* 2013). This diversity provides a rich socio-ecological gradient against which to assess the role of context in the shaping of indigenous knowledge systems and diffusion practices.

By documenting how local communities propagate native trees, this study provides practical insights for policy and reforestation planning. It supports more culturally grounded and ecologically sound restoration efforts. Such knowledge can inform reforms that promote native species in afforestation, enhance seedling survivorship through locally adapted techniques, and enrich the participation of local communities in conservation. This study therefore, assessed the indigenous knowledge related to the propagation of four multipurpose native trees, *Adansonia digitata*, *Parkia biglobosa*, *Lannea microcarpa*, and *Bombax costatum,* across three locations in the Guinean savanna agro-ecological zone of northern Ghana. Specifically, the study investigated: (i) the local experiences in propagating these species, (ii) the variations in fruiting seasons across locations, (iii) the changes in tree population status over the past two decades, and (iv) the key constraints to tree seedling survival, among informants age groups across the three locations.

Hypothesis

This study tested the hypothesis that indigenous knowledge on propagation, fruiting periods, and perceived population trends of *A. digitata, P. biglobosa, L. microcarpa*, and *B. costatum* significantly differs across age groups and study locations.

Null Hypothesis (H_0): There are no significant differences in indigenous knowledge on the propagation, fruiting periods, and perceived population trends of native trees across age groups and study locations.

Alternative Hypothesis (H_1): Indigenous knowledge on the propagation, fruiting periods, and perceived population trends of native trees significantly varies across age groups and study locations.

3.2 Materials and Methods

3.2.1 Study Area

The study was carried out from September to October 2022 in 13 communities within the Guinean savanna agro-ecological zone of Ghana, specifically in the Kassena Nankana Municipality (Upper East Region), Kumbungu District (Northern Region), and Nandom Municipality (Upper West Region) (Figure 3.1). These sites were deliberately chosen based on the presence of the four key native species (*Adansonia digitata, Parkia biglobosa, Lannea microcarpa,* and *Bombax costatum*), their socio-economic and livelihood importance, cultural significance, ease of access for fieldwork, and variations in exposure to afforestation and conservation initiatives. The Kassena Nankana Municipality lies between latitudes 10°40′N to 11°10′N and longitudes 1°10′W to 1°00′W. It receives an average annual rainfall of approximately 950 mm, with temperatures ranging between 18°C and 42°C. Common trees include *Parkia biglobosa, Adansonia digitata, Vitellaria paradoxa,* and *Mangifera indica* (GSS, 2014).

The Kumbungu District extends from 9°35′N to 9°45′N latitude and 0°57′W to 1°07′W longitude, with an average annual rainfall of approximately 1000 mm and temperatures ranging from 15°C to 42°C. The vegetation is made up of grassland dotted with drought-tolerant trees such as *P. biglobosa, V. paradoxa,* and *M. indica* (GSS, 2014).

Nandom Municipality lies between latitudes 10°20′N to 11°00′N and longitudes 2°25′W to 2°45′W. It experiences daily temperatures from 23°C to 42°C and about 950 mm of annual rainfall. Its vegetation comprises short grasses and scattered fire-resistant species like *V. paradoxa, A. digitata,* and *Acacia Senegal* (GSS, 2014). The study communities included Chiana, Kologo, Naaga, and Pindaa (Kassena Nankana); Gbullung, Gizaa, Gundaa, Jakpahi, and Kpalga (Kumbungu); and Kussele, Lisa, Munyapelli, and Tuoperi (Nandom). Figure 3.1 shows the geographic locations of these communities, based on GPS coordinates collected during field reconnaissance, to illustrate the spatial distribution of the study sites within the Guinean savanna agro-ecological zone.

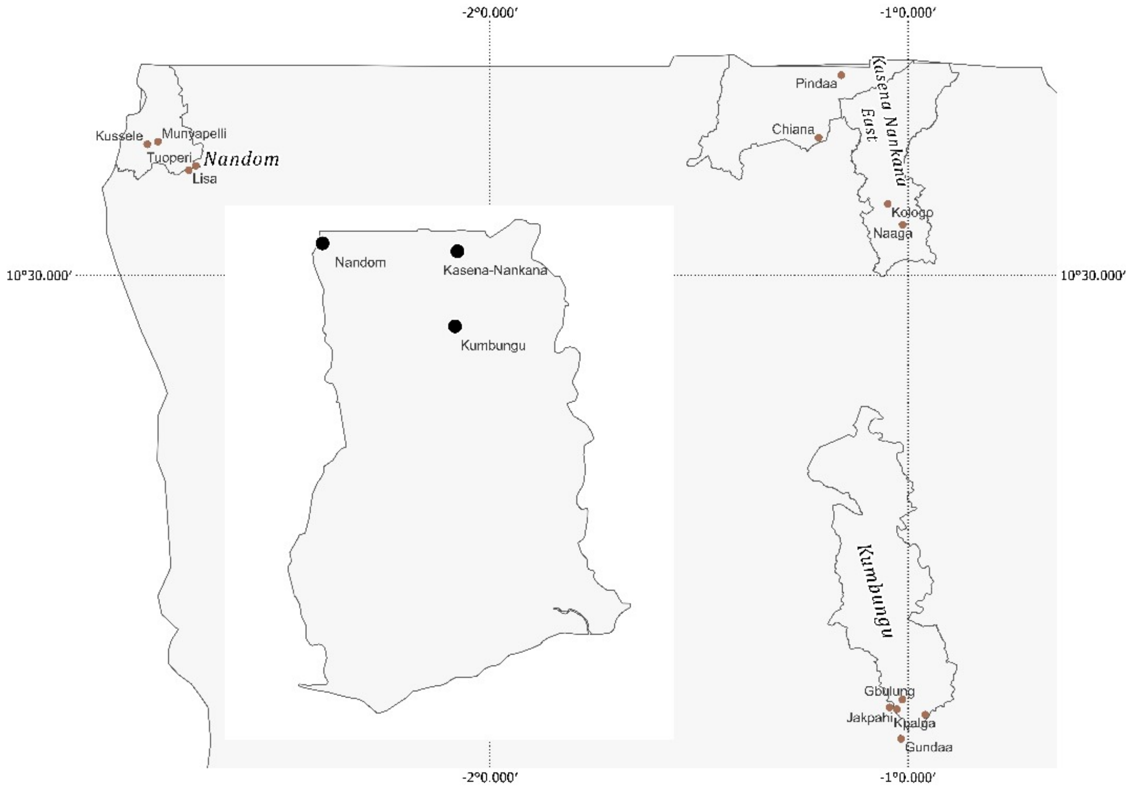

Figure 3.1: Map of study communities in the Guinean savanna agroecological zone

3.2.2 Data Collection

3.2.2.1 Sampling Design and Rationale

The study adopted a multistage purposive sampling approach. At the national level, the northern ecological belt was chosen based on its rich biodiversity in these multipurpose native trees. Within this belt, three administrative regions and their respective districts were selected based on their variation in socio-cultural practices, land and tree tenure arrangements relevant to management of native tree species. Communities within each district were identified by the presence of native tree populations and their willingness to participate.

3.2.2.2 Sample Size Determination

A total of 260 respondents were selected using Cochran's formula for categorical data (Cochran, 1977).

The formula is given as: $$n_0 = \frac{Z^2.p.(1-p)}{e^2},$$

Where: n_0=sample size; Z= Z-value (1.96 for 95% confidence level), p= estimated proportion of an attribute (commonly 0.5 when large or unknown), e= desired level of precision or margin of error (eg 0.06 for ±6%).

$$n_0 = \frac{(1.96)^2.0.5.(1-0.5)}{(0.06)^2} \qquad n_0 = 267$$

Although the calculated sample size was 267, we used a final sample of 260 respondents for practical implementation. This number was considered statistically robust, logistically feasible, and consistent with standard practices in ethnobotanical and indigenous knowledge research, where depth of information is prioritized over broad population generalizability (Tongco, 2007). The sample allowed adequate representation across the 13 study communities and four generational age groups.

The combined population of the three study districts (Kassena Nankana Municipality, Kumbungu District, and Nandom Municipality) is about 261,809 (GSS, 2021). The sample size of 260, therefore, represents about 0.10% of the total population. Although this percentage may seem low, it is appropriate for qualitative research designed to achieve a deep, rich, contextual understanding of individuals who have specific information.

Stratification by age and spatial distribution across all communities further strengthened the representativeness of the sample within the study's scope and objectives.

3.2.2.3 Participant Selection and Ethical Considerations

The informants were selected by criterion-based purposive sampling. Participants were identified with the help of community leaders based on their observable engagement with native tree propagation. Participants included farmers, herbalists, traditional custodians, and traders. The participants were categorized into four age categories (15–29, 30–49, 50–69, 70+ years), guided by generational cohorts often used in rural demographic studies (Ayantunde *et al*., 2008, Berkes, 2012). Age was prioritized as it is known to be positively correlated with ecological knowledge, and older people are more likely to possess long-term experiential knowledge of tree use, fruiting behavior, and regeneration patterns (Brook and McLachlan 2008). Although gender and community role diversity were considered during participant selection to ensure inclusivity, the major variable in the classification of participants was age, given its well-established association with knowledge accumulation and transmission in ecological research (Ayantunde *et al.,* 2008). Socioeconomic variables such as income and education were excluded to maintain focus on ecological knowledge transmission.

Before data collection, verbal informed consent was obtained after explaining the purpose of the study, confidentiality, and voluntary participation. The research protocol was reviewed and approved by the supervisory team. No personal identifiers were recorded. Community entry was facilitated through local leaders to ensure cultural appropriateness and consent.

3.2.2.4 Data Collection Procedure

Prior to fieldwork, three research assistants and six community-based facilitators were trained. The interview guide was pre-tested in August 2022 with 12 respondents from demographically similar but non-sampled communities. The pre-test helped refine question clarity, sequencing, and cultural sensitivity.

Data were collected simultaneously across all three districts within one month (September–October 2022). This was made possible through planning, team deployment across sites, and coordination with local leaders. The use of semi-structured interviews allowed flexibility and depth during interactions, supporting high-quality data within a short timeframe.

3.2.3 Data Analysis

Quantitative data were analyzed using SPSS Version 26.0. Chi-square (χ^2) tests were used to test associations between demographic variables (location and age) and indigenous knowledge variables (propagation methods, fruiting seasons, population trends, and survival constraints). Statistical significance was determined at $p < 0.05$.

3.2.4 Limitations

While this study provides valuable insights, it has limitations. Socioeconomic variables were not examined, limiting the analysis of broader social determinants. The purposive sampling technique, while effective for accessing knowledge-rich individuals, may limit generalizability. Additionally, recall bias may have affected responses regarding historical population trends and fruiting periods.

3.3 Results

3.3.1 Indigenous Knowledge on Tree propagation Across study locations

Indigenous knowledge on the propagation of native trees varied significantly among the three study locations for *Adansonia digitata* ($\chi^2 = 21.9$, $p < 0.005$), *Parkia biglobosa* ($\chi^2 = 39.0$, $p < 0.000$), and *Lannea microcarpa* ($\chi^2 = 22.4$, $p < 0.001$). The highest levels of propagation experience for *A. digitata* (32.0%) and *P. biglobosa* (29.0%) were recorded in Kassena Nankana, in contrast to 8.0% and 12.0% respectively, in Kumbungu. For *L. microcarpa*, the highest experience (17.6%) was observed in Nandom compared to 5.1% in Kumbungu.

The relatively low propagation experience in Kumbungu may reflect a combination of factors, as reveal from field interviews and participants observations including customary beliefs about tree planting, land tenure arrangements, limited incentives for active propagation, and/or a greater reliance on natural regeneration. Respondents indicated that tree planting on farmlands is often constrained by customary land tenure arrangements, where land is predominantly controlled by traditional authorities and individual farmers may have limited rights to plant or claim ownership over trees, particularly economically valuable species. This arrangement was described as reducing incentives for deliberate tree establishment, particularly for long-term species. In contrast to Kassena Nankana and Nandom, where respondents reported clearer individual tree-use rights and greater incentives to establish and manage trees. Farmers in Kumbungu more commonly relied on natural regeneration rather than deliberate propagation. Additionally, some participants in Kumbungu reported culturally embedded beliefs specifically associated with *Adansonia digitata*, including fears that deliberate planting of baobab could invite spiritual attacks or misfortune. Such beliefs were described as discouraging intentional propagation of the species, independent of formal land tenure arrangements.

Seed propagation was the dominant method used across all species, practiced by an average of 29.4% of respondents. In contrast, budding was the least used method (0.3%). Specifically, for *A. digitata*, 51.0% of respondents used seeds, while only 1.0% used grafting or budding. For *P. biglobosa*, 49.0% relied on seeds, with only 1.0% using grafting and none using budding. *L. microcarpa* was mostly propagated by seeds (13.8%), and rarely through grafting (1.3%). For *Bombax costatum*, 3.8% each used seeds and cuttings, with no reports of grafting or budding use (Figure 3.2). This pattern suggests a general familiarity with seed-based techniques among respondents, possibly due to their simplicity, accessibility, or traditional use.

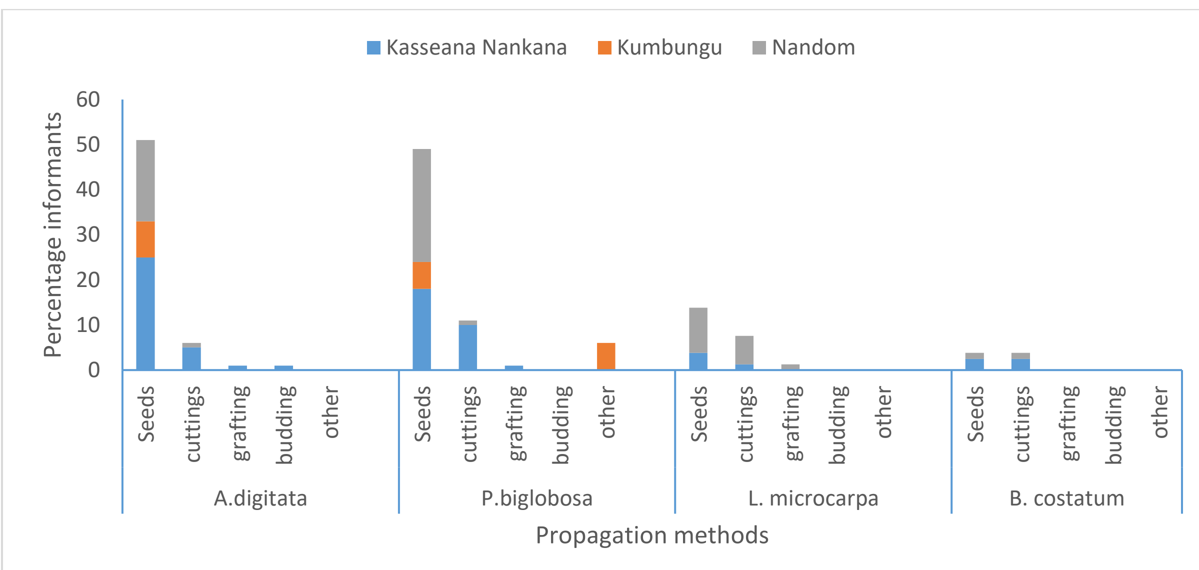

Figure 3.2: Propagation knowledge and experience of indigenous trees

3.3.2 Local Knowledge of Fruit Maturity Periods

Perceptions of fruit maturity periods differed significantly across study locations for *A. digitata* ($\chi^2 = 55.2$, $p < 0.000$), *P. biglobosa* ($\chi^2 = 30.1$, $p < 0.000$), *L. microcarpa* ($\chi^2 = 12.7$, $p < 0.048$), and *B. costatum* ($\chi^2 = 35.1$, $p < 0.000$). In Kumbungu, 68.0% of respondents observed that *A. digitata* fruits mature between October and December, compared to 30.0% in Kassena Nankana. For *P. biglobosa*, 81.0% of respondents in Kumbungu reported fruiting between April and June (onset of rains), against 47.0% in Kassena Nankana. For *L. microcarpa*, 90.0% of Kassena Nankana informants reported fruit maturity in April to June, compared to 75.0% in Kumbungu. *B. costatum* maturity was most commonly observed between January and March in Kumbungu (68.0%) versus 32.0% in Kassena Nankana (Figure 3.3).

Species-specific comparisons revealed distinct spatial patterns in perceived fruit maturity periods of the species, while *A. digitata* maturity between (October–December) was reported more frequently in Kumbungu than in Kassena Nankana, *B. costatum* showed a similar spatial contrast, with higher reports of (January–March) maturity in Kumbungu. For *P. biglobosa*, and *L. microcarpa* fruit maturity was more strongly linked to the onset of the rainy season (April–June) in the locations.

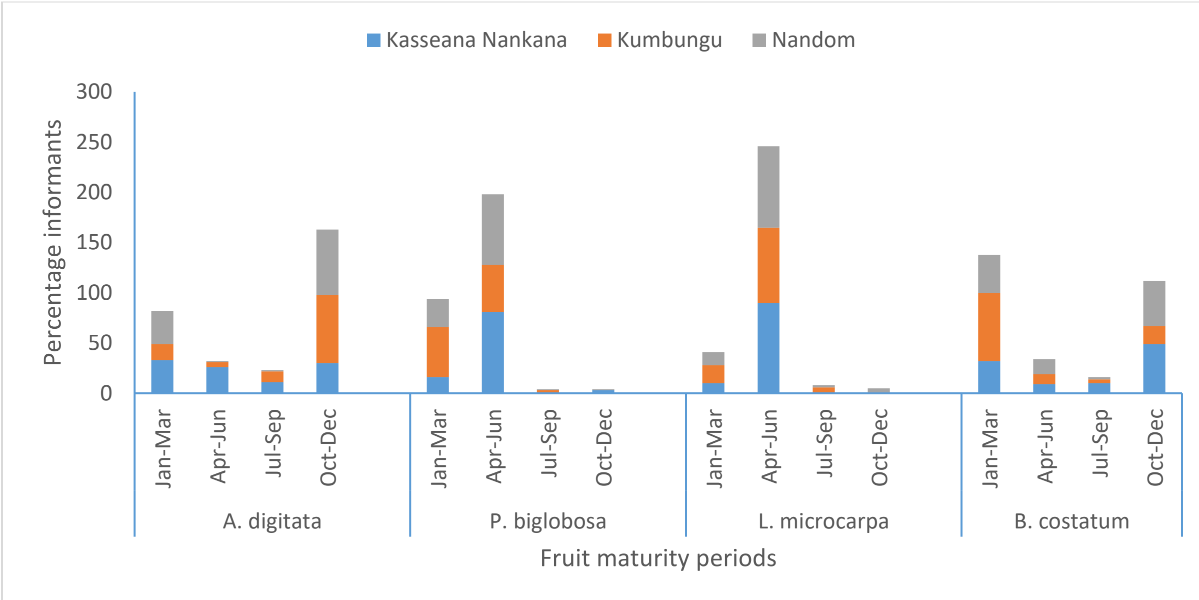

Figure 3.3: Fruit maturity periods in the study location

3.3.3 Local Perception of Tree Population Trends

Observations of changes in tree population status over the past two decades varied significantly across the study sites. Significant differences were observed for *A. digitata* ($\chi^2 = 61.7$, $p < 0.000$), *P. biglobosa* ($\chi^2 = 44.5$, $p < 0.000$), *L. microcarpa* ($\chi^2 = 75.9$, $p < 0.000$), and *B. costatum* ($\chi^2 = 59.6$, $p < 0.000$). Kumbungu recorded the highest average decline (93.0%) across all four species. Specifically, 96.0% of respondents in Kumbungu reported declines in both *A. digitata* and *P. biglobosa*, 91.0% in *L. microcarpa*, and 88.0% in *B. costatum*. This contrasts with Kassena Nankana, where respective decline rates were lower: 65.0%, 72.0%, 56.0%, and 58.8% (Figure 3.4).

Species-specific patterns of perceived highest population decline were evident in Kumbungu as 96% of respondents reported declines in *A. digitata* and *P. biglobosa* and *L. microcarpa* (91.0%) and *B. costatum* (88.0%), may reflect limited deliberate planting despite their multipurpose value, coupled with dependence on natural regeneration. In Kassena Nankana, comparatively lower decline rates across all species suggest differences in land management practices and regeneration opportunities.

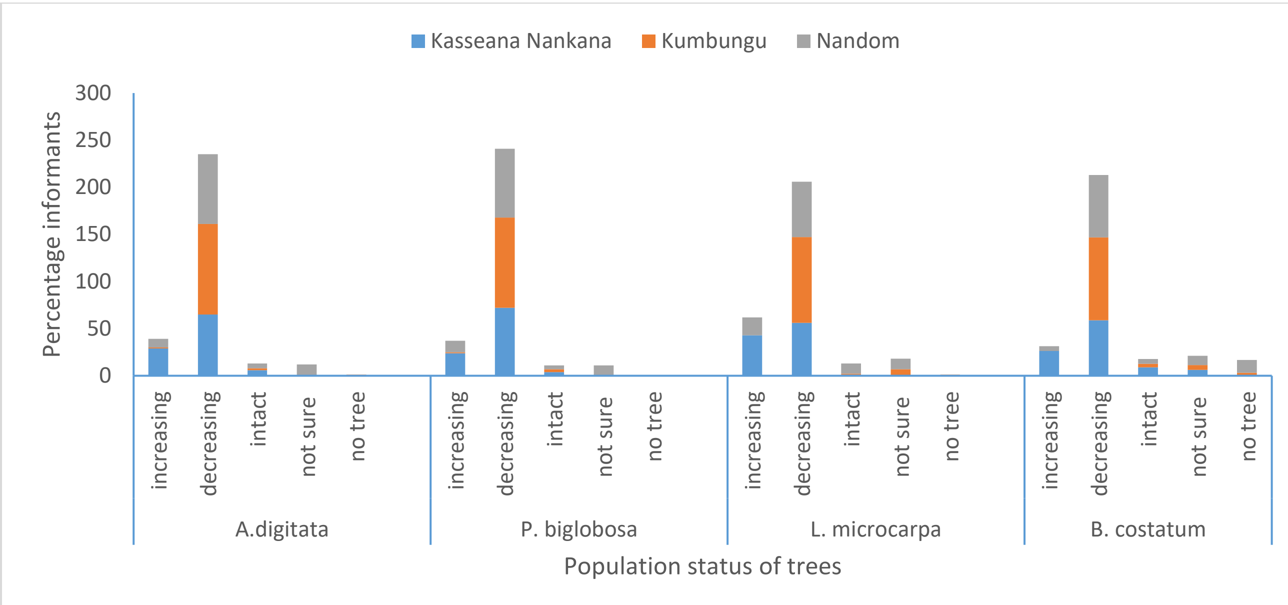

Figure 3.4: Population status of native trees in the study location

3.3.4 Influence of Informant Age on Tree Knowledge

Age significantly influenced propagation knowledge for *P. biglobosa* ($\chi^2 = 25.65$, $p < 0.012$), with the 50–69 age group reporting the highest experience (35.3%), compared to only 3.6% in the 15–29 age group. Age also significantly influenced perceptions of population decline in *A. digitata* ($\chi^2 = 26.85$, $p < 0.008$), with respondents aged over 70 reporting the highest perceived decline (93.4%), compared to 63.6% in the youngest group.

However, age did not significantly influence knowledge of fruiting periods for any of the species, nor did it significantly affect propagation knowledge for *A. digitata*, *L. microcarpa*, or *B. costatum* (Table 3.1).

Older respondents reporting more propagation experience for *P. biglobosa* and perceive population declines in *A. digitata,* may reflect their longer-term engagement with the landscape and cumulative knowledge. These highlight a clear intergenerational knowledge gap, with younger respondents possessing limited propagation knowledge and less awareness of tree population changes. This gap poses a potential risk for the continuity of indigenous ecological knowledge, particularly as older knowledge holders age.

Table 3.1: Relations between the age group and tree knowledge

Tree	Age group (years)	Percentage informants													
		Seeds	Cuttings	Grafting	Budding	other	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Increasing	Declining	intact	not sure	no tree
Adansonia digitata	15-29	5.5	0	0	0	0	33	18	5	44	23.6	63.6	5.5	7.3	0
	30-49	17.8	1.9	0	0	0	25	6	11	58	10.3	79.4	5.6	4.7	0
	50-69	25	4.4	1.5	1.5	0	25	13	6	56	10.3	86.7	1.5	1.5	0
	>70	10	0	0	0	0	20	7	7	66	0	93.4	3.3	0	3.3
Parkia biglobosa	15-29	1.8	0	0	0	1.8	27	71	0	2	16.3	69.1	7.3	7.3	0
	30-49	19.6	2.8	0	0	2.8	36	59	3	2	10.3	81.3	4.7	3.7	0
	50-69	23.5	7.4	1.5	0	2.9	31	68	1	0	13.2	85.3	0	1.5	0
	>70	6.7	3.3	0	0	0	33	67	0	0	3.3	96.7	0	0	0
Lannea microcarpa	15-29	0	0	0	0	0	7	89	2	2	34	58	4	4	0
	30-49	6.5	2.8	0	0	0	18	76	4	2	13	73	6	8	0
	50-69	5.9	1.5	1.5	0	0	15	79	4	2	19.1	69.1	4.4	5.9	1.5
	>70	0	6.7	0	0	0	7	93	0	0	10	86.7	0	3.3	0
Bombax costatum	15-29	0	0	0	0	0	38.2	18.2	3.6	40	12.7	61.8	9.1	9.1	7.3
	30-49	2.8	0.9	0	0	0	51.4	11.2	5.6	31.8	10.4	68.2	8.4	6.5	6.5
	50-69	0	1.5	0	0	0	48.5	8.8	5.9	36.8	8.8	80.9	0	8.9	1.4
	>70	0	3.3	0	0	0	50	3.3	6.7	40	3.3	86.7	3.3	0	6.7

3.3.5 Constraints to seedling survival in the study locations

Livestock herbivory was the major constraint to seedling survival across all locations, with an average of 42.0% of informants attributing seedling destruction by herbivory, followed by drought (18.0%) and bushfires (16.0%), and the least was mechanization (3.0%) (agricultural land preparation) (Figure 3.5).

Livestock herbivory as the main constraint indicates a widespread challenge in protecting young trees in open landscapes. Drought and bushfires were also notable concerns, while mechanized land preparation was mentioned less frequently. These findings suggest that natural and human-induced pressures continue to affect early-stage regeneration.

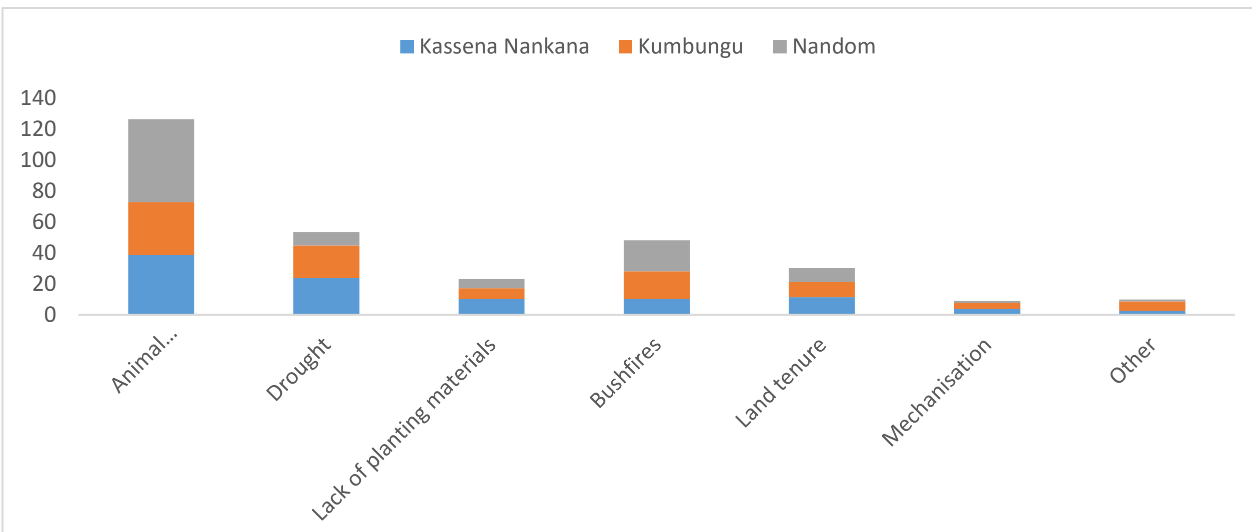

Figure 3.5: Constraints to survival of tree seedlings in study locations

3.4 Discussions

3.4.1 Knowledge of the propagation of trees in the study locations

The study found significant geographic variations in indigenous knowledge of tree propagation, statistically supported by Chi-square results for *Adansonia digitata* ($\chi^2 = 21.9$, $p < 0.005$), *Parkia biglobosa* ($\chi^2 = 39.0$, $p < 0.000$), and *Lannea microcarpa* ($\chi^2 = 22.4$, $p < 0.001$). These findings suggest that the differences in propagation experience across locations may reflect both cultural beliefs and structural land-tenure arrangements that shape respondents' practices. In Kumbungu, some respondents reported culturally embedded myths surrounding the planting of *Adansonia digitata*, including beliefs that deliberate planting could result in spiritual attacks or misfortune, which discouraged active propagation of the species. In addition, respondents indicated that certain economically valuable indigenous trees such as *P. biglobosa* are customarily vested in traditional authorities, limiting individual incentives to plant or manage such species. In contrast, some respondents in the Kassena Nankana and Nandom areas indicated tree tenure were vested in families and individuals. Together, these factors contribute to district-level differences in knowledge systems and experiences related to tree propagation.

Specifically, the higher propagation experience Kassena Nankana and Nandom, for all three species, could be attributed to higher community reliance on the ecosystem services rendered by these trees and on the interventions targeting the domestication of these trees.

In Kassena-Nankana, respondents identified ORGIIS-Ghana (Organization for Indigenous Initiatives and Sustainability), which purchases baobab (*Adansonia digitata*) fruits, as a key driver of deliberate planting due to the enhanced economic value associated with the species. In contrast, although the SFC (Savanna Fruit Company) operates in Kumbungu and Nandom, its activities primarily target shea (*Vitellaria paradoxa*) rather than the focal study species. Consequently, no comparable organized market incentives were reported for *A. digitata*, *P. biglobosa*, *L. microcarpa*, or *B. costatum* in those locations. These findings align with literature emphasizing the role of market integration and livelihood incentives in shaping domestication and propagation behavior (Assogbadjo *et al*., 2012; Gouwakinnou *et al*., 2011; Schreckenberg *et al*., 2006).

On the other hand, the Chi-square analysis revealed consistently lower propagation experience in Kumbungu across all species. This pattern suggests structural limitations beyond just ecological conditions. It may reflect local socio-cultural constraints, such as spiritual taboos associated with planting *Adansonia digitata*, and limited extension exposure, both of which restrict the diffusion of propagation knowledge. Previous studies by Wickens & Lowe (2008) and also Smith *et al*. (1996) confirm that in some African communities, *A. digitata* planting is discouraged by beliefs in spiritual ownership or ancestral custodianship. Such taboos can discourage proactive cultivation even where ecological conditions are suitable.

Furthermore, as stated by Tomomatsu (2014), land tenure insecurity and fragmented local governance systems could hinder collective planting efforts. In Kassena-Nankana and Nandom, land and trees were reported as largely vested in families or individuals, enabling farmers to claim ownership of planted or protected trees and thereby providing incentives for active propagation and management. In contrast, respondents in Kumbungu indicated that authority over certain economically valuable species, particularly *Parkia biglobosa*, is vested in traditional leaders (tree chiefs), limiting individual rights and discouraging deliberate planting. These institutional differences correspond with the lower propagation engagement observed in Kumbungu. This suggests that propagation outcomes are shaped not only by technical knowledge gaps but also by underlying cultural and governance structures.

The adaptation of agroforestry interventions to support these localized cultural beliefs and governance dynamics is necessary to achieve higher adoption. In areas like Kumbungu, where statistical results point to minimal propagation knowledge, participatory dialogue and culturally sensitive educational outreach can help demystify traditional taboos and encourage tree planting.

Importantly, the widespread reliance on seed propagation across all districts, despite its well-known constraints, may be attributed to its simplicity and local familiarity (Franzel *et al.,* 2008). Nevertheless, seed-based methods pose challenges such as dormancy and long juvenile phases, which likely contribute to the overall low propagation engagement observed across the study locations. For instance, *A. digitata* and *P. biglobosa* are known to reach flowering age only after 23 and 15 years, respectively (Diop *et al.,* 2005, Sambe *et al.,* 2010), making them less attractive to farmers. Low germination rates due to seed coat-imposed dormancy also serve as a major barrier to cultivation. *A. digitata* seeds, for instance, can exhibit germination rates as low as 20% without pretreatment (Danthu *et al*., 1995; Egbadzor & Akuaku, 2022). Similar challenges have been reported for *P. biglobosa* (Hall *et al.,* 1997) and oil-rich seed physiology in *L. microcarpa* further reduce success rates Neya *et al*., 2008).

The extremely low uptake of vegetative propagation techniques (1.0% grafting; 0.3% budding) indicates a substantial technical constraint rather than mere farmer reluctance.

Evidence from domestication research shows that vegetative propagation can offer clear advantages over seed-based systems for some of the studied species. For *A. digitata*, grafted trees have been reported to fruit within two years and maintain desirable traits such as high vitamin C content (Sidibé *et al*., 1996; Egbadzor & Akuaku, 2022). Similarly, clonal techniques such as root cuttings and air layering have been tested in *P. biglobosa* to address the variability and long juvenile phases associated with seed propagation (Lamien *et al*., 2011). *Lannea microcarpa*, vegetative propagation has shown limited rooting success in early trials (Loada, 2004; Sereme *et al*., 2008), while clonal multiplication of *Bombax costatum* through induced root suckering remains promising but not widely standardized (Belem *et al*., 2008). These mixed levels of technical maturity suggest that the low adoption observed in this study reflects both limited farmer capacity and the uneven development and dissemination of reliable propagation protocols. Strengthening adaptive research alongside participatory extension (Tchoundjeu *et al*., 2006; Leakey *et al*., 2005) is therefore critical to realizing the demonstrated benefits of clonal propagation.

Geographic variation in propagation knowledge emphasizes the value of culturally appropriate policies, participatory extension approaches, and conservation strategies that combine local beliefs, land tenure situations, and extension support with practical experience to enhance the adoption of native tree propagation across Ghana's savanna zones.

3.4.2 Knowledge of fruit maturity periods in the study locations

The results showed a significant difference in the perceived period of maturity for fruit of *Adansonia digitata*, *Parkia biglobosa*, *Lannea microcarpa*, and *Bombax costatum* across the study locations, as confirmed by Chi-square tests: *A. digitata* ($\chi^2 = 25.2$, $p < 0.001$), *P.*

biglobosa ($\chi^2 = 32.6$, $p < 0.001$), *L. microcarpa* ($\chi^2 = 28.7$, $p < 0.001$), and *B. costatum* ($\chi^2 = 30.5$, $p < 0.001$). These statistically significant differences suggest that community perceptions of fruit maturity are not uniform and likely reflect localized environmental, cultural, and observational factors. Such differences could also be due to soil type, as well as microclimates, which affect the flowering and fruiting cycles of native trees. This localized knowledge is critical for guiding effective seed collection, conservation planning, and domestication programs. Aligning propagation calendars with community observations of fruit maturity can enhance both seed harvest success and community involvement in conservation. This knowledge correlates with phenological data published for some species. For example, the observed peak in *A. digitata* fruit maturation during the first part of the dry season is consistent with previous observations that baobab fruits usually ripen in dry periods (Assogbadjo *et al.,* 2005).

Likewise, the reported maturity of *P. biglobosa* and *L. microcarpa* between April and June corresponds to the findings of Sina & Traoré (2002), who noted that these species tend to fruit during the transition from dry to rainy seasons. Sacande (2007) similarly documented that *L. microcarpa* fruits mature at the onset of the rainy season, reinforcing the validity of local knowledge as an essential complement to scientific understanding in propagation planning.

Contrastingly, with the other trees assessed, the fruiting period reported by the respondents on *B. costatum*, differed from established literature. Most informants perceived the fruit to ripen during January and March, in contrast to previous accounts where fruiting was recorded to occur between August and October for the West African region (Orwa *et al*., 2009; Oyen, 2011). This discrepancy may signify variations in land or disturbance history, environmental tolerances or genetic variability of local *B. costatum* populations. A number of studies have indicated that fire frequency, grazing intensity and drought stress can determine the reproductive phenology of native trees, including *B. costatum*. In particular, Belem *et al*., 2008 reported that *B. costatum* reallocates resources to vegetative growth (as opposed to reproduction) in response to root disruption and fire injury. *B. costatum* exhibits phenological plasticity, and local ecotypes of this species may have adapted to differing climatic triggers for flowering and fruiting. These observations were in agreement with those of Ouédraogo *et al.*, 2006, which noted that flowering and fruiting phenology of native tree populations varied substantially across ecological gradients due to long-term environmental pressures.

Despite that variability is observed in savanna trees, this study emphasized that further studies of ecophysiology and phenology are necessary to determine whether different local ecotypes truly exist. Such studies would be particularly valuable regarding intraspecific variation, and also the types would inform site-specific propagation and conservation activities. The observed differences in understanding of fruit maturity indicate that there is a need for policies and extension work to take community-based phenological knowledge into account in the site-specific propagation calendars, seed collection strategies and conservation planning to make the local relevance of native tree domestication more effective.

3.4.3 Influence of informant's age on knowledge of trees

The results of this study showed that age had a significant effect on the knowledge of propagation of *Parkia biglobosa* ($\chi^2 = 25.6$, $p < 0.01$) and the perception of the decline of population ($\chi^2 = 26.9$, $p < 0.01$) of *Adansonia digitata*. Notably, 35.3% of respondents aged

50–69 years reported experience in propagating *P. biglobosa*, while 93.4% of those aged over 70 identified *A. digitata* as declining in population. These quantitative trends indicate greater, more nuanced knowledge among older people concerning native tree propagation and ecological change. These findings support previous findings that traditional ecological knowledge increases with the age of respondents, particularly in situations where long periods of land use and observation of the environment are practiced. Ayantunde *et al*. (2008) have shown the importance of experience and its role in species diversity and ecological dynamics, while Brook and McLachlan, 2008 highlighted the role of elders in preserving biodiversity knowledge through long-term landscape interaction. The current findings confirm these patterns statistically and reinforce the importance of older generations in indigenous tree conservation and propagation practices.

In contrast, no significant age-related differences were observed for fruiting knowledge across all species studied, as confirmed by Chi-square results: *A. digitata* (χ^2 =12.4, $p > 0.05$), *P. biglobosa* ($\chi^2 = 6.3$, $p > 0.05$), *L. microcarpa* ($\chi^2 = 8.4$, $p > 0.05$), and *B. costatum* ($\chi^2 = 7.2$, $p > 0.05$). This suggests that phenological knowledge, such as fruiting periods, is communal and commonly shared by all age groups. Unlike propagation knowledge, fruiting is a highly visible and repeated event, observed by community members of all ages during harvesting, food preparation, or market participation. These trends suggest a strong correlation between age and the depth of traditional ecological knowledge, consistent with patterns observed in other ethnobotanical studies (Gouwakinnou *et al*., 2011; Lunelli *et al.*, 2016). The absence of age-related difference in propagation knowledge for *A. digitata, L. microcarpa*, and *B. costatum* may reflect technical constraints that limit active engagement with propagation tasks across all demographic groups. Seed dormancy, long juvenile periods, and limited execution of vegetative methods such as grafting may deter learning new skills, even in older populations. This can be explained by the quite low responses for grafting and budding, which accounted for 1.0% and 0.3%, respectively.

These patterns confirm that indigenous knowledge is domain-specific. While communal knowledge systems support widespread understanding of fruiting phenology, specialized knowledge such as tree propagation and long-term ecological trends to a greater extent concentrated among older adults with more prolonged engagement in farming and natural resource management. Identification and harnessing of this difference is necessary when developing age-appropriate education and extension approaches. Programs that actively engage older knowledge holders while encouraging intergenerational transmission can help strengthen conservation efforts and sustain local knowledge systems for native tree propagation.

Although our study emphasized age as the most important factor associated with traditional ecological knowledge, we also recognize that other demographic categories such as gender, education, and income may play a role in the acquisition and passing on of knowledge about propagation. For example, agroforestry and land management gendered division of labor might result in differentiated knowledge domains, while education influences external conservation messages (Howard, 2003, Lozada *et al.,* 2006). These were not quantitatively tested in this study in order to preserve analytic focus; however, future inquiries need to consider these variables to achieve a more intersectional understanding of indigenous ecological knowledge systems.

3.4.4 Knowledge on changes in tree population status

The study revealed widespread perception of declined native tree species, including particularly *Adansonia digitata, Parkia biglobosa, Lannea microcarpa,* and *Bombax costatum*. Those perceptions were corroborated statistically by significant Chi-square results indicating non-random variation in responses across locations: *A. digitata* ($\chi^2 = 61.7$, $p<0.000$), *P. biglobosa* ($\chi^2 = 44.5$, $p<0.000$), *L. microcarpa* ($\chi^2 = 75.9$, $p<0.000$), and *B. costatum* ($\chi^2 = 59.6$, $p<0.000$). These results reflect a consistent awareness of population decline, but also reveal site-specific differences in how communities perceive and experience these changes.

The widespread perception of declining populations of native tree species is consistent with ecological studies that document reduced natural regeneration across various landscapes. Informants' observations likely reflect real ecological trends, especially the limited recruitment of young individuals into mature populations, a key indicator of demographic decline. This pattern is well demonstrated by regional size-class distribution analyses of *A. digitata* across West African savanna systems, including Ghana, which show severe declines in sapling and juvenile trees, suggesting disrupted regeneration dynamics (Wickens & Lowe, 2008; Lykke *et al*., 2025). Similarly, reported population declines of *P. biglobosa*, *L. microcarpa*, and *B. costatum* align with findings by Sina (2006), Belem *et al*. (2008), and Ouédraogo *et al*. (2006). During field data collection, transect walks conducted across the study sites revealed very limited occurrence of saplings and juvenile individuals of these species, indicating weak natural recruitment and reinforcing both the regional ecological evidence and respondents' reported perceptions of population decline. These convergences between published ecological assessments, field observations, and indigenous knowledge underscore the value of integrating local and scientific evidence in evaluating long-term vegetation change.

The confirmed local perceptions of native tree decline emphasize the need for conservation actions, extension services and policies to integrate community ecological knowledge into forest monitoring, restoration planning, and sustainable regeneration strategies.

3.4.5 Constraints to seedling survival in study locations

The results reveal that livestock herbivory as the most significant constraint to seedling survival across all study locations, with an average of 42.0% of informants citing it as the primary cause of seedling mortality. This indicates strongly the popularity of free-range livestock management systems in the Guinean savanna agro-ecological zone. Animals are allowed to wander freely in such systems, increasing the likelihood of browsing and trampling of young seedlings. These uncontrolled interactions between livestock and young trees severely compromise early establishment of trees, especially in communal or unprotected landscapes. Similar constraints were reported in Uganda, where Nyamukuru (2015), identified livestock interference as a major barrier to successful tree planting, prompting farmers to prioritize protected homestead planting. In response to this challenge, farmers often choose to plant trees within homestead boundaries where protection can be assured, thereby limiting the spatial expansion of reforestation or agroforestry initiatives. Physical protection (e.g., fencing) is commonly identified as a key requirement for successful seedling establishment, but is often hindered by a lack of resources, such as cost and labor in rural communities.

Drought and bushfires were recorded as the second and third most common perceived limitations of young tree survival, and both are the most common stressors in the Guinean savanna zone. These limitations are particularly severe in areas of little or no irrigation, fire suppression, and land management. Similar results were obtained by Engelbrecht *et al*. (2005) and Odhiambo (2015), suggest that restricted water and fire management create a deficit of seedling survival and establishment by magnifying the effect of drought-induced stress and exposing juvenile, fire-sensitive trees to episodic recurrent devastating fires that interfere with natural germination and prevent the progress to maturity.

Mechanized land preparation, although cited by only 3.0% of the respondents, is an emerging factor in regions of agricultural intensification. The expansion of mechanized farming, often without integrated land-use planning, can lead to the destruction of seedlings during ploughing and harrowing activities. While this constraint is currently minimal compared to others, its importance may grow with increasing adoption of tractors and other machinery in smallholder systems.

In general, such results illustrate the intricate integration of natural and human pressures on tree seedling survival in the studied locations. Typical solutions involve a combination of physical defensive measures (fences, living hedges), better fire management, community-driven grazing management, and water-saving measures adapted to their context. In addition, dedicated developmental extension support focusing on early seedling care and community enlightenment on the protective roles of trees is important to improving the success of domestication and reforestation.

Recognition of the key constraints to seedling survival emphasizes the importance of policies for promoting protective infrastructure, extension strategies to promote local tree-care capacity, and conservation interventions to manage livestock pressure, fire risk, and climate stress in savanna landscapes.

3.5 Conclusion

The study highlights the intricate interplay of cultural, ecological, and demographic factors shaping native knowledge on indigenous tree propagation in northern Ghana.

Although seed propagation remains the most common method used, its shortcomings, such as dormancy and long juvenile phase of growth, make it necessary for propagators to acquire practical knowledge through vegetative propagation training. The findings also reveal that propagation knowledge is not uniform and is influenced by both geographic location and age, reflecting localized exposure to conservation efforts and generational knowledge transmission patterns.

More broadly, the study strengthens the role of indigenous knowledge about how localized ecological knowledge of local peoples plays a vital role in conserving biodiversity and helping to develop sustainable agroforestry. The loss of such knowledge, especially among the young, demands urgent measures both in intergenerational learning and integrate traditional practices into formal extension systems. Moreover, addressing socio-cultural constraints, such as spiritual taboos and land-use practices, is essential for the successful domestication of native species.

Essentially, these findings highlight the need for integrating indigenous knowledge into restoration programs, especially community-based insights on optimal fruiting periods for seed collection and seed sowing based on rainfall onset, promoting technical training in vegetative propagation in local communities, and strengthening seedling protection strategies. Doing so can enhance the sustainability of native tree domestication and improve the cultural relevance and ecological success of afforestation efforts in the Guinean savanna zone.

CHAPTER FOUR

EFFECT OF PRETREATMENT AND ITS DURATION ON GERMINATION AND EARLY GROWTH OF *Adansonia digitata* SEEDS FROM THREE LOCATIONS IN GHANA

Abstract

The baobab (*Adansonia digitata*) is an important indigenous species that provides significant socio-economic and ecological benefits across sub-Saharan Africa. Despite its importance, its natural regeneration is poor, mainly due to seed coat-imposed dormancy, resulting in low germination rates under natural conditions. This study investigated the impact of different pretreatment methods, soaking durations and seed provenance on the germination and early growth performance of *A. digitata.* Seeds obtained from Kassena-Nankana, Kumbungu, and Nandom agro-climatic locations in Ghana, were subjected to four pretreatment methods: scarification, and varying soaking durations for acid, hot water, and ambient-water pretreatment methods. Results indicated that both germination percentage and rate were significantly influenced by pretreatment method ($p < 0.001$), with scarification achieving the highest percentage germination (90.0%), seed rate (1.9) and fastest emergence (within 7 days after sowing). Cold-water soaking for 48 hours appeared as the most effective duration-based treatment, producing a 60.0% germination, 1.0 seed rate and early emergence (8 days). In contrast, hot water and acid treatments resulted in significantly lower germination performance. Seed provenance also significantly affected germination outcomes ($p < 0.01$), with seeds from Kassena-Nankana showing the highest germination percentage (54.6%). Also, pretreatment significantly improved seedling

development parameters such as height, stem girth, and leaf number, indicating that its benefits are not only limited to the germination phase but are also extended to early stages of seedling establishment. These findings offer useful information for the improvement of propagation procedures of *A. digitata*, with important implications for its conservation, domestication, and integration into agroforestry systems.

Keywords: Pretreatment, scarification, conservation, germination, *Adansonia digitata*.

4.1 Introduction

The baobab (*Adansonia digitata*) is among the most popular and ecologically valuable indigenous fruit tree species in sub-Saharan Africa, largely recognized for its high socio-economic and nutritional importance (Sidibé & Williams, 2002; Wiehle *et al*., 2014). Apart from being used as a food source, the fruit pulp, seeds, and leaves of *A. digitata* provide a wide range of non-food products, including medicinal compounds, fibers, oils, tannins, and fodder (Gebauer *et al*., 2016). These multifunctional products are locally and internationally traded and play a significant role in household incomes and rural economies (Chládová *et al*., 2019; Lykke *et al*., 2021).

Despite its value, *A. digitata* has limited natural regeneration in all parts of its natural range within Africa (Venter & Witkowski, 2010; Chirwa *et al*., 2006; Lykke *et al*., 2025). Seed dormancy, caused essentially by a hard, impermeable seed coat, is a major limitation, leading to prolonged germination time and low germination percentages, often below 20% in the absence of pretreatment (Danthu *et al*., 1995; Egbadzor, 2020). The impermeable testa prevents adequate water and oxygen uptake, thereby inhibiting germination (Lennart *et al*., 2021). In natural environments, the seed dormancy of various plants is usually broken by their passage into the digestive tracts of large herbivores, or through insects, such as cotton stainers, that feed on the seed coat, thus damaging the seed coat and aiding in seed germination (Gruenwald & Galizia, 2005; SCUC, 2006).

Seed pretreatments are necessary for increasing germination rates by allowing water and gas to enter the hard-coated seed before planting (Gebauer *et al*., 2002). Several dormancy-breaking treatments, such as cold and hot water soaking, acid, and mechanical scarification, have been applied, each treatment being species and seed morphology-specific and with different levels of efficiency (Baskin *et al*., 2000; Sidibé & Williams, 2002; Kumar *et al*., 2015a, 2015b).

In addition to pretreatment, seed provenance plays a pivotal role in determining germination capacity and early seedling vigor. Factors such as genetic variability, ecological adaptation, temperature, and rainfall seasonality significantly influence seed performance and the suitability of source material for domestication and reforestation programs (Ndong *et al*., 2024; Sanchez *et al*., 2010; Azad *et al*., 2013). Although the effects of individual pretreatment methods on baobab seed germination have been previously reported (Usman & Asan, 2017; Abubakar *et al*., 2023), the combined effects of pretreatment method, duration, and seed source on both germination and early growth are not well documented.

It is thus the objective of this study: (i) to investigate the effects of various pretreatment methods on seed germination and early seedling growth of *A. digitata*, and

(ii) to assess the influence of pretreatments on seeds from three different locations within the guinea savanna agro-ecological zone in Ghana.

4.2 Materials and Methods

4.2.1 Study sites and seed collection

Seeds of *A. digitata* were collected during the dry season (December 2022–January 2023) from mature, phenotypically superior trees located in three locations in the guinea savanna agro-climatic zone of Ghana. These included: Kassena-Nankana Municipality (10°59′N, 1°05′W), characterized by an average annual rainfall of approximately 950 mm and temperature ranges between 18°C and 42°C; Kumbungu District (9°32′N, 1°02′W), with temperatures fluctuating between 15°C and 42°C and an average rainfall of about 1000 mm; and Nandom Municipality (10°57′N, 2°26′W), which experiences temperatures ranging from 23°C to 42°C and receives approximately 950 mm of rainfall annually (GSS, 2014).

The experiment was carried out at the nursery site of the West African Centre for Water, Irrigation, and Sustainable Agriculture (WACWISA), located at the University for Development Studies, Nyankpala (9°23.7'N, 0°31.8'W). The site experiences a unimodal rainfall pattern with an annual mean precipitation of approximately 1000 mm, with temperature ranges between 20°C and 42°C (GSS, 2014; SARI, 2016).

4.2.2 Study species

A. digitata is a highly resistant and long-lived tree species of the African savanna, with heights of up to 25 m and a lifespan of several hundreds of years (Wickens & Lowe, 2008; Rahul *et al*., 2015). It thrives in hot, arid climatic conditions and is commonly found at low altitudes, usually growing as solitary individuals, though occasionally it grows in groups, depending on soil texture and ground topography (Salim *et al*., 2012). The fruits are big, oval, non-splitting and hard-shelled hanging from long peduncles. The interior contains dry, powdery pulp and fibrous matter surrounding the seeds, which are kidney-shaped and dark brown to black (Asogwa *et al*., 2020; Hankey, 2004; Sacande *et al*., 2006).

4.2.3 Seed extraction and experimental design

Five mature fruits were collected from each of five randomly chosen phenotypically healthy *A. digitata* trees per location, yielding a total of 25 fruits per site. After seed removal, all seeds from each location were pooled to adequately represent the local population. Seeds were soaked in distilled water for six hours to facilitate the removal of non-viable material; floating seeds were discarded, and only sunken, viable seeds were retained (Sacande *et al*., 2006). The selected seeds were then rinsed and air-dried under ambient conditions for 48 hours prior to pretreatment.

Three hundred and thirty seeds from each of the three locations were used (n=990). The experiment employed a Randomized Complete Block Design (RCBD) with five treatment groups:

Figure 4.1. Pictural arrangement of experiment

T0 (Control): Untreated seeds (90 seeds).

T1 (Scarification): Manual scarification with sandpaper (90 seeds).

T2 (Acid treatment): Soaking in 50% H_2SO_4 for 5, 10, and 15 minutes (270 seeds in total).

T3 (Hot water treatment): Soaking in 100°C water for 5, 10, and 15 minutes (270 seeds in total).

T4 (Cold water treatment): Soaking in room-temperature water (25–30°C) for 12, 24, and 48 hours (270 seeds in total).

Each duration group was proportionally assigned across seed sources and replicates.

4.2.4 Data collection and analysis

Seed germination was monitored every three days for eight weeks after sowing. Germination percentage, average daily germination, and days until first emergence were recorded. The number of leaves, plant height, and stem girth were measured from week 4 to week 10 using a measuring tape and vernier caliper.

Data were analyzed using Analysis of Variance (ANOVA) in Genstat version 16 to test the main and interaction effects of treatment and location. Post hoc comparisons were performed using Tukey's Honest Significant Difference (HSD) test at $p < 0.05$. Q–Q plots were inspected to assess normality of residuals, and Levene's test was employed to evaluate the homogeneity of variances.

4.3 Results

4.3.1 Effects of pretreatment on germination of seeds

Pretreatment methods significantly influenced the germination percentage of *Adansonia digitata* seeds ($F = 17.29$, $p < 0.001$). Seeds subjected to scarification recorded the highest germination percentage (90.0%), while those treated with hot water (averaged across all durations) exhibited the lowest germination (28.9%) (Figure 4.2).

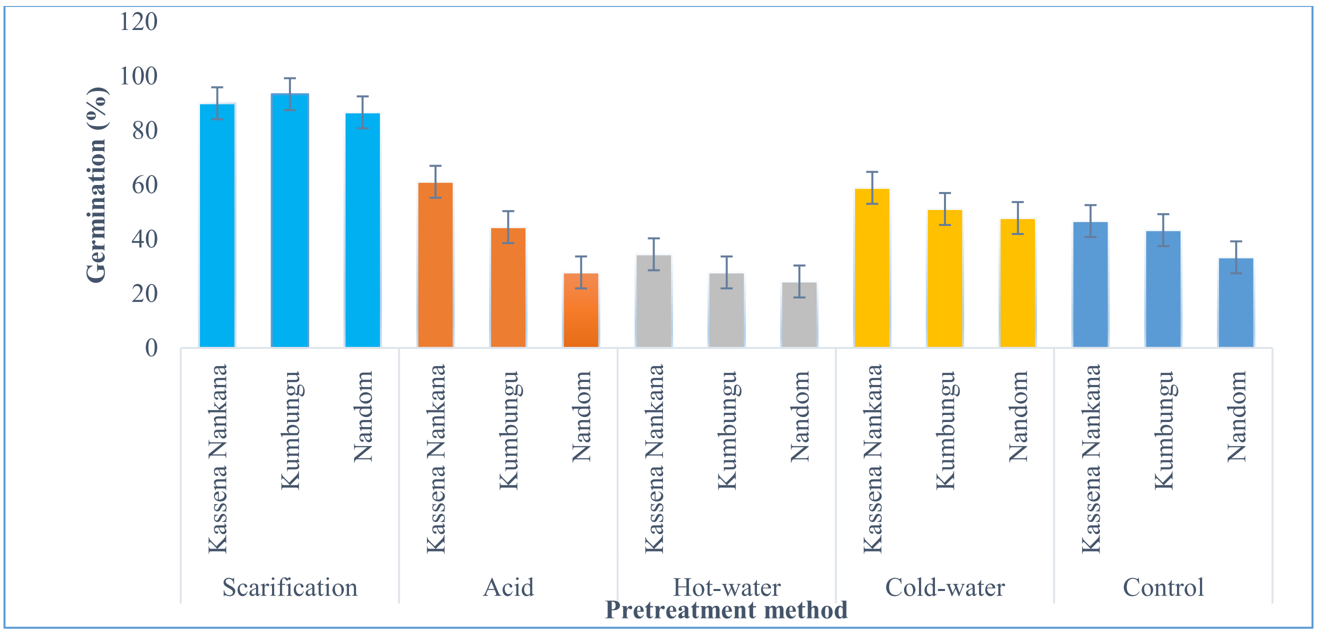

Figure 4.2. Effect of pretreatment method on germination percentage of seed

4.3.2 Effects of pretreatment on germination rate and growth of seedling

Pretreatment method also significantly affected the rate of germination ($F = 29.02$, $p < 0.001$). Scarified seeds had the highest germination rate (1.9 seeds per day), whereas seeds treated with hot water showed the lowest rate (0.3 seeds per day) (Figure 3a). Growth performance, measured over the 4–10 week period after germination, was significantly influenced by the pretreatment method. Scarification resulted in the greatest seedling height, number of leaves, and stem girth, while hot water treatment consistently produced the lowest values across all three parameters: Number of leaves: F = 8.52, $p < 0.001$, Height: F = 12.59, $p < 0.001$ and Girth: F = 18.30, $p < 0.001$ (Figure 3b, c & d). Seed origin did not significantly influence seedling growth in terms of leaf number, height, or girth.

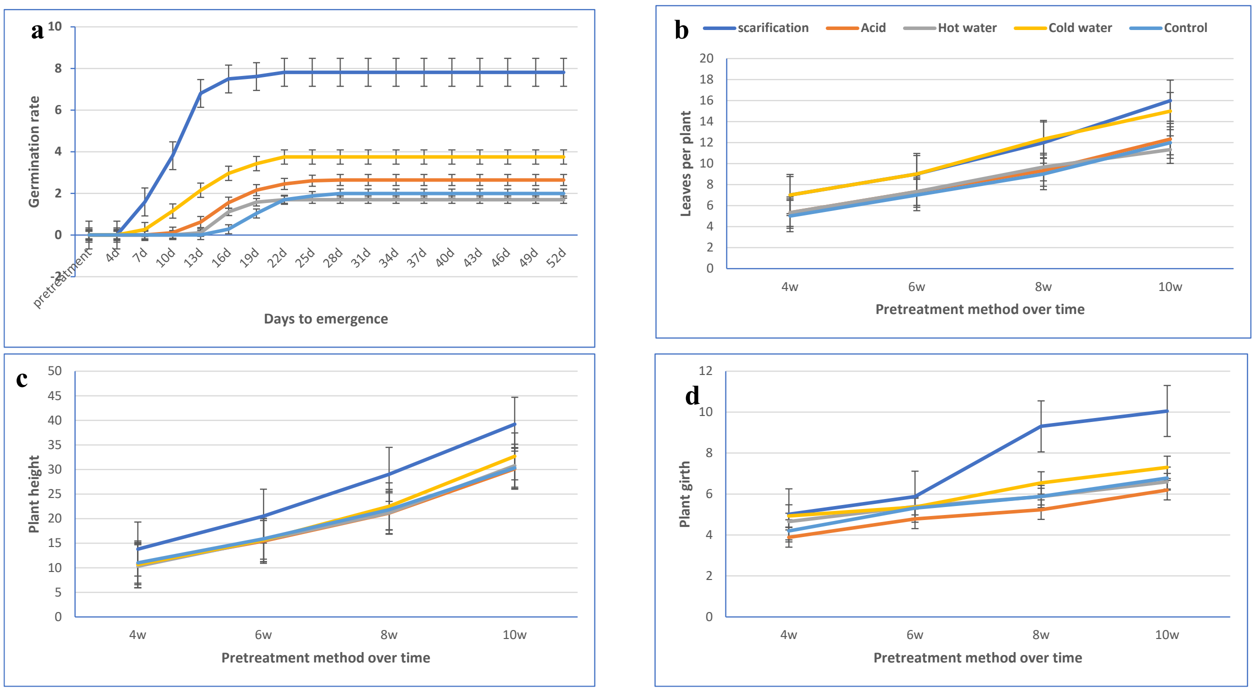

Figure 4.3. Effect of pretreatment method on germination rate (a) and growth parameters (b, c & d).

4.3.3 Effect of pretreatment duration on germination and growth

Pretreatment duration significantly affected both germination percentage and germination rate (F = 17.21, $p < 0.001$). Within the cold-water treatments, soaking duration influenced germination performance, with 48 hours yielding the highest germination percentage (60.0%) and germination rate (1.03 seeds/day), while 12 hours produced the lowest values. In contrast, varying exposure time within the acid treatments (5, 10, and 15 minutes) did not significantly influence germination percentage or germination rate, although 10 minutes recorded the highest germination percentage within this group. Similarly, hot water duration did not significantly affect germination performance, with 5 minutes yielding the highest germination percentage (35.6%). When the best-performing duration from each pretreatment category was considered, cold water soaking for 48 hours demonstrated superior performance relative to other treatments durations (Table 4.1).

Table 4.1: Effects of pretreatment durations on germination percentage, germination rate, and time to emergence in *A. digitata*.

Pretreatment	**Duration**	**Germination (%)**	**Germination Rate (seeds/day)**	**Days to Emergence**
Scarification	—	**90.0**	**1.90**	**7**
Acid	5 min	41.1^{ab}	0.48^{bc}	12^{ab}
	10 min	54.5^{ab}	0.41^{bc}	14^{b}
	15 min	41.1^{ab}	0.45^{bc}	13^{ab}
Hot Water	5 min	35.6^{ab}	0.40^{bc}	15^{b}
	10 min	27.8^{ab}	0.28^{c}	15^{b}
	15 min	23.3^{b}	0.29^{c}	16^{b}
Cold Water	12 hours	44.4^{ab}	0.44^{bc}	14^{b}
	24 hours	53.3^{ab}	0.68^{b}	11^{ab}
	48 hours	$\mathbf{60.0^{a}}$	$\mathbf{1.03^{a}}$	$\mathbf{8^{a}}$
Control	—	41.1	0.29	17

Note: Means in the same column with different superscript letters differ significantly at $p < 0.05$

4.3.4 Effect of Seed Location on Germination Success

Seed location significantly influenced the germination percentage of *Adansonia digitata* ($F = 7.5$, $p < 0.003$). Seeds sourced from the Kassena-Nankana Municipality exhibited the highest germination percentage (54.6%), while those from the Nandom Municipality recorded the lowest germination rate (39.1%). This variation suggests potential differences in seed viability or dormancy depth attributable to environmental or genetic factors specific to each location (Figure 4.4).

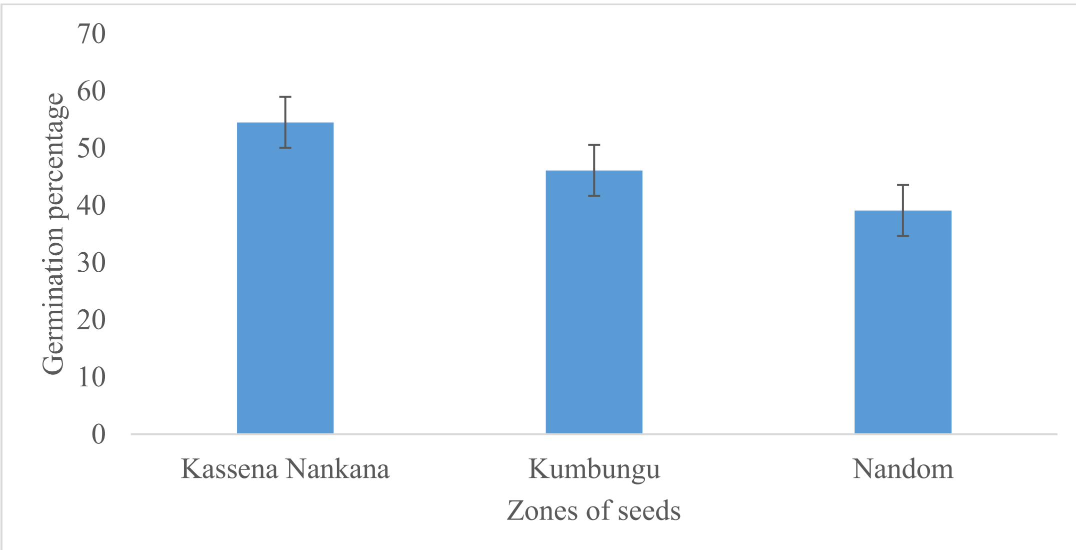

Figure 4.4. Effect of seed origin on germination percentage of *Adansonia digitata*

4.4 Discussion

The germination percentage and rate of *A. digitata* seeds were significantly influenced by the type of pretreatment applied, likely due to the removal or softening of the hard seed coat, allowing unhindered uptake of water and exchange of gases (Azad *et al*., 2010). Among the methods tested, scarification was the most efficient method that resulted in the highest germination response. These results are in agreement with earlier reports on hard-seeded tropical species such as *Acacia polyacantha* and *Pouteria campechiana*, where scarification also yielded superior germination performance (Missanjo *et al*., 2014; Amoakoh *et al*., 2017).

Soaking seeds for 48 hours in cold water showed the highest improvement in germination percentage, rate and emergence as compared to other pretreatment durations. This enhanced performance is likely due to the ability of cold water to gradually soften the hard seed coat, thereby increasing its permeability and facilitating imbibition (Baatuuwie *et al*., 2019). Enhanced permeability facilitates effective gaseous exchange and enzymatic hydrolysis, both of which are vital processes for embryo activation and further seedling growth (Olatunji *et al*., 2013). These findings align with those reported for *Detarium microcarpum*, where cold water pretreatment also significantly enhanced germination (Baatuuwie *et al*., 2019).

On the other hand, acid and hot water treatment failed to create a positive impact on germination performance in the present investigation. This may be attributed to physiological damage to seed tissues, particularly when pretreatment durations are prolonged. Singh *et al*. (2019) observed that hot water treatments can be detrimental to enzymatic processes essential for germination, while Amosa (2011) reported that excessive exposure to high temperatures can kill the cotyledons. This result is in contrast with the work of Niang *et al*. (2015), who reported acid pretreatment to be effective for baobab seeds in Senegal. These differences could be the result of differences in acid concentration, the duration of the soaking period, or differences in the source of the seed and status of the physiological level at the time of treatment.

The site of seed collection had a highly significant effect on germination percentage, suggesting that genetic or environmental variation within provenances might influence the dormancy-breaking response. Seeds collected from Kassena-Nankana had greater germination ability than those from other collection sites, indicating seeds from different climatic regimes might have intrinsic dormancy differences, such as acclimation to a higher diurnal temperature range or drier environment. Environmental factors such as rainfall, temperature extremes, and edaphic conditions at the source site could influence seed coat thickness, permeability, or internal moisture content (Loha *et al*., 2006; Gosh & Singh, 2011).

In addition to the effect of pretreatments on germination, the methods significantly affected seedling growth, especially plant height, number of leaves, and stem girth. Scarified seeds consistently produced the most vigorous seedlings, while those subjected to hot water treatment demonstrated reduced performance across all measured growth parameters. These findings indicate that the advantages of pretreatment are not limited to seed activation but also to seedling establishment. Increased seedling vigor is important in arid or semi-arid areas, where early growth can influence survival under moisture and nutrient stress. The positive influence of pretreatment on seedling development aligns with findings by El-Bably & Rashed (2018), who reported enhanced growth performance in *A. digitata* seedlings following effective dormancy-breaking treatments. This underscores the prospect of pretreatment not only as a trigger for increasing germination efficiency but also as a feasible approach to boost early seedling vigor, which is a fundamental requirement for the success of domestication and afforestation programs for *A. digitata*.

4.5 Conclusion

This study demonstrated that seed pretreatment methods, particularly scarification and prolonged cold-water soaking, significantly enhance the germination and early growth performance of *Adansonia digitata*. Scarification achieved the highest germination percentage (90%) and the fastest emergence, while cold-water soaking for 48 hours emerged as the most effective duration-based treatment. In contrast, hot water and acid treatments were largely ineffective, likely due to seed tissue damage.

Furthermore, seed origin resulted in significant germination success; seeds from Kassena-Nankana Municipality germinated much better in respect to Kumbungu and Nandom, implying potential hereditary or environmental adaptations. Pretreatments also significantly improved early seedling vigor as evidenced by increases in height, stem girth, and leaf number. These findings provide simple, low-cost, practical propagation strategies that can enhance the domestication, conservation, and reforestation potential of *A. digitata*, an important African tree in the savanna. Implementing these protocols can support restoration programs and agroforestry initiatives aimed at improving food security, biodiversity, and climate resilience in dryland ecosystems.

CHAPTER FIVE

EFFECT OF PRETREATMENT AND DURATION ON GERMINATION AND GROWTH OF THREE VALUABLE NATIVE TREE SPECIES FROM GHANA

Abstract

Limited seed germination remains a key barrier to the propagation and domestication of economically important native tree species in northern Ghana. This study evaluated the effects of various pretreatment methods, scarification, and different soaking durations for acid, hot water, and cold-water pretreatments on the germination and early growth performance of *Parkia biglobosa, Lannea macrocarpa* and *Bombax costatum* seeds under nursery conditions. Germination response differed significantly among treatment types and durations. Mechanical scarification produced the highest germination and growth performance in *P. biglobosa* (84.4%) and *L. microcarpa* (51.1%). In contrast, *B. costatum* responded more favorably to hot water treatment, achieving a maximum germination of 58.5%. Seed provenance also contributed to variation in performance, with materials sourced from Kassena-Nankana recording superior germination (63.0%) relative to other locations. Duration effects were species-dependent: acid soaking for 10 minutes was most effective for *P. biglobosa* (74.4%), cold water soaking for 6 hours enhanced *L. microcarpa* (45.6%), and hot water exposure for 5 minutes improved *B. costatum* (61.1%). Overall, the findings demonstrate that seed treatment protocols must be optimized according to species characteristics and seed origin to maximize propagation success. The results provide practical guidance for nursery management, domestication programs, and restoration

initiatives aimed at strengthening sustainable agroforestry systems in the Guinean savanna zone.

Keywords: Native trees, seed dormancy, pretreatment, germination, domestication

5.1 Introduction

Native tree species have long supported rural communities in sub-Saharan Africa by providing essential livelihood resources such as food, medicine, timber, and materials of cultural and spiritual significance (Larwanou *et al*., 2010; Haarmeyer *et al.*, 2013; Goudegnon *et al*., 2016). These species play a crucial role in ecosystem functioning by enhancing nutrient cycling, improving soil fertility, and promoting biodiversity. Their integration into agroforestry systems further strengthens their utility, particularly in semi-arid environments where they provide shade, wind protection, and microclimate stabilization (Sinsin & Kampmann, 2010).

In northern Ghana, *Parkia biglobosa*, *Lannea microcarpa*, *Bombax costatum*, and *Adansonia digitata* are among the most valued native species. *P. biglobosa* is widely recognized as a key species in parkland agroforestry systems and serves as an economically important multipurpose tree across West Africa (Sacande & Clethero, 2007). Likewise*, L. microcarpa* is a common agroforestry species that plays a vital role in food security and provides multiple resources including timber, firewood, fodder, medicinal products, dyes, and soil fertility enhancement (Maroyi, 2018). *B. costatum* has been identified as the most preferred species for food crop association and is also culturally significant due to its use in religious practices in Ghana (Owusu-Sekyere, 1999). Collectively, these species contribute to carbon sequestration, biodiversity conservation, and climate resilience (Gbadamosi, 2005; Oyen, 2011; Mbayngone & Thiombiano, 2011; Sanogo *et al*., 2023).

Despite their value, these species are often neglected in conservation initiatives (Hawthorne & Jongkind, 2006; Lemmens *et al*., 2008; Awoyemi *et al*., 2024). Consequently, their populations are declining due to deforestation, land use change, and poor natural regeneration. Reports have documented the depletion of existing stands of *P. biglobosa*, *L. microcarpa*, and *B. costatum* in many parts of West Africa (Dotchamou *et al*., 2016; Haarmeyer *et al*., 2013; Belem *et al*., 2008). A major bottleneck to regeneration is seed dormancy, which delays or prevents germination, thereby hindering propagation and natural recruitment (Falemara *et al*., 2014; Hall *et al.,* 1997; Abubakar *et al*., 2023).

Seed dormancy, often due to hard seed coats, has been widely recognized as a limiting factor in the propagation of tropical trees (Neya *et al*., 2008). In natural ecosystems, dormancy is sometimes overcome by environmental fluctuations, fire exposure, or passage through animal digestive tracts (Baskin & Baskin, 1998). However, under nursery conditions, dormancy-breaking treatments such as mechanical scarification, acid soaking, hot water, and cold water have proven effective in enhancing germination (Baskin et al., 2000; Sidibé & Williams, 2002). The effectiveness of these pretreatments is highly species-specific and can vary based on seed physiology and environmental conditions (Ren & Tao, 2004).

Although seed dormancy of *P. biglobosa* is well studied, far less is known about the germination ecology and pre-treatment responses of *L. microcarpa* and *B. costatum*, especially under open nursery conditions often experienced in rural agroforestry. While deep physiological dormancy may not be expressed by *L. microcarpa* and *B. costatum,* erratic or generally poor germination in practice stresses the importance of examining both the method and duration of pretreatment options in these species. Therefore, to support the domestication of these valuable native tree species through seed propagation, it is important to understand the germination and growth responses of their seeds to different pretreatment methods over varying durations.

This study therefore, aimed to evaluate the effects of various pretreatment methods and durations on seed germination and seedling growth of three valuable native trees. The specific objectives were to: (i) assess the effect of different pretreatment methods on seed germination and growth performance; and (ii) evaluate the influence of pretreatment durations under uncontrolled nursery conditions.

5.2 Materials and Methods

5.2.1 Study sites and seed collection

Seeds of *P. biglobosa*, *L. microcarpa*, and *B. costatum* were sampled and collected from phenotypically superior mother trees with characteristics including healthy and well-developed canopy structure, high fruit productivity and absence of visible pest and diseases symptoms and well-formed fruits, from January to May 2023 in three agro-ecological locations in the Guinean savanna zone of Ghana. These included: Kassena-Nankana Municipality (10°59′N, 1°05′W), characterized by an average annual rainfall of approximately 950 mm and temperature ranges between 18°C and 42°C; Kumbungu District (9°32′N, 1°02′W), with temperatures fluctuating between 15°C and 42°C and an average rainfall of about 1000 mm; and Nandom Municipality (10°57′N, 2°26′W), which experiences temperatures ranging from 23°C to 42°C and receives approximately 950 mm of rainfall annually (GSS, 2014).

The experiment was conducted at the nursery of the West African Centre for Water, Irrigation, and Sustainable Agriculture (WACWISA), inside the University for Development Studies, Nyankpala (9°23.7'N, 0°31.8'W). The site experiences a monomodal rainfall pattern with a mean annual rainfall of approximately 1000 mm, with temperature ranges between 20°C and 42°C (GSS, 2014; SARI, 2016).

5.2.2 Study species

P. biglobosa is a perennial deciduous tree that can grow up to 20 m in height, with a broad crown. It bears indehiscent pods with yellow pulp and globose-ovoid seeds (Sina & Traoré, 2002; Orwa *et al*., 2009). *L. microcarpa* is a deciduous tree that grows to approximately 16 m in height. Its fruits are one-seeded ellipsoid drupes that transition from green to black-purple when ripe. The seeds contain high oil content, causing rapid viability loss and lower germination rates (Neya, 2006; Marquet & Jansen, 2005). *B. costatum* produces ellipsoidal brown capsules that split open to release several small, light seeds enveloped in white floss. Most fruit dehisces on the tree with wind and gravity contributing to the dissemination of seed (Oyen, 2011; Assogba *et al*., 2018; Orwa *et al*., 2009).

5.2.3 Seed extraction and experimental design

Ripe fruits of the three species were harvested from each of five randomly selected, healthy phenological trees per location. Seeds were extracted and pooled to achieve a representative sample of the local population and pre-sorted by immersing them in distilled water for six hours to standardize hydration conditions and avoid mineral interference during flotation testing. In practical applications, clean potable water may be used for this purpose. Non-viable seeds (empty, immature, or damaged) floated and were separated from the viable seeds that sank and were retained (Sacande *et al*., 2006). Potential seeds were washed and air-dried. In total, 2970 seeds were used (990 seeds/species). The experiment was laid out in Randomized Complete Block Design (RCBD). Five treatment groups were established with three replicates.

T0: Control (no pretreatment), 90 seeds per species.

T1: Mechanical scarification using sandpaper, 90 seeds per species (30 seeds per location).

T2: Acid soaking in 50% sulfuric acid (H_2SO_4), 270 seeds per species (90 per location), with soaking durations of 2, 5, and 10 minutes.

T3: Hot water treatment at 100°C, 270 seeds per species (90 per location), with durations of 2, 5, and 10 minutes.

T4: Cold water soaking at room temperature, 270 seeds per species (90 per location), with durations of 6, 12, and 24 hours.

Each treatment group included seeds from all three locations (Kassena-Nankana, Kumbungu, and Nandom) to assess potential site-based variation.

5.2.4 Data Collection and Analysis

At the end of the experiment, germination percentage, germination time, number of leaves per seedling, height, and girth were recorded as response variables. Pretreatment method, duration (which was relevant for acid, hot water, and cold-water pretreatments), and location were employed as predictor variables. Germination percentage was calculated as the total number of seeds germinated out of the total sown multiplied by a hundred. Germination was recorded at three-day intervals until 45 days after sowing. The number of leaves was counted per seedling, and averages were taken. A measuring tape and a vernier caliper were used to measure plant height and girth, respectively, from the 4^{th} week to the 10^{th} week.

Data were analyzed by analysis of variance (ANOVA) and tested for differences between pretreatment and control using Genstat 16. ANOVAs were conducted for each group, with a post hoc Tukey's test on the crude values for pretreatment methods and for location. Normality of the residuals was examined by Q-Q scatterplot and homogeneity of the variances was examined by Levene's test.

5.3 Results

5.3.1 Pretreatment effects on *Parkia biglobosa* germinations

Pretreatment method significantly influenced the germination percentage of *P. biglobosa* ($F(4, 28) = 3.37$, $p < 0.023$). Seeds subjected to scarification recorded the highest germination percentage (84.4%), while hot water treatment yielded the lowest (52.6%). Pretreatment duration also had a significant effect on germination success ($F(10, 22) = 4.64$, $p < 0.001$). Among the durations tested, acid soaking for 10 minutes resulted in the highest germination percentage (74.4%), while a 5-minute acid soak yielded the lowest (38.9%).

Pretreatment methods significantly influenced seedling height ($F(10, 22) = 3.42$, $p < 0.009$) and stem girth ($F(10, 22) = 2.48$, $p < 0.040$). Scarification-treated seedlings consistently exhibited superior performance across both parameters. However, the number of leaves per seedling was not significantly affected by the pretreatment methods. Notably, the location of seed origin did not significantly influence germination percentage (Table 5.1).

Table 5.1: Effects of pretreatment duration on germination and early growth of *Parkia biglobosa.*

Pretreatment	**Duration**	**Germination (%)**	**Days to Emergence**	**No of Leaves**	**Height (cm)**	**Girth (mm)**
Scarification	—	**84.44**	7	13	**25.6**	**8.353**
Acid	2 mins	70.00^{ab}	11^{abcd}	12	21.7^{ab}	7.277^{ab}
	5 mins	38.89^{c}	8^{ab}	12	18.1^{b}	6.103^{b}
	10 mins	74.44^{ab}	11^{abcd}	11	20.7^{ab}	6.693^{ab}
Hot water	2 mins	54.44^{abc}	11^{abcd}	12	20.7^{ab}	7.170^{ab}
	5 mins	50.00^{bc}	12^{cd}	12	21.7^{ab}	7.533^{ab}
	10 mins	53.33^{abc}	14^{d}	12	23.0^{ab}	7.737^{ab}
Cold water	6 hours	50.00^{bc}	11^{abcd}	13	22.3^{ab}	7.540^{ab}
	12 hours	60.00^{abc}	8^{ab}	12	23.5^{a}	8.063^{ab}
	24 hours	65.56^{abc}	9^{abc}	12	23.2^{ab}	7.963^{ab}
Control	—	52.22	14	12	21.3	7.333

Note: Superscript letters indicate significant differences based on Tukey's test at $\alpha = 0.05$.

5.3.2 Pretreatment effect on the germination and initial growth of *Lannea macrocarpa* seeds

The germination percentage of *L. microcarpa* was significantly influenced by pretreatment method ($F(4, 28) = 19.40$, $p < 0.001$), with scarification producing the highest germination (51.1%) and acid treatment the lowest (11.1%). Duration also significantly influenced germination ($F(10, 22) = 13.89$, $p < 0.001$). The best result was obtained from cold water soaking for 6 hours (45.6%), whereas acid treatment for 2 minutes gave the lowest (6.7%). Pretreatment method significantly affected seedling height ($F(4, 28) = 3.21$, $p < 0.011$) and girth ($F(4, 28) = 3.43$, $p < 0.008$), with scarification again producing the most vigorous seedlings. Seed origin had no significant effect on germination or seedling performance (Table 5.2).

Table 5.2: Effects of pretreatment duration on germination and initial growth of *Lannea microcarpa*

Pretreatment	Duration	Germination (%)	Days to Emergence	No of Leaves	Height (cm)	Girth (mm)
Scarification	—	**51.11**	11	14	**30.3**	**5.010**
Acid	2 mins	17.78^{bc}	15^{e}	10	26.0^{b}	4.743^{b}
	5 mins	6.67^{c}	13^{cd}	9	26.7^{ab}	4.817^{ab}
	10 mins	8.89^{c}	12^{bc}	9	27.0^{ab}	4.883^{ab}
Hot water	2 mins	37.78^{ab}	12^{bc}	12	28.0^{ab}	4.943^{ab}
	5 mins	18.89^{bc}	12^{bc}	10	27.0^{ab}	4.850^{ab}
	10 mins	16.67^{bc}	14^{de}	8	25.3^{b}	4.700^{b}
Cold water	6 hours	45.56^{a}	10^{a}	11	25.3^{b}	4.737^{b}
	12 hours	34.44^{ab}	11^{ab}	11	27.0^{ab}	4.873^{ab}
	24 hours	43.33^{a}	10^{a}	11	27.3^{ab}	4.860^{ab}
Control	—	48.89	12	13	28.7	4.957

Note: Superscript letters indicate significant differences based on Tukey's test at $\alpha = 0.05$.

5.3.3 Effect of pretreatment on germination and initial growth of *Bombax costatum* seeds

Pretreatment method significantly affected the germination of *B. costatum* ($F(4, 28) = 3.65$, $p < 0.017$), with hot water treatment yielding the highest germination percentage (58.5%), and cold water the lowest (37.8%). Pretreatment duration also had a significant effect ($F(10, 22) = 4.34$, $p < 0.003$). Soaking in hot water for 5 minutes resulted in the highest germination (61.1%), while soaking in cold water for 24 hours gave the lowest (20.0%).

There were also variations in days to emergence and initial seedling growth across treatments (Table 5.3).

Table 5.3: Effects of pretreatment duration on germination and initial growth of *Bombax costatum*

Pretreatment	Duration	Germination (%)	Days to Emergence	No of Leaves	Height (cm)	Girth (mm)
Scarification	—	40.00	9	26	20.7	7.037
Acid	2 mins	31.11^{ab}	15	26	20.4	7.073
	5 mins	44.44^{ab}	14	23	21.0	7.067
	10 mins	56.67^{a}	14	24	21.6	6.987
Hot water	2 mins	56.67^{a}	14	24	23.4	7.023
	5 mins	**61.11^{a}**	14	23	22.3	7.000
	10 mins	57.78^{a}	13	23	23.0	**8.053**
Cold water	6 hours	43.33^{ab}	12	23	21.4	7.990
	12 hours	50.00^{ab}	11	23	21.2	7.637
	24 hours	**20.00^{b}**	14	24	21.2	7.697
Control	—	31.11	17	23	20.4	7.647

Note: Superscript letters indicate significant differences based on Tukey's test at $\alpha = 0.05$.

5.3.4 Effect of seed location on germination success of *Bombax costatum*

Seed location significantly influenced the germination success of *B. costatum* ($F(2, 30) = 11.17$, $p < 0.001$). Seeds collected from the Kassena-Nankana location exhibited the highest germination percentage (63.03%), while those from Nandom recorded the lowest (32.42%) (Figure 5.1).

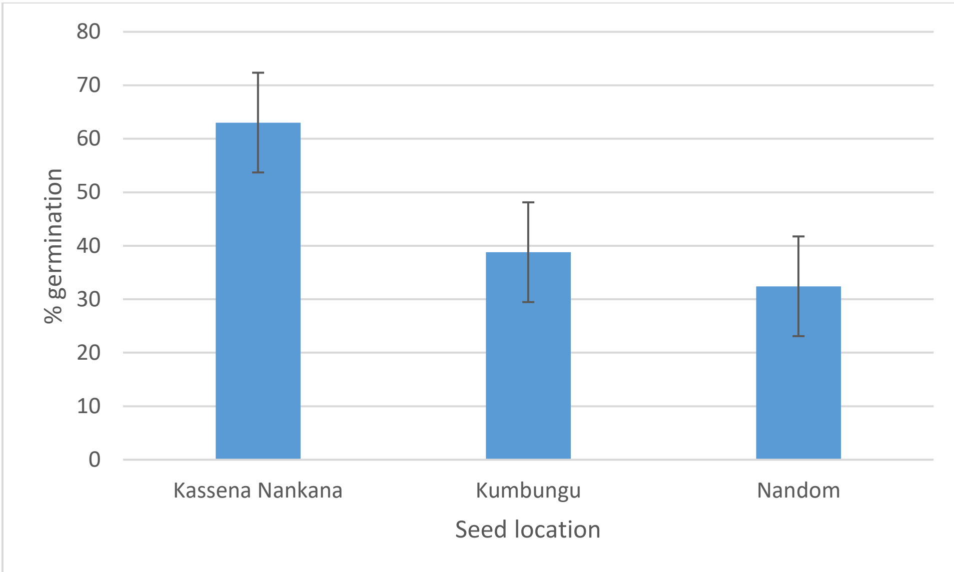

Figure 5.1: Effect of seed collection location on germination percentage of *Bombax costatum*

5.4 Discussion

The results of this investigation substantiate that pretreatment of seed has a significant effect on germination and initial seedling growth of *P. biglobosa, L. microcarpa,* and *B. costatum* and that the response of the species to treatment is unique. Scarification was the most effective method for enhancing germination in *P. biglobosa* and *L. microcarpa*.

This is likely due to the physical breakage of seed coat dormancy that allow for water to enter and for gas exchange as a result of the separation of the embryo from the mechanical restraint preventing expansion and the removal of the mechanical barrier regulating access to imbibition and germination (Azad *et al*., 2010). Similar observations have been reported in *Senna spectabilis* and *Albizia lebbeck*, where nicking or mechanical scarification significantly improved germination rates (Zembele & Ngulube, 2022; Missanjo *et al.*, 2013). Teklehaimanot *et al.* (2000) also highlighted scarification among other efficient approaches to improve seed coat permeability, and Ubaidillah *et al*. (2020) reported enhanced germination in *Moringa oleifera* using similar techniques. Neya (2006) reported increased germination of *L. microcarpa* following mechanical scarification and Adam *et al*. (in press) further observed higher germination percentage in sandpaper-scarified *Adansonia digitata* seeds further validating these findings.

Hot water treatment was more successful for *B. costatum* than the others; this is likely because it thins or softens the seed coat, which facilitates imbibition. This finding is consistent with results in *Dalbergia cochinchinensis* and *Xylia xylocarpa* (Seng & Cheong, 2020; Azad *et al*., 2006), as well as in *Albizia lebbeck* and *Melia azedarach* (Sharma *et al.*, 2008; Azad *et al*., 2010). However, not all studies agree with these findings. Okunlola *et al*. (2011) noted that hot water pretreatment caused the lowest germination in some tropical species, indicating a considerable variation in temperature response. Singh *et al*. (2019) further cautioned that excessive heat may be detrimental to enzymatic activity required for germination and that this may contribute to varying outcomes among species and treatment durations.

The positive response of *B. costatum* to hot water treatment in this study may likely be attributable to the controlled, short-duration thermal exposure applied, which likely softened seed coat and increased permeability without causing embryo injury. This response may also reflect species-specific thermal tolerance associated with adaptation to fire-prone savanna environments. In the Guinean savanna, seasonal fires generate transient heat pulses at the soil surface, which may select for seeds capable of withstanding short-term high temperatures (Willis *et al*., 2014). The hot water treatment may therefore have simulated these natural thermal cues, enhancing dormancy release while avoiding prolonged heat damage.

The effectiveness of acid pretreatment was species-specific and depended on treatment duration. The efficacy of acid soaking might be attributed to the removal of the seed coat and disruption of cell wall, which enhance water absorption and germination (Aliero, 2004). Our findings are in partial agreement with Niang *et al*. (2015), who found significant germination improvement in baobab seeds following acid pretreatment across different provenances in Senegal. Dauda *et al*. (2019) and Abubakar *et al*. (2023) also reported enhanced germination of acid-treated seeds of *P. biglobosa* and *L. microcarpa*. However, the mixed outcomes in this study may be attributed to variations in acid concentration, exposure duration, or inherent species-specific seed coat structures. In this study, 50% sulphuric acid was applied at short durations, whereas Dauda *et al*. (2019) applied concentrated (100%) sulfuric acid for short periods (2–10 minutes), whereas Abubakar *et al.* (2023) used diluted (50%) acid for extended exposure (up to 3 hours). Such differences in concentration–time combinations would influence the extent of seed coat modification and the potential for embryonic injury. Moreover, *P. biglobosa* has a thick palisade layer, making it more responsive to chemical scarification, whereas *L. microcarpa* likely has a less impermeable coat and greater sensitivity to prolonged chemical exposure (Aliero, 2004, Bewley *et al*., 2013). These anatomical and methodological differences likely explain the contrasting germination outcomes.

Cold water soaking yielded moderate improvements in germination, particularly for *P. biglobosa* and *L. microcarpa*. This corroborates the report of observations of Emerhi & Nwiisuator (2010) and Falemara *et al*. (2013), who demonstrated that long periods of water soaking efficiently can overcome physical dormancy in numerous tropical species. Additionally, Owonubi *et al*. (2005) and Okunlola *et al*. (2011), cited increased germination in *Azadirachta indica* and *P. biglobosa* following cold water treatment. The mechanism may relate to the gradual softening of the seed coat and improved moisture absorption over time.

Seed location significantly influenced the germination performance of *B. costatum,* with seeds from Kassena-Nankana showing the highest germination success. This suggests that environmental conditions at the source location may influence seed quality and physiological dormancy characteristics. This is in agreement with previous studies highlighting the importance of seed provenance on germination performance (Fredrick *et al*., 2017). Uniyal *et al*. (2000) and Aigbe *et al*. (2016) observed similar variation in *Grewia oppositifolia* and *Heinsia crinita*, respectively, indicating that seed response to pretreatment is not only species-specific but also origin-dependent. Luna *et al*. (2009) also highlighted that germination requirements may vary not only among species but also among different populations of the same species due to genetic and ecological adaptation.

5.5 Conclusion

The study has demonstrated the importance of pretreatments in improving seed germination and early seedling vigor of *Parkia biglobosa, Lannea microcarpa* and *Bombax costatum*. The findings revealed that scarification was the most effective pretreatment for *P. biglobosa* and *L. microcarpa*, while hot water treatment significantly improved germination in *B. costatum*. These results underscore the species-specificity of responses to seed dormancy-breaking methods and the requirement for species-specific protocols for propagation.

Additionally, the effect of the seed source on germination, especially in *B. costatum*, highlights the need to take into account ecological and genetic diversity in selecting seed sources for reforestation. Seeds from the Kassena-Nankana location exhibited superior germination, suggesting that environmental conditions may impact seed viability and dormancy traits.

Overall, this study provides valuable insights into low-cost, practical strategies for improving the propagation of ecologically and economically important native trees in Ghana's savanna regions. The findings are of great importance for the domestication and conservation of these species and their sustainable use in agroforestry systems for rural livelihoods security.

CHAPTER SIX

DETERMINING THE AMENABILITY OF NATIVE TREES TO GRAFTING UNDER AN UNCONTROLLED ENVIRONMENT TO SUPPORT THEIR DOMESTICATION.

Abstract

Native tree species play a significant role in the food, nutrition, and livelihood of the people of rural areas of sub-Saharan Africa and, at large, in ecological soundness and biodiversity of the world's resource base. Nonetheless, their domestication and cultivation have been limited by the use of seed-based propagation through which there is a long juvenile phase, seed dormancy, and genetic segregation. Vegetative propagation methods, including grafting, provide a reliable way to reduce juvenility and maintain desirable characters. Although grafting has proven successful in a set of controlled conditions, these conditions are largely not likely to be available in rural settings. This study evaluated the grafting compatibility in the open of *Adansonia digitata, Parkia biglobosa*, *Lannea microcarpa* and *Bombax costatum.* Using two grafting techniques (top cleft and side veneer), 220 grafts were established, using scions from phenotypically superior mother trees, categorized by fruit traits. Results indicated that only *A. digitata* achieved grafting success (6.67%), with top cleft grafting yielding the highest success (10.00%). The scion source did not significantly affect graft success, but scions from "bigger fruit" parent trees performed relatively better. The findings suggest that grafting under uncontrolled environments is feasible, though with low success rates. The study underscores the importance of further optimizing grafting procedures for native species and adapting propagation strategies to the realities of rural farming systems. The study provides critical insights for tree

domestication programs aiming to enhance genetic conservation and agroforestry adoption in the agroecological zone of Ghana.

Keywords: Native trees, vegetative propagation, uncontrolled environment, grafting, domestication.

6.1 Introduction

There is growing evidence that the restoration of native trees is paramount for maintaining ecological integrity and ecosystem functions, including soil nutrient cycling, water purification, and carbon sequestration (Wilkinson *et al*., 2014). They also serve as important sources of food, providing fruits, oils, fats, leafy vegetables, nuts, and condiments that complement staple crops in local diets. Furthermore, these species contribute significantly to rural health care through the provision of traditional medicines (Fortin *et al*., 2000; Kalinganire *et al*., 2007).

Farmers maintain and manage diverse range of native trees as a part of their livelihood activities within their farmlands. However, the abundance and diversity of these native species have been increasingly diminished as a result of multiple pressures of land-use change, over-exploitation, and climatic variability, hence limiting access to their critical assets for enhancing rural nutrition, health, and household income (Eyog Matig & Ouedraogo, 1999; FAO, 2000; Kalinganire *et al*., 2007).

The spontaneous regeneration of indigenous species, which is often characterized by a high seed-based type of regeneration, generally is hindered by seed dormancy, low germination rate, and slow juvenile growth (Munthali *et al*., 2012; Rolli *et al*., 2016; Sidibé & Williams, 2002; Jenya *et al*., 2018). As a result, these constraints have not encouraged much cultivation and domestication. Particularly, slow growth rates of important indigenous species like *A. digitata, P. biglobosa, L. microcarpa*, and *B. costatum* have been observed in different ecological zones (Sidibé and Williams, 2002; Sambe et al., 2010; Sacande and Clethero, 2007; Orwa et al., 2009; Oyen, 2011).

It has been reported that vegetative propagation, particularly grafting, can significantly shorten the juvenile phase in many indigenous tree species and, therefore, make them more beneficial for cultivation (Tsobeng *et al*., 2017). Therefore, the use of vegetative propagation represents a viable alternative for enhancing the efficiency of domestication efforts and preservation of desirable genetic traits. This approach is especially relevant in farmer-managed systems where early returns on investment are critical for adoption (Egbadzor & Akuaku, 2022).

Grafting is the combination of two plant tissues, usually a scion and a rootstock, in which both tissues unite physically and continue to grow as a single plant that has a functional output (Chander *et al*., 2016). Successful grafting depends on several factors, such as the compatibility between plants, the physiological conditions of the cells and tissues of the graft components, and the environmental conditions in which the process is done (Reis *et al.*, 2010). Hygrometric conditions inside controlled environments such as greenhouses, glasshouses, polyhouses, net houses, and mist chambers create excellent humidity and temperature gradients in the atmosphere that influence the percentage of success of graft by decreasing the loss of moisture and promoting quick wound healing (Bhandari, 2021). The successful grafting of *A. digitata* and other indigenous species has, in fact, been achieved under these regulated environments (Jenya *et al*., 2018; Anjarwalla *et al*., 2016).

However, in many of the rural areas where native trees are so critical and valued, such environments for managed propagation are nonexistent or not available. As a result, there is a need to test the feasibility of grafting under uncontrolled, ambient environmental conditions that more accurately reflect the realities faced by smallholder farmers. Knowledge of the amenability of wild trees to grafting in these situations is important for developing low-cost, scalable domestication to suit local capacity and resource availability. This study, therefore, aims to evaluate the amenability of four priority native tree species, *Adansonia digitata*, *Parkia biglobosa*, *Lannea microcarpa*, and *Bombax costatum,* to grafting under uncontrolled environmental conditions. Specifically, the objectives are to: (i) assess the overall success of grafting under uncontrolled environments; (ii) determine the influence of grafting methods on graft success; and (iii) evaluate the effect of scion source on graft performance across the four species.

6.2 Materials and methods

6.2.1 Study site

The experiment was conducted at the nursery of the West African Centre for Water, Irrigation, and Sustainable Agriculture (WACWISA), located at the University for Development Studies, Nyankpala (9°23.7'N, 0°31.8'W). The site experiences a monomodal rainfall pattern with an annual mean precipitation of approximately 1000 mm, with temperature ranges between 20°C and 42°C (GSS, 2014; SARI, 2016). The experimental period spanned from August 2023 to March 2024.

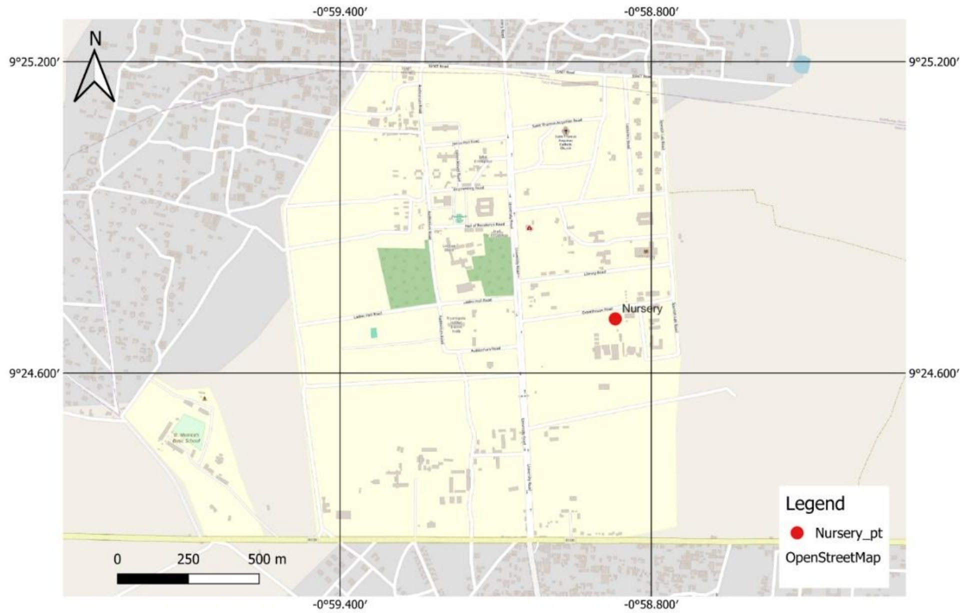

Figure 6.1. Map of experimental site

6.2.2 Study species

Baobab (*A. digitata*) is an important native fruit tree species of the sub-Saharan drylands, which provide significant income and food and nutrition security to local communities through its edible leaves, fruit pulp, and seeds (Anjarwalla *et al*., 2016). Despite its value, baobab is largely propagated by seed, which presents several limitations. The species exhibits a long juvenile phase, with first flowering occurring only between 8 and 23 years after germination (Diop *et al*., 2005). Furthermore, owing to its highly outcrossing nature, the seed-generated offspring typically vary greatly from the mother in both phenotype and yield, thus restricting the efficiency of selection and breeding (Assogbadjo *et al*., 2006).

P. biglobosa is an important multipurpose tree species, distributed throughout West Africa, and is valuable for its multiple uses in food, medicine, and agro-ecosystem. The tree provides shade, contributes to nutrient cycling, and helps stabilize degraded soils (Teklehaimanot *et al.*, 2000; Olorunmaiye *et al.*, 2011; Oluwafemi *et al.*, 2014). It is especially appreciated for its seeds, which yield a high-protein condiment fermented into dawadawa, a high-quality foodstuff and economic commodity in many rural societies (Campbell-Platt 1980). Flowering usually occurs at 5 to 7 years and full maturity and maximum height are within 30 to 50 years (Sina & Traoré, 2002; Pasiecznik, 2014). Although vegetative propagation methods such as air layering, root cuttings, and tissue culture have been explored, seed propagation remains the predominant method (Lamien *et al*., 2011).

L. microcarpa is a deciduous tree endowed with great economic potential throughout the West African region. It provides essential goods such as fuelwood, medicinal bark, edible leaves, fodder and construction material, thereby supporting rural livelihoods and household economies (Mbayngone & Thiombiano, 2011; Sawadogo *et al.*, 2012). Besides its livelihood functions, the species also plays significant ecological roles, including carbon cycling, shading, and providing habitats for a wide range of fauna (Dimobe *et al*., 2018). Seed is the most common means of propagation, but it is limited by high genetic variability in seed-derived offspring, which makes the choice and multiplication of elite genotypes difficult (Sereme *et al*., 2014). Vegetative propagation through root suckers and stem cuttings has been attempted, however, rooting percentage for cuttings has been low in general (Loada, 2004; Sereme *et al*., 2008).

Bombax costatum is a species with great socioeconomic, nutritional, and ecological value in West Africa. It is widely recognized for its contributions to rural food systems, traditional medicine, and cultural practices, as well as for its industrial and environmental importance (Coulibaly *et al*., 2023; Guidawa *et al*., 2023). The species is mainly propagated by seed, although natural wildings are sometimes used in regeneration efforts (Oyen, 2011). Despite its value, little progress has been made in optimizing its vegetative propagation, which could support efforts to conserve and domesticate elite phenotypes.

6.2.3 Scion collection and preparation

Scions used in this experiment were collected between August 2023 and February 2024 from selected trees located in the Kassena-Nankana and Kumbungu districts of northern Ghana. The timing was guided by species phenology and rootstock developmental readiness to ensure physiological compatibility during grafting. At the time of grafting, rootstocks possessed sufficient stem diameter, established root systems, and active cambial tissues to support vascular alignment and callus formation. Scions of *Adansonia digitata* and *Parkia biglobosa* were harvested during the rainy season under active cambial growth, whereas *Lannea microcarpa* and *Bombax costatum* scions were collected in the dry season when transpiration demand is lower and carbohydrate reserves may be higher. Mature scions (30 cm in length) were harvested from the uppermost part of the tree crown, ensuring the presence of active vegetative buds. Trees were selected based on observable superior phenotypic traits, specifically large fruit size, high fruit yield, and desirable taste characteristics. Care was taken to ensure uniformity in tree size and phenological stage at the time of scion collection. Details of the selected mother trees, including tree identification codes, trait classification, and number of scions harvested per category, are presented in Table 6.1.

Immediately after harvesting, scions were labeled according to their mother tree and trait classification, then wrapped in moist jute sacks to preserve moisture. The scions were transported to the nursery at the West African Centre for Water, Irrigation and Sustainable Agriculture (WACWISA), University for Development Studies, and were kept in cool, shaded conditions. Grafting were performed within 48 hours of collection to maximize viability.

Table 6.1: Source trees, phenotypic trait classification, number of scions harvested, number of scions harvested, and collection period for grafting experiments

Species	Tree ID / Coordinates	Mother Tree Trait	No. of Scions Harvested	Collection Month
	UL-1558-9307	Bigger fruits	20	Aug-23
	UL-1558-7330	More fruits	20	Aug-23
Adansonia digitata	UL-1433-5924	Sweet fruits	20	Aug-23
	NL-0490-7199	Bigger fruits	20	Aug-23
	NL-0829-0941	More fruits	20	Aug-23
Parkia biglobosa	NL-1368-4435	Sweet fruits	20	Aug-23
	NK-1596-7189	Bigger fruits	20	Feb-24
	NK-1595-5889	More fruits	20	Feb-24
Lannea microcarpa	NK-1522-2661	Sweet fruits	20	Feb-24
	NK-6293-1596	Bigger fruits	20	Feb-24
Bombax costatum	NK-6233-1093	More fruits	20	Feb-24

6.2.4 Experimental Design

Two grafting techniques, top cleft and side veneer, were used in the experiment. Scions were sourced from mother trees previously identified as phenotypically superior based on fruit size, sweetness, and productivity. For each mother tree (ortets), 10 scions were grafted with the top cleft technique, whereas another 10 with the side veneer technique. All grafts were performed on well-established rootstocks raised in polythene tubes under natural nursery conditions.

Figure 6.2. Picture of Two grafting techniques

A total of 220 grafts were performed across all four species. Specifically, 60 grafted plants each were produced for *A. digitata*, *P. biglobosa*, and *L. microcarpa*, and 40 grafts for *B. costatum*. The experimental layout followed a two-factor factorial design, with the two factors being (factor 1= grafting method (top cleft, side veneer) and factor 2= Scion source (mother tree based on trait: bigger fruits, sweet fruits, more fruits). Each treatment combination was replicated twice, with five grafted ramets per replicate, resulting in a structured and balanced design for statistical comparison. Photographic evidence of the nursery arrangement and representative grafted plants is provided in Figure 6.3.

Figure 6.3. Pictorial arrangement of grafts

6.2.5 Data Collection

Grafts were monitored over a three-month period following grafting. Graft success was assessed based on visual and physiological indicators. A graft was considered successful if one or more of the following criteria were met: emergence and sustained growth of new shoots from the scion; presence of fresh green cambial tissue under the scion bark, and development of new leaves indicative of physiological integration with the rootstock. Observations were recorded periodically to capture early success and post-union growth stability.

6.2.6 Data analysis

The collected data on graft success were subjected to analysis of variance (ANOVA) to evaluate the effects of grafting method and scion source (mother tree), as well as their interaction. The aim was to determine whether graft success differed significantly across treatment combinations. All statistical analyses were conducted using Genstat, Version 16. Results were considered statistically significant at $p < 0.05$.

6.3 Results

6.3.1 Graft success across species

Graft success was significantly influenced by species type ($F = 8.73$, $p < 0.001$). Among the four native tree species evaluated, only *A. digitata* recorded successful graft unions, with an overall success rate of 6.67% (Table 6.2). No successful grafts were recorded for *P. biglobosa*, *L. microcarpa*, or *B. costatum* under the prevailing uncontrolled nursery conditions.

6.3.2 Effect of grafting method

Although grafting method did not significantly affect graft success, the top cleft technique exhibited a higher success rate (10%) compared to side veneer grafting (3.3%). This suggests that top cleft grafting may offer better cambial alignment or wound closure, particularly for *A. digitata*, although the difference was not statistically significant (Table 6.2).

6.3.3 Effect of scion source

Similarly, scion source (mother tree category based on fruit traits) did not show a statistically significant influence on graft success. Nonetheless, scions collected from mother trees classified as having "bigger fruits" yielded the highest success rate (10%), compared to 5% for both "more fruits" and "sweet fruits" categories (Table 6.2). This trend may reflect underlying genetic or physiological factors influencing scion-rootstock compatibility.

Table 6.2: Graft success (%) of four native tree species under uncontrolled nursery conditions

Tree Species	Scion Source	Top Cleft (%)	Side Veneer (%)	Overall Graft Success (%)
Adansonia digitata	Bigger fruits	5	5	
	More fruits	5	0	
	Sweet fruits	5	0	6.67

Tree Species	Scion Source	Top Cleft (%)	Side Veneer (%)	Overall Graft Success (%)
Parkia biglobosa	All categories	0	0	0.00
Lannea microcarpa	All categories	0	0	0.00
Bombax costatum	All categories	0	0	0.00

6.4 Discussions

The findings of this study show that among the four native species evaluated, *A. digitata* exhibited a measurable potential for successful grafting under uncontrolled environmental conditions. Though the overall success rate (6.67%) was low, it does indicate the possibility of using grafting techniques for the domestication of *A. digitata* even in resource-limited rural settings. The low success rate under natural nursery conditions may have been influenced by environmental fluctuations, especially in temperature and humidity, which are known to affect callus formation and the physiological acclimatization of grafted tissues (Ahmed *et al*., 2012; Vu *et al*., 2014). However, microclimatic parameters such as temperature, relative humidity, and rainfall were not systematically recorded during the grafting period. This limits the ability to quantitatively relate environmental variability to graft performance. Future studies should incorporate detailed environmental monitoring to better determine optimal seasonal and climatic windows for grafting under field conditions.

The sole success in *A. digitata* confirms prior studies suggesting its relatively higher graft compatibility compared to other native species (Anjarwalla *et al*., 2016; Egbadzor & Akuaku, 2022).

Though no significant difference was observed in the grafting method, it had a practical effect. The better success rate of the top cleft grafting is consistent with previous reports showing that this method provides improved vascular connection because of the simple juxtaposition of cambial tissues (Kalinganire *et al*., 2007; Ofori *et al*., 2008).

Similar findings have been reported by Ahmed *et al*. (2012), who observed significantly reduced graft success in *Juglans regia* under open conditions compared to polyhouse or poly trench environments. Their study demonstrated that controlled microclimatic conditions enhance callus proliferation and vascular reconnection higher success observed in controlled settings is mainly due to the stimulation of both callus proliferation and vascular reconnection facilitated by congenial microclimatic conditions factors absent in uncontrolled environments. Although the present study was conducted solely under uncontrolled nursery conditions, these findings provide contextual support for the low graft success observed.

In addition to the environmental constraints, specific anatomical and physiological features of the species may also account for the variation in grafting success. The lack of successful graft unions in *P. biglobosa*, *L. microcarpa*, and *B. costatum* may be due to differences in cellular structure or poor scion–rootstock compatibility, which inhibit vascular fusion. These issues have previously been highlighted by Anjarwalla *et al*. (2016) and Egbadzor and Akuaku (2022), who reported successful grafting for *A. digitata* but emphasized the limitations of vegetative propagation in other native species, where root cuttings, air layering, or tissue culture (e.g., *P. biglobosa*: Lamien *et al*., 2011; *L. microcarpa*: Loada, 2004; Sereme *et al*., 2008; *B. costatum*: Oyen, 2011) are more commonly practiced.

The grafting technique did not significantly influence the success rate, yet it tended to be higher when using the top-clipping cleft technique vs. the side veneer (10% vs. 3.3%). This aligns with the reports of Kalinganire *et al*. (2007) and Ahmed *et al*. (2012), who suggested that the above cleft grafting technique allows better cambial contact between the scion and the rootstock, leading to improved vascular connections and a stronger union. Similar results were observed by Ofori *et al*. (2008) for *Allanblackia parviflora*, where top cleft grafting was shown to enhance the likelihood of successful scion-rootstock fusion.

In addition to grafting method and environmental factors, the compatibility between scion and rootstock may also significantly influence graft success. Garner & Bradley (2013) noted that successful graft union formation depends on both botanical relatedness and the physiological age of the tissues involved. Early and effective contact between the cambial layers is essential for callus formation and secondary growth induction (Bhandari, 2021).

Furthermore, the observed differences in graft success among scions sourced from different mother trees, specifically the higher success associated with scions from "bigger fruit" trees, may also indicate inherent genetic or physiological compatibility with the rootstock. These differences suggest that intra-specific genetic variability could influence graft compatibility, as has been demonstrated for *Cola nitida* by Dadzie *et al*. (2014). Such findings underscore the importance of mother tree selection in developing reliable vegetative propagation protocols.

6.5 Conclusion

The study revealed limited grafting success for selected native tree species under uncontrolled environmental conditions, which provides insight into the potential and limitations of grafting as a domestication method. Although there was some degree of graft success on *A. digitata,* albeit low. The inability of *P. biglobosa, L. microcarpa,* and *B. costatum* to form successful grafts also highlights the species-specific nature of graft compatibility and the problems of environmental variability. These findings offer important information towards the practical use of grafting as a vegetative propagation method for the domestication of native tree species. To support the implementation of such strategies, further investigation is needed to refine grafting protocols, explore alternative propagation methods, and increase our knowledge of the physiological and anatomical factors determining inter-specific graft compatibility across species.

CHAPTER SEVEN

GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

This study has shown the important role of integrating biological techniques with indigenous knowledge to improve the propagation and conservation of native savanna trees in the Guinean Savanna agro-ecological zone of Ghana. It was found that although the local communities have useful propagative knowledge, the level of usage of vegetative propagation was low. Germination rates were significantly increased by experimental seed pretreatment for all four species monitored, and species had species-specific responses to scarification and hot water treatments. Seed sources also affected germination success, indicating genetic differences among regions.

Vegetative propagation, particularly grafting, showed limited success under uncontrolled conditions, with only *Adansonia digitata* responding positively to top cleft grafting. These findings highlight the need to develop both seed and vegetative propagation approaches toward more successful domestication. The study provides evidence that combining socially resilient practices (community knowledge and involvement) with biologically resilient techniques (effective pretreatments and propagation methods) can support large-scale native tree restoration and germplasm conservation.

7.2 Recommendation

Based on the findings, the following recommendations are made**:**

1. **Incorporate Indigenous Knowledge into Formal Propagation Initiatives**

   Local propagation knowledge, though underutilized, remains a valuable asset. It needs to be documented and integrated into extension program and training packages to enhance participation by the community and adoption of domestication interventions

2. **Native Tree Domestication Policies and Institutions**

   Government, NGOs, and research should promote the integration of native trees in afforestation and agroforestry programs by providing technical training, seed/planting material, and market access for tree products.

3. **Develop Species-Specific Seed Pretreatment Protocols**

   Based on the study's findings, pretreatment methods such as mechanical scarification and hot water soaking should be standardized for each species to optimize germination and seedling performance, particularly for community nurseries.

4. **Strengthen Research on Vegetative Propagation**

   The other important requirement is more study and development of vegetative propagation methods under protected and open field environments. Particular attention should be given to the enhancement of graft success and survival in *Parkia biglobosa, Lannea microcarpa*, and *Bombax costatum.*

5. **Promote Community-Based Germplasm Conservation**

Establish community-managed seed and field genebanks, if necessary, to store superior genetic material. These small-scale conservation actions can also help to protect plant diversity and maintain restoration programs.

6. **Incentivize Farmer Participation in Domestication Efforts** Promote mechanisms of incentives including market access, certification for sustainably harvested trees, and input subsidies, to motivate farmers to grow and protect native tree species on their lands.

7. **Long-Term Monitoring and Evaluation**

   Establish systems to monitor the survival, growth, and ecological outcomes of domestically grown native trees planted in the landscape, which can be used to guide adaptive management and the effectiveness of future interventions.

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