KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF BIOSCIENCES

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

EFFECT OF DIFFERENT PRE-SOWING TREATMENTS ON THE GERMINATION AND INITIAL GROWTH OF *Pterocarpus erinaceus* SEEDS

By

KYEI, RICHARD KOFI

BSc. (HONS)

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF BIOSCIENCES

DEPARTMENT OF THEORETICAL AND APLLIED BIOLOGY

EFFECT OF DIFFERENT PRE-SOWING TREATMENTS ON THE GERMINATION AND INITIAL GROWTH OF *Pterocarpus erinaceus* SEEDS

A thesis submitted to the Institute of Distance Learning, Kwame Nkrumah University of Science and Technology in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (MSc.) DEGREE IN ENVIRONMENTAL SCIENCE

By

KYEI RICHARD KOFI

BSc. (HONS)

SEPTEMBER 2016

DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree in Environmental Science and thus all references and quotations cited in support of the results and the concomitant arguments have been duly acknowledged.

Kyei Richard Kofi ....……. …….

(ID PG8940313) *SIGNATURE* *DATE*

Martin Abed Arkoh …….. ……..

(Supervisor) SIGNATURE DATE

Dr. Matthew G. Addo …….. ……..

(Head of Department) SIGNATURE DATE

DEDICATION

This work is dedicated to my dad Mr. Joseph Kwaku Adomako and my late mum, Madam Victoria Abena Osei Pokuaa.

ABSTRACT

Pterocarpus erinaceus plants are being used in the afforestation programme implementation in the savanna ecological zone of the Northern Region of Ghana but there is a problem with the germination rate and efficiency of the seeds. This study was therefore initiated to investigate the effects of different pre-sowing treatments on seed germination and seedling growth rate of *Pterocarpus erinaceus*. Seeds from *Pterocarpus erinaceus* plant were collected and subjected to five different pre-sowing treatments. The seeds soaked in cold water at room temperature for 24 hours (T2), in hot water (100 $_0$C) for 1 hour (T3), in concentrated sulphuric acid for 1 hour (T5), mechanical scarification (T4), and no treatment (T1) as control. The treatments were arranged using Completely Randomized Design. Each treatment had 50 seeds making a total of 250 seeds as the sample size. After the treatments, the seeds were sown in 10cm black polythene tubes filled with loamy soil. One seed was sown per tube at a depth of 2cm. Growth features of the seeds were assessed 7 days after sowing, and daily thereafter for 25 days. Data collected were subjected to ANOVA and the significant means separated using the F-LSD. The results indicate that pre-sowing seed treatments have positive influence on percentage germination. However, seed treatment had no significant effect on the seedling growth. Highest percentage germination (70%) was attained with seeds soaked in cold water (T2) at 25C. ^{0} This was followed by those which were mechanical scarification (T4) which recorded percentage germination of 66%. Control (T1) and hot water (T3) treatments recorded percentage germination of 62% and 58% respectively. No germination was recorded for acid treatment. Seeds that were treated with cold water had the best results as compared to the other treatments. Therefore, it is recommended that using cold water at room temperature as a pre-sowing method should be encouraged for early germination of *P. erinaceus*.

ACKNOWLEDGEMENT

I am very grateful to my supervisor, Mr. Martin Abed Arkoh of the Biological Science Department of the College of Science, for his attention, dedication and direction exhibited during the supervision of my work.

I wish to express my heartfelt appreciation to my dad Mr. Joseph Kwaku Adomako for living up to utmost expectation as a dad. Also to my boss Mr. Kwaku Antwi-Boasiako for his support and advice which led to the successful completion of this programme. My siblings and friends, I say thank you for your support and motivation. I sincerely thank my wife Mrs. Christian Kyei and my kids Diana, Prince, Richard, Angela, Victoria, Emmanuel, Britney and Nana Antwi for their lovely support.

My greatest thanks go to the Almighty God for his guidance and protection throughout the programme.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

 LIST OF PLATES

PLATES **PAGE**

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Pterocarpus erinaceus, otherwise, referred to as rosewood is a leguminous tree of African savannas and dry forests famous for producing one of the finest woods in its native region. The tree produces attractive golden yellow flowers that completely cover the canopy and has considerable potential as an ornamental. Rosewood is a small to medium-sized tree with a diameter of 1.2 – 1.8 m. It grows up to a height of 12 – 15 m with exceptionally tall ones growing up to 35 m as reported by von Maydell (1983). Lely (1925), reports that larger *Pterocarpus erinaceus* trees have clean straight boles of 6 – 8 m long. Rosewood begins to flower from December and ends in February (ICRAF 1998). The leaves of *Pterocarpus erinaceus* are 30 cm long and have about 10 – 15 alternate leaflets. The leaf measures 6 -11 cm long and 3 – 6 cm wide according to Hutchinson *et al*. (1958) and Lely, (1925). The bark is dark grey with rough scales. The fruit is 4 – 7 cm in diameter, indehiscent, and broadly winged. Medicinally, rosewood leaves has been found to be effective in the treatment of fever whilst the bark helps in curing tooth and mouth troubles (Hutchinson *et. al.* 1958). The flowers usually attract bees and may thus have value for producing honey. The seeds are also reported to induce intoxication (Hutchinson et. al., 1958). Local blacksmiths have also found value in the tree as it makes very good charcoal. Rosewood tree is able to thrive at low altitudes (0 – 600 m) and even on shallow soils and once established, it survives yearly dry seasons and savanna bush fires. Recent demand for its high-value timber by the Chinese is threatening its existing natural stands. The fruit is easy to propagate and thus make it a good candidate for afforestation and reforestation programmes. In Ghana, *Pterocarpus erinaceus* has received very little research attention, neither

is it grown on a large scale by farmers or incorporated into the Government's Plantation Programmes due to inadequate knowledge about it. This studies therefore would assist in providing information on this tree to enable it be integrated into agroforestry systems.

1.2 Problem Statement

Pterocarpus erinaceus popularly referred to as Rosewood, until a government ban was the most sought after timber in Ghana for export mainly to China where the demand for it is high. A Ghana News Agency report of July 2014 quotes the Minister of Lands and Natural Resources as saying "the ban on the harvesting, transportation, processing, export or sale of rosewood in any form still remains in force". Harvesting and trade in rosewood in the fragile savanna zones of the country has raised concerns on the environmental consequence of a sustained harvesting of rosewood in that part of country. Information is also scanty on the regeneration potentials (natural and artificial) of this species in Ghana as there is no known plantation establishment of rosewood in the country. The current ban is the third since the inception of rosewood trade (from 2005) in Ghana. The first in January 2012 to be followed by another in January 2014, with the latest arising out of Cabinet of Ghana meeting on rosewood trade in September 2013.

It has great potential to provide different products and services such as forage and traditional medicine. Because of their importance in providing many uses and services, they have attracted some attention. However, there has been little experimental research dealing with the seed germination and seedling emergence. The available information about this species is its botany, cultivation method, taxanomy, genetic diversity, brief descriptions of their habitat conditions and the range of their geographical distribution. One of the problems with this species is the

difficulty of raising seedlings from seeds. It is against this background that this study was initiated to generate interest for more studies to be conducted on this species in the country to serve as basis for decision-maker in proffering informed and appropriate management prescriptions in the management of *Pterocarpus erinaceus* in Ghana. Results of this study would make a case for rosewood to be considered in future government of Ghana plantation development programmes in the savanna zones where this species predominates.

FAO (1955) has reported that in any planting programme, an assured supply of seeds must be of immense priority, hence the choice of this topic. The success or failure of any artificial or natural regeneration is mostly hinged on the quality of the seed. This is corroborated by Nwoboshi, (1982). Several efforts to achieve effective afforestation have been inadequately rewarding due to lack of quality seed. A successful plantation is largely dependent on healthy nursery seedlings. Troupe (1921) reveals that the need for quality seed has increased considerably in the tropics following the unprecedented increases in afforestation programmes. There is inadequate information on *P. erinaceus* on its suitability for large plantations particularly on its seedling growth characteristics. This study therefore attempts to investigate the best treatment method that would ensure the fast germination of the rosewood seeds for incorporation into plantations programmes.

1.3 Justification of Research

The resource potentials of indigenous trees can be tapped through the process of domestication. Researchers have to identify these trees with the help of farmers, who know, appreciate and depend on these species for a number of tree products, before embarking on domestication

(Leakey, 1994). *Pterocarpus erinaceus* is of great interest for agroforestry systems, as it helps to improve soil fertility. Increased demand for rosewood as a timber species is competing greatly with its importance as a source of fodder and also for soil improvement, uses that are crucial to the livelihoods of the farmers and cattle rearing in the northern regions of Ghana. *Pterocarpus erinaceus* has valuable medicinal uses such as antimicrobial, wound-healing and antioxidant effects, which makes it a good candidate for more research attention. Studies such as this would assist in the provision of information required to facilitate its integration into future plantation programmes in Ghana. This study would provide for plantation developers and farmers, modern procedures and treatments given to the seeds to enrich their germination. These treatments and procedures would afford farmers in the study area an opportunity to increase the number of seedlings available to them for planting and hence increase the number of trees of *Pterocarpus erinaceus*. The management practices of seedlings that would be recommended in this study would be modern and scientific that can be adopted for fast propagation and growth of the plant. The detailed botanical description of the plant that would be given in this study would help researchers and other scientists to identify the plant growing elsewhere with ease. The medicinal properties of the plant that would be provided in this study can be explored for herbal medicine. The findings of this study will increase the scientific knowledge in the field and the appropriate method for breaking the seed dormancy to enhance germination.

1.4 Aims and Objectives of the Research

The aim of this research was to identify the effects different pre-sowing treatment method on the germination and initial growth of *P. erinaceus* seed.

The objectives were:

- To determine the effects of different pre-sowing treatments on seed germination *P. erinaceus* seeds.
- To determine the effect of different pre-sowing treatments on the seedling growth rate of *P. erinaceus*.
- To determine the best pre-sowing treatment for seed germination and seedling growth rate of *P. erinaceus.*

CHAPTER TWO

LITERATURE REVIEW

2.1 Description of the study Plant: *Pterocarpus erinaceus*

Pterocarpus erinaceus (**as shown in Plate 1**) is a leguminous tree of African savannas and dry forests that produces quality woods in its native region. It also produces fodder that is high in protein and makes an excellent feed for livestock in the dry season. *P. erinaceus* produces attractive golden-yellow flowers and has great potential as an ornamental. High demand for its quality timber and fodder threatens existing natural stands. However, the tree fruits very well and is easy to propagate, and thus qualifies to be selected for reforestation programmes. *P. erinaceus* has many common names including rosewood, vene, madobia, krayie and kino.

2.1.1 Taxonomy of *Pterocarpus erinaceus*

Pterocarpus erinaceus comes from the family of Leguminosae and subfamily Papilionoideae. It is a small to medium-sized tree usually 12 – 15 m tall with a diameter of 1.2 – 1.8 m. Lely (1925), reports that larger *P. erinaceus* trees have clean straight boles of 6 – 8 m long. Rosewood begins to flower from December and ends in February (ICRAF 1998). The leaves of *P. erinaceus* are once-compound, and 30 cm long and have about 10 – 15 alternate leaflets. The leaf measures 6 -11 cm long and 3 – 6 cm wide according to Hutchinson et al. (1958) and Lely (1925). The bark is dark gray with rough scales. The fruit (**as shown in Plate 2**) is 4 – 7 cm in diameter, indehiscent, and broadly winged. The seeds (**as shown in Plate 3**) are kidney-shaped to oblong.

Plate 1: Typical tree of *Pterocarpus erinaceus*

Plate 2 The Fruit of *Pterocarpus erinaceus*

Plate 3 The Seed of *Pterocarpus erinaceus*

2.1.2 The Ecology of *Pterocarpus erinaceus*

Pterocarpus erinaceus adapts well in dry forests of semi-arid and sub-humid area with an average annual rainfall of 600 – 1200 mm. It is able to survive long dry season lasting between 8 – 9 months. The tree's natural range has an average annual temperature of 15 – 30 ^{o}C, but has the ability to tolerate high temperatures exceeding 40 ^{o}C. Rosewood tree is able to survive at low altitudes (0 – 600 m) and on shallow soils as well and once established, survives yearly dry seasons and savanna bush fires (Aubreville 1950).

2.2 Uses of *Pterocarpus erinaceus*

2.2.1 Wood and wood products

Pterocarpus erinaceus provides quality wood from dry forests of the region. The wood is a beautiful, rich rose-red or dark brown, mottled with dark streaks (NAS, 1979). It has a finegrained appearance and it is used for door and window frames, furniture, decorative paneling and parquet flooring. It does very well when used to produce charcoal, which is highly patronized by blacksmiths.

2.2.2 Medicine

Rosewood has varied medicinal uses. Rosewood leaves are used for the treatment of fever. The bark is used for the treatment of diarrhoea, dysentery, tooth and mouth troubles. The grated root when combined with tobacco is used to treat coughs. The bark or the roots is also used in the

treatment of dysentery, menstrual disorders, anaemia, gonorrhoea, ringworm infections, leprosy, wounds, tumours and ulcers (ICRAF 1997).

2.3 Propagation and planting

Pterocarpus erinaceus is easy to propagate by planting nursery-raised seedlings or rooted cuttings. The recommended pre-treatment method for the seed is immersion in water at room temperature for 18–24 hours. Soaking in sulfuric acid for 30–60 minutes and then in tap water for 5–10 minutes has also been recommended by Roussel (1996). The seeds may either be sown in pots (2 – 3 seeds per pot) or in nursery beds at spacing of 20 x 30 cm or 30 x 30 cm. the planted seedlings must be watered two times daily, morning and then late afternoon. Pruning must be done frequently as the seedlings develop deep taproots, beginning six (6) weeks after sowing, then every three (3) weeks afterwards. Planting out can be done with both potted seedlings or bare-root seedlings, as stumps or entire seedlings. Recommended hole for planting in dry areas should be 40 x 40 cm. The recommended spacing for woodlots is 5 x 5 m and that for fodder banks should be 1 x 2 m. In timber plantations, 3 – 5 m × 3 – 5 m spacing is recommended whereas for fodder production 1 m × 2 m is recommended.

2.4 Seed Viability, Test for Seed Viability and Dormancy of seeds

2.4.1 Seed Viability

Hanson (1985) defines seed viability as the measure of how many seeds are alive and could develop into plants which will reproduce themselves, given the appropriate conditions. Roberts (1972) also defined a viable seed as one which can germinate provided any dormancy that may

be present is removed. Seed viability can be tested using several established methods such as germination test, tetrazolium test, excised-embryo test and flotation as reported by Hartmann, Kester, Davies and Geneve (1997).

2.4.2 Test for Seed Viability

Factors that affect viability of a seed include its time of collection, its treatment between collection and storage and the conditions in which it is stored (William, 1985). There are several methods of seed viability testing which helps to determine seed quality as well as establish sowing rates for a given standard of seedlings (Hartmann, *et. al*., 1997).

Standard Germination Test: this is described by Hanson (1985) and Hartmann, *et al.,* (1997) as the most accurate test for seed viability. Standard germination test is conducted under controlled conditions to determine how many seeds will germinate and generate normal seedlings that could develop into normal reproductively matured plants. However, conventional germination test requires a relatively longer time for results to be obtained at least two weeks or more (Hanson, 1985).

Tetrazolium Test: it is a biochemical test which is used to test seed viability. It is quicker, but not as accurate and requires appreciable skills and practice in its application and interpretation (Hanson, 1985). The tetrazolium test is a fast biochemical test which determines seed viability by the red colour appearance of seeds when soaked in 0.1 % dilute solution of 2, 3, 5-triphenyl tetrazolium chloride (TTC). Respiratory enzymes in the tissues of the seeds change the TTC to an insoluble red compound (triphenyl for maize) while in non-living tissues, the TTC remains colorless (Hartmann *et. al.*, 1997). Production of light pink colour shows seeds with reduced

viability compared to seeds which stain dark red, which can be considered as viable (Hanson, 1985).

Excised-Embryo Test: this is used to test the viability of seeds whose dormant embryo require long periods of after-ripening before true germination takes place. The embryo is taken off from the seed and cultured in petri dishes with moist filter paper under light with a temperature of 18 – ^{0} 20 C. Non-viable seeds become soft, turn brown and die within 2 – 10 days whilst viable embryos remain firm and show some signs of viability such as spreading of the cotyledons or growth of the radicle and plumule (Hartmann *et. al.*, 1997).

Cut and Floating Test: this is the simplest and most rapid viability test. Here the seed is cut open with a knife to determine if the embryo appears normal and has completely filled seed coat. Normal appearance of the embryo does not always predict good germination, so it can be misleading (Hartmann *et. al.*, 1997). This involves placing the seeds in water. The heavy sound seeds sink to the bottom and the light empty seeds float on top and are poured out (Hartmann *et. al.*, 1997).

2.4.3 Dormancy of Seeds

Seeds which do not germinate when put under conditions normally defined as ideal for germination are said to be dormant. Or dormancy is a condition whereby seeds placed under the environment normally considered ideal for germination fail to germinate (Hartmann and Kester, 1990). There are different types of dormancy: primary dormancy, (innate, inherent, natural, endogenous), secondary (enforced) and induced types of dormancy.

2.4.3.1 Types of Seed Dormancy

Innate/primary dormancy: is that type with which the seed is shed. It is developed during maturation on the parent plant and persists for a variable length of time after the seed has been shed (Hartmann *et al*., 1990).

Enforced dormancy: is that which occurs when the seed is not itself dormant but fails to germinate due to adverse environmental conditions; however, when conditions become favourable the seeds would germinate (Hartmann *et al.,* 1990).

Induced dormancy: also referred to as secondary dormancy is a condition where a non-dormant seed acquires dormancy. It is induced in seeds by a particular climatic or environmental condition and will persist even after the inductive conditions are passed and the environment has become favourable for germination (Hartmann *et al.,* 1990).

2.4.3.2 Causes and Methods of Breaking Seed Dormancy

There are five causes of seed dormancy, these are: impermeability of the seed coat to oxygen and water; undeveloped/immature embryo; by chemical inhibitors – for example, abscisic acid (ABA); absence of certain hormones – for example cytokinins and gibberellins; lack of special requirement for light or temperature (Hartmann *et al*., 1990). Some of the simple and widely used methods for breaking seed dormancy are described in the following section. These include, impaction, scarification, stratification, leaching, and by the use of chemicals. Scarification is any process which involves scratching, breaking, mechanically altering, or softening the seed coverings to permit the entry of water and gases (Hartmann *et al.,* 1990). Scarified seeds are

more susceptible to injury from pathogenic organisms, however, and will not store as well, comparably, as non-scarified seeds. Small seeds of legumes, such as alfalfa and clover, are often treated in this manner to increase germination. Seeds may be tumbled in drums lined with sandpaper or in concrete mixers, combined with sand and gravel. The sand or gravel should be of different size from the seed to facilitate subsequent separation. Scarification must not be done in a way that injures seeds. To determine the optimum time, a test lot can be germinated, the seed coats may then be soaked to study swelling. Otherwise the seed coats may be examined with a hand-lens. To expose the inner parts of the seed, seed coats generally should be dull but not so deeply pitted or cracked (Hartmann *et al*., 1990). Seeds with hard coverings may be germinated by any method which artificially breaks or marks the seed coat, provided another type of dormancy is not present. In nature, softening the seed coat comes about through agencies of the environment: mechanical abrasion, alternate freezing and thawing, attack by microorganisms in the soil or passage through the digestive tract of birds or other animals. For effective seed coat decomposition, the seeds must be held moist at warm temperatures in the soil. Addition of nitrates to the medium could increase seed softening, presumably because it stimulates fungus activity (Hartmann *et al.,* 1990). One of the environmental conditions affecting germination is water (Hartmann *et al.,* 1990). Imbibition of water is the first step in the germination process. The most important factors which affect water uptake by seeds are the nature of seeds and its coverings, and the amount of available water in the surrounding medium. Seeds have great absorbing power, owing to their colloidal nature. In storage, seeds can absorb moisture/water from the surrounding air. Different kinds of seeds vary greatly in the amount and rate of water absorbed, in storage or during germination. The rate of water uptake is also influenced by temperature, favouring an increased rate. The seed covering also plays an

important role in water uptake. In some seeds, it is so impermeable to water that germination will not occur until the seed covering has been altered in some manner. Soaking seeds before planting is sometimes utilized to initiate the germination process and to shorten the time required for seedlings to emerge from the soil. Seeds which are hard and dry, therefore slow to germinate, may be given such a treatment, but if the seeds ordinarily germinate without difficulty, there is little need for soaking. Prolonged soaking can result in injury to the seed, and reduce germination. These harmful effects have been attributed principally to the presence of microorganisms and to poor aeration although there seems to be other effects that are not well understood. If soaking is to be prolonged, the water should be changed at least every 24 hours (Hartmann *et al*., 1990).

2.5 Seed Germination, Measurement of Germination and Germination of *P. erinaceus* 2.5.1

Seed Germination

Seed germination has been defined in many ways. According to Taiz and Zeiger (2002), seed germination is the resumption of growth of the embryo of a matured seed. In addition, Heydecker (1969) also defined germination as the occurrence of rapid metabolic activity within the seed that results in a perceptive growth of the embryo.

At the process of seed germination, the embryo absorbs water, resumes growth and breaks through the seed coat. The amount of moisture and oxygen, the temperature, the number of daylight hours and other aspects of the environment influence germination. Mature seeds do not contain enough water for cell expansion or metabolism. Usually, water availability is seasonal

and germination coincides with the return of a spring rain. Water molecules move into the seed in a process called imbibition, being especially attracted to hydrophilic groups of the stored proteins. As more and more water molecules move inside, seed swells and the coat finally raptures. Once the seed coat splits, oxygen moves more easily from the surrounding air into the seed cells of the embryo to engage in aerobic respiration; and metabolism moves into high gear. Cells divide and elongate continuously to produce the seedlings (Cercie and Ralph, 1992).

2.5.1.1 Types of Seed Germination

When the seed germinates, the seed coat ruptures by growth of the plumule and radicle. The plumule either grows upwards and the radicle downwards. Two types of germination may be distinguished:

Hypogeal germination: it takes place by the elongation of the epicotyls, with the results that the plumule move upwards out of the ground, leaving the cotyledons, still trapped within the ruptured seed coat, below the ground. This provides the growing embryo with nourishment until the green leaves develop at the tip of the plumule.

Epigeal germination: the hypocotyls elongates with the result that the plumule and the cotyledons are thrust upwards out of the ground. Seeds that germinate in this way generally have small cotyledons, which once exposed to light, develop chlorophyll and then begin to photosynthesize. Before this happens, nourishment is provided by the endosperm of which there is often a large amount in such seed.

2.5.1.2 Environmental Factors Affecting Seed Germination

Moisture, temperature, light and oxygen are the environmental factors that affect seed germination.

Moisture: Germination of seeds, for example those with dormancy problems, are inhibited by reduced moisture levels. It is therefore necessary to retain a high moisture supply in the seed bed. In order to initiate biochemical and physiological processes needed for germination to take place, most seeds must absorb additional water beyond what is present at maturity (Hartmann *et al.,* 1997).

Oxygen: During the early phases of germination, respiration of germinating seeds is important, since gaseous exchange between the germination medium and the embryo is essential for a rapid and uniform germination.

Temperature: Hartmann *et al.,* (1997) reported that temperature is the most important environmental factor that regulates the timing of germination.

Light: Seeds of many species need exposure to light to germinate and the germination of some species are inhibited by light.

Soil: The rate of water movement into seeds is largely premised on the structure of the soil pores (texture), the soil packing/closeness and the distribution of the seed-soil contact. A firm finetextured seed bed, closely compacted to the seed is necessary in maintaining a uniform moisture supply and a uniform germination (Hartmann *et al.*, 1997).

2.5.1.3 Germination of *Pterocarpus erinaceus*

Germination takes place from 6 – 10 days after sowing and would normally result in a germination rate of about 70% or more. Untreated seeds has germination rate of about 50%. The optimal germination temperature is 25–35 °C.

2.5.2 Measurement of Germination

Nwoboshi (1982) and Hartmann *et al.* (1997) mentioned that the two parameters used to measure germination are Percent Germination (G %) and Rate of Germination (GR). Percent Germination (G%) was defined by William (1985) as the number of seeds germinating relative to total number of seeds sowed in space and time:

$$G\ \% = \frac{\text{Total number of seeds germinating}}{\text{Total number of seeds sowed}} \times 100$$

2.5.3 Seed Pre-sowing Treatments

Different types of pre-sowing treatments of seeds have been used to hasten germination for trees species in the tropical areas. Some of the methods include soaking in hot water, soaking in acid, soaking in cold water, mechanical scarification and low temperature storage (Nwoboshi, 1982).

Mechanical scarification: Methods employed here include chipping of hard coats with sandpaper, cracking with a hammer for small amounts of seeds of relatively large size or cutting with a file (Hartmann *et al.*, 1997). Scarred seeds, however, should be dried and stored in sealed containers. Otherwise they must be planted immediately as the seeds may be susceptible to pathogenic attacks (Nwoboshi, 1982).

Soaking seed in acid: Seeds are soaked in concentrated sulphuric acid (H_2SO_4) in a ratio of one part of seed to two parts of acid until the seed coats are soft and permeable.

Soaking in hot water: Maydell (1986) confirms that, seeds with hard coats should be soaked in 4 - 10 times their volume of boiling water (or if possible in water of 60 – 90 ºC to avoid loses).

Dry heat treatment: Schmidt (2000) reported that in many hard seed coats, dormancy can be broken by abrasion of seed coats through the use of high temperatures (burning or roasting). The germination of other species such *as Exragrostis lehmannia* Nees (Lehman love grass) was reported by Haferkamp and Jordan (1997) to be significantly increased by oven drying of seeds for 24 hours at 70 ºC prior to sowing.

2.6 Seedling Transplanting

Successful transplanting usually depends on selecting a healthy and high quality nursery stock based on planting site characteristics, care after planting, transplant size, root ball characteristics and nursery production practices. In transplanting a woody plant, steps must be taken to evaluate whether or not the seedling is likely to survive.

2.7 Growth and Development

2.7.1 General tree growth and development

Growth is defined as the advancement towards the attainment of full size or maturity. Growth can be measured as increase in diameter and height. Plant growth and development involves quantitative increases in the number and size of cells and qualitative differentiation in types of cells (Jensen, 1988).

2.7.2 Height and Diameter Growth in Plants

Height growth results from apical meristems which happen close to the tips of roots and shoots to produce primary tissues. The meristems define the primary growth which is elongation of roots and shoots resulting in increase in height. Unlike apical meristems which increase the length of roots and shoots, vascular cambium and phellogen (cork cambium) increase the girth of stems and roots by a process called secondary growth. Height growth has a direct relationship with the number of leaves produced by seedlings and the diameter can also serve as an expression of soil fertility level (Jensen, 1988).

2.7.3 Measurement of Growth

Growth can be measured as an increase in length, width or area: often it is measured as increase in volume mass or height (either fresh or dry weight). Each of these parameters describes something different and there is a simple relationship among them in growing organism. This is because growth often occurs in different directions at different and possible rates, so that simple linear-area-volume ratios do not persist in time. Despite difficulties in measuring growth, the general pattern turns out to be the same for most organisms. Growth tends to be slow at first, then it speeds up and finally it slows down as adult size is reached giving an S-shaped curve (Mohr & Schopfer, 1995).

2.7.4 Rate of Growth

The growth curve enables us to re-express the growth of an organism in terms of growth rate. Estimating the increase in size that takes place during successive intervals of time, that is growth increments and plotting these against time can do this. In most organisms, the growth rate

increase steadily until it reaches maximum, after which it gradually falls, giving a bell shaped curve (Mohr & Schopfer, 1995).

2.7.5 Factors that influence growth and development

The two main factors influencing growth and development are climatic and soil or edaphic. According to Russell (1988), the principal factors influencing the rate of development are temperature and photoperiod while those determining growth are numerous and include light, carbon dioxide, nutrients and water. Soil affects the plant primarily through its root growth. Many factors affect root growth such as pH, aluminium toxicity, specific nutrient deficiencies etc. the principal factors affecting growth are: the soil moisture content; the soil temperature; the oxygen supply; the level of toxins and pathogens in the soil and the nutrient supply (Stanley, 1995).

2.8 Growth and development of *Pterocarpus erinaceus*

The seedlings of P. erinaceus develop long taproots and grow slowly. It is reported that in Mali, the seedlings grew 15 cm tall after one year and then up to 42 cm after two years. However, under good conditions tree height of up to 25 cm was reported 21 weeks after germination and up to 100 cm after 2 years. Rosewood is deciduous and loses most of its leaves getting to the end of the dry season. When coppiced, the trees can grow more than 1 m per year. In December–February (–April), the trees flower when leafless before developing new leaves. The flowers are much visited by bees, which are probably responsible for pollination.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

This study was carried out in Buipe (Central Gonja District) of the Northern Region of Ghana. Annual rainfall is limited to six months from May to October. The average annual rainfall ranges from 1000 – 1500 mm with its peak in September (Ghanadistricts.com).

3.2 Characteristics of the Study Area

3.2.1 Drainage and relief

The topography of the study area is generally flat with few areas having a diversity of patterns in terms of height. The area has streams, dams and dugouts which serve varied needs of human beings and animals (Agyare, 2004).

3.2.2 Climate and Vegetation

Climatic conditions of the area are the tropical continental type. The highest rainfall is experienced between July and September. Monthly rainfall figures ranges between 200 mm to 300 mm. The vegetation is principally the savanna with trees such as Kapok (*Ceiba pentandra*), dawadawa (*Parkia biglobosa*), sheanut (*Vitelleria paradoxa*), teak (*Tectona grandis*), and mango (*Mangifera indica*). Tall grasses and shrubs are common with other thorny species.

3.2.2.1 Temperature

The area experiences extremes of temperature. Temperature figures during the day ranges between 28 ºC and 40 ºC. The coldest nights in the year is experienced between December–February. During these months, the air becomes dry and the atmosphere hazy with blurred vision

due to fine dust particles in the air. Night temperatures can record below 18 ºC making the night very cold (harmattan period) (Agyare, 2004).

3.3 Seed Collection, Seed Viability test and Pre-sowing Treatments

3.3.1 Seed Collection

The seeds were sourced from the Forest Services Division of Buipe.

3.3.2 Seed Viability Test

The seed were subjected to a viability test using the Float Test Method. Seeds were put in a basin of water and left undisturbed for an hour. All suspended seeds were discarded and the sunken ones collected. Seeds which sunk were perceived to have had higher specific gravity due to more stored food reserves.

3.3.3 Seed pre-sowing treatments

The seeds were pre-treated as follows:

1. Untreated seeds as control
2. Cold water treatment: The seeds were soaked in cold water at 25 ºC for 24 hours
3. Hot water treatment: water was boiled and allowed to cool for ten minutes before the seeds were soaked in it for 24 hours
4. Mechanical scarification: was done by cutting the testa of the seeds with a knife
5. Acid treatment: The seeds were soaked in concentrated Sulphuric acid (95% for 10 minutes)

3.4 Experiments Conducted

The study involved experiments that were conducted between October 2014 and March 2015. The germination experiment started in October 2014 and terminated after twenty-five (25) days. A total of 250 seeds were used with fifty (50) seeds allocated to each treatment. There were ten (10) seeds per replicate. The seeds were subjected to the five (5) pre-sowing treatments after which they were sown in polythene bags.

Two (2) seedlings (**as shown in Plate 4**) were randomly, sampled from the germinating plots for each treatment to study the growth rate of the seedlings raised. Weekly measurements of seedling height, number of leaves, length and breadth of leaves were done over a period of twelve (12) weeks beginning from November 2014 to January 2015. Straight rule was used to measure seedling height, leaf length and leaf breadth whilst physical counting was used to get the number of leaves.

Watering: the seedlings were watered twice daily throughout the experiment.

Plate 4: Seedlings of *Pterocarpus erinaceus* 65 days after sowing

3.4.1 Experimental Design and Layout

A Completely Randomized Design (CRD) involving one factor (one species) was used (because the seeds were sown in a controlled environment and provided with the same environmental conditions) for the study. It involved five treatments with each replicated five times by complete randomization. The treatments were observed for signs of germination from the second day after the set-up of the germination experiment. A seed was considered to have germinated when the plumule emerged above the soil (William, 1985). Germination counts were made daily for each replicate throughout the experimental period. The Germination Percentage (G %) for each treatment was determined using William (1985) formula :

$$G\% = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sowed}} \times 100$$

Graphs and tables were used to compare the daily germination and percentage germination of the various treatments. After the germination period of the seeds, their initial growth rates were taken to determine the effects of pre-sowing treatments on the growth of the seedlings. The initial growth parameters taken were plant height, length and breadth of leaves and number of leaves. An Analysis of Variance (ANOVA) test was used to find the significant differences among the germination of seeds of the various treatments. The Least Square Difference test was also used to compare treatment means.

The following treatments were applied to the *P. erinaceus* seeds:

T1: Control (untreated seeds)

T2: Cold water treatment

T3: Hot water treatment

T4: Mechanical scarification

T5: Acid scarification

Layout of the experimental plots for the seed germination experiment is indicated in Table 1:

Table 1 Experimental Layout of the germination plots

Plot 1 T5	Plot 2 T4	Plot 3 T1	Plot 4 T3	Plot 5 T2
Plot 6 T4	Plot 7 T2	Plot 8 T3	Plot 9 T5	Plot 10 T1
Plot 11 T3	Plot 12 T1	Plot 13 T5	Plot 14 T2	Plot 15 T4
Plot 16 T1	Plot 17 T5	Plot 18 T2	Plot 19 T4	Plot 20 T3
Plot 21 T2	Plot 22 T3	Plot 23 T4	Plot 24 T1	Plot 25 T5

CHAPTER FOUR

RESULTS

4.1 Germination Rate of *Pterocarpus Erinaceus* Seeds

The highest initial germination number was recorded for seeds soaked in cold water (for 24 hours) Treatment (T2), which started on the 7th day after sowing with 2 seeds germinating. Germination of seeds which were soaked in hot water (T3) also started on the 8th day with 2 seeds. The seed under control treatment (T1) started germinating on the 9th day after sowing with an initial number of 3 seeds. Seed germination under Mechanical scarification (T4) also started germinating on the 9th day after sowing with an initial number of 1 seed. Acid treatment (T5) was however completely inhibited and recorded zero (0). At the end of the germination period the number of seeds that germinated was as follows: T1 = 31, T2 = 35, T3 = 29, T4 =33 and T5 = 0. Fifty (50) seeds were sown for each of the treatment (Table 1).

Table 2: Germination Rate of *Pterocarpus erinaceus* Seeds

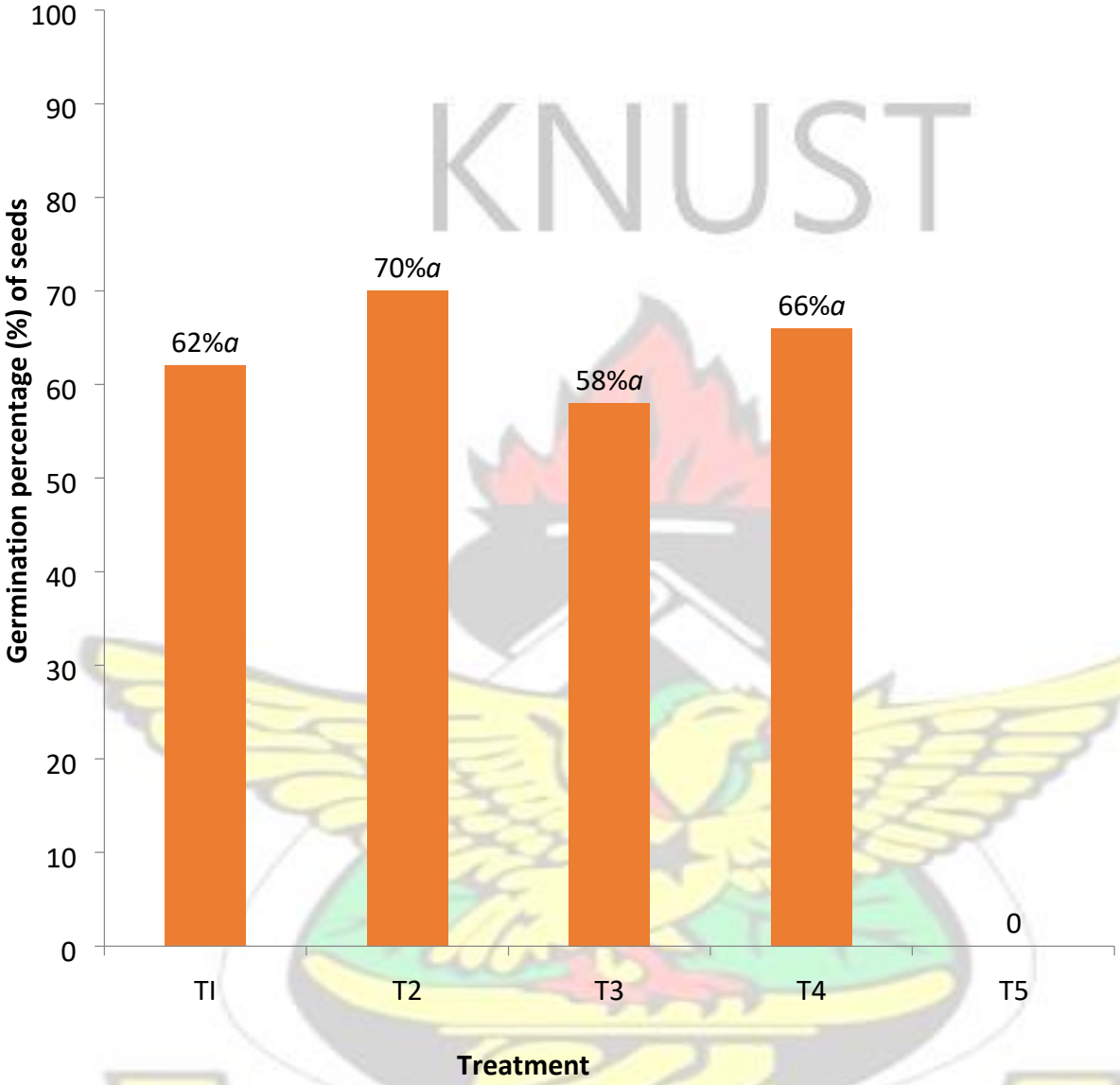
DAYS	TREATMETS

		T1	T2	T3	T4	T5
	0	0	0	0	0	0
	3	0	0	0	0	0
	6	0	0	0	0	0
	9	3	2	2	1	0
	12	8	12	12	8	0
	15	9	9	6	4	0
	18	7	3	8	10	0
	21	5	9	2	8	0
	25	0	0	0	0	0
TOTAL SEEDS	**GERMINATED**	**31**	**35**	**29**	**33**	**0**

4.2 Germination Percentage of *Pterocarpus erinaceus* Seeds

Cold water (at a temperature of 25 ^{0}C) treatment (T2) recorded the highest percentage germination with 70%. Germination percentages of 66% and 62% were recorded for both mechanical scarification treatment (T4) and untreated seeds (T1) respectively. Hot water (at a mean temperature of ^{0} 100 C) treatment (T3) followed with germination percentage of 58%. No germination was recorded for acid treatment (T5) (Figure 1). However, from Appendix 2, the results show that statistically, the treatments did not significantly affect the germination percentages recorded for the different treatment methods.

Figure 1: Germination percentages of the seeds under the treatments



Values with the same subscript letters do not differ significantly from each other according to the Least Significant Difference test.

4.3 Initial Growth Rate of *Pterocarpus erinaceus* Seedlings

The mean initial growth measurements of the seedlings 25 days after emerging from the seeds that were subjected to the different pre-germination treatments are shown in Table 2.

Table 3: Effects of different pre-sowing treatments on the initial mean growth parameters of *Pterocarpus erinaceus* seedlings

TREATMENT APPLICATIONS	MEAN HEIGHT OF SEEDLINGS (cm)	MEAN LENGTH OF LEAVES (cm)	MEAN WIDTH OF LEAVES (cm)	MEAN NUMBER OF LEAVES
Control (T1)	9.7 ± 0.092*a*	5.8 ± 0.156*a*	4.3 ± 0.402*a*	4.2 ± 0.447*a*
Cold water (T2)	17.1 ± 0.162*b*	7.0 ± 0.195*a*	4.7 ± 0.489*a*	4.8 ± 0.447*a*
Hot water (T3)	8.2 ± 0.103*c*	5.8 ± 0.493*a*	4.1 ± 0.299*a*	4.4 ± 0.548*a*
Mechanical (T4)	10.3 ± 0.110*a*	5.8 ± 0.301*a*	3.9 ± 0.215*a*	5.0 ± 0.00*a*
p-values	*0.248*	*0.8582*	*0.1125*	*0.9052*

Values (in the same column) with the same subscript letters do not differ significantly from each other according to the Least Significant Difference test.

It could be seen from the results presented in Table 2 that seedlings which germinated under T2 (seed soaked in cold water for 24 hours) produced the highest mean height of 17.1 cm, followed by T4 (mechanical scarification) with a height of 10.3 cm. However, the significant effect of the control and mechanical treatments on the seedlings were the same when they were compared using the LSD test. The results also showed that seedlings which germinated under T2 (seeds soaked in cold water for 24 hours) produced the highest results for all other growth parameters under study except for number of leaves which recorded the highest mean value for T4 (mechanical scarification).

4.4 Initial Growth of Height of *Pterocarpus erinaceus* Seedlings

From Figure 1, initial height growth for all the treatments, generally, started slowly from week 1 to week 3. Growth in height, however, saw a steady rise from week 3 to week 5. It then increased marginally between weeks 5 and 7 and sharply thereon to week 11 and maintaining same height growth for week 12. Cold water treatment (T2) exhibited the above growth description from the first week to the 12th week. Mechanical scarification (T4) as seen from Figure 2 extended its marginal growth to the 8th week before rising in the 9th week and plateaued to the 10th week. The control (T1) also exhibited the same growth characteristics as cold water (T2) followed by hot treatment (T3) which showed marginal increases at two stages: weeks 5 – 8 and then from 10 – 12. Despite the differences observed for height for the different treatments, ANOVA (Appendix 3) showed that treating the seeds did not significantly affect the height growth of the seedlings at 5% significance level.

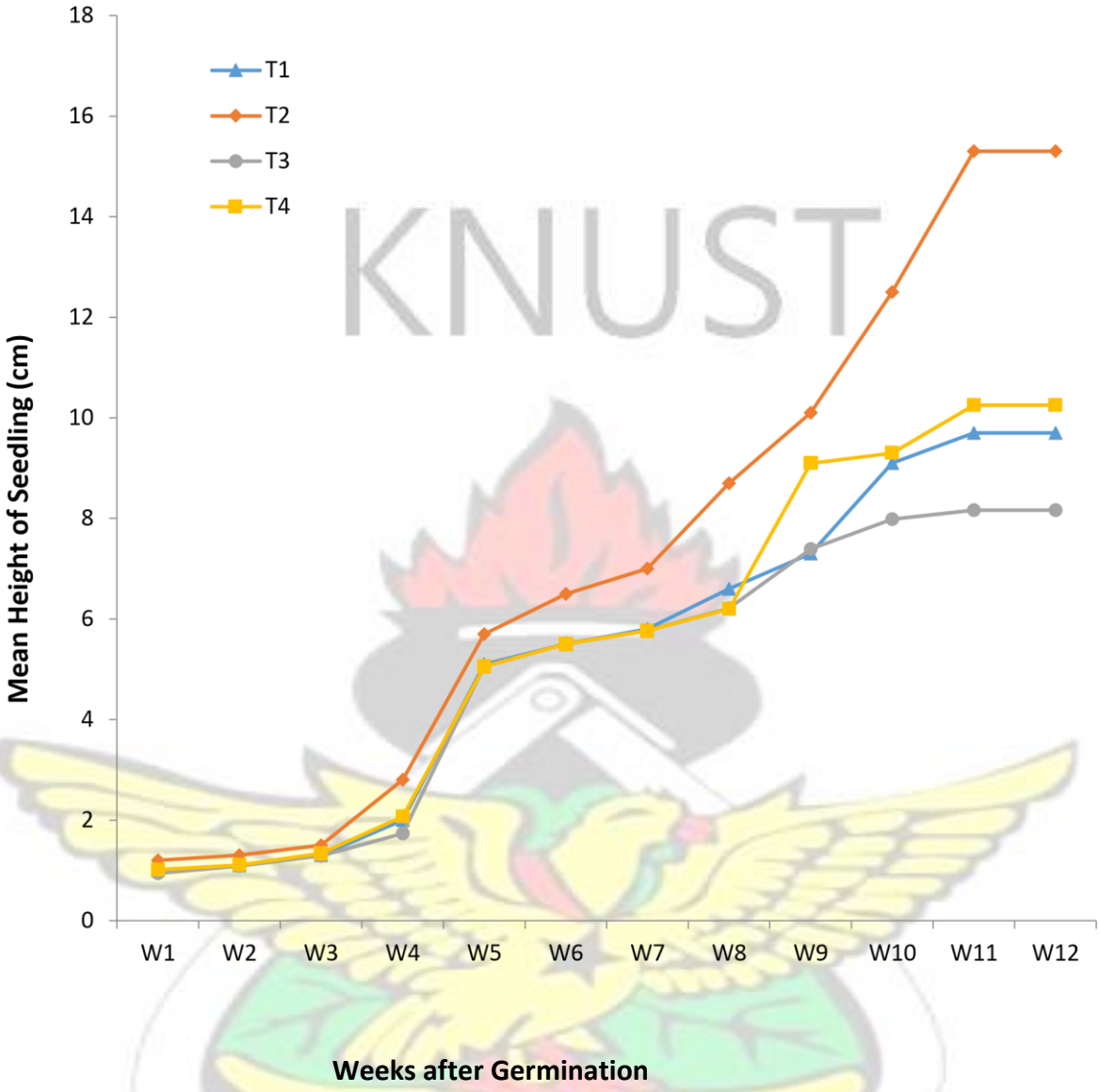


Figure 2: Effect of different pre-sowing treatment on the mean height of *Pterocarpus erinaceus* seedlings after germination.

4.5 Length of Leaf of *Pterocarpus erinaceus* Seedlings

Length of *P. erinaceus* seedling leaves increased for all the treatments with marginal increments from week 1 through to week 7. Growth of leaf length increased significantly from week 7 to week 8 and maintained the same value for the period of week 8 – 9. Further increments were recorded from the 9th week through to the 12th week. Cold water treatment (T2) exhibited the highest leaf length of 0.5 cm for the 1st week to 7.1 cm by the 12th week. This was followed by mechanical treatment (T4) which was higher than T1 (untreated seeds) as shown in Figure 2.

The Least Significant Difference (LSD) test of the different treatments on the mean length of leaf of *Pterocarpus erinaceus* showed that each treatment mean did not differ significantly from the other (Appendix 2). Also, from Appendix 4, the analysis of variance indicated that the treatment means did not significantly affect the leaf length of seedlings produced from seeds under all the treatments.

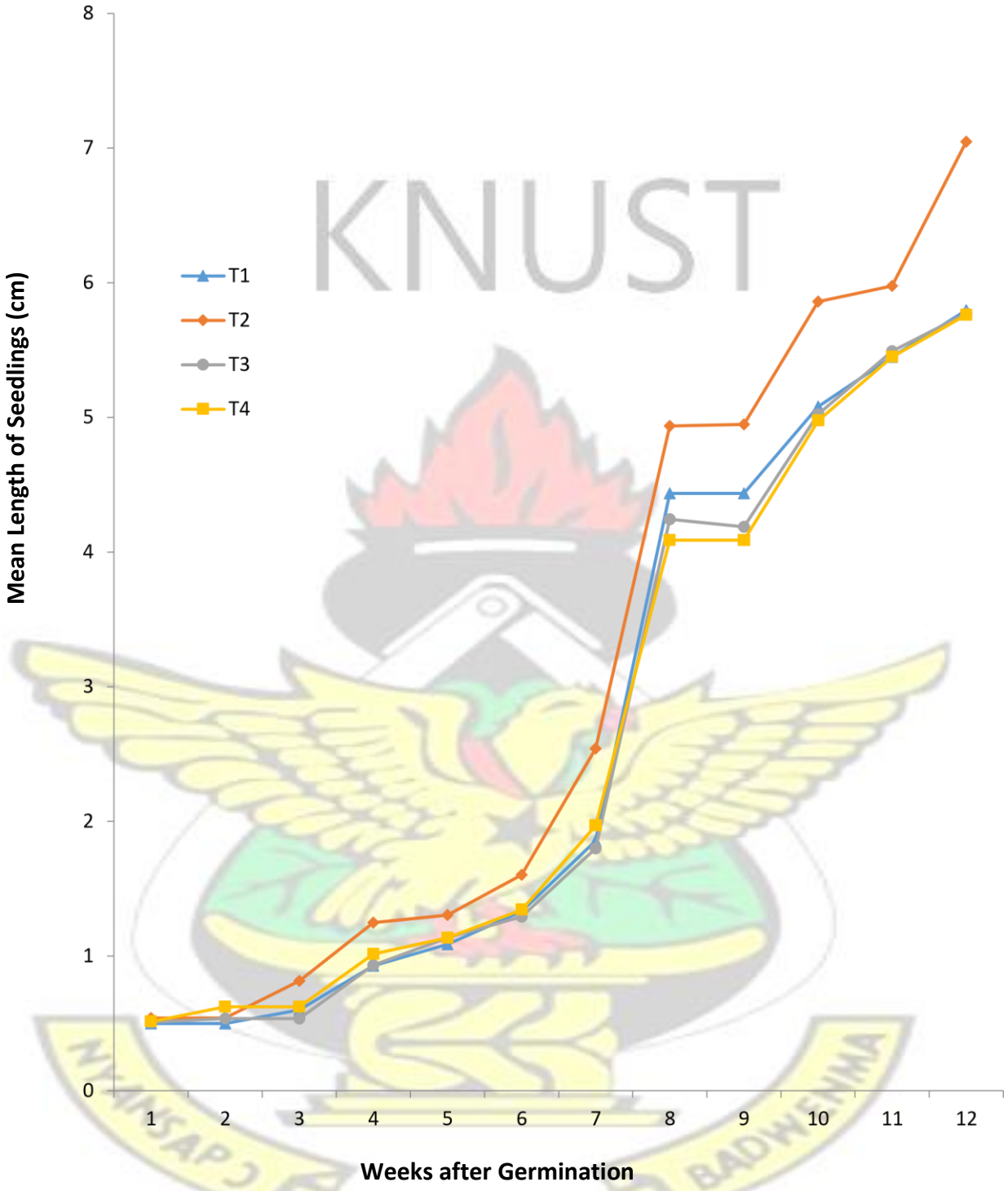


Figure 3: Effects of different pre-sowing treatments on the mean length of *Pterocarpus erinaceus* seedlings after germination

4.6 Width of Leaf of *Pterocarpus erinaceus* Seedlings

Generally, the width of *P. erinaceus* leaves increased for week 1 to week 11 whilst it maintained the same width for the 12th week for all the treatments. Cold water treatment (T2) exhibited the highest leaf width from the 1st week to the 11th week. This was followed by mechanical treatment (T4) which was higher than T1 (untreated seeds) as shown in Figure 3. Least Significance Difference (LSD) test of the various treatments on the mean width of leaves of *Pterocarpus erinaceus* showed that each treatment mean does not differ significantly from the other (Appendix 2).

From Appendix 4, the analysis of variance indicated that the treatment means significantly affected the leaf width of seedlings produced from seeds under all the treatments.

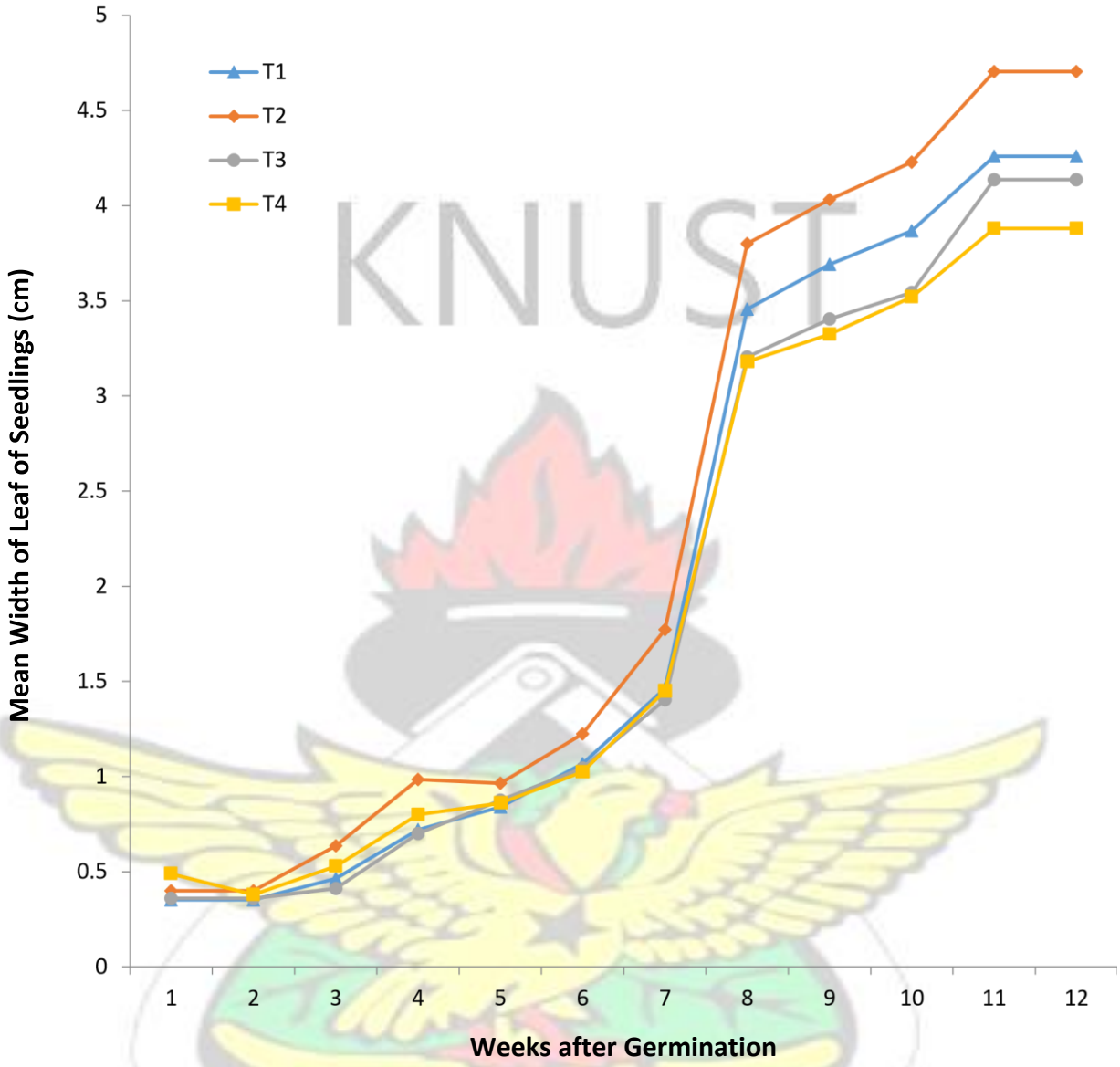


Figure 4: Effects of different pre-sowing treatments on the mean width of *Pterocarpus erinaceus* seedlings after germination.

4.7 Number of Leaves of *Pterocarpus erinaceus* Seedlings

As shown in Table 2, seeds mechanically scarified (T4) had seedlings with average number of leaves of 5, followed by seeds soaked in cold water (T2) with average number of 4.8, whereas the seeds that were soaked in hot water (T3) and control (T1) recorded average values of 4.4 and 4.2, respectively. The number of leaves of *P. erinaceus* leaves remained the same for all the treatments from week 2 to week 4 and increasing slightly in week 5 for T2 and T4. Mechanical scarification treatment (T4) exhibited the highest number of leaves by end of the 12^{th} week followed by cold water treatment (T2) which was higher than T1 (untreated seeds) (Figure 4).

Least Significance Difference (LSD) test of the various treatments on the mean number of *P. erinaceus* showed that each treatment mean did not significantly differ from the other (Appendix 2). Pre-sowing treatments had no significant effect ($p<0.05$) on leaves production by the seedlings (Appendix 3).

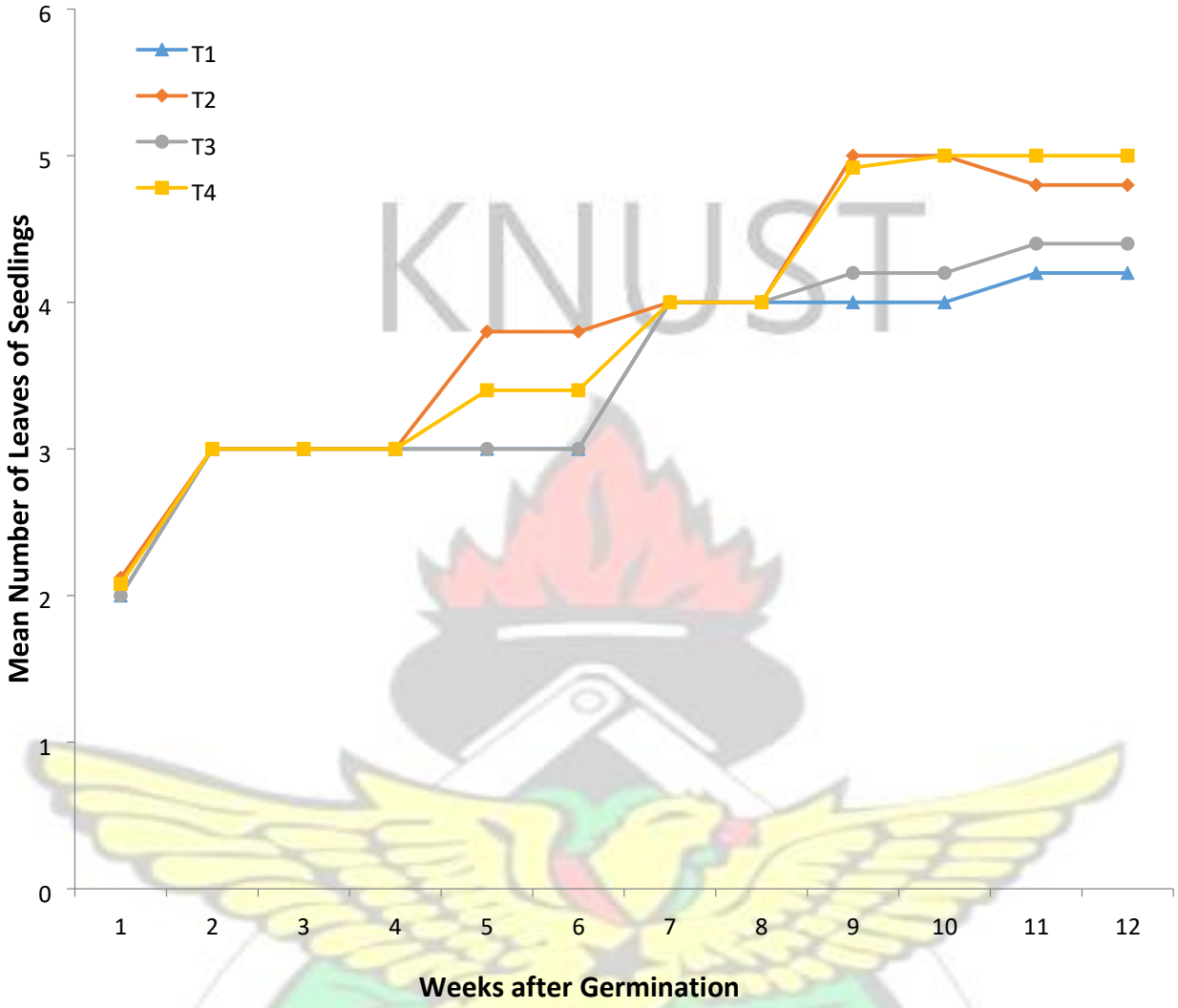


Figure 5: Effects of different pre-sowing treatments on the mean number of leaves *Pterocarpus erinaceus* seedlings after germination.

CHAPTER FIVE

DISCUSSION

5.1 Germination Rate of *Pterocarpus erinaceus* Seeds

Germination of the seeds began differently for the different treatments. Seeds under cold water treatment emerged on the 7th day with two seeds (Appendix 1) and this agrees with Bonkoungou (1999) who in studying *P. erinaceus* stated that germination of *P. erinaceus* seeds normally emerges within 6 – 10 days under cold treatment.

This was followed by hot water (T3) on the 8th day with two (2) seeds. Mechanical scarification (T4) and the control (T1) emerged on day 9 with one (1) and three (3) seeds respectively. The slight delay in germination on the part of hot water treatment (T3) may be due to the effect of heat generated on the embryo by the hot water.

5.2 Effects of Different Pre-Sowing Treatments on Percentage Germination of *P. erinaceus* Seeds

From Figure 1, seeds soaked in cold water (at 25 ºC) for 24 hours (T2) recorded the highest percentage (70%) than all the other treatments. According to Deghan *et al*., (2003), seeds that are soaked in cold water dissolve and leach out the chemicals causing dormancy which, otherwise, would have prevented the smooth growth of the seedlings produced by such seeds. Pre-sowing treatments such as soaking seeds in cold water have been used successfully to reduce seed dormancy. The seed soaked in cold water treatment germinated earlier, thus reducing dormancy period. It also gave a considerable germination percentage which is in contrast to the

report of Danthu *et al*. (1995). He reported that seeds soaked in cold water were generally ineffective in the treatment of Baobab seeds. Earlier studies by (Ibrahim and Otegbeye (2004), Agboola and Adebire (1998); and Aduradola and Shinkafi (1999) and cited in Emerhi and Nwiisuator (2010) have shown that soaking in cold water is a feature that enhances germination in seeds of some tropical trees. Owonubi *et al*. (2005) observed that *Azadirachta indica* seeds soaked for 1, 12 and 24 h in cold water resulted in increasing rate of seed germination. Deduction can thus be made that different species have different rates at which their seed coat is permeable to water.

Germination percentage of 66% was recorded for mechanical scarification treatment (T4) as indicated in Figure 1. This fairly impressive germination percentage result conforms to earlier studies done by Awodola (1994), Aduradola (1999) when the studied the seed germination of *Pterocarpus osun.* In their study it was revealed that when *P. osun* is subjected to filling and clipping at their micropyle end, they recorded higher germination percentage. Duguma *et al*. (1998) stated scarification of seed is the most effective method of improving seed coat permeability in the seeds of *Leucaena leucocephala.* Mechanical scarification allows entry of air and water into the seed at a faster rate to stimulate germination. The improved germination of seedlings subjected to the mechanical treatment could be attributed to water uptake by the damaged dry seed, which ended up with the elongation of the embryonic axis. This phenomenon was observed by Holdsworth *et al*. (2008). The percentage germination of *P. erinaceus* under mechanical scarification treatment (66%) in this study was similar to that recorded by Nainar *et al*. (1999) who used different pre-treatments in *Terminalia chebula* seeds and observed that mechanical scarification recorded a higher germination of 60%. Soaking seeds in hot water recorded a germination percentage of 58%. Mwase *et al*. (2011) and Azad *et al.* (2011) reported

that soaking seed in hot water may soften hard seed coats; this makes the seed coat permeable to water and air. The seeds imbibe and swell as the water cools. The results of this study sharply contrast that of Gill and Asemota (1992) which concluded that the seeds of *Calliandra prototricensis* failed to germinate in hot water. Following from this, one could state that different species exhibit varying abilities to withstand inadequate levels of oxygen in hot water which is one of the primary conditions suitable for germination. This assertion is confirmed by Amusa, (2011) who stated that hot water treatment is not a suitable technique in seeds of *Adansonia digitata* as well as *Afzelia africana* from his work. He opined also that, subjecting the seeds to hot water could lead to the seed embryo being killed because of prolonged contact with high temperature/boiled water. This differs from the observations made by Saikou *et al.*, (2008), that pre-treatment of *Acacia senegal* seeds in hot water for 10 mins increased its growth potential.

Acid treatment (T5) in this study recorded no germination. This result is contrary to earlier research studies on *Enterolobium cyclocarpum* by Agboola and Adedire (1998), *Adansonia digitata* (Adio *et al*., 2006) and *Piliostigma reticulatum* (Aduradola, 1999). They reported that acid treatment of seeds considerably promoted the germination of the seeds. Likoswe *et al* (2008), also, reported that soaking seeds of *Terminalia sericea* for 3-4 hours resulted in high germination percentage. It was observed from this study that soaking of *P. erinaceus* seeds in 95% of sulphuric acid for 1 hour was highly injurious to the seeds as it burnt the soft seed coat and destroyed the embryo.

5.3 Effects of Pre-Sowing Treatment on the Initial Growth of *Pterocarpus erinaceus* Seedlings

Pterocarpus erinaceus seedlings tend to have a slow growth rate. Results obtained on the initial growth rate of pre-treated seeds of *P. erinaceus* agree with the results of the work done by Bobtoya (2006). She reported that the pre-sowing treatments had a significant effect on the germination of *P. biglobosa.* However, once the seeds had germinated, this influence was hardly seen on the initial growth and development of the seedlings. The results obtained revealed that once the seeds germinated, the treatments did not have significant influence on the growth of the seedlings. Hence the slight differences in growth rate among the treatments might be due to differences in environmental conditions such as light and as well as physiological processes like the reallocation of plant resources. According to McConnaughay and Coleman (1999), favorable partitioning theories and models states that plants adapt to variation in the environment by partitioning biomass among various plant organs to maximize the capture nutrients, light, water and carbon dioxide in a manner that enhances plant growth rate.

From this study, it was observed that seeds soaked in cold water substantially affected significant structural parameters such as length, seedling height, and width of leaves of the seedlings. This observation agrees with that of Hossain *et al.*, (2001) who reported that seeds of *Terminalia chebula* when soaked in cold water (for 48 hours) promoted the growth of seedlings height, number of leaves, stem collar diameter and shoot dry weight. However, root dry weight was enhanced by the seeds that were treated with boiled water.

Results from the ANOVA test revealed that the treatments (T1, T2, T3 and T4) significantly influenced the height growth of seedlings. Although treatments tested significant on the height

growth of *Pterocarpus erinaceus*, the variation in growth can be attributed to environmental conditions and early germination of seeds (Hartmann *et al*., 1997). Seeds that germinated early had the tendency to increase in height since they were exposed earlier to the environmental conditions. This agrees with results obtained for seeds that germinated under the cold water treatment. They were the first to emerge and continued to lead in height growth from the 1st week of Experiment II to the 12th week. According to Hartmann *et al.* (1997) essential environmental factors regulate the variation and timing of germination of plant species and orientation of the sun might have had some effects on the randomization of the samples studied. This might have caused changes in the growth pattern of treatments.

The result of the initial growth parameters revealed that treatment methods did not significantly affect the number of leaves that were produced.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the results obtained, it can be concluded that the different pre-sowing treatments had significant effect on the germination of *P. erinaceus* seeds. However, once the seeds germinated, this influence was hardly observed in the growth and development of the seedlings. Seeds under cold water treatment recorded an overall percentage germination of 70% by the end of the germination period. Therefore, in order to enhance optimum and uniform germination soaking of *P. erinaceus* seeds in cold water for 24 hours is the best pre-sowing treatment for germination of *P. erinaceus.*

Mechanical scarification followed in higher percentage germination of 66% with the seeds, also germinating early after cold water treatment as compared to the hot water and control treatments.

Acid treatment of the seeds was the worst as no seed germinated from this treatment. The acid might have killed all the seeds.

6.2 Recommendations

The following are my recommendations:

- It is recommended that farmers, who are interested in the production of *P. erinaceus* seedlings, should be advised to use cold water treatment to ensure early germination of the seeds. Seeds should be soaked in cold water (at a temperature of ^{o} 25 C) for 24 hours.
- In addition, mechanical scarification of seeds can be employed by farmers to hasten the germination of seeds.
- The use of acid treatment must be stopped or the percentage or concentration reduced to prevent the killing of the seed embryo.

REFERENCES

Adio, A. F, Odigie, G. A., and Imran, G. T. (2006). The influence of pre-treatments on germination of seeds of *Adansonia digitata* (Baobab). *J. For. Res. and manage.* 5 (3):23-29.

Aduradola, A. M. (1999). Preliminary investigation of some factors affecting germination in seed of *Piliostigma recticulatum*. Hochstl. *J. Trop. Ethnofor.* 2(1):47-52.

Aduradola, A. M and Shinkafi, M. A. (1999). Germination factors in seeds of *Tamarindus indica. Zure Journal of Agriculture.* Volume 2: 1-7

Agboola, D. A. and Adebire, M. O. (1998). Response of treated dormant seeds of three tropical species to germination promoters. *Nigeria Journal of Biology* 11: pp. 103-110

Agyare, W. A. (2004). Soil characterization and modeling of spatial distribution of saturated hydraulic conductivity at two sites in the Volta Basin of Ghana. Ecology and Development Series
No.17.<http://books.google.com.gh/books?id=OZtoEvOgR6kc&pg=PA14&lpg=PA14&dq=information+on+the+relief+and+drainage+of+northern> Accessed November 16, 2011.

Amusa, T. O. (2011). Effects of three pre-treatment techniques on dormancy and germination of seeds of Afzelia Africana (Sm. Ex pers). *Journal of Horticulture and Forestry.* Vol. 3(4): 96103

Aubreville, A. (1950). Flore forestière soudano-guinéenne. A.OF – Cameroun-AEF. Société d'Editions Géographiques, Maritimes et Coloniales, Paris. 523 p.

Awodola, A. M. (1994). Aspect of germination in seeds of African locust bean tree Parkia biglobosa (Jacq) Beth. *J. Trop. For. Res.* 9+10:8298.

Azad, S., M. R. Manik, Hasan, S., and Matin, A. (2011). "Effect of different pre-sowing treatments on seed germination percentage and growth performance of *Acacia auriculiformis*," *Journal of Forestry Research*, vol. 22, no. 2, pp. 183–188, 2011.

Bonkoungou, E. G. (1999). *Pterocarpus erinaceus*: an important legume tree in African savannas. [Internet] FACT Sheet, FACT 99–03, Forest, Farm and Community Tree Network. Winrock International, Morrilton AR, United States. http://food-security.info/ foodsecurity.info/Winrock%20Archive/ p_erinaceus.html. Accessed June 2007.

Bonkoungou, G. E., Djimde, M., Ayuk, E.T., Zoungrana, I., and Tchoundjeu, Z. (1998). Taking stock of agroforestry in the Sahel—harvesting results for the future. ICRAF, Nairobi, Kenya. 58 p.

Cecie, S & Ralph, T. (1992). Biology, the unity and diversity of Life. 6th Edition. Wadsmorth Publishing Company, Belmont, California. P 517 – 518 pp

Danthu, P., Roussel, J., Gaye, A. and El Mazzoudi, E. H. (1995). Baobab (*Adansonia digitata L.*) seed pre-treatment for germination improvement. Seed Science and Technology, 23: 469475

Deghan, B., Norcini, J. G., Kabat, S. M., and Perez, H. E. (2003). Effects of Seed scarification and gibberellic acid treatment on seedlings emergence of Sky-Blue Lupine (*Lupinus diffsus*). J. Environ. Hortic. 21(2):64-67.

Duguma, B., Kang, B.T and Okali, D. U. (1998). Factors affecting germination of *Leuceana leucocephala* seed. Science and Technology 16:489-500

Emerhi, E.A and Nwiisuator, D., (2010). Germination of *Baillonella toxisperma* (Pierre) Seeds as Influenced by Seed Pre-Treatment. *In the Proceedings of the 2nd Biennial National Conference of the Forests and Forest Products Society. pp 323-328*

FAO (1995). Forest Resources Assessment, 1992, Tropical Forest Plantation Resources FAD Forestry Paper.

Ghana Districts (2014). http://www.ghanadistricts.com/districts/?news&r=6&_=95 **Ghana**

News Agency (2014). Ban on Rosewood Timber, still in Force.

Gill, L. S, Onyibe, H. I and Asemota, B. P. (1992). Studies on the germination of *Calliandra portoricensis* (Benth). *The Nigerian Journal of Forestry.* Vol.22, No1 and 2:53-57.

Haferkamp, M. R and Jordan, G. L. (1997). The effect of selected pre-sowing seed treatment on germination of Lehmann Lovegrass seeds. Journal of Range Management 30(2), March 1977. P 150 – 153.

Hanson, J. (1985). Practical Manuals for Gene banks No. 1. Procedures for Handling Seeds in Gene banks. International Board for Plant Genetic Resources (IBPGR), Rome, Italy. 115pp

Hartmann, H. T., Kester, D. E., Davies, F. T. Jr., and Geneve, R. L. (1997). Plant Propagation Principles and Practices. Sixth Edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey, USA. 770pp

Hartmann, H. T., and Kester, D. E. (1990). Plant Propagation, Principles and Practices. 3rd Edition. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA.

Heydecker, W. (1969). Seed Ecology: Proceedings of the 19th Easter School in Agricultural Science, University of Nottingham.

Holdsworth, M.J., Bentsink, L., and Soppe, W.J.J. (2008). Molecular networks regulating Arabidopsis seed maturation, after-ripening, dormancy and germination. New Phytologist179(1):33-54,

Hossain, M. K., Khan, B. M. and Koirala, B. (2001). Effects of Pre-sowing Treatments on Tectona grandis L. f. Seeds and Initial Seedling development in the Nursery. In: K. Connor, T. beardmore, Jr. Enrique L. Tolentino and W.M. Carandang, (eds). Proceedings of the IUFRO Joint Symposium on Tree Seed Technology, Physiology and Tropical Silviculture. College of Forestry and Natural Resources, university of Philippines, April 30-May 03, 2001. pp 23-30

Hutchinson, J., Dalziel, J. M., and Keay, R.W.J. (1958). Flora of west tropical Africa. Vol. 1, part 2. Crown Agents for Overseas Governments and Administrations, London. 531 p.

Ibrahim A., and Otegbeye, G.O. (2004). Methods of achieving optimum germination in *Adansonia digitata. Bowen Journal of Agriculture.* Volume 1 (1). pp:53-58 **ICRAF**

(1997). Annual Report 1996. ICRAF, Nairobi, Kenya. 340 p.

ICRAF (1998). Agroforestry tree database (CD ROM). ICRAF, Nairobi.

Jensen, F. N. (1988). Plant Breeding Methodology, a Wiley Interscience Publication. New York. 123pp.

Leakey, R. B. B. (1994). 'Cinderalla' tree species …… the clock strikes eleven. Agroforestry Today 6 (2): 2

Lely, H. V. (1925). The useful trees of northern Nigeria. Crown Agents for the Colonies, London. 128 p.

Likoswe, M. G., Njoloma, J.P., Mwase, W.F. and Chilima, C.Z. (2008). Effect of seed collection times and pre-treatment methods on germination of *Terminalia sericea* Burch. Ex DC. *African Journal of Biotechnology* 7(16): 2840-2846

Maydell, H. J. (1986). Trees and Shrubs of the Sahel: their characteristics and uses. (Photo: Uta and H. J. Von Maydell. Engl. Text rev. by John Brase). Weikersheim: Magraf. Typo-duckossdorf gmbh, D-6101 RoBdorf. 523pp.

Mcconnaughay, K. D. M and Coleman, J. S. (1999). Biomass Allocation in Plants: Ontogeny or Optimality? A Test Along Three Resource Gradients. Available at www.findarticles.com/planticles/mi_2121/is_8_80/ai_58517872. Accessed on 8th February, 2006.

Mohr, H. and Schopfer, P. (1995). Plant Physiology. Sprinter-verlog. Berlin Heidelberg. P. 409 – 422,692 pp.

Mwase W. F. and Mvula, T. (2011). "Effect of seed size and pre-treatment methods of *Bauhinia thonningii* Schum. on germination and seedling growth," *African Journal of Biotechnology*, vol. 10, no. 26, pp. 5143–5148

Nainar, P., Sundharaiya, K. and Ponnuswamy, V. (1999). Germination studies in kadukkai (*Terminalia chebula*). South Indian Horticulture 47(1/6):373374

NAS (National Academy of Sciences) (1979). Tropical legumes: Resources for the future. National Academy of Sciences, Washington, D.C. 331 p.

Nwoboshi, L. C. (1982). Tropical Silviculture, Principles and Techniques. Ibadan University Press, Ibandan, Nigeria. 333pp

Owonubi, J. J., Otegbeye, G.O and Nwokedi, C. (2005). Development of Pre-germination Technique for *Azadirachta indica*: Preliminary investigation. Proceeding of the 30th Annual Conference of the Forestry Association of Nigeria. Pp 508-516. (*V. paradoxa*) Agroforestry systems 48(3); 273-283

Pandey, S. N and Sinha, B. K. (2006). Plant Physiology. Fourth Edition. 525 – 531 pp

Roberts, E.H. (1972). Predicting Storage Life of Seeds, Seed Science and Technology. 514pp

Roussel, J. (1996). Pépinière et plantations forestières en Afrique tropicale sèche. ISRA/CIRAD, Dakar, Senegal. 435 p.

Russel, E. W. (1988). Soil conditions and plant growth. Eleventh Edition, Longman Publications, UK. 322pp

Saikou, E. S., Kabura, B. H. and Huang, Wen Chi (2008). Effects of some seed pretreatments on emergence of Acacia senegal (L.). World Journal of Agricultural Sciences 4(2): 213-219

Schmidt, L. (2000). Dormancy and pre-treatment. Guide to Handling of Tropical and Subtropical seed. DANIDA Forest Seed Center: http://dsfc.dk/pdf/handbook/chapter9.pdf. Accessed 2nd February, 2006.

Stanley, A. B. (1995). Soil Nutrient Bioavailability, Mechanistic Approach. Second Edition, John Wiley and Sons INC. New York, USA, 414pp.

Taiz, L and Zeiger, E. (2002). A companion to plant physiology, 3rd Edition. Sinaver Associates, Inc. Sunderland, Mass, USA.

Troupe, R. S. (1921). The Silviculture of India Trees. Oxford University Press, London. Vol. Dellenian Cease Published Clarendon Press India. 336p.

von Maydell, H. J. (1983). Arbes et arbustes du Sahel. Leurs caractéristiques et leurs utilisations. Eschnorn, GTZ. 531 p.

William, R. L. (1985). A Guide to Forest Seed Handling with special Reference to the Tropics. FAO Forestry Paper 20/2, Rome. 379pp

APPENDICES

APPENDIX 1: No. of Seeds germinating on a particular day after sowing *Pterocarpus erinaceus* seeds

Days after sowing	Treatments				
	T1	T2	T3	T4	T5
7	0	2	0	0	0
8	0	0	2	0	0

9	3	0	0	1	0
10	3	9	5	5	0
11	3	3	4	2	0
12	2	0	3	1	0
13	0	0	0	0	0
14	4	4	2	3	0
15	5	5	4	1	0
16	2	0	3	4	0
17	5	2	5	2	0
18	0	1	0	4	0
19	4	5	1	4	0
20	1	4	1	4	0
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
25	0	0	0	0	0

APPENDIX 2: Test for significance difference between pairs of treatments using the Least Squared Difference (LSD) test

Parameter	**LSD value**	**Treatment means**	**Difference in Treatment means**

Percentage Germination	2.854	$t_1 = 6.2$	$t_1 - t_2 = 0.8$ $t_1 - t_3 = 0.4$ $t_1 - t_4 = -0.4$ $t_1 - t_5 = 6.2$
		$t_2 = 7$	$t_2 - t_3 = 1.2$ $t_2 - t_4 = 0.4$ $t_2 - t_5 = 7.0$
		$t_3 = 5.8$	$t_3 - t_4 = -0.8$ $t_3 - t_5 = 5.8$
		$t_4 = 6.6$	$T_4 - t_5 = 6.6$
		$t_5 = 0$	

Parameter	**LSD value**	**Treatment means**	**Difference in Treatment means**

Mean height	0.64	$t_1 = 9.704$	$t_1 - t_2 = -7.432$ $t_1 - t_3 = 1.46$ $t_1 - t_4 = -0.568$
		$t_2 = 17.136$	$t_2 - t_3 = 8.892$ $t_2 - t_4 = 6.864$
		$t_3 = 8.244$	$t_3 - t_4 = -2.028$
		$t_4 = 10.272$	

Parameter	**LSD value**	**Treatment means**	**Difference in Treatment means**
Mean length	1.69	$t_1 = 5.796$	$t_1 - t_2 = -1.252$ $t_1 - t_3 = 0.024$ $t_1 - t_4 = 0.036$
		$t_2 = 7.048$	$t_2 - t_3 = 1.276$ $t_2 - t_4 = 1.288$
		$t_3 = 5.772$	$t_3 - t_4 = 0.012$
		$t_4 = 5.76$	

Parameter	**LSD value**	**Treatment means**	**Difference in Treatment means**

Mean breadth	1.96	$t_1 = 4.26$	$t_1 - t_2 = -0.444$ $t_1 - t_3 = 0.124$ $t_1 - t_4 = 0.38$
		$t_2 = 4.704$	$t_2 - t_3 = 0.568$ $t_2 - t_4 = 0.824$
		$t_3 = 4.136$	$t_3 - t_4 = 0.256$
		$t_4 = 3.88$	

Parameter	**LSD value**	**Treatment means**	**Difference in Treatment means**
Mean number of leaves	2.24	$t_1 = 4.2$	$t_1 - t_2 = -0.6$ $t_1 - t_3 = -0.2$ $t_1 - t_4 = -0.8$
		$t_2 = 4.8$	$t_2 - t_3 = 0.4$ $t_2 - t_4 = -0.2$
		$t_3 = 4.4$	$t_3 - t_4 = -0.6$
		$t_4 = 5$	

APPENDIX 3: Analysis of Variance (ANOVA) for the different pre-sowing treatments effect on growth parameters of seedlings of *Pterocarpus erinaceus*

No.	**Parameters**	**Degree of freedom**	**Means of squares**	**F-ratio**	**P-value**	**CV (%)**

1	Mean germination percentage					
	Treatment	4	0.36	0.042	0.996**	0.334
	Error	20	8.56			
	Total	24				
2	Seedling height					
	Treatment	4	0.01632	0.00104	0.248**	1.383
	Error	15	15.6763			
	Total	19				
3	Seedling leaf length					
	Treatment	4	0.15177	0.333	0.858**	0.308
	Error	15	0.4698			
	Total	19				
4	Seedling leaf breadth					
	Treatment	4	0.3679	2.248	0.1125*	0.039
	Error	15	0.1636			
	Total	19				
5	Number of leaves					
	Treatment	4	0.075	0.25	0.905**	0.065
	Error	15	0.3			
	Total	19				

* Significant at 5%

** Not significant at 5%