EVALUATION OF GERMINATION AND GROWTH PERFORMANCE OF JUVENILE OF FIVE INDIGENOUS FOREST TREE SPECIES IN THE RAINFOREST ECOSYSTEM, EDO STATE.

BY

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OCTOBER, 2023

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A PROJECT SUBMITTED TO THE DEPARTMENT OF FOREST RESOURCES AND WILDLIFE MANAGEMENT, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILMENT FOR THE AWARD OF BACHELOR'S DEGREE IN AGRICULTURE (FOREST RESOURCES AND WILDLIFE MANAGEMENT)

SUPERVISOR: PROF. E.M ISIKHUEMEN

OCTOBER, 2023

CERTIFICATION

This is to certify that this project was carried out by me, Orode Eyonju KAYOH, of the Department of Forest Resources and Wildlife management, Faculty of Agriculture, University of Benin, Benin City.

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(Head of Department)

DATE ____________________

DATE____________________

DEDICATION

This project is dedicated first to God Almighty who in his undeserved love saw me through the period of this project. It is also dedicated to my loving parents, Mr. and Mrs. Ken Kayoh and my husband, Mr. Kennedy Aliu for their constant prayers.

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ABSTRACT

Study on the evaluation of germination and growth performance of juveneles of five indigenous forest tree species in the rainforest ecosystem was conducted at a nursery located at Ekosodin community in Ovia North East Local Government Area of Edo State. Matured fruits of fives indigenous forest tree species were collected under their mother tree and their seeds extracted. 120 polypots filled with topsoil and stacked in 25 plots with 5 observations each was used. 25 seeds per species were randomly assigned to plots and sown at 1cm depth. Data were collected in three stages: germination, seedling pre-establishment and establishment stages. Germination data was analyzed using descriptive statistics one-way ANOVA in a CRD design was used to test the significance of the species growth and development and means separated using Duncan Multiple Range Test (DMRT). Result shows *Hildergadia bacteri* and *Terminalia ivorensis* had the highest number of germinant (76%) while all species exhibited epigeal germination. Data analysis (ANOVA) shows significant difference between species in all parameter measured for seedling pre-establishment stage ($P < 0.05$). Morphological observation at establishment stage reveal *T. ivorensis* had the longest radicle and plumule length of 23cm and 22cm respectively, *Terminalia ivicennioides* had short radicle and plumule length. Well-developed root system was observed in *H. bacteri* compared to the other species while *Albizia lebbeck* showed high proliferation of lateral roots followed by *Pericopsis elata* (60) while *T. ivorensis* had the least lateral root production. This study has shown that for some species, especially with fleshy and foliaceous cotyledons, the cotyledons servers as a natural food reserve, protection and medium of photosynthesis for the emerging seedling against the vagaries of the environment and its retention aids the early growth and survival processes of the young seedlings.

CHAPTER ONE

1.0 INTRODUCTION

Germination, the critical phase in the lifecycle of a crop plant is subjected to numerous environmental factors (Cooper, 1979). The natural environment is favoured for growth and development of plant communities (Anamica and Dhaka, 2004). When the seeds are grown in a wide range of environmental factors, it will reflect in the germination performance and the establishment of healthy young seedlings (Bentsen, 2002). Seed germination and growth are of vital importance for continuation of plant life. Seed germination is defined as the resumption of metabolic activity (Vaithiyanathan and Sundaramoorthy, 2016). The growth of an embryo starts with the rupture of the seed coat and the emergence of the young seedlings. The time between the seed sowing and seedling establishment is considered to be the crucial period of any plant (Vaithiyanathan and Sundaramoorthy, 2016).

Seed germination is defined as the sum of events that begin with hydration of the seed and culminate in emergence of the embryonic axis (usually the radicle) from the seed coat (Srivastava, 2002). Seed germination depends on both internal and external conditions (Rajjou *et al*., 2012). The most important external factors include right temperature, water, oxygen or air and sometimes light or darkness (Raven *et al*., 2005). Various plants require different variables for successful seed germination (Deno, 2014). Often this depends on the individual seed variety and is closely linked to the ecological conditions of a plant's natural habitat (Rout *et al.,* 2000). For some seeds, their future germination response is affected by environmental conditions during seed formation; most often these responses are types of seed dormancy (Baskin and Baskin, 2014).

Pericopsis elata (family: Fabaceae) is a high commercial value timber species, restricted to moist semi-deciduous African forests (West and Central Africa) (Momo Solefack *et al*., 2017). This species is valued for the high quality of its wood, and its exploitation started more than 50 years ago, mainly in Ghana and Côte d'Ivoire (Dickson *et al*., 2005). *P. elata* is defined as a gregarious species (Boyemba, 2011), meaning large numbers of trees generally and naturally occur within spatially restricted areas.

Terminalia ivorensis, of the family *Combretaceae* is an important timber species in Nigeria (Aigbokhan, 2014). The tree of the species attains the heights of up to 50 m and girth of 5 m, while young trees often attain only 1-1.5 m height after 5 years, compared to some other timber species, which are fast-growing (Ibe *et al*., 2015). It occurs in evergreen and moist semideciduous forests, where larger trees are most common in low-lying localities or lowlands (Bakshi *et al.*, 1972; Keay, 1989). It also serves as reforestation and afforestation species for devastated forest ecosystem (Jones and Averre, 2000).

Albizia lebbeck is widely spread in the world, and its tree has large leaves and fragrant cluster of green-yellow flowers and long seed pods (Missanjo *et al*., 2013). Belonging to the family of Leguminosae (Bhat and Chauhan, 2002), it is native to tropical Asia and widely cultivated and naturalized in other tropical and subtropical regions including Malawi (Faisal *et al*., 2012; Jøker, 2000). *Albizia lebbeck* grows to the height of 18–30mwith a trunk diameter of 50 cm to 1mat maturity. The leaves are 7 to 15 cm long with one to four pairs of pinnae, and each pinna has 6 to 8 leaflets (Missanjo *et al*., 2013). The flowers are white with numerous stamens and very fragrant. The fruit pods are 15 to 30cm long and 2.5 to 5.0 cm broad containing six to twelve seeds (Msanga, 2000).

Hildegardia barteri (Mast.) Kosterm in the family Malvaceae, is a fast-growing, deciduous tree that can reach a height of 24 - 30 metres or more (Aigbokhan, 2014). Its Common names include: Hildegardia (English), Ufuku, Shishi (Igbo), Eso, Okurugbedu (Yoruba) (Aigbokhan, 2014). The tree is buttressed, with a clear bole 9 - 12 metres or more tall and a girth of up to 3.5 metres. The tree is harvested from the wild and used locally as a food and source of timber and fibre. It is also sometimes grown as a living fence (Fern, 2013).

1.1 STATEMENT OF PROBLEMS

Seed germination of many tree species are affected by several climate and edaphic factors like temperature, light, soil depth etc (Lal *et al*., 1984; Shivaa *et al*., 2003; Devendra *et al*., 2007). This has led to increasing demand for bigger, better, faster-growing seedlings that result in forest seedling production continually evolving technology in reforestation (Haase, 2007).

Seed morphology influences seed germination and environmental factors such as temperature, light, soil moisture content, and soil depth affect seed germination and seedling establishment (Benvenuti *et al*., 2001).

Post establishment requirement for optimum growth is also critical if plantation with vigorous seedlings is the goal (Aiyelagbe, 1989). Such requirements will include the use of appropriate propagation methods apart from overcoming seeds dormancy problems (Oni and Uzokwe, 2014).

1.2 JUSTIFICATION OF PROBLEMS

Minimal attention is given to the indigenous species in the afforestation programme of government; but it is these indigenous tree species that the private individuals especially those in rural communities whose livelihoods depend essentially on (Oboho, 2015). Therefore to promote their active cultivation/planting and inclusion in regular farming or plantation establishment there is the need for additional silvicultural information.

Several biotic and abiotic stresses are known to limit productivity of many indigenous tree species, though not much research has been done on the seed depth on germination, resistance to; drought, salinity, pests and diseases (Okeno *et al*., 2003).

The discovery that some rainforest species and species guilds of high endemism provides criteria for the design and conservation of most taxa and ecosystems (Whitmore, 1999).

1.3 AIM OF THE STUDY

This study is aimed at evaluating the germination, seedling establishment and growth performance of five indigenous forest tree species, ex situ.

1.4 OBJECTIVES OF THE STUDY

The specific objectives of this study are to:

i. identify germination type of the selected tree species,

ii. examine the pre-establishment growth performance of the species,

iii. determine the morphological state at the stage of seedling establishment and

iv. assess the post-establishment growth performance of the species

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Description, Uses and Geographic Distribution of Species

Albizia lebbeck is a very fast-growing deciduous tree with an open, large, spreading crown; it usually reaches a height of 15 - 20 metres, with exceptional specimens growing up to 30 metres (Fern, 2013). The flowers, bark, fruits, roots, and stems of *Albizia lebbeck* are all used for medicine. A paste of leaves is used to treat skin problems. *Albizia lebbeck* is also known for treating respiratory problems including allergies (Khera and Singh, 2005). Furthermore, other parts of the plants are used to treat eye problem, purify blood, and promote health in teeth. Most importantly, ethanol extract fromits pods is effective against some formof cancer (Tigabu and Odèn, 2001).The leaves are nutritious as they contain proteins, calcium, phosphorous, and amino acids (Faisal *et al*., 2012; Msanga, 2000).

Albizia lebbeck is one of the most promising fodder trees. It has leaves during a large part of the rainy season, and digestibility of the twigs is considerably higher than that of most fodder trees. The concentration of crude protein is about 20% for green leaves, 13% for leaf litter, and 10% for twigs (Missanjo *et al*., 2013). *In vitro* digestibility is about 45% for mature leaves, 70% for young leaves and 40% for twigs. Leaves, flowers, and pods fall to the ground gradually during the dry season and can be browsed on the ground (Jøker, 2000). It is an excellent fuelwood and charcoal species, and the wood is suitable for construction, furniture, and veneer. The shallow root system makes it a good soil binder and recommendable for soil conservation and erosion control (Khera and Singh, 2005; Tigabu and Odèn, 2001).

Hildegardia barteri widely distributed, occurring mainly on rocky terrain and hills in drier parts of lowland rainforest. It ranges from Western tropical Africa - Cote D'Ivoire to Nigeria. A fibre is obtained from the bark used to make cloth and ropes. The fibre is harsh and fairly strong. The whitish wood is light and very soft. It is used for making floats, plates and dishes.

Terminalia avicennioides occurs in savanna and dry forest, especially on sandy soils and in fallow land, from sea-level up to 1600 m altitude

2.2 Seed Germination

Germination is the sprouting of a seed, spore, or other reproductive body, usually after a period of dormancy (Heslop-Harrison, 2019). It refers to the process by which an organism grows from a seed or a spore. The most common forms of germination include a seed sprouting to form a seedling and the formation of a sporeling from a spore. Thus, germination occurs primarily in plant and fungal species (Bushart and Roux, 2007). Germination demarcates the transition from the seed being dependent on food sources from the mother plant to an independent plant capable of taking up nutrients and growing independently (Bentsen, 2002). Hence, germination also makes up the last link in the chain of seed handling processes. Whereas most seeds are relatively resistant to environmental impact, germinating seeds and young seedlings are often very vulnerable (Bentsen, 2002).

Germination, the critical phase in the lifecycle of a crop plant is subjected to numerous environmental factors (Cooper, 1979). The natural environment is favoured for growth and development of plant communities (Anamica and Dhaka, 2004). When the seeds are grown in a wide range of environmental factors, it will reflect in the germination performance and the establishment of healthy young seedlings (Bentsen, 2002). Seed germination and growth are of vital importance for continuation of plant life. Seed germination is defined as the resumption of metabolic activity (Vaithiyanathan and Sundaramoorthy, 2016). The growth of an embryo starts with the rupture of the seed coat and the emergence of the young seedlings. The time between the seed sowing and seedling establishment is considered to be the crucial period of any plant (Vaithiyanathan and Sundaramoorthy, 2016).

The effect of the environment on germination is quite complex because of external and internal factors that modify germination patterns (Rout *et al.,* 2000). Germination conditions as well as tolerance range under which seeds will germinate vary with species, and are related to the environment in which the plants normally grow (Bentsen, 2002). Temperate and high altitude species may germinate under temperatures of only a few degrees centigrade, while most tropical lowland species require temperatures of 20°C or more for germination to proceed; most pioneer species have a much wider tolerance level than climax forest species (Bentsen, 2002). Factors that affect seed germination in the soil may include; soil type, water needed by a dormant seed, Oxygen in very small quantities for seeds respiration, Temperature for germination between 5-40'C though the optimum for most of the crops is between 25-30'C and light where some seeds need light for germination others may be hindered by light (Opande *et al*., 2017). Thus there is a constant pressure on crop production from available cultivable land with limited water resources in order to keep face with the food requirements for an ever-increasing population (Vaithiyanathan and Sundaramoorthy, 2016).

In most plant species, the seeds vary in their degree of germinability inter and intra individuals and populations. Some of this variation may be of genetic origin, but much of it is known to be phenotypic. That is, it is caused by the local conditions under which the seeds matured. These conditions consist of a combination of the microenvironment experienced by the seed due to its position on the parent plant and the abiotic environment of the plant (Müller *et al*., 2014). In different plant species, maternal factors, such as the position of the inflorescence on the mother plants or the position of the seeds in the fruit, can markedly influence the germinability of seeds

(Gutterman 1994, 1996; Grey and Thomas 1982), also the age of the mother plant during flower induction (Kigel *et al*., 1979) or seed maturation (Gutterman 1978). The age of the mother plant can affect the germination parameters of its seeds.

Imbibition is a precondition for the metabolic processes that ultimately lead to completion of the germination process (Bewley and Black, 1994). However, imbibition is a purely physical process which occurs whether the seed is dormant or non-dormant (except physical dormancy), viable or non-viable (Mayer and Poljakoff-Mayber, 1982). Hence, dormant or dead seed may imbibe normally without it leading to germination. Physically dormant seed will not imbibe unless their seed-coat has been made permeable by pretreatment or natural processes (Bentsen, 2002). Even where viable seeds have imbibed, germination may be impeded or delayed by the presence of other types of dormancy or by absence of appropriate germination temperature. Seeds in soil seed banks are often fully imbibed unless physically dormant (Bentsen, 2002).

The normal pattern of germination starts with radicle protrusion, followed by elongation of the part of the embryonic axis that develops into the main stem (Bewley and Black, 1982). In a few species elongation takes place in the reverse order. The seedling stem is divided into the hypocotyl and the epicotyl, the former being the section below the cotyledons, the latter is the section above the cotyledons (Bewley and Black, 1982). Elongation of the hypocotyl has two forms that divide the mode of germination and seedling development into two main distinctive groups, hypogeal (or hypogeous) and epigeal (or epigeous) (Bentsen, 2002). In hypogeal germination the hypocotyl does not expand or expands only slightly so that the cotyledons (and hence the seed) remain below the ground during germination and do not become photosynthetic (cryptocotylar). In epigeal germination the hypocotyls expands and hence pushes the cotyledons above the ground, often together with the seed-coat and possible remaining endosperm. The first appearance of an epigeal germination is the loop of the elongated hypocotyl above the ground (Bentsen, 2002). As the hypocotyl straightens, the seed is lifted. The cotyledons then normally separate from each other and become the first photosynthetic leaves (phanerocotylar), in angiosperms sometimes termed paracotyledons to distinguish them from the embryonic cotyledons (Vogel, 1980). Paracotyledons of angiosperms are normally morphologically different from subsequent leaves as they do not expand, have no veins and retain a fleshy structure. As the epicotyls expands and leaves appear, the paracotyledons lose their importance and wither (Bewley and Black, 1982). In gymnosperms, cotyledons resemble subsequent leaves and are normally retained for a longer time after germination (Mayer and Poljakoff-Mayber, 1982).

Intermediate types between hypogeal and epigeal occur. Ng (1991) observed two other classes viz. semi-hypogeal and durian type. In the semi-hypogeal type the hypocotyl does not elongate but cotyledons are emergent, sometimes because of elongation of the cotyledonary stalks. In the durian type the hypocotyl elongates but the cotyledons are non-emergent and hence do not become photosynthetic (epigeal, cryptocotylar sensu) (Vogel, 1980). The latter occurs, apart from durian, also in viviparous mangrove seedlings and some dipterocarps (Burger, 1972).

2.2.1 Seed Germination and Seedling Establishment

Natural population regeneration comprises seed production, dispersal, germination and successful seedling establishment (Baeten *et al*., 2009). Seed germination and seedling establishment are critical stages in life cycle, which determine plant population dynamics and ultimately community development, structure and sustainability in the recruitment of plant populations (Chen and Xie, 2007). On the other hand, seed germination and seedling establishment are the most vulnerable stages to environmental stress and are characterized by extremely high mortality rate and most intense natural selection of the entire life-cycle (Leck *et al*., 2008; Kolb and Barsch, 2010). Seedlings are therefore often regarded as the bottleneck in the life histories of species (Kolb and Barsch, 2010).

A large proportion of plant species are becoming rare and endangered in the world because the processes of development, dispersal, and germination of diaspore are hampered or limited (Colin and Linda, 2002; Gulias *et al*., 2004; Manfred *et al*., 2004). Light, temperature and moisture are the three main factors which influence germination. During seedling establishment, conditions and properties of growth medium, e.g. such factors as pH, salinity and drainage become increasingly important (Bentsen, 2002). During germination and the early establishment phase, seeds and seedlings are extremely susceptible to physiological stress, mechanical damage and infection. Therefore, a secondary purpose of providing optimal environmental conditions is to speed up germination so that the seedlings pass through the most vulnerable stage as fast as possible (Bentsen, 2002).

Pattern of seedling recruitment depends on a number of factors, particularly the availability of seed production, heritability, viability and adaptability as well as germination conditions (Quilichinia and Debusschea, 2000; Frey *et al*., 2007). Emergence, survival and final establishment of seedlings are greatly affected by habitat characteristics (Lee *et al*., 2004; Gomez-Aparicio *et al*., 2005; Jusaitisa *et al*., 2004). Of the habitat characteristics, ground cover, elevation, soil depth, slope and canopy openness are the main parameters that classified seedling habitat with respect to their emergence (Politi *et al*., 2009; Chen and Z. Q. Xie, 2009). Establishment limitation may be caused by germination failure, seedling mortality, or juvenile death, all of which may be caused by adverse environmental conditions (Münzbergová and Herben, 2005; Nathan and Muller-Landau, 2000; Turnbull *et al*., 2000). Each seed-bearing species has its own characteristic set of requirements for germination that may be regarded as adaptations for maximizing survival in a patchy and unpredictable environment (Fenner, 1985). For conservation purposes, it is important to characterize traits of seed germination and seedling establishment which limit endangered species from expanding its geographic range, increasing in abundance, or persisting even at low abundances (Yates and Broadhurst, 2002).

2.3 The State of Tropical Rainforest

Many tropical forests are under great anthropogenic pressure and require management interventions to maintain the overall biodiversity, productivity and sustainability (Kumar *et al*., 2006) Understanding tree composition and structure of forest is a vital instrument in assessing the sustainability of the forest, species conservation and management of forest ecosystems (Kacholi, 2014). Long-term biodiversity conservation depends basically on the knowledge of the structure, species richness, and the ecological characteristics of vegetation (Kuobouana *et al*., 2016). Tropical forests are the subject of several studies to better understand the role they could play in sustainable development, climate change, and floristic biodiversity (Lewis *et al*., 2009; Djuikouo *et al*., 2010). Tropical forests provide many goods and ecosystem services, such as prevention of soil erosion and preservation of habitats for plants and animals. Globally, 52% of the total forests are in tropical regions and they are known to be the most important areas in terms of biodiversity (Djuikouo *et al*., 2010; Holdridge, 1967). This diversity is an indicator that allows appreciating links between the richness and the abundance of individuals' trees; it reflects the degree of heterogeneity or stability of vegetation (Trichon, 1997).

Lafrankie e*t al*. (2006) noted that the tropical rainforests are vulnerable to deforestation and degradation. In Nigeria, population growth has led to an astronomical increase in anthropogenic activities, excessive logging and over exploitation. As a result, most of these forest reserves now exist only on paper (Adekunle *et al.*, 2013). They have either been converted to farmland of arable and cash crops or other land uses, such as large scale afforestation programmes. In addition, the lucrative nature of timber trade attracted many Nigerians into the business, causing continuous timber harvesting in both the constituted forest and the free areas (Adekunle *et al.*, 2013). According to website reports, about 48 species of animals, and 431 species of plants are endangered, of which 16 species of mammals and 45 species of plant are categorized as rare, 30 species of animals and 20 species of plants are endemic (www.onlinenigeria.com/links/bioticadv.asp?). All these are of conservation concern to the country. Also Adekunle *et al.,* (2010), affirmed that a total of 111,377 timber stems, belonging to 62 different indigenous hardwood species of tropical rainforest ecosystem, distributed among 16 families, were exploited from Ondo State forest ecosystem between 2003 and 2005.

Other factors responsible for the drastic reduction of the rich floristic resources of Nigeria are illegal activities in the forest, declining manpower and capacity in Forestry Department, inadequate forest patrol, stoppage of the payment of annual royalty (formerly 5% of total income) from what accrued from logging activities to rural communities, outdated forestry laws and regulations (Adekunle *et al.*, 2013). Similarly, Maliyat & Datt (2010) reported that the expansion of biotic activities is also responsible for overexploitation of natural resources, and this has subsequently disturbed the delicate equilibrium that exists between living organisms and their environment. So, both the reserve where logging is allowed with government regulations and the free areas that are not under strict regulations have suffered devastation in Nigeria. It appears, therefore, that intact old-growth forests, where biodiversity is conserved for posterity are restricted only to the SNRs, Biosphere/Conservation reserves and the sacred groves and community forests. These now serve as refuges for animals driven by human disturbances from other forests and free areas, and home for so many endangered indigenous plant species (Adekunle *et al.*, 2013).

In situ conservation methods are veritable tools for the preservation of genetic resources currently decreasing at an alarming rate. To promote nature conservation worldwide, Myers *et al.* (2000) brought about the concept of hotspot that considered the regions with exceptional concentration and assemblage of endemic species that are experiencing a high rate of habitat loss. They noted that conservation and protection efforts should be prioritised in these areas. Presently, thirty-four such biodiversity hotspots were identified worldwide (Mittermeier *et al*., 2005). At present, there is no recognised biodiversity hotspot in Nigeria. The country is not also among the 16 mega-diverse countries of the world. This does not preclude that there are potential biodiversity hotspots in the country (Adekunle *et al.*, 2013). The country is very rich in forest resources, with eight important tropical ecological zones, broadly categorised into three (the tropical rainforest ecosystem, the mangrove in the southern part and the savannah in the northern part). The Biosphere Reserve and SNRs in the country could be potential biodiversity hotspots, which could qualify the country to be among the mega-diverse countries of the world if adequate biodiversity assessments are carried out and documented (Adekunle *et al.*, 2013). According to a study on land-use changes (Geomatics, 1998), undisturbed forest including rainforests and savanna woodlands made up 2.9 percent of the total area of Nigeria in 1976-78 but only 1.3 percent in 1993-95. The extent of disturbed forests has similarly increased (FAO, 2006a). Although rainforest patches still are found in southern Nigeria in a belt that runs from the western to eastern borders of the country, the largest remaining tracts of rainforest are primarily found in Cross River, Bendel (now Edo and Delta), and Ondo states (FAO, 2006a)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of study site

This study was carried out at a temporary nursery (Latitude 06˚24'32.2" N and Longitude 005˚37'07.3" E) located at Ekosodin community in Ovia North East Local Government Area of Edo State, Nigeria. Ekosodin community which was established as a farm settlement in the 19th century shares southern boundary with the University of Benin and is border by Eguoveon community in the East and Evbomore community in the West and North.

3.2 Collection of Planting Materials

Matured fruits of the fives indigenous forest tree species (plates 1a - 1e) were collected under their mother tree and their seeds (plates 2a – 2e) extracted.

120 polypots (10 by 9 inches dimension) were filled with topsoil and stacked in 25 plots having 5 pots each (plate 3).

25 seeds per species were randomly assigned to plots and sown at 1cm depth (i.e 5 seeds per plot for each species replicated five times).

(A) Pericopsis eleta

(B) Hildergadia Barteri

(C) Terminalia avicennoides

(D) Albizia lebbeck

(E) Terminalia ivorensis

Plate 1a – 1e Showing fruits of the five indigenous forest trees

Plate 3 Plot showing stacked 25 experimental plots having 5 pots each

3.3 Data collection

The data collected for germination include type of germination based on Miquel (1987) description, number of germinant per day (GPD) and total germinants per day (TGPD) for each treatment (i.e tree species). The five distinctive seedling types illustrated by Miquel (1987) are:

1) Exposed leafy cotyledons above ground level (epigeal), with photosynthetic capacity and no reserve.
2) Exposed fleshy cotyledons above ground level (epigeal),
3) Exposed fleshy cotyledons at ground level (semi-hypogeal),
4) Cryptic cotyledons at ground level or below ground (hypogeal) and
5) Cryptic cotyledons above ground level (epigeal)

Data collected for seedling pre-establishment stage include epicotyl and hypocotyl length, seedling height and collar girth while the seedling post-establishment stage data collected include seedling height, collar girth and leaf area. At the stage of establishment, the data collected are: radicle length, plumule length, total seedling height, epicotyl and hypocotyl length, average length of lateral roots, range of lateral root length, average size of cotyledon.

3.4 Data Analysis

Germination and seedling establishment stage data was analyzed using descriptive statistics such as tables and graphs. Also germination percentage for each treatment (species) was calculated as follows;

$$\%\ \mathbf{Germinant} = \frac{\mathbf{Total\ germinant}}{\mathbf{Total\ seeds\ sown}} \times \mathbf{100}$$

Data obtained from the seedling pre- and post-establishment stage measured will be subjected to a one-way ANOVA in a CRD experimental design to test the significance of the species growth and development. Significant parameter means was separated using Duncan Multiple Range Test (DMRT) to determine the level of significance between the treatments (species).

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 RESULTS

4.1.1 Germination

The result of the seed germination (Table 1) of the five forest tree species investigated in this study shows that *Hildergadia bacteri* and *Terminalia ivorensis* had the highest number of germinant of 19 (76%) at the end of germination. The least germinant 5 (20%) was recorded in *Albizia lebbeck*. *T. ivorensis* and *T. avicennioides* expressed epigeal type of germination with exposed leafy cotyledon above ground level, having photosynthetic capacity and no reserve (Plates 4 and 5), while *Pericopsis elata* and *Albizia lebbeck* exhibited epigeal germination with exposed fleshy cotyledons above ground level (Plate 6). Cryptic cotyledons above ground level (epigeal germination), was presented by *Hildergadia bacteri*.

Table 1: Germination of the Five Species

DAYS AFTER SOWING	*Pericopsis elata*		*Hildergadia bacteri*		*Terminalia ivorensis*		*Terminalia avicennioides*		*Albizia lebbeck*	
	GD	TGD	GD	TGD	GD	TGD	GD	TGD	GD	TGD
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	3	3	0	0	0	0	0	0	0	0
10	2	5	2	2	0	0	0	0	0	0
11	4	9	2	4	0	0	0	0	0	0
12	3	12	2	6	0	0	0	0	0	0
13	1	13	3	9	0	0	0	0	0	0
14	0	13	3	11	0	0	0	0	0	0
15	1	14	1	12	3	3	0	0	0	0
16	0	14	0	12	2	5	0	0	0	0
17	0	14	0	12	1	6	0	0	0	0
18	0	14	3	15	2	8	0	0	0	0
19	0	14	2	17	0	8	0	0	0	0
20	0	14	0	17	0	8	0	0	0	0
21	0	14	0	17	5	13	0	0	0	0
22	0	14	0	17	2	15	0	0	0	0
23	0	14	1	18	0	15	4	4	0	0
24	0	14	0	18	0	15	0	4	1	1
25	0	14	0	18	0	15	1	5	1	2
26	0	14	0	18	3	18	2	7	0	2
27	0	14	1	19	0	18	2	7	0	2
28	0	14	0	19	1	19	1	8	2	4
29	0	14	0	19	0	19	3	11	0	4
30	0	14	0	19	0	19	2	13	0	4
31	0	14	0	19	0	19	0	13	0	4
32	0	14	0	19	0	19	0	13	0	4
33	0	14	0	19	0	19	3	16	1	5
34	0	14	0	19	0	19	0	16	0	5
35	0	14	0	19	0	19	0	16	0	5
TOTAL	**14**		**19**		**19**		**16**		**5**	
PERCENT	**56%**		**76%**		**76%**		**64%**		**20%**	

TGD: total germinant per day, GD: germinant per day

Plate 4: ***Terminalia ivorensis***

Plate 5: ***Terminalia avicennioides***

Plate 6: ***Albizia lebbeck*.**

Figure 1 below reveals that *Pericopsis elata* had the shortest germination period which started 9 Days After Sowing (DAS) and ended on the 15 DAS with peak germinant per day (GD) of 4 observed on the 11 DAS. This was followed closely by *H. bacteri* that started 10 DAS and ended 19 DAS with varied peaked GD. The longest germination period was observed in *Albizia lebbeck* (started 24 DAS and ended 33 DAS) with peak GD of 2 occurred on the 28 DAS

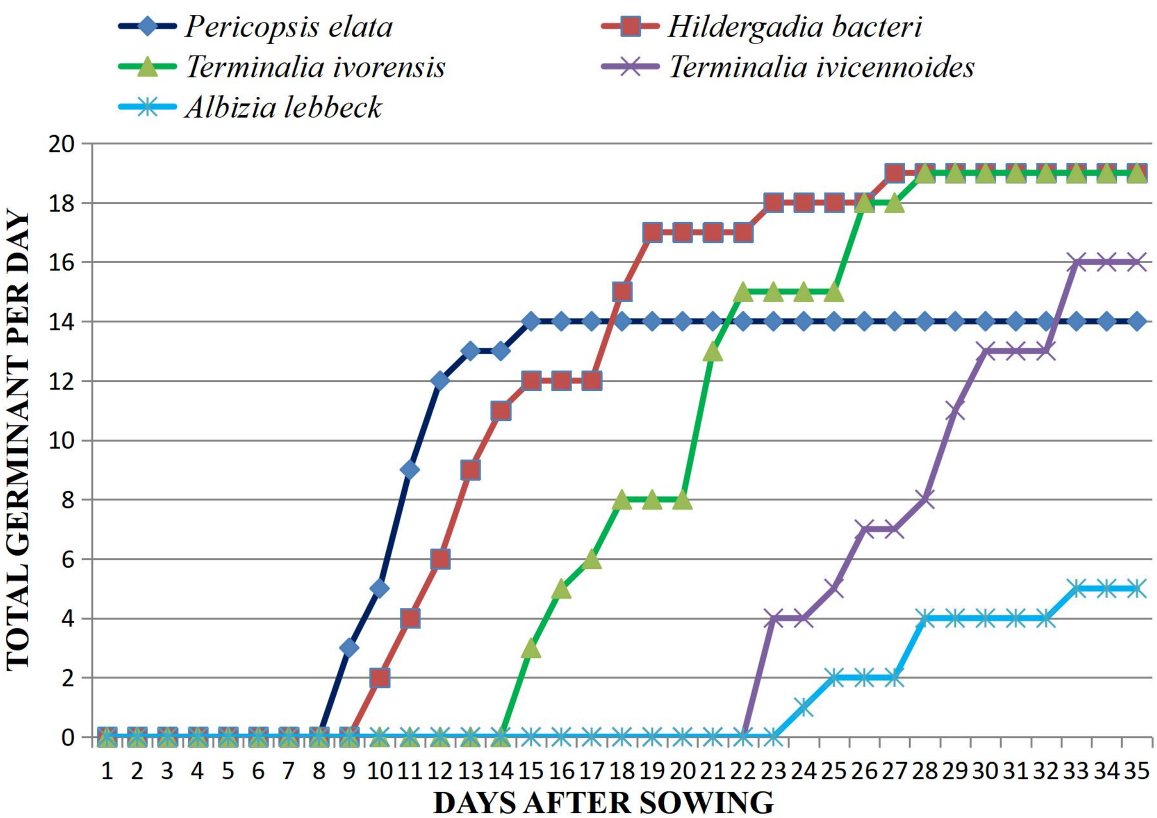

Figure 1: Germination Trend of the Five Species

4.1.2 Seedling Pre-establishment Stage

4.1.2.1 Hypocotyl and Epicotyl length

Plumule elongation during seed germination, recorded by the increase in hypocotyl and epicotyl length is shown in Figure 2. From the figure, *Hildergadia bacteri* had the longest hypocotyl length (7.23cm) at the 9th Week After Sowing (WAS) followed by *Albizia lebbeck* (4.42cm) at 13 WAS. The least hypocotyl increase (0.67cm) was observed in *Terminalia avicennioides*. On the other hand, the longest epicotyl length of 6.42cm was recorded for *Pericopsis elata* while the least length of 3.34cm was recorded for both *H. bacteri* and *A. lebbeck*

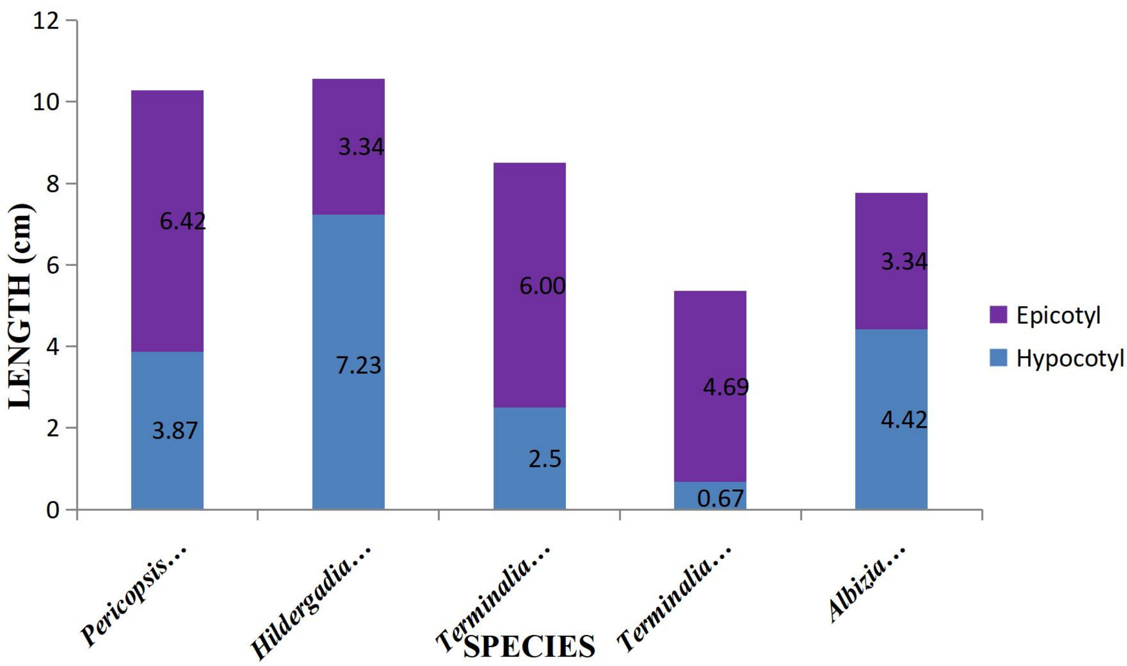

Figure 2: Average Hypocotyl and Epicotyl length

Data analysis shows significant difference in the elongation of hypocotyl (Appendix 2) and epicotyl (Appendix 3) length. Mean separation (Table 2) indicates significant difference of hypocotyl length across species while there was no difference in epicotyl length between *P. elata*, *T. ivorensis* and *T. avicennioides*. Also the epicotyl length between *H. bacteri*, *A. lebbeck* and *T. avicennioides* had no significant difference ($P < 0.05$).

Table 2: Mean Separation of Seedlings Pre-establishment Stage

	Pericopsis elata	***Hildergadia bacteri***	***Terminalia ivorensis***	***Terminalia ivicennoides***	***Albizia lebbeck***
EPICOTYL	6.42^{a}	3.34^{b}	6.00^{a}	4.69^{ab}	3.34^{b}
HYPOCOTYL	3.87^{c}	7.23^{a}	2.50^{d}	0.67^{e}	4.42^{b}
COLLAR GIRTH	1.736^{ab}	2.663^{a}	1.912^{ab}	0.593^{b}	0.883^{b}
SEEDLING HEIGHT	5.14^{a}	4.16^{a}	6.98^{a}	6.21^{a}	1.645^{a}

Means with the same superscript letter are not significantly different.

4.1.2.2 Seedlings Collar Girth

The average collar girth increased gradually across each species (Appendix 4) even as the analysis of variance (ANOVA) shows significant difference at $P < 0.05$ (Appendix 4). Mean separation reveals that *H. bacteri* with the largest collar girth of 2.663mm had no significant difference with collar girth of *P. elata* and *T. ivorensis* but is significantly different from *T. avicennioides*. and *A. lebbeck* (Table 2).

4.1.2.3 Seedlings Total Height

Although there was delay in the germination of the tree species, especially *Albizia lebbeck* (Appendix 6), the seedling growth in height was consistent. This fact is made clear by the mean separation (Table 2), which shows no significant difference in species height growth even though the ANOVA for seedling height growth indicates a significant difference at $p > 0.05$ (Appendix 7)

4.1.3 Species Establishment stage

Table 3 gives a physical observation of the forest species at stage of establishment- point when the cotyledons fall off from the seedling stem (Plates 7-11). The table shows that *Terminalia ivorensis* had the longest radicle and plumule length of 23cm and 22cm respectively, thus its high total seedling length of 45cm (Plate 12). *Terminalia avicennioides* had the least total seedling length of 23.4cm due to its short radicle length (plate 13). A well-developed root system was observed in *Hildergadia bacteri* compared to the other species. This is denoted by its high average lateral root of 8.63cm that ranges from 0.9cm to 12.5cm. *Albizia lebbeck* showed high proliferation of lateral roots (69), followed by *Pericopsis elata* (60) while *T. ivorensis* had the least lateral root production.

Table 3: Morphological State at Seedling Establishment Stage

PARAMETERS	*Pericopsis elata*	*Hildergadia bacteri*	*Terminalia ivorensis*	*Terminalia avicennioides*	*Albizia lebbeck*
TLR (cm)	17.5	22.5	23.0	13.0	18.6
TSL (cm)	31.8	32.0	45.0	23.4	25.6
EL (cm)	6.3	7.9	2.1	7.1	2.5
HL (cm)	8.0	2.1	1.0	3.7	3.9
NLF	5	2	17	17	5
NLR	60	28	26	51	69
TPL (cm)	14.3	10.0	22	11.1	7.0
CG (mm)	4.2	1.7	2.5	1.4	1.5
RLL (cm)	0.4 – 3.3	0.9 – 12.5	1.6 – 7.9	0.1 – 1.4	0.4 – 5.7
ALLR (cm)	1.58	8.63	6.60	0.95	3.55

TLR: total length of radicle, TSL: total seedling length, EL: epicotyl length, HL hypocotyl length, NLF: number of leaves, NLR: number of lateral root, TPL: total plumule length, CG: collar girth, RLL: range of lateral root, ALLR: average length of lateral root

Plate 7: ***Terminalia ivorensis***

Plate 8: ***Terminalia avicennioides***

Plate 9: ***Albizia lebbeck***

Plate 10: ***Hildergadia bacteri***

Plate 11: ***Pericopsis elata*** **Plate 12:** ***Terminalia ivorensis*** **showing TSL**

Plate 13: ***T. avicennioides*** **showing Radicle** **Plate 14:** ***A. lebbeck*** **proliferation of NLR**

4.1.4 Seedling Post-establishment Stage

4.1.4.1 Seedlings Total Height

The average total seedling height at the termination of the experiment is represented in figure 3. It shows best height growth performance of *Albizia lebbeck* followed by *Hildergadia bacteri* while *Terminalia avicennioides* had the least height growth. Data analysis reveals no significant difference in the general growth performance of the species (Appendix 8).

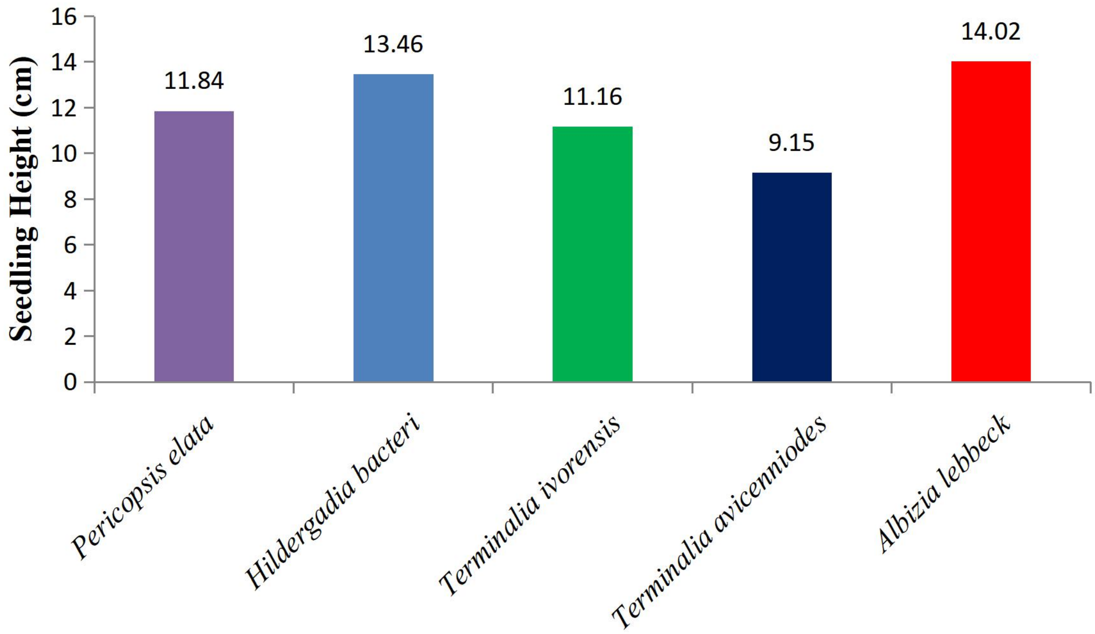

Figure 3: Average Total Seedling Height

4.1.4.2 Seedlings Collar Girth

The data collected for post-establishment seedling collar girth is shown in table 4. The table indicate that species collar girth was recorded at different weeks after sowing due to their varying establishment stage. Analysis of variance showed significant difference in collar girth increment (Appendix 10) while mean separation reveals that *P. elata* had the largest average collar girth, significant different from other species except *H. bacteri* (Table 4).

Table 4: Average Collar Girth

Weeks After Sowing	*P. elata*	*A. lebbeck*	*H. bacteri*	*T. ivorensis*	*T. avicenniodes*
6	6.0	0	0	0	0
7	6.23	3.9	5.37	0	0
8	6.42	4.54	5.88	0	0
9	6.85	5.06	6.44	0	0
10	7.22	5.06	7	4.13	2.41
11	7.48	5.86	7.44	4.69	2.80
12	7.73	6.16	7.82	5.73	3.11
13	7.89	6.42	8.29	5.73	3.11
14	8.82	6.88	8.39	5.73	3.11
Mean	**7.182^{a}**	**4.876^{bc}**	**6.292^{ab}**	**2.890^{cd}**	**1.616^{d}**

Means with the same superscript letter are not significantly different

4.2 DISCUSSION

Result from this study which shows *Hildergadia bacteria* and *Terminalia ivorensis* having high percentage germinant of 76% at the end of germination is an indication of their regeneration potential in the rainforest. This result agrees with that of Ken Fern (2013) who stated that germination rate up to 80% and 93% has been achieved under experimental process for *H. bacteria* and *T. ivorensis* respectively. Also, the epigeal type of germination exhibited by the five species shows typical characteristics of rainforest tree species. According to Hladik and Mitja (1996) the most abundant seedling type among the tropical rain forest species are those with foliaceous photosynthetic cotyledons followed by fleshy cotyledons and cryptic cotyledons, both above ground level.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The growth of trees from seeds is an important factor in plant evolution and in the development of an optimal state of vegetation, communities, and ecosystems. Knowledge of the natural regeneration of forests tree species is important for developing scientific models, techniques and new guidelines to conserve dwindling natural forest areas especially the rainforest region. The results presented in this study are a small contribution to the broad issues contained within the Nigerian rainforest.

From this study, the rate of seedling growth and establishment supported by cotyledons could have been determined by all or any of the following factors:

a. uncovered cotyledons easily dry up and once dessication takes place, they become unable to attain the photosynthetic status and soon wither off,

b. the fleshy nature of the cotyledon makes them susceptible to attack by herbivorous animals and

c. fungi and other micro-organism could also destroy the exposed cotyledons.

The aspect of survival of seedling after germination was supported by researchers who opined that protecting seeds against predation, permitting them to reach seedling establishment stage is important to rainforest restoration programs. This study has shown that for some species, especially with fleshy and foliaceous cotyledons, the cotyledons servers as a natural food reserve, protection and medium of photosynthesis for the emerging seedling against the vagaries of the environment and its retention aids the early growth and survival processes of the young seedlings.

5.2 RECOMMENDATION

It is hereby recommended that seeds of the rainforest zones be raised with consideration of protecting the cotyledons in order to obtain the best results. This method could also be easily practised by interested silviculturists. The study is therefore an asset to reforestation and regeneration of rainforest tree species.

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APPENDIX

Appendix 1: Average Hypocotyl and Epicotyl length

DAS	*Pericopsis elata*		*Hildergadia bacteri*		*Terminalia ivorensis*		*Terminalia avicennioides*		*Albizia lebbeck*	
	HYL (cm)	EPL (cm)	HYL (cm)	EPL (cm)	HYL (cm)	EPL (cm)	HYL (cm)	EPL (cm)	HYL (cm)	EPL (cm)
11	1.90	0								
12	2.20	1.7								
13	2.65	1.8								
14	3.28	1.85	5.75	0						
15	3.59	3.27	5.75	0						
16	3.80	3.40	5.80	0						
17	3.80	3.54	5.80	0	0.75	0				
18	3.83	3.96	6.15	0	0.75	0				
19	3.83	3.97	6.15	0	0.81	0				
20	3.83	4.10	6.35	0	1.11	0				
21	3.83	4.10	6.50	1.45	1.68	0				
22	3.83	5.48	6.50	1.45	1.71	0				
23	4.31	5.86	6.70	1.45	2.59	1.84				
24	4.18	6.0	6.70	1.45	2.50	1.98	0.38	0	2.0	0
25	4.30	6.0	6.70	1.45	2.33	2.59	0.38	0.80	2.0	0
26	4.30	9.12	6.70	1.45	2.53	1.95	0.38	0.62	2.6	0
27	4.31	9.79	6.70	2.05	2.66	2.5	0.38	0.62	2.6	0
28	4.31	9.92	6.71	2.05	2.66	2.5	0.46	0.74	2.6	0
29	4.31	10.10	6.71	2.05	2.66	2.1	0.46	1.06	2.6	0
30	4.31	10.10	6.75	2.05	2.66	2.1	0.45	0.9	2.6	0
31	4.31	10.30	6.75	2.19	2.66	2.1	0.50	1.05	3.04	0
32	4.31	10.33	6.75	2.19	2.66	2.1	0.57	1.18	3.3	0
33	4.31	10.42	7.15	2.19	2.66	2.1	0.62	1.2	3.3	0
34	4.31	10.49	7.15	2.19	2.66	2.1	0.62	1.45	3.3	1.9
35	4.31	10.52	7.15	2.19	2.66	2.1	0.62	1.45	3.3	1.9
36	4.31	10.69	7.29	2.21	2.66	2.1	0.64	1.65	3.34	1.9
37			7.29	2.21	2.66	2.78	0.64	1.67	3.34	1.9
38			7.56	2.45	2.66	2.78	0.64	1.78	3.37	2.2
39			7.56	2.45	2.66	2.78	0.67	1.78	3.37	2.2
40			7.70	2.45	2.66	3.39	0.67	1.99	3.40	2.2
41			7.70	2.45	2.66	4.78	0.68	2.28	3.42	2.2
42			7.70	2.45	2.66	4.78	0.71	2.76	3.46	2.2
43			7.77	2.45	2.66	4.93	0.72	2.88	3.46	2.2
44			7.77	2.45	2.66	5.13	0.72	2.88	3.46	2.2
45			7.77	2.83	2.66	5.14	0.72	2.88	3.46	2.2
46			7.77	2.83	2.66	5.27	0.72	2.88	3.78	2.35
47			7.77	2.83	2.66	5.65	0.72	3.03	3.78	2.35

48			7.77	3.33	2.66	5.66	0.72	3.03	3.78	2.35
49			7.77	3.33	2.66	6.0	0.72	3.13	3.78	2.38
50			7.77	3.33	2.66	6.31	0.72	3.13	3.80	2.38
51			7.77	4.30	2.66	6.34	0.72	3.15	3.80	2.38
52			7.77	4.30	2.66	6.6	0.72	3.21	4.12	2.45
53			7.77	5.42	2.66	6.93	0.72	3.21	4.12	2.45
54			7.77	5.42	2.66	7.23	0.72	3.35	4.43	2.55
55			7.77	5.80	2.66	7.46	0.72	3.73	4.43	2.55
56			7.77	6.42	2.66	7.55	0.72	3.90	4.43	2.55
57			7.77	6.42	2.66	7.85	0.72	4.10	4.78	2.90
58			7.77	7.15	2.66	8.14	0.72	4.28	4.78	2.90
59			7.77	7.15	2.66	8.46	0.72	4.44	4.78	2.90
60			7.77	7.29	2.66	8.81	0.72	4.61	5.45	3.13
61			7.77	7.29	2.66	9.17	0.72	5.0	5.45	3.13
62			7.77	7.29	2.66	10.27	0.72	5.1	5.45	3.13
63			7.77	7.50	2.66	10.44	0.72	5.23	5.45	3.13
64			7.77	7.50	2.66	10.58	0.72	5.28	5.45	3.54
65			7.77	7.56	2.66	10.85	0.72	5.63	5.45	3.54
66			7.77	7.70	2.66	11.06	0.72	5.63	5.45	3.55
67			7.77	7.70	2.66	11.22	0.72	6.87	5.45	3.55
68					2.66	12.29	0.72	6.87	5.45	4.10
69					2.66	12.29	0.72	6.87	5.45	4.10
70					2.66	12.57	0.72	6.87	5.45	5.07
71					2.66	12.57	0.72	7.31	5.45	5.23
72					2.66	12.96	0.72	7.31	5.45	5.23
73					2.66	12.96	0.72	8.13	5.45	5.73
74					2.66	13.35	0.72	8.13	5.45	5.73
75					2.66	13.35	0.72	8.14	5.45	5.73
76					2.66	13.35	0.72	8.14	5.45	5.73
77							0.72	8.93	5.45	5.73
78							0.72	8.93	5.45	5.73
79							0.72	8.93	5.45	5.73
80							0.72	9.29	5.45	5.90
81							0.72	9.29	5.45	5.90
82							0.72	9.29	5.45	5.90
83							0.72	9.29	5.45	5.90
84							0.72	9.29	5.45	6.28
85							0.72	9.29	5.45	6.28
86							0.72	9.42	5.45	6.28
87							0.72	9.81	5.45	6.28
88							0.72	10.04	5.45	6.64
89									5.45	6.64
90									5.45	6.92
91									5.45	6.92

TOTAL	**100.56**	**166.81**	**390.42**	**180.11**	**149.76**	**360.19**	**43.59**	**305.11**	**300.31**	**227.02**
AVERA	**3.87**	**6.42**	**7.23**	**3.34**	**2.50**	**6.00**	**0.67**	**4.69**	**4.42**	**3.34**

EPL: Epicotyl length, HYL: Hypocotyl length

Appendix 3: ANOVA of Hypocotyl length

Source	DF	SS	MS	F-Value	P-Value
Species	4	1389.6	347.408	709.50	0.000
Error	268	131.2	0.490		
Total	272	1520.9			

Appendix 3: ANOVA of Epicotyl length

Source	DF	SS	MS	F-Value	P-Value
Species	4	398.0	99.499	10.24	0.000
Error	268	2603.2	9.714		
Total	272	3001.2			

Appendix 4: Average Collar Girth

WEEKS AFTER SOWING	***Pericopsis elata***	***Hildergadia bacteri***	***Terminalia ivorensis***	***Terminalia avicennioides***	***Albizia lebbeck***
1	0	0	0	0	0
2	0	0	0	0	0
3	2.18	3.76	0	0	0
4	2.74	3.93	1.66	0	0
5	3.76	3.97	1.66	0.43	1.1
6		4.32	1.76	0.51	1.2
7			1.79	0.85	1.2
8			2.82	0.86	1.3
9			3.09	0.91	1.3

10			4.06	1.03	1.4
11			4.19	1.24	1.5
12				1.29	1.6
TOTAL					
MEAN					

Appendix 5: ANOVA of Collar Girth

Source	DF	SS	MS	F-Value	P-Value
Species	4	24.01	6.003	3.87	0.009
Error	41	63.57	1.551		
Total	45	87.58			

Appendix 6: Seedling Total height for Pre- establishment Stage

WEEKS AFTER SOWING	***Pericopsis elata***	***Hildergadia bacteri***	***Terminalia ivorensis***	***Terminalia avicennioides***	***Albizia lebbeck***
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	5.73	0
4	9.97	8.18	6.75	7.0	0
5	10.28	8.29	8.68	8.15	0
6	10.56	8.46	10.04	8.63	0
7			11.62	9.52	0
8			12.74	10.68	0
9			12.97		0
10					0
11					0
12					6.4
13					8.15
14					8.48

Appendix 7: ANOVA of Pre- establishment Seedling Height

Source	DF	SS	MS	F-Value	P-Value
Seedling height	4	195.9	48.97	2.41	0.066
Error	38	771.0	20.29		
Total	42	966.9			

Appendix 8: ANOVA of Post-establishment Seedling Height

Source	DF	SS	MS	F-Value	P-Value
Seedling height	4	135.7	33.93	0.56	0.695
Error	40	2433.9	60.85		
Total	44	2569.6			

Appendix 9: Total Seedling Height Post Establishment

Weeks	Pericopsis elata	Albizia lebbeck	Hildergadia bacteri	Terminalia Ivorensis	Terminalia Avicenniodes
6	10.57	0	0	0	0
7	10.76	0	11.39	0	0
8	11.22	13.44	11.60	0	0
9	11.45	14.96	12.41	0	0
10	11.75	16.4	15.08	14.16	12.64
11	12.14	18.3	16.17	18.31	13.9
12	12.57	19.9	17.29	22.65	18.59
13	12.94	21.24	18.62	22.65	18.59
14	13.17	21.94	18.62	22.65	18.59

Appendix 10: ANOVA of Post-establishment Collar Girth

Source	DF	SS	MS	F-Value	P-Value
Collar Girth	4	192.9	48.227	11.01	0.000
Error	40	175.2	4.381		
Total	44	368.1			