

Sokoine University of Agriculture



MSc Dissertation

Assessment of Germination Behaviour and Nursery Performance of *Pericopsis angolensis*

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May 2024

**ASSESSMENT OF GERMINATION BEHAVIOUR AND NURSERY
PERFORMANCE OF *PERICOPSIS ANGOLENSIS***

**The dissertation is submitted in fulfilment of the requirements
for the Master Degree in Forestry of Sokoine University of
Agriculture, Morogoro**

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EXTENDED ABSTRACT

Successful tree planting and forest restoration efforts often rely on nursery practices to ensure the successful germination, growth, and survival of tree species. However, indigenous tree species like *Pericopsis angolensis* have received limited attention in terms of establishment, management, and performance in nursery settings, despite their significant ecological and socio-economic importance. This study investigated the influences of two major aspects of tree seedling establishment practices: seed pretreatments and seedling production techniques to provide a comprehensive understanding of optimizing nursery practices for *Pericopsis angolensis* seedlings in forest restoration. Seed germinability of *Pericopsis angolensis* was assessed through a germinability test using a complete randomized block design (CRBD) with four replications and five pre-treatments, involving soaking in normal and boiling water at different time intervals. Germination value, germination percent, mean germination time, germination index and germination capacity were used as potential indicators for seed germinability. A CRBD with a 3 x 3 x 3 factorial arrangement was employed to assess seedling performance under varying nursery conditions, including shading intensities (SIs) (0%, 50%, and 75%), pot sizes (PSs) (10 cm, 15 cm, and 20 cm), and potting mixtures (PMs) (PM0 [sand: cow manure: forest topsoil (1:2:4)], PM1 [sand: cow manure: forest topsoil (1:2:3)], PM2 [sand: cow manure: forest topsoil (1:4:3)], PM3 [forest topsoil only], and PM4 [PM0 with an additional 5 gm of NPK]). Performance of tree seedlings was assessed using growth parameters namely leaf counts, root collar diameter, root length, shoot height, total dry biomass, survival percentage, and seedling quality in terms of sturdiness quotient. This study showed that germinability was higher in the control treatment, indicating that pre-treating *Pericopsis angolensis* seeds by soaking in cold and hot water had no additional effect on germination. On the other hand, SI was found to significantly affect growth parameters, with 75% SI having the most substantial impact. PS and PM composition also played crucial roles, with larger pots and the use of forest topsoil contributing to increased seedling productivity. While suggesting that forest restoration using *Pericopsis angolensis* seeds

may not require such pre-treatments, this study recommended maintaining 50% SI to optimize seedling growth and highlighted the benefits of larger PS and the inclusion of forest topsoil for biomass production. The duration for both experiments of seed pre-sowing treatments and nursery techniques were 28 days and 4.5 months respectively. In conclusion, the findings underscore the importance of careful nursery management for *Pericopsis angolensis*, an indigenous tree species critical for forest restoration, ultimately contributing to the conservation and restoration of vital ecosystems.

MUHTASARI

Juhudi zenye mafanikio za upandaji miti na urejeshaji wa misitu mara nyingi hutegemea mbinu za uoteshaji katika kitalu ili kuhakikisha kuota kwa mafanikio, ukuaji na uhai wa aina mbalimbali za miti. Hata hivyo, aina za miti asilia kama Mbanga (*Pericopsis angolensis*) zimepata ufuatiliaji mdogo katika suala la uanzishwaji, usimamizi, na hali ya ukuaji katika mazingira ya kitaluni, licha ya umuhimu wao mkubwa wa kiikolojia, kijamii na kiuchumi. Utafiti huu ulichunguza vipengele viwili vikuu vya uanzishaji wa miche ya miti: matayarisho ya mbegu na mbinu za uzalishaji wa miche ili kutoa uelewa mpana wa kuboresha mbinu za kitalu kwa miche ya Mbanga katika urejeshaji wa misitu. Kuota kwa mbegu za Mbanga kulitathminiwa kupitia jaribio la kuota kwa kutumia muundo kamili wa kuzuia nasibu (CRBD) na marudio manne na uondoaji ubwete wa mbegu, ikihusisha kulowekwa kwenye maji ya jotoridi la mazingira na kuchemsha kwa vipindi tofauti. Thamani ya uotaji mbegu (GV), asilimia ya uotaji mbegu (GP), wastani wa muda wa kuota mbegu (MGT), jumla ya uotaji wa mbegu katika siku husika (GI) na uwezo wa kuota mbegu (GC) zilitumika kama viashirio vinavyoweza kuashiria uotaji wa mbegu. CRBD yenye mpangilio wa 3 x 3 x 3 wa kiwanda ilitumika kutathmini ustawi wa miche chini ya hali tofauti za kitalu, ikiwa ni pamoja na nguvu ya kivuli [SI0 (0%), SI1 (50%), na SI2 (75%)], urefu wa kiriba [PS1 (sm 10), PS2 (sm 15) na PS3 (sm 20)], na michanganyiko ya udongo [PM0 (mchanga: samadi ya ng'ombe: udongo wa juu wa msituni (1:2:4), PM1 (mchanga: samadi ya ng'ombe: udongo wa juu wa msituni (1:2:3), PM2 (mchanga: samadi ya ng'ombe: udongo wa juu wa msitu (1:4:3), PM3 (udongo wa juu wa msitu pekee), na PM4 (PM0 yenye gramu 5 ya ziada ya NPK)]. Ustawi wa miche ya miti ulitathminiwa kwa kutumia vigezo vya ukuaji yaani hesabu za majani (LC), kipenyo cha kiuno cha mzizi (RCD), urefu wa urefu wa mzizi (RL), kimo cha mmea (SH), uzito wa mmea wote baada ya kukaushwa (TDB), asilimia ya mimea iliyoishi (SP), na ubora wa miche katika suala la uimara wa mgawo (SQ). Utafiti huu ulionyesha kuwa uwezo wa mbegu kuota ulikuwa wa juu zaidi katika mbegu ambazo hazikufanyiwa huduma yoyote kuondoa ubwete, ikionyesha kwamba kuzifanyia huduma ya kuondoa ubwete katika mbegu za Mbanga kwa kulowekwa kwenye maji baridi na moto hakukuwa na

athari ya ziada kwenye kuotaji. Kwa upande mwingine, SI ilionekana kuathiri pakubwa vigezo vya ukuaji, huku 75% SI ikiwa na athari kubwa zaidi. Muundo wa PS na PM pia ulitoa umuhimu mkubwa, huku viriba vikubwa na utumiaji wa udongo wa juu wa msitu ukichangia kuongezeka kwa uzalishaji wa miche. Huku ikipendekeza kwamba urejeshaji wa misitu kwa kutumia mbegu za Mbanga huenda usihitaji maandalizi yeyote ya kuondoa ubwete katika mbegu, utafiti huu ulipendekeza kudumisha kivuli cha 50% (SI) ili kuboresha ukuaji wa miche na utumiaji wa kiriba kikubwa (PS) kilicho na udongo wa juu wa msituni kwa uzalishaji wa mche uliyo bora. Kwa kumalizia, matokeo yanasisitiza umuhimu wa usimamizi makini wa kitalu kwa miche ya Mbanga, ambayo ni aina ya miti asilia yenye muhimu kwenye urejeshaji wa misitu, hatimaye kuchangia katika uhifadhi na urejeshaji wa mifumo ikolojia asilia.

DECLARATION

I, YAHYA SAID MBAILWA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Yahya Said Mbailwa
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Date

The above is confirmed by;

Professor S. A. O. Chamshama
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Date

Dr. B. A. Mwendwa
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Date

LIST OF MANUSCRIPTS

- Manuscript 1:** Effects of Different Pre-Sowing Treatments on Germination of *Pericopsis angolensis* Seeds of Tabora Miombo Woodlands, Tanzania – Published in *Tanzania Journal of Forestry and Nature Conservation*, Vol 92, No. 1 (2023) pp 202-213.
- Manuscript 2:** Effects of nursery shading intensity, potting mixture and pot size on the performance of *Pericopsis angolensis* (baker) meeuwen seedlings. Submitted for publication.

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Last but not least, I would want to extend my profound gratitude to my fellow students for their collaboration with me. Be blessed by God, everyone.

DEDICATION

The work is dedicated to my beloved parents (Mr. and Mrs. Mbailwa) and my children (Husna, Haafidh and Najiyah Mbailwa).

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
LC	Leaf count
PM	Potting mixture
PS	Pot size
RCD	Root collar diameter
RL	Root length
SH	Shoot height
SI	Shade intensity
SQ	Sturdiness quotient
TDB	Total dry biomass

CHAPTER ONE

1.0 General Introduction

1.1 Background Information

Pericopsis angolensis (Baker) Meeuwen is a common tree species in Miombo woodlands belongs to the family Fabaceae (Leguminosea) (Deklerck *et al.*, 2017). This hardwood species is native to Southern and Eastern African countries including Tanzania and Burundi (Manyanda *et al.*, 2020; Nkengurutse *et al.*, 2016). The species is highly useful for firewood, timber, charcoal making (Manyanda *et al.*, 2020), carvings (Frost, 1996) and has long been used as a medicinal plant; where leaves, bark and roots are commonly used to cure ailments such as diarrhoea (Chingwaru *et al.*, 2019). Its reputation for yielding strong, durable, and visually appealing timber has positioned it as a sought-after resource in various industries, particularly in the construction, furniture, and artisanal crafts sectors (De Cauwer *et al.*, 2018).

In natural forests, the majority of indigenous trees develop naturally and are influenced by a number of factors, including the local climate and soil. However, some of them are unable to develop or regenerate as a result of several circumstances, including the removal of the tree, seed dormancy, and forest fires (Masao *et al.*, 2023; Manyanda *et al.*, 2020; James *et al.*, 2018).

It has been observed that indigenous tree species including *Pericopsis angolensis* have the highest priority for restoration and conservation programmes to prevent their extinction in their threatened natural habitat. However, due to overexploitation in some places, such as Malawi, where the boles are gathered for poles and firewood as well as the roots and bark for traditional medicines, it has become vulnerable. In these regions, it is challenging to obtain larger trees, whilst inferior trees predominate in the remaining populations (PROTA, 2022). Unfortunately, Manyanda *et al.* (2020) reported that tree species that were highly removed in terms of volume among many others in Tanzania include *Pericopsis angolensis* due to its

potential uses. Thus, it is necessary to supplement its natural regeneration through an afforestation programme supported by the adoption of appropriate germination and nursery techniques such as shade intensity, pot size, and soil mixture.

1.2 Problem Statement and Justification

1.2.1 Problem statement

Despite different importance of *Pericopsis angolensis* which include timber production, the species faces several challenges such as slow growth of the trees which makes it vulnerable to over exploitation as well as low survival rate in nurseries due to among others high dormancy. These challenges affect sustainable utilization of the species (Carrasco *et al.*, 2022; Schwartz *et al.*, 2002).

Some studies show that required light, potting mixture (PM), and pot size (PS) in the nursery vary with species and habitats where they grow (Hau and Corlett, 2003; Gopikumar and Bindu, 1999). Both shade intensity (SI), PS and PM affect seed germination, seedlings growth and survival of tree species significantly; such as *Ailanthus triphysa*, *Valeria mangachopi* and *Prosopis glandulosa* (Sood *et al.*, 2018; De La Fuente *et al.*, 2017). Therefore, during the containerised seedling production, container size, and growth medium are important determinants of seedling quality. However, there is scarce information on germination and nursery performance of some indigenous tree species including *P. angolensis* (Vyamana *et al.*, 2007) and readily available data on the proper PS particularly length, PM, and seed dormancy (Tura *et al.*, 2016; Mulugeta, 2014). Hence the present study was undertaken to obtain appropriate information about the germination behaviour and performance of species in the nursery for quality seedlings production.

1.2.2 Justification of the study

Information on germination and nursery performance of *Pericopsis angolensis* is crucial and important to forest plantation managers and communities for appropriate nursery techniques for the species under study. Also, its germination behaviour and nursery performance are essential for informed conservation strategies aimed at restoring its

populations in degraded or deforested areas. By providing insights into successful propagation techniques, this study contributes to the preservation of a species that plays a key role in maintaining ecosystem balance. Also, this study's findings can guide the development of sustainable logging practices by offering information on how to replenish *Pericopsis angolensis* populations through effective nursery management and successful seedling establishment. This, in turn, supports the timber industry's efforts to maintain a balance between economic interests and ecological responsibilities. Furthermore, the study aligns with the Sustainable Development Goals by contributing to biodiversity conservation, climate action, economic growth, responsible consumption and production, poverty reduction, quality education, and partnerships for sustainable development through its potential to inform reforestation efforts, enhance ecosystem resilience, support local livelihoods, and advance scientific knowledge for sustainable resource management.

1.3 Objectives

1.3.1 Main objective

To assess germination behaviour and nursery performance of *Pericopsis angolensis*.

1.3.2 Specific objectives

The specific objectives of the study were:

- i. To assess seed pre-sowing treatments of *P. angolensis* in the laboratory.
- ii. To assess the effects of SI, PS and PM on survival and growth of *P. angolensis* in the nursery.

1.4 Research Questions

The study attempted to answer the following questions:

- i. What is an effective pre-sowing treatment which facilitate germination of *P. angolensis* seeds?
- ii. Is there any effect of SI, PS, and PM on survival and growth of *P. angolensis* in the nursery?

1.5 Dissertation Organization

This dissertation has five main chapters and was developed in the format of publishable manuscripts. Except for Chapter 1 and Chapter 5 that present synopsis of the theme studied, conclusions and recommendations, other Chapters comprise a published article and submitted manuscript. The content presented in the chapters is the same as the content in the journal or the submitted manuscript. Chapter one consists of the introduction, which provides background information on the study, a problem statement and justification, along with the study objectives and research questions. The second chapter (Manuscript 1) describes the effects of different pre-sowing treatments on germination of *Pericopsis angolensis* seeds of Tabora Miombo Woodlands, Tanzania. Chapter three (Manuscript 2) is about the effect of nursery SI, PM and PS on the performance of *Pericopsis angolensis* (Baker) Meeuwen Seedlings. Chapter four is on general discussion. Chapter 5 summarizes conclusions and recommendations.

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CHAPTER TWO

Manuscript One

2.0 Effects of Different Pre-Sowing Treatments on Germination of *Pericopsis angolensis* Seeds of Tabora Miombo Woodlands, Tanzania

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Effects of Different Pre-Sowing Treatments on Germination of *Pericopsis angolensis* seeds of Tabora Miombo Woodlands, Tanzania

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ABSTRACT

Pericopsis angolensis species survival is reported to be low in nurseries. Given the high dormancy tendency of Legume family, it is speculated that, pre-sowing treatment of *Pericopsis angolensis* seeds may result in improved germinability. Different attempts of breaking the dormancy to enhance germination have been done. However, the difference in environmental conditions - soil pH, temperature, and water availability - which parental plants experienced during their growth and seed maturation, have an impact on seed germination patterns. This study assessed the effects of pretreatments (soaking in cold and boiling water at different time intervals) on the germination of *Pericopsis angolensis* seeds collected in Tabora, Tanzania. Analysis of Variance (ANOVA) was done to show differences in seed germination parameters under different pretreatments. Results show that, there was significant ($P < 0.001$) difference in germination parameters between the control and pretreated seeds except for the Mean Germination Time ($P > 0.05$). The highest Germination Value, Germination Percent and Germination Capacity were found under control. The findings prove that pretreating *Pericopsis angolensis* seeds by soaking in cold and hot water have no additional effect on germination. Thus, the study suggests that the restoration of the forests using *Pericopsis*

angolensis species can be achieved even without seed pretreatments.

Keywords: Seed pre-sowing treatments - Germination Parameters - *Pericopsis angolensis* - Miombo woodlands.

INTRODUCTION

Miombo woodland ecosystem forms an extensive range of tropical deciduous woodland in Africa, covering an area of approximately 2.7 million km² in Southern, Central, and Eastern Africa (Timberlake *et al.* 2020, Mgumia 2017, Shirima *et al.* 2011). The ecosystem supports unique and rich flora dominated by tree species in the family Leguminosae, subfamily Caesalpinioideae, with genera of *Brachystegia*, *Julbernardia*, and *Isobertinia* (Mgumia, 2017). Miombo woodlands support millions of rural and urban dwellers, with the majority of them relying on miombo wood, fuelwood, traditional medicines, food and charcoal as a source of energy (Mgumia *et al.* 2017, Njana *et al.* 2013, Dewees *et al.* 2010, Frost, 1996). Majority of the neighboring communities contribute to the problems of overexploitation when extracting potential resources from Miombo woodlands, through conversion of woodlands to farmland, seasonal forest fires, and livestock grazing (Campbell *et al.* 2007, Fors 2002, Campbell 1996). It is through this nexus of concerns that knowledge about the ability of the trees



to regenerate, succession, and re-colonize degraded areas is of particular importance.

Germination of seeds is among the biodiversity restoration and conservation methods that have saved many threatened indigenous plant species worldwide (Vodouhè *et al.* 2011) through propagation of seeds for mass production. However, seeds of many native species in Miombo woodlands are difficult to regenerate naturally (Luna *et al.* 2011). This may be due to suffering from intense seed latency, which may be due to undeveloped embryo, and impermeable thick seed coat which resist the growth of the embryo (Amoakoh *et al.* 2017). This is considered the main problem in establishing forests of legume species which makes them hard to germinate (Opoku *et al.* 2018). Different approaches of breaking seed dormancy in order to enhance germination rate and increase the germination process have been suggested by many authors (Bano *et al.* 2021; Nourmohammadi *et al.* 2019, Airi *et al.* 2009). However, the conditions necessary to allow seeds to break dormancy and germinate easily varies among family members, species or among seed sources of the same species. For example; *Acacia nilotica* and *Leucaena leucocephala*, require hot water soaking before germinating while *Brachystegia spiciformis* does not need pretreatment (PROTA, 2022).

Pericopsis angolensis (Baker) Meeuwen belongs to the Fabaceae/Leguminosae family found in Miombo woodlands (Deklerck *et al.* 2017). The species is highly useful for firewood, timber, charcoal making (Manyanda *et al.* 2020), carvings (Frost, 1996) and has long been used as a medicinal plant; where leaves, bark and roots are commonly used to cure ailments such as: diarrhea (Chingwaru *et al.* 2019). However, little is documented about the germination performance of *Pericopsis angolensis* seeds in nurseries. *Pericopsis angolensis* survival is reported to be extremely low in a study by Vyamana *et al.* (2007), that attempted to test the effect of nursery practices on seedling

survival of five selected Miombo species. Moreover, given the high dormancy tendency of Legume family, it was speculated that, pre-sowing treatment of *Pericopsis angolensis* seeds may result in improved germinability of the seeds hence high performance in the nursery. However, a study conducted in Burundi wet Miombo woodlands by Nkengurutse *et al.* (2016), found that seed pretreatment such as sulfuric acid, scraping, or boiling water on *Pericopsis angolensis* seeds decreased germination percentage, demonstrating the absence of dormancy.

In Tanzania on the other hand, where forest sector operations are governed by the Forest and Beekeeping Division (FBD) through Technical Orders, information on plant propagation such as seed germination of some tree species, including *Pericopsis angolensis*, is lacking (FBD, 2021). Despite, the findings by Nkengurutse *et al.* (2016) that *Pericopsis angolensis* seeds of Burundi wet Miombo woodland lack dormancy, the environmental conditions that the parental plants were exposed to during their growth and seed maturation have impacts on the seed germination patterns. Depending on the species locality, difference in environmental factors, such as: soil pH, temperature, and water availability, affects the ideal conditions for seed germination (Farooq *et al.* 2021, Daddario *et al.* 2017). This study, therefore sought to evaluate the effects of seed pre-sowing treatments on germination of *Pericopsis angolensis* in a laboratory setting as for the seeds from Tabora dry Miombo woodland. According to research, imbibition is the simplest way to increase seed germination rates and establishment under stressful conditions (Mwami *et al.* 2017, Merou *et al.* 2011, Choudhury *et al.* 2009). Mwami *et al.* (2017) argued that water imbibition is crucial for germination because it activates enzymes and speeds up the metabolism of the starch and protein that are stored in the seed. Thus, our study evaluated the effects of pre-sowing treatments (soaking in normal water at different time intervals and hot water) on



seed germination of *Pericopsis angolensis*. The study assessed the effects of pretreatments (soaking in cold and boiling water at different time intervals) on the germination of *Pericopsis angolensis* seeds collected in Tabora.

MATERIALS AND METHODS

The study was conducted as on station experiment in the laboratory of Tree Seed Production Station (TSPS – TFS) Headquarters in December 2021. The station is in Morogoro municipality at 6.8278° S and 37.6591° E with an altitude of 550 m.a.s.l; 3 km from Msamvu bus stand on the road to Dodoma, Tanzania.

Seed Collection and Sample Preparation

Seeds of *P. angolensis* was obtained from Shinyanga Tree Seed Centre (STSC) in November 2021. The obtained seeds were formally collected from the dry Miombo woodlands of Tabora, Tanzania. Most of Miombo tree species experience fruits and seed dispersal in dry season i.e., July – Dec, (Campbell, 1996). Seed sample for experiment was drawn from seed-lot storage by using Riffle Sample Divider to avoid biasness, and enough samples was repacked and labeled prior to information available for further procedure.

Experimental Design, Seed Pre-sowing Treatments and Germination

The experiment was laid out using a complete randomized block design (CRBD) with four (4) replications and five (5) pretreatments: T1 = soaking seed in normal water (at room temperature = 25°C) for 6 hrs., T2 = soaking seed in normal water for 12 hrs., T3 = soaking seed in normal water for 24 hrs., T4 = soaking seed in boiled water till it cools and T0 = untreated seeds. For T4, water was firstly boiled at 100°C and then poured into seeds and the seeds were left till the water has cooled down to room temperature (25°C) before sowing. Each replicate contained 50 seeds, making a total of 200 seeds per pretreatment. Sand was

sterilized by oven dry method at 180°C for 2 hrs. prior to seed sowing (Sinegani and Hosseinpur, 2010).

The study was done in a temperature-controlled Plant Growth Chamber with temperatures set at a maximum of 28°C during the day and a low of 18°C at night, respectively. The seeds were placed on top of sand and arranged in square manner at a space of approximately its seed size. A layer of 0.5 cm thick of sand was then used to cover the seeds. To maintain adequate moisture for germination and seedling growth, sown seeds were watered once a day (morning) using watering spray bottle and each replicate/germination tray received 200 ml of distilled water for four weeks (28 days).

Data Collection

The effects of pretreatments on seed germination was assessed by counting and recording germinated seeds at an interval of four (4) days until no further germination took place (Likoswe *et al.* 2008, Msanga, 1998). There was no more germination after four weeks. A seed was regarded to be germinated if there is a visible radicle emergence (Tian *et al.* 2014). At the end of experiment (before termination), ungerminated seeds from each treatment were tested for viability by cutting test, where the seeds with white, firm embryos were recorded as viable, while those with brownish-yellow, squishy embryos were recorded as non-viable (Fan *et al.* 2016).

Data Analysis

To assess the effects of pre-sowing treatments on germination of *Pericopsis angolensis* in the laboratory, germination parameters under different pre-sowing treatment conditions were assessed. Seed germination parameters were firstly computed (Table 1) for each seed pre-sowing treatment and then, one-way analysis of variance (ANOVA) was performed to determine treatment effects on seed germination. For the germination parameters which were significantly different between



pre-sowing treatments, a pair-wise test using Tukey HSD comparison was done. Germination computation was done by package “*GerminaR*” and ANOVA and Tukey HSD test were performed by the ‘*stats*’ package in the R software (v. 4.1.2).

Table 1: Seed Germination Parameters

Germination parameter	Code	Formula	Reference
Mean Germination Time	MGT	$MGT = \frac{(n1 \times d1 + n2 \times d2 + \dots + n \times dn)}{\text{Total number of seeds germinated}}$ n = number of germinated seed and d = number of days	(Mojeremane <i>et al.</i> 2017)
Germination Percentage	GP	$GP = \frac{\text{Germinated seeds (GS)}}{\text{Total seed sown (TSS)}} \times 100$	(Mwendwa <i>et al.</i> 2020).
Germination Index	GI	$GI = \frac{n}{d}$ n = number of seedlings emerging on day ‘d’ and d = day after planting	(AOSA, 1983)
Germination Value	GV	$GV = \frac{\sum DGS}{N} \times (GP \times 10)$ DGS = Daily germination speed GP = Germination percentage	(Djavanshir and Pourbeik, 1976)
Germination Capacity	GC	$GC = \frac{\sum GS + \sum \text{Ungerm. sound seeds}}{\text{Total seeds tested}} \times 100$ GS = Germinated seeds	(Paul, 1972)

RESULTS

Effects of Seed Pre-sowing Treatments

Mean Germination Time (MGT)

The germination of *Pericopsis angolensis* seeds started on the fourth and eighth day in pretreatments (T0 and T1) and (T2, T3 and T4) respectively. Meanwhile the germination was completed on the twelfth and sixteenth day in pretreatments (T0, T1,

T2 and T3) and (T4) respectively. At the end of this period, 57.2% of seeds had germinated in all pretreatments, while 42.8% of the remaining seeds did not germinate. The mean germination time (MGT) for *Pericopsis angolensis* seeds was approximately 8 days under all pre-sowing conditions (Table 2). Moreover, there was no significant difference ($P > 0.05$) in MGT between the treatments.

Table 2: Summary information (Mean ± SD) and post-hoc analysis of mean effects of different pre – treatment tests on germination parameters of *Pericopsis angolensis* seeds

Treatments	MGT (days)	GP (%)	GI (Seeds/day)	GV	GC (%)
T0	8 ±0.15 ^(a)	94 ±4.32 ^(a)	5.75±0.20 ^(a)	48 ±4.16 ^(a)	94 ±3.27 ^(a)
T1	8±0.00 ^(a)	50±3.00 ^(b)	3.04±0.19 ^(b)	13.3±5.50 ^(b)	56±3 ^(b)
T2	8±0.18 ^(a)	52±2.31 ^(b)	3.25±0.14 ^(b)	16.3±3.83 ^(b)	52±2.31 ^(b)
T3	8±0.16 ^(a)	44±1.91 ^(c)	2.7±0.09 ^(c)	9.3±3.21 ^(b)	44±1.91 ^(c)
T4	8±0.07 ^(a)	44±3.46 ^(c)	2.7±0.34 ^(c)	10.3±1.28 ^(b)	44±3.46 ^(c)

[Difference in letter labels (a, b, c) in a plot shows that there is significance difference among the respective pre-treatments and vice-versa.]

Germination Percentage (GP)

The cumulative germination percent GP of *Pericopsis angolensis* seeds, gradually increased from the fourth day (4th) and

reached its maximum values on the eighth (8th) day with the exception of seeds under T0 and T1, where the GP slightly increased up to the 12th day. During the following days (up to the 28th day), the curve was almost



constant (Figure 1). There was significant difference ($F_{(4,15)} = 193.2, P < 0.001$) in GP between seeds under control and treated seeds, whereas the highest GP (94%) was obtained in seeds under control, with lower numbers of ungerminated seeds compared to most of the treatments. T2 had a germination slightly higher (55%) compared to the treatments which had $< 50\%$. Soaking the seeds in water did not work well, where seeds in both T3 and T4 resulted in lowest GP (44%). However, there was no significant difference in GP between T1 and T2 and T3 and T4 treatments (Fig 1).

Germination Index (GI)

Similar to GP, the highest GI values were obtained in seeds under control (6 seeds/day) compared to other sowing treatments. Untreated seeds differed significantly ($F_{(4,15)} = 173.9, P < 0.001$) from treated seeds while *Pericopsis angolensis* seeds under T1 and T2 (3 seeds/day) had significantly higher GI value ($P > 0.05$) than T3 and T4 (Figure 2).

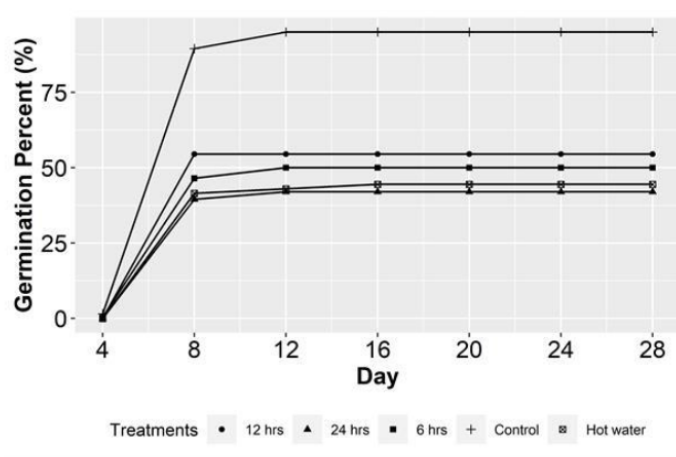


Figure 1: The trend cumulative Germination of *Pericopsis angolensis* seeds under different pre-sowing treatment conditions

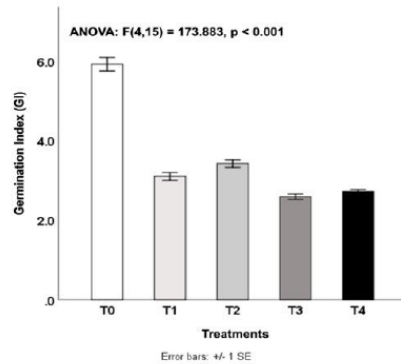


Figure 2: Germination index (GI) of *Pericopsis angolensis* at different pre-sowing treatment conditions. [The vertical line outside the box represents the minimum and maximum values. Difference in letters (a, b, c) signifies that, GI differs among the specified pre-treatment conditions.]

Germination Value (GV)

One-way ANOVA of final germination showed significant variation in seed GV among treatments were significant ($F_{(4, 30)} = 15.52, P < 0.001$). Germination value of *Pericopsis angolensis* was approximately three times higher under control condition (T0) compared to pre-treated seeds. For T0, germination value increased significantly up to the 12th day (GV = 62) and then started to

drop on the following days. Meanwhile, the remaining pre-treated seeds peaked on the 8th day, except for seeds under T1, where the GV slightly increased up to the 12th day and then decreased (Fig 3). The highest GV in T0 was followed by soaking seeds in water for a period of 12 hrs (T2). However, difference in GV ($P > 0.05$) among all the pre-treated seeds were not significant.

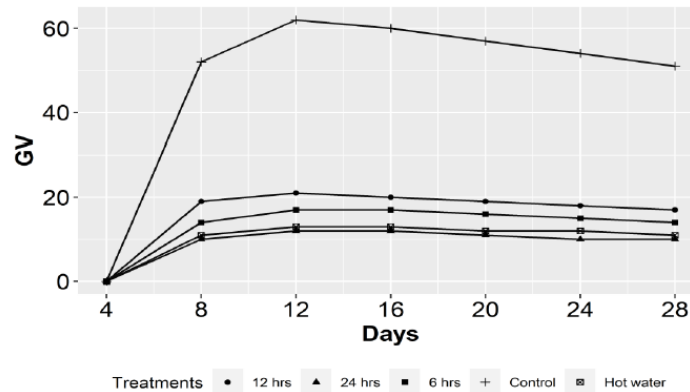


Figure 3: Germination value of *Perocopsis angolensis* under different pre-sowing treatment conditions. [The treatments indicate the difference in soaking (imbibition) period of *Pericopsis angolensis* species]



Germination Capacity (GC)

The highest germination capacity of *P. angolensis* seeds was obtained under control condition (T0) (94%), followed by seeds soaked in water for a period of 6 hrs. (T1). Generally, the mean GC decreased with

increase in time of imbibition (Table 2). There was significant difference between in GC between treated and untreated seeds ($F_{(4,15)} = 224.1, P < 0.001$). The seeds of treatment T1 and T2 had the same GC (>55%), that were significantly higher than ($P > 0.05$) between T3 and T4 (Fig 5).

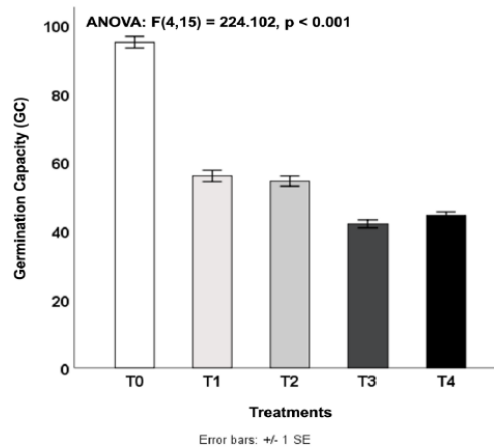


Figure 4: Germination capacity (GC) of *P. angolensis* seeds under different pre-sowing treatments. [The vertical line outside the box represents the minimum and maximum values. Difference in letters (a, b, c) signifies that GC differs among the specified pre-treatment conditions.]

DISCUSSION

Tropical indigenous tree seeds, especially those of Miombo woodlands, are reported to have difficulty in germinating due to seed dormancy tendencies (Martins *et al.* 2019, Malmer 2007, Msanga 1998). Many seeds from legume family species including *Pericopsis angolensis* are reported to have physical dormancy (Jaganathan 2020, Mira *et al.* 2017). As a consequence, different seed pre-sowing treatment methods have been used to break dormancy and stimulate prompt and uniform germination of seeds (PROTA 2022, Mojeremane *et al.* 2017).

This study found out that all germination parameters were lower in treated *Pericopsis angolensis* seeds, compared to those under the control treatment. The findings are in agreement with Nkengurutse *et al.* (2016), who

reported that seeds of some indigenous Fabaceae tree species in Burundi wet Miombo woodland including *Pericopsis angolensis*, *Brachystegia microphylla*, *Brachystegia utilis*, *Brachystegia bussei* and *Julbernardia globiflora* did not require special germination condition however the study was testing the effects of germination temperature and imbibition time on germination. However, despite the effort of National Tree Seed Programme and earlier Tanzania Tree Seed Agency to conduct germination trials for many indigenous tree species including of dry Miombo woodlands, the information on seed germination of *Pericopsis angolensis* has not been documented in Tanzania (TTSA 2017, Msanga 2017, Msanga 1998).

It was also found in this study that, germination percentage (GP) was highest for untreated seeds/control (94%), compared to



pre-treated seeds (T1, T2, T3 and T4) (Figure 1). Observation on germination test revealed that any seed pre-sowing treatment of *Pericopsis angolensis* (soaking in tap water for 6 hrs, 12 hrs, 24 hrs, and boiling water) had lower germination percentage. This indicates that *Pericopsis angolensis* seeds do not need pre-treatment since they might have no dormancy (Nkengurutse *et al.* 2016).

It was also, observed that both pretreated and unpretreated seeds shared the same mean germination time/day (MGT); where on day 8 both seed pre-sowing treatments attained higher germination (Table 2). Nevertheless, the MGT were not improved by pre-treatment condition of the seed at different durations implying another proof of absence of dormancy of the seed.

Moreover, results on other germination parameters including germination capacity (GC), germination index (GI) and germination value (GV) scored higher values in control/untreated seeds (T0) compared to other remaining pretreatments (T1, T2, T3, and T4). There was no significant difference in GC of pretreatments T1 and T2 and T3 and T4 (Figures 4). In general, for a seed to activate the embryo and begin the process of cell division, differentiation, and multiplication to grow into a seedling, it needs an optimal level of moisture rather than full saturation. Sabongari and Aliero (2004), reported that, too much soaking time exposure e.g., T3, causes seeds to have higher concentrations of Carbon dioxide, ethanol, and lactic acids and lower levels of Oxygen, which results in poor germination. Moreover, the effect of hot water treatment on seed embryo was also reported by (McDonnell *et al.* 2012, Hopkinson and English, 2004) to have negative effects on germination as happened in T4. The immersion of seeds in boiling water of temperatures above 80°C was reported to be too hot water, which could result into injuring or killing of the seed embryo, and resulting in lower GC which is unsound in seedlings production (McDonnell *et al.* 2012).

Generally, this study found that, soaking time exposure and temperature of water used to pretreat seeds have no positive additional effect in comparable to untreated seeds. Considering the same germination time between treated seeds and untreated seeds, then pre-treatment of *Pericopsis angolensis* seeds by soaking in water proves to be unnecessary. This is in contrast to several researches which argue that species of Fabaceae family such as *Acacia nilotica*, *Faidherbia albida*, *Vachellia rehmanniana*, *Pterocarpus angolensis*, *Leucaena leucocephala* and *Dicrostachys cinerea*, presents high physical dormancy, and hence requiring pretreatments before germinating (Gilani *et al.* 2019, Kheloufi *et al.* 2018, Mojeremane *et al.* 2017, Idu and Omonhinmin 1999, Msanga 1998). However, sometimes all viable seeds in batch do not germinate at a limited/set period of time; some fail due to unforeseen factors that happen during the process of germination (Fan *et al.* 2016, Pace *et al.* 2016) other than dormancy of the seeds.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Understanding the ability of the common suspected dormant tree seeds, to germinate after pre-sowing treatment is of particular importance for sustainable forest management, including the recovery of the desired native species composition. The findings of this study suggest that pre-treating *Pericopsis angolensis* by soaking the seeds at different time exposure and temperature of water have no positive additional effect on germination of the seeds. This suggests that *Pericopsis angolensis* seed species do not require any pretreatment before sowing or planting, implying that they have no physical seed dormancy. This is different from what has been reported about tree seeds from the legume family, having hard seed coats and thus being the most dormant. Thus, our study provides baseline report that the restoration of Miombo



woodlands through the use of indigenous *Pericopsis angolensis* species can be easily achieved even without seed pre-treatments.

Recommendations

In order to ensure sustainable conservation and restoration of Miombo woodland are successful taking in place in Tanzania the government through Tanzania Forest Services Agency (TFS), local government authorities, communities, and other stake holders should establish plantations of native tree species including *Pericopsis angolensis* because the seeds do not require pre-sowing treatment. However, further studies on field performance especially from nursery stage of this species should be taken.

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CHAPTER THREE

Manuscript Two

3.0 Effect of Nursery Shading Intensity, Potting Mixture and Pot Size on The Performance of *Pericopsis angolensis* (Baker) Meeuwen Seedlings

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Abstract

Nursery practices are integral to the successful germination, growth, and survival of tree species. However, limited attention has been given to the establishment, management, and performance of seedlings of many indigenous tree species in nursery settings. This study investigated the performance of *Pericopsis angolensis* seedlings under varying nursery conditions, including shading intensities (SI) (0%, 50%, and 75%), pot sizes (PS) (10 cm, 15 cm, and 20 cm), and potting mixtures (PM) (PM0 [sand: cow manure: forest topsoil (1:2:4)], PM1 [sand: cow manure: forest topsoil (1:2:3)], PM2 [sand: cow manure: forest topsoil (1:4:3)], PM3 [forest topsoil only], and PM4 [PM0 with an additional 5 gm of NPK]). A Completely Randomized Block Design (CRBD) with a 3 x 3 x 3 factorial arrangement was employed. The results revealed that SI had a significant influence on various growth parameters, including root-collar diameter (RCD), shoot height (SH), and leaf count (LC). Specifically, the highest SI (75%) was found to be the primary factor influencing these parameters. Moreover, the study demonstrated that both PS and PM composition significantly influenced leaf development. Larger PSs were associated with increased LC. Notably, seedling biomass was highly affected by SI and PS, with larger pots resulting in greater seedling productivity. It is suggested that shade circumstances be carefully managed, with a focus on maintaining 50% SI for the best results, to maximize the growth of *Pericopsis angolensis* seedlings. This can be accomplished by choosing planting areas with naturally occurring shade or by using shade structures. In addition, this study emphasizes the potential advantages of employing larger PSs composed of forest topsoil to increase seedling productivity, and thus biomass production.

Keywords: Growth parameters - *Pericopsis angolensis* - Miombo woodlands - Nursery practices

3.1 Introduction

Nursery practices play a critical role in the performance and growth of seedlings because they provide optimal conditions for seed germination and seedling development (Okunomo, 2010; Agbo Cu, 2006). Proper nursery management practices can prevent overcrowding and competition for resources, which lead to stronger and more vigorous tree seedlings (Ladd and Facelli, 2005). Many studies have reported on the importance of proper nursery practices on seedling health and field performance (Ancha *et al.*, 2020; Sarangi *et al.*, 2015; Zhang *et al.*, 2012; Muriuki *et al.*, 2007). Thus, with the increased effects of climate change in the forest community, the establishment of a proper environment for the effective performance of the indigenous tree species in the field is of paramount importance.

Shading intensity (SI) is an important aspect of nursery practices as it controls the amount of light that reaches seedlings, which can be beneficial in preventing sun damage and reducing water loss (Formisano *et al.*, 2022). However, excessive shading can also inhibit photosynthesis and reduce seedling survival (Duan *et al.*, 2018). The importance of adopting the appropriate potting mixture (PM) cannot be overstressed since the physical and chemical properties of the PM can significantly affect the growth of *Pericopsis angolensis* (Khurana and Singh, 2001). Another important factor in seedling development is the choice of pot size (PS); increasing PS tends to have a positive relationship with seedling growth parameters (Abebe, 2021). However, Weraduwage *et al.* (2015) reported a significant interaction effect between PS and PM ratio, with growth parameters being smaller in smaller pots in Miombo plants.

Pericopsis angolensis also known as 'Mbanga' in Kiswahili language is a deciduous shrub or tree native to tropical forests of Africa, including Tanzania, where it is found in Miombo woodlands and is used for construction and furniture making, as well as traditional medicine to treat fever, diarrhoea, and skin diseases (Njana *et al.*, 2013; Vyamana *et al.*, 2007; Munyanzinza and Oldoman, 1994).

Therefore, whereas the conservation and domestication of native species is important for the restoration of the deforested land, the use of *Pericopsis angolensis* is constrained by poor survival and growth rate in the nursery and early establishment in the field (Vyamana *et al.*, 2007; Munyanziza and Oldeman, 1994).

Generally, there is scarce information on the seedling growth performance of different indigenous tree species especially of *Pericopsis angolensis* during establishment in the nursery (Kinho *et al.*, 2023). Vyamana *et al.* (2007) conducted an experiment on growing *Pericopsis angolensis* under different nursery practices, but only assessed few growth parameters such as survival and growth, seedling diameter, and seedling height. Therefore, this study assessed the performance of the *Pericopsis angolensis* seedlings under different nursery treatments of SI, PS and PM. It is expected that the information obtained will inform further research and operationalization process by adopting efficient procedures and practices to ensure high survival and performance of *Pericopsis angolensis* during establishment.

3.2 Material and Methods

3.2.1 Experimental site

The study was conducted from December 2021 to May 2022 at the Tanzania Forest Services Agency (TFS) Tree Seed Production Station (TSPS) nursery, in Kihonda - Mbuyuni, Morogoro municipality, Tanzania. The station is 3 km from Msamvu bus stand on the road to Dodoma region. TSPS is located 511 m a.s.l. at latitude and longitude 6° 49' 12" and 37° 38' 36" respectively. The station has minimum and maximum temperatures of 16°C and 33°C respectively and annually the area receives rainfall ranging between 821 mm - 1505 mm (Ernest *et al.*, 2017).

3.2.2 Experimental design and treatments

A 3 x 3 x 3 factorial arrangement fitted into a Completely Randomized Block Design (CRBD) was employed in this study. The three factors investigated were SI, PS and PM. SI was regulated at three different levels (intensities) by shade nets, resulting in 0% (SI0), 50% (SI1),

and 75% (SI2) relative SI (Pach *et al.*, 2022). PS was varied by using three different heights: 10 cm (PS1), 15 cm (PS2), and 20 cm (PS3). Each experimental container (made of polyethene tube) had a standardized lay-flat diameter of 10.16 cm (Vyamana *et al.*, 2007). The PMs were based on volumetric ratios as outlined by Vyamana *et al.* (2007) where:

- PM0: sand: cow manure: forest top soil (1:2:4);
- PM1: sand: cow manure: forest top soil (1:2:3);
- PM2: sand: cow manure: forest top soil (1:4:3);
- PM3: forest top soil only; and
- PM4: PM0 with an additional 0.5 gm of NPK.

Three major plots were established, representing a different SI (SI0, SI1, and SI2). Each major plot was further sub-divided into five sub-plots, each corresponding to a specific PM (PM0, PM1, PM2, PM3, and PM4). Finally, within each sub-plot, the three different PSs were tested (PS1, PS2, and PS3) producing 30 pots per treatment combination. Additionally, each PS was replicated ten times, resulting in a total of 150 pots for each SI and a grand total of 450 pots for the entire experiment, allowing for a comprehensive assessment of the combined effects of the treatment factors on *P. angolensis* seedling performance.

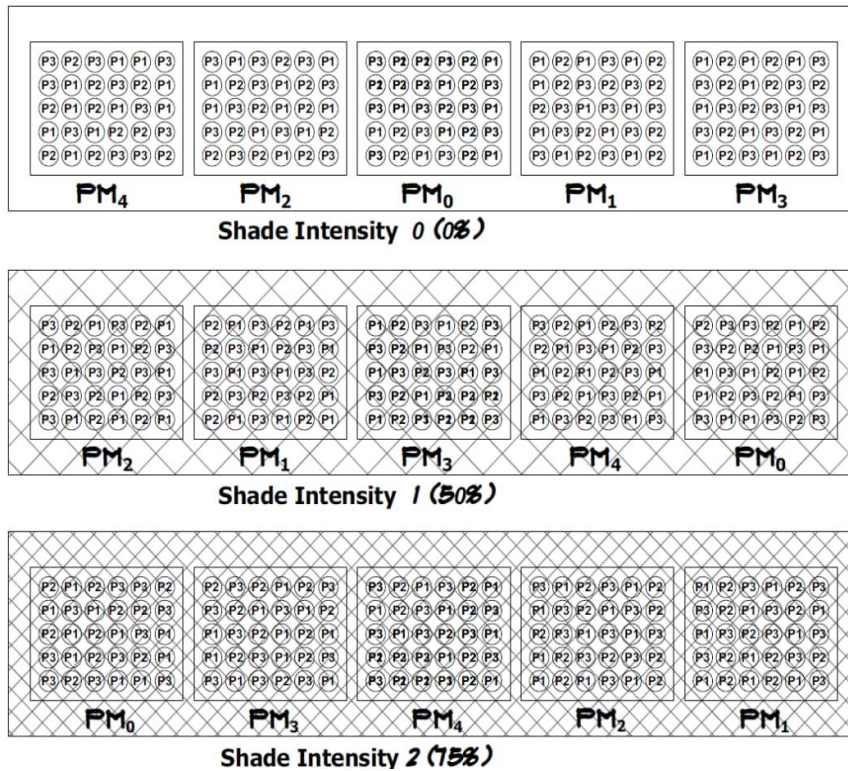


Figure 3.1: Arrangement of shade intensity, potting mixtures and pots in the nursery

3.2.3 Data collection

3.2.3.1 Growth parameters

The assessment of growth parameters namely root collar diameter (RCD), shoot height (SH) and leaf count (LC) as non-destructive parameters were recorded after every 2 weeks for 4.5 months; while root length (RL) and total dry biomass (TDB) were recorded at the end of the experiment. The first data collection was taken on the 30th day after seed sowing date. SH was taken from the plant emerging point in a container at the level of soil surface to the highest apical meristem and RCD was measured at the level of soil surface/line. The recognizable leaf was counted from each plant/seedling. Seedling survival was recorded by counting the surviving seedlings at the end of the experiment.

3.2.3.2 Seedling quality parameter

Seedling quality in terms of the sturdiness quotient (SQ) was also evaluated. This is a measure of the vigour and robustness of a seedling. It was calculated by dividing SH by RCD, which is the point on the stem where the root system begins. The SQ provides a quick and simple method of evaluating seedling quality, as it considers both above-ground growth and root development.

3.2.4 Statistical analysis

Three-factor analysis of variance (ANOVA) was employed to test the effects of SI, PS and PM treatments on the changes in RCD, SH, LC, RL, TDB and SQ of the seedlings. A total of 30 seedlings per plot were used in the data analysis. Tukey's HD multiple comparisons test was used separate treatment means that were significantly different. All statistical analyses and visualizations were performed using R-software and Excel software respectively. All probabilities were tested at $p = 0.05$ significance level.

3.3 Results

3.3.1 Treatment effects on *P. angolensis* survival rate

The investigation into the effects of the experimental treatments on seedling survival rate revealed distinct patterns. SI emerged as a critical determinant, where seedlings under SI0 exhibited 0% survival rate, in contrast to SI1 and SI2, where all of the seedlings survived (100%) (Figure 3.2) during the experimental period.

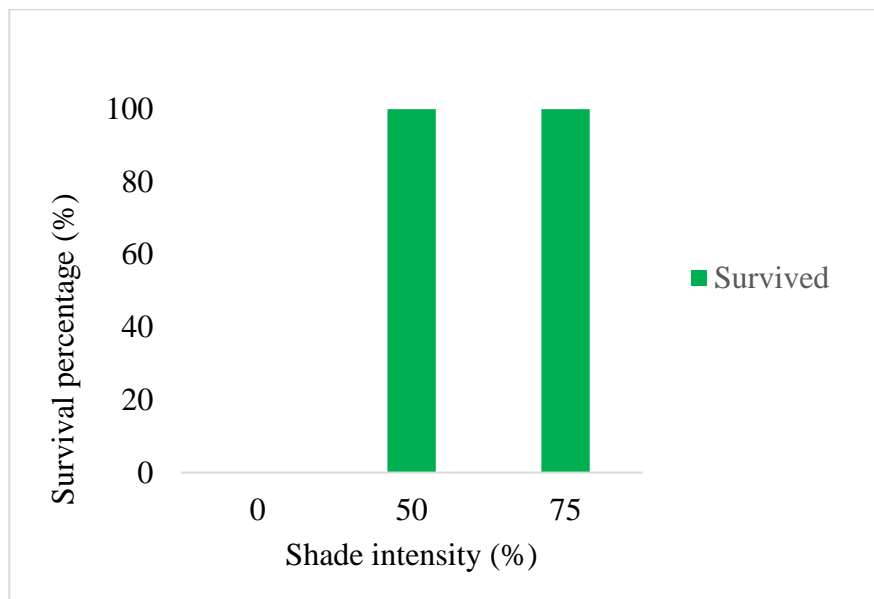


Figure 3.2: Effect of shade intensity on seedlings survival rate

3.3.2 Treatment effects on *P. angolensis* seedling growth parameters

The analysis of how different treatments impacted the growth of *Pericopsis angolensis* seedlings provided valuable insights. SI had a strong influence on RCD, with a statistically significant effect. SH was significantly affected by SI, PM, PS, and their interactions. Similarly, LC was significantly influenced by SI, PS, PM, and the interactions between them, with SI having the strongest impact. RL was affected by all factors and their interactions. TDB was impacted by most treatments except the interactions between SI and PS, and between PS and PM (Table 3.1, Figures 3.3-3.7). Notably, PS had the most significant influence on the growth parameters of *Pericopsis angolensis* seedlings, highlighting its importance.

Table 3.1: ANOVA results of treatment effects on *P. angolensis* seedling growth parameters

Growth parameter	Source of variation	Mean Sq	F-value	p-value
Root collar diameter (RCD)	SI	139.754	308.333	<0.001
	PM	0.470	1.038	0.3857
	PS	0.005	0.011	0.9889
	SI:PM	0.228	0.503	0.8544
	SI:PS	0.095	0.211	0.9323
	PM:PS	0.060	0.134	0.9977
	SI:PM:PS	0.192	0.424	0.9771
Shoot height (SH)	SI	221.502	449.096	<0.001
	PM	3.833	7.772	<0.001
	PS	2.642	5.358	0.0048
	SI:PM	5.543	11.238	<0.001
	SI:PS	12.836	26.026	<0.001
	PM:PS	5.571	11.093	<0.001
	SI:PM:PS	4.472	9.060	<0.001
Leaf count (LC)	SI	708.883	130.266	<0.001
	PM	240.101	44.121	<0.001
	PS	45.292	8.323	<0.001
	SI:PM	16.920	3.109	0.0017
	SI:PS	20.599	3.785	0.0044
	PM:PS	29.820	5.479	<0.001
	SI:PM:PS	10.270	1.880	0.0173
Root length (RL)	SI	164.280	20.573	<0.001
	PM	99.388	12.446	<0.001
	PS	1351.263	169.221	<0.001
	SI:PM	42.721	5.350	<0.001
	SI:PS	63.210	7.915	<0.001
	PM:PS	26.475	3.315	0.0012
	SI:PM:PS	29.514	3.690	0.0004
Total dry biomass (TDB)	SI	1.684	19.616	<0.001
	PM	1.011	11.781	<0.001
	PS	2.560	29.822	<0.001
	SI:PM	0.689	8.035	<0.001
	SI:PS	0.102	1.195	0.304
	PM:PS	0.062	0.200	0.674
	SI:PM:PS	0.242	2.820	0.005

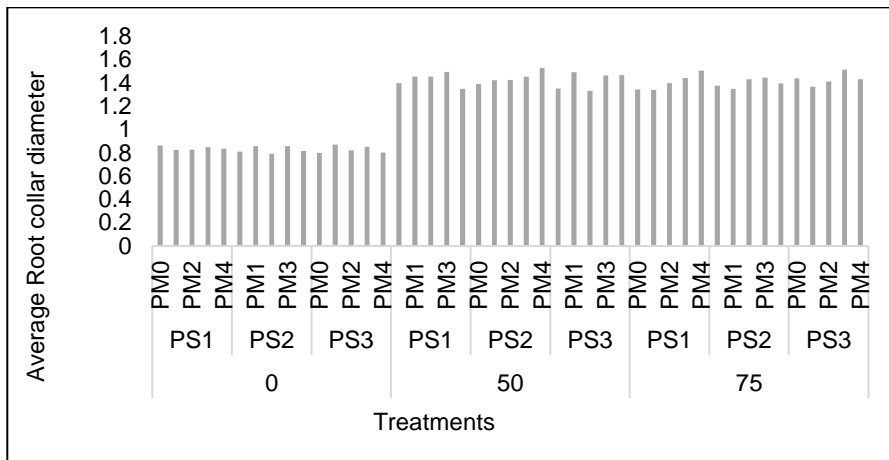


Figure 3.3: Influence of treatment factors on average root collar diameter

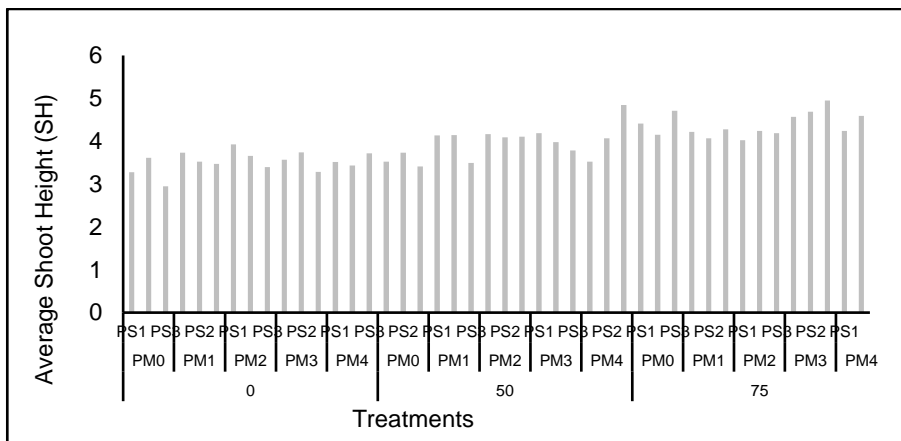


Figure 3.4: Influence of treatment factors on average shoot height

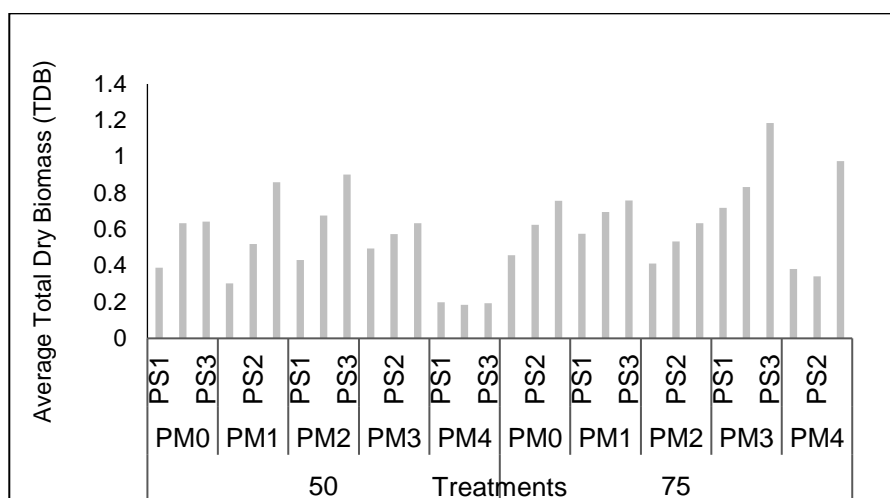


Figure 3.7: Influence of treatment factors on average total dry biomass

3.3.3 Treatment effects on sturdiness quotient

The analysis of treatment effects on *P. angolensis* seedling quality as indicated by SQ showed significant effects from two factors: SI and PM (Table 3.2). SI showed a highly significant effect on SQ ($F = 54.313$; $P < 0.001$), with the lowest SI level (SI0) resulting in relatively higher SQ compared to other levels. Similarly, PM showed a significant influence on SQ ($F = 2.630$; $P < 0.05$), with PM0 and PM2 contributing to higher SQ than other PM (Table 3.2). These findings are represented visually in Figures 3.7 and 3.8, showing the noticeable trends in seedling quality with varying SIs and PMs.

Table 3.2: ANOVA results on *P. angolensis* seedling sturdiness quotient

Seedling quality indicator	Source of variation	Mean Sq	F-value	p-value
Sturdiness quotient	SI	1201.728	54.313	0.000
	PM	58.202	2.630	0.033
	PS	2.141	0.096	0.908
	SI:PM	17.661	0.798	0.604
	SI:PS	20.440	0.923	0.448
	PM:PS	19.541	0.883	0.529
	SI:PM:PS	10.354	0.468	0.962

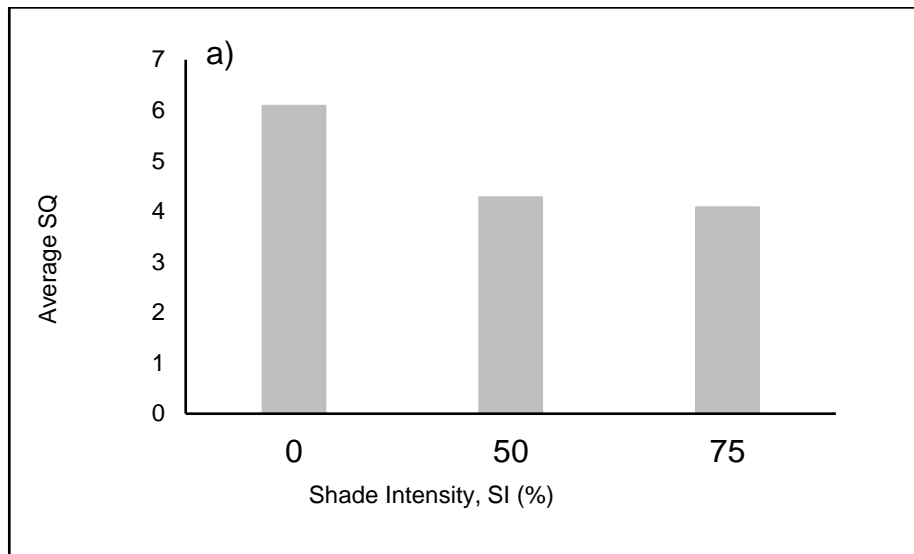


Figure 3.8: Influence of (a) shading intensity on *P. angolensis* sturdiness quotient

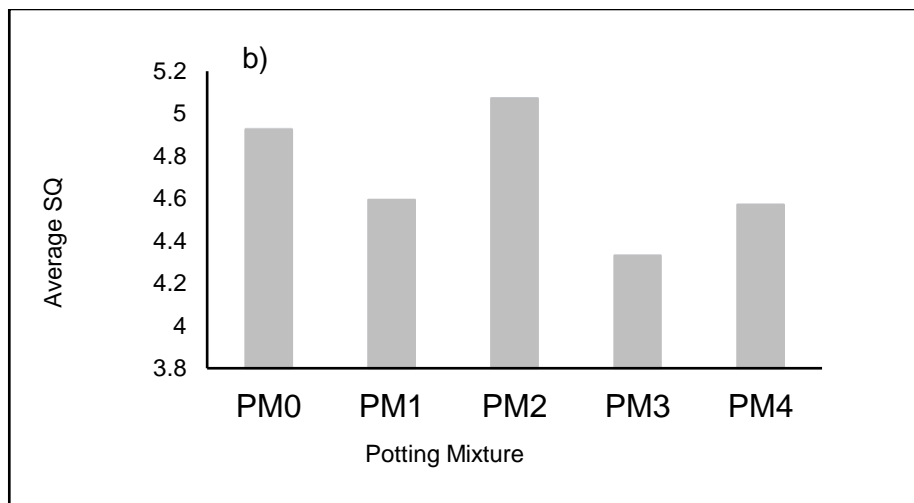


Figure 3.9: Influence of potting mixture on *P. angolensis* sturdiness quotient

3.4 Discussion

The development of seedlings in a nursery is a crucial aspect of successful tree planting and restoration programmes in tropical countries. In order to ensure the survival and smooth growth of seedlings, it is essential to have proper facilities in place within the nursery setting. Experiments on seedling establishment for various tropical tree species, such as those found in Tanzania, have yielded positive results. However, many nurseries in Tanzania are locally run and may lack proper regulation of important elements, such as shade. Shade can greatly impact field-grown seedlings by reducing plant and soil evaporative demands (Holmgren, 2010), or by decreasing the risk of photodamage (Valladares *et al.*, 2005; Prider and Facelli, 2004). The effect of shading on plants may also depend on the soil moisture content (Prider and Facelli, 2004; Holmgren *et al.*, 1997). The facilitation effect of shading is explained to be one of the factors for reduced mortality of seedlings during establishment stage in Mediterranean region (Gómez-aporicio *et al.*, 2019; Castro *et al.*, 2004). These results are in agreement with findings of to this study as there was high mortality of seedlings under full sun.

The study reported that shade acted as the mediating factor to regulate the seedling performance in the sense that, the success growth performance was experienced highly when full sun was escaped. Also, the higher seedling RCD (2.18 cm) was observed under 50% and 75% SI. Increase in SI here was associated with the increased RCD in both treatment of PS and PM. Thus, although there was different performance of the tree growth in PS and PM, when categorized into three SI classes, increasing in SI positively improved the diameter values significantly. RCD in 75% shade was lower than those in 50%. These results concur with those reported by Kennedy *et al.* (2007) where RCD of seedlings decreased with increase in SI. Plants usually respond to decreasing light availability by reducing growth (Wang *et al.*, 1994). On the other hand, SH in this study increased with increasing in SI. Whereby, SH values of the seedling planted under 75% SI showed consistent SH during the whole study period. These results are also consistent with Kennedy *et al.* (2007) whose results reported SH increase with the increase in SI.

The results contrast with Beaudet and Messier (1998) who reported decline of the SH with increasing in SI of *Betula alleghaniensis* and *Fagus grandifolia* species. In conclusion, the influence of the shade on the performance of the seedling development is also linked to the specific tolerance level of the species to shading, either shade tolerant species and shade intolerant species (Kaelke *et al.*, 2001).

Shade enhances photosynthesis by reducing the intensity of light, which allows the seedlings to absorb light and convert it into energy. This increased energy production promotes the growth of new leaves and enhances leaf number development. In this study we have observed that the increased SI promoted higher LC than the full sun exposure. The decreased LC on the low SI would be associated with the high moisture stress that also accelerated the leaf dropping as the seedling grows. These results were also observed by Welander and Ottosson, (1998), when assessing the influence of shading on growth and morphology in seedlings of *Quercus robur L.* and *Fagus sylvatica L.* This tendency is linked to the shade acclimated plants where with increasing shade, biomass allocation shifts from root to leaves and shoots (Givnish, 1988).

The statistical analysis revealed that out of all the factors tested, only two showed a significant influence on the SQ of the seedlings. These two factors were SI and PM. Results suggest that SI and PM are important factors to consider when aiming to improve the quality of seedlings in terms of SQ. SQ is one of the important scanty information regarding the quality of planting stock that has implication on survival and field performance of out planted tree seedlings (Gebretsadik, 2018).

The present study also investigated the effect of SI, PM, and PS on the RL of seedlings. The results showed that all three factors, as well as their interactions, had a significant influence on the RL of the seedlings. These findings are consistent with previous studies that have reported the effects of environmental factors on seedling growth and development. For example, it has been shown that shade can affect root growth by altering the photosynthetic rates of the plant

(Rosado *et al.*, 2022). Small RL was observed in 75% shade compared to 50% shade in this study similar to what was reported by Panetta (1977), where small RL of *Baccharis halimifolia* L. was measured in shaded treatments. Similarly, the type of PM and PS can influence root growth by affecting nutrient availability and water retention. The interaction effect observed in our study suggests that the effects of these factors on seedling RL are not independent, but rather depend on their combined influence. This highlights the complexity of seedling growth and development, and the importance of considering multiple factors when aiming to optimize seedling production.

Findings suggest that PS has a greater impact on seedling dry biomass compared to SI and PM. The significant effect of PS on seedling growth and biomass can be attributed to the fact that larger pots provide more space and nutrients for root development, leading to increased biomass production. This finding is consistent with previous studies that have shown that larger pots can enhance plant growth and biomass by increasing the availability of soil nutrients and water (Poorter *et al.*, 2012). The significant effects of SI and PM on seedling growth and biomass indicate that these factors also play a role in determining seedling survival and development in the field site. The SI may affect photosynthesis and nutrient uptake in plants, leading to changes in growth and biomass. Similarly, the PM can influence the physical and chemical properties of the soil, affecting nutrient availability and water retention, which in turn can impact seedling growth.

3.5 Conclusion

This study clearly demonstrated that nursery conditions significantly impact the growth and survival of *Pericopsis angolensis* seedlings. Our key findings indicate that shading intensities SI1 and SI2 optimize seedling performance, while shade intensity SI0 reduces survival. Larger PS (PS3) also promote increased growth and survival compared to smaller containers. Although PM had a less pronounced effect, tailored compositions can help meet specific management goals and resource constraints. To optimize the growth of *Pericopsis*

angolensis seedlings, it is recommended to carefully manage shading conditions, with a particular emphasis on maintaining 50% SI for ideal outcomes. This can be achieved through the use of shade structures or by selecting planting sites with natural shade. Furthermore, the study highlights the potential benefits of using larger PSs consisting forest top soil to enhance seedling productivity, with implications for biomass production.

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Conflict of Interest

No conflict of interest.

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CHAPTER FOUR

4.0 General Discussion

The first study investigated the influence of seed pre-sowing treatment on germinability of *Pericopsis angolensis*, although different studies have shown the importance of pre-treatments (Kumar *et al.*, 2018; Hasnat *et al.*, 2016; Azad *et al.*, 2011; Azad and Matin, 2010). Our study observed no significant differences between pre-treated seeds and untreated seeds (control) in terms of germination percent, germination value and germination capacity. The findings agree with Nkengurutse *et al.* (2016), who reported that seeds of some indigenous Fabaceae tree species in Burundi wet Miombo woodland including *Pericopsis angolensis*, *Brachystegia microphylla*, *Brachystegia utilis*, *Brachystegia bussei* and *Julbernardia globiflora* did not require special germination condition.

Generally, this study found that, soaking time exposure and temperature of water used to pretreat seeds have no positive additional effect in comparable to untreated seeds. Considering the same germination time between treated seeds and untreated seeds, then pretreatment of *Pericopsis angolensis* seeds by soaking in water proves to be unnecessary. This is in contrast to several researches which argue that species of Fabaceae family such as *Acacia nilotica*, *Faidherbia albida*, *Vachellia rehmanniana*, *Pterocarpus angolensis*, *Leucaena leucocephala* and *Dicrostachys cinerea*, present high physical dormancy, and hence requiring pretreatments before germinating (Gilani *et al.* 2019, Kheloufi *et al.* 2018, Mojeremane *et al.* 2017, Idu and Omonhinmin 1999, Msanga 1998).

Experiments which involve alteration of different nursery treatments like soil amendment and PS have also been used highly to assess the performance response of the seedlings (Munyanziza and Oldeman, 1994). Our results showed that SI was the significant predictor of the seedling performance which include RCD, SH, and LC with the 50% and 75% SI being the most useful factor. Positive influence of SI on seedling performance has also been reported in other studies (Kennedy *et al.*, 2007; Castro-Díez *et al.*, 2006). In nurseries, shade

is essential for seedling survival and growth since it helps to create a suitable micro-climate. It controls temperature by reducing overheating in hot areas and shielding seedlings from stress and desiccation. Additionally, the presence of shade reduces the intensity of the light, protecting the sensitive plant tissues and promoting proper photosynthesis (Al Pavel *et al.*, 2023; de Araújo *et al.*, 2023).

On the other hand, PS also influenced productivity of the seedlings in our study which aligns with different studies conducted for example Poorter *et al.* (2012). The effect of PS here would be the ability to hold more resources in terms of nutrients and porosity as well as to hold enough soil moisture for steady growth. Successful afforestation and reforestation projects depend also on understanding how different potting combinations affect seedling survival and growth (Mulugeta, 2014; Vyamana *et al.*, 2007). This is a crucial component of nursery management. The microenvironment in which seedlings develop has a direct correlation with the PM's composition. The type of organic matter used, the soil's nutrient composition, and other variables can all have a big impact on how well seedlings do (Kakoei and Salehi, 2013). The growth of seedlings can be impacted by various potting combinations in a number of different ways. Aeration, root growth, and water retention are all impacted by the mixture's texture and structure (Kakoei and Salehi, 2013; Mulugeta, 2014; Vyamana *et al.*, 2007). Root rot can be avoided by using a well-balanced PM with excellent drainage. Another critical element is the availability of nutrients; mixes rich in vital minerals can promote strong seedling growth. This theoretical knowledge is aligned with our results which indicated that, root development in our study was highly influenced by PM with higher number of nutrients both from cow manure and the addition of NPK similar to SH and the total productivity. The results indicate that, amendment and enhancement of the growing medium for the survival and growth of the indigenous seed in nursery setting is very important. Enhancing overall nursery cultural techniques increases the possibility of successful afforestation and reforestation in the face of the global climate change (Liu *et al.*, 2012; *et al.*, 2017).

CHAPTER FIVE

5.0 Key Contributions, Conclusions and Recommendations

5.1 Key Contributions and Conclusions

This study observed that:

- i. Our study showed that *Pericopsis angolensis* seeds do not require pre-sowing treatments, indicating an absence of physical seed dormancy.
- ii. SI matters. SI1 and SI2 are optimal for seedling performance, while SI0 reduces survival.
- iii. PS matters. Larger PS3 containers promote increased growth and survival compared to smaller containers.
- iv. PM matters. Using forest topsoil in larger PSs can enhance seedling productivity and has implications for biomass production.
- v. Generally, nursery conditions influence seedling performance. Nursery conditions significantly impact the growth and survival of *Pericopsis angolensis* seedlings.

5.2 Recommendations

Following the conclusion from this study, it is recommended that:

- i. No pre-treatment required
Continue with the practice of direct sowing or planting of *Pericopsis angolensis* seeds without any pre-treatment.
- ii. Shade Management
Maintain 50% SI for ideal seedling outcomes. Use shade structures or select planting sites with natural shade to achieve this.
- iii. Container Size
Prioritize the use of larger PS containers to enhance seedling growth and survival during nursery cultivation.
- iv. Soil Composition
Consider using only forest topsoil in larger containers to improve seedling productivity and biomass production potential.

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