EFFECT OF STEM SIZE AND PLANTING ORIENTATION ON VEGETATIVE PROPAGATION OF African Teak *(Milicia excelsa* (Welw.) ECOTYPES IN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this University or any other institution for the award of a degree.

Signature   Date 01.08. 2023

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Recommendation

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DEDICATION

I dedicate this work to my mother, Seraphine Barakagwira, and my father, Cyprien Gatambara.

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ABSTRACT

African Teak (*Milicia excelsa* (Welw.) is a giant deciduous forest tree which belongs to the Moraceae family. Slow and erratic seed germination and the dioecy characterize the species. Vegetative propagation has been proposed to overcome some of the reproductive biology challenges in the species. This study therefore assessed the effect of stem size and planting orientation on vegetative propagation of *Milicia excelsa* (Welw.) ecotypes in Kenya. The experiment was conducted at the Agroforestry Tree Nursery, Egerton University, Njoro, Kenya. The aim of this study was to investigate the ideal stem cutting method of *M. excelsa* based on size (length) and planting orientation of stem cuttings. The propagation materials were collected from healthy mother trees from the Coast and Western regions of Kenya. A factorial experiment of two factors (cutting lengths and planting orientations), with 3 levels each, was laid in a Randomized Complete Block Design (RCBD) with nine treatments, replicated 3 times. The cutting lengths were 3, 6 and 9 cm, which were then planted in three positions (horizontal, vertical, and slanting angle). The planting medium was composed of river sand. The polyethene sheet tunnel with 1 m and 1.5 m height and width respectively was established and the nursery containers were covered inside. Data was collected monthly on the number and height of sprouts and the cutting survival at the end of 150 days. Data was then subjected to analysis of variance (ANOVA) using GENSTAT 15th Edition. Separation of means was performed using the SED. The results showed that the cutting length had a significant effect on the number of sprouts, $F_{43.45}$, df=2, p= 0.001 and height of sprouts produced, $F_{48.25}$, df=2, p=0.001. The planting orientation had a significant effect ($p \leq 0.05$) on the number and height of sprouts produced by cuttings throughout the experiment as well as survival of cuttings at the end of experiment. The ecotype had a significant effect, $F_{6.99}$, df=1, p=0.012 on the number of sprouts obtained by stem cuttings at 30,120 and 150 days after propagation. The highest percentage of cutting survival obtained was 48.41% from the cuttings of 9 cm length and the least was 31.75% from cuttings of 3 cm length. The ecotype and length interaction, and length and orientation were also significant, $F_{3.31}$, df=4, p=0.001. It was concluded that vertical and slanting positions should be considered as well as the 9 cm length of the cuttings before planting, and their interaction as well as ecotype and length interaction. Further studies should consider the optimum cutting length, age and position of stem cutting.

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LIST OF ABBREVIATIONS AND ACRONYMS

IBA	Indole-3-Butyric Acid
IAA	Indole-3-Acetic Acid
NAA	1-Naphtalene Acetic Acid
a.s.l	above sea level
spp	Species
KEFRI	Kenya Forestry Research Institute
FAO	Food and Agriculture Organization of the United Nations
IUCN	International Union for Conservation of Nature
FORIG	Forestry Research Institute of Ghana
SED	Standard Error of Differences

CHAPTER ONE

INTRODUCTION

1.1. Background Information

African Teak *(Milicia excelsa* (Welw.) is a deciduous forest tree with potential to grow very large up to 50m or occasionally even more, that belongs to the family of Moraceae. The species is indigenous to African habitat ranging from Guineo-Congolian-East African forest belt (Daïnou, 2017). An old tree may have a straight trunk up to 2m diameter, umbrella-like crown, growing from a few thick branches and is common at the coast of Kenya (Mbuvi *et al*., 2016). At the age of 50, trees are ready to be harvested. It is one of the most important timber species in Sub-Saharan Africa, but it is now threatened in Kenya because of over- exploitation, deforestation, and human (Iralu *et al*., 2019; Maundu & Tengnas, 2005). The species was found to be sparsely distributed on farmlands which represented the main conservation sites for the remnant trees in Kenya.

The African teak is vulnerable to assaults by the gall- forming bug, *Phytolyma lata* which makes it difficult to cultivate in plantations. The production of pest -resistant planting stock through a genetic improvement program, according to research conducted at the Forestry Research Institute of Ghana (FORIG) in 1996, reported initial results from seedling screening trials which indicate that pest-resistant genotypes may exist in natural populations (Ugwu & Omoloye, 2015b). Vegetative propagation strategies are necessary to replicate genotypes that exhibit pest resistance. *Milicia excelsa* can be propagated through seedlings and wildings although their seeds are susceptible to pests (Ugwu & Omoloye, 2015b). African teak is not a prolific seed producer, with delayed and poor germination (Maundu & Tengnas, 2005). Normally the seeds mature before the syncarp is fully ripe, if the syncarps are not totally ripe they should be spread out in the shade for ripening. When ripe, they are soaked in water overnight and the seeds are squeezed off the fruits. Seeds are surrounded by sticky, oily substances which could impose seed dormancy. Studies reported that the presence of oily substances surrounding seeds delay seed germination (Costa *et al*., 2019; Ubani & Chukwunonso, 2017).

Asexual propagation is the process of using a fragment of a parent plant and inducing it to grow into a new plant. The offspring shares the same genetic makeup as the parent plant. Asexual reproduction uses a plant's vegetative components, such as its stems, roots, or leaves

(Tchinda *et al*., 2013). Asexual reproduction has several benefits, such as being simpler and quicker than in woody perennials like *Milicia* and being the only method to duplicate cultivars while avoiding the juvenile features of some species. To encourage the establishment of trees in agrosystems, a number of propagation tactics have been developed, including the propagation of seeds and vegetative propagation techniques (Meunier *et al*., 2016a).

Studies have shown that the ease of forming adventitious roots in the stem cuttings decreases as the ortet becomes older (Gonin *et al*., 2019; Tahir *et al*., 2022) . This is a significant issue since desired phenotypic features are rarely manifested until a plant has grown to a significant size or maturity (Ofori *et al*., 1997). The loss of rooting ability with age potentially may be overcome by coppicing or regular pruning, since cuttings from coppice shoots generally root more readily than cuttings from mature trees (Leakey *et al*., 1982; Nath *et al*., 2022).

The African teak is dioecious, male, and female trees are slightly different in appearance. Male trees have longer and slenderer trunk and crown and forking being more common than in female trees (Djagbletey *et al*., 2011). Male flowers are white and closely clustered in a slender, pendulous catkin up to 20cm long; female is greenish, in a hairy spike that is shorter and wider planting seedlings may be required. There is a problem in determining sex of the seedlings raised or planted as this species is dioecious meaning that it has separate male and female plants. Seed germination is slow and might take a long time; consequently, strategies to improve seed germination are needed (Trivedi *et al*., 2020). To address the sluggish and unpredictable seed germination as well as the dioecy phenomena in the species reproductive biology, vegetative propagation could be employed to solve the problem from the projecting styles (Avana *et al*., 2019).

Seed can be separated from the pulp by floating them in water, whereas the seeds will sink (Schmidt *et al*., 2019). Dry the seeds in the shade for a week before sowing since seed loses viability quickly (Avana-Tientcheu *et al*., 2019). It is fast growing compared with other hardwoods. It may be pruned or coppiced. Regeneration rates are low in most areas. Occurs in plantations and mixed planting; young trees should be protected from browsing. Rooting has been found to be positively linked with cutting length in a variety of tree propagation experiments. This is due to the presence of carbohydrates and mineral elements in longer cuttings, which are essential for root formations. It has also been shown that in many plant species, taken from different positions within a shoot differ in their rooting ability. Cuttings from the upper portion of *Triplochiton scleloxylon* and *Lovoa trichilioides*, for example, had better rooting capabilities than those from the bottom portions, whereas *Khaya ivorensis* had a reserve (Ofori *et al*., 1997).

1.2. Statement of the problem

The use of seeds and seedlings of *M. excelsa* in domestication is limited by its recalcitrant nature, seed dormancy and limitations in seed storage technology. It has been observed that the development or degree of dormancy changes during the lifetime of the seed, usually as a response to external conditions. Seedlings may be required for planting, although determining the sex of the seedlings raised or planted is a challenge since this species is dioecious. In addressing domestication and conservation challenges regarding sexual propagation, vegetative propagation and particularly the stem cuttings method provides potential for production of propagules with high social and economic value and provide numerous advantages, even though it has been proposed, but not widely tested and limited work has been done so far. There is still little information on factors influencing the shoot and root formation of this species. Efforts aimed to preserve the species have not progressed significantly due to inadequate suitable propagation techniques and cultivation knowledge. In this study, the overall objective is to assess the effect of stem size, planting orientation and ecotype on sprouting in *Milicia excelsa* with a view of establishing efficient propagation techniques.

1.3. Objectives of the study

1.3.1. Broad objective

To evaluate the effect of vegetative propagation on sprouting of *Milicia excelsa* to contribute to conservation and management of this highly valued indigenous species in Kenya.

1.3.2. Specific objectives

i. To evaluate the influence of stem size of cuttings on sprouting of *Milicia excelsa*
ii. To investigate the effect of stem planting orientation on sprouting of *Milicia excelsa* cuttings
iii. To determine the effect of ecotypes on sprouting of *Milicia excelsa* cuttings
iv. To assess the effect of interaction of ecotype, length, and orientation on sprouting of *Milicia excelsa* cuttings

1.4. Study Hypotheses

i. Stem size cuttings statistically have no influence on sprouting of *Milicia excelsa* cuttings.

ii. Stem planting orientation statistically has no effect on sprouting of *M. excelsa* cuttings.

iii. *M. excelsa* ecotypes has statistically no effect on its sprouting

iv. The interaction of ecotype, length and orientation has no effect on the sprouting.

1.5. Justification of the study

African Teak is critically endangered timber species in Sub Saharan Africa, threatened by overexploitation, deforestation, and many other human activities in Kenya (Iralu *et al*., 2019). This species is being exploited in the wild for timber production with little or no regard for its protection, and with current lack of propagation knowledge, will threaten it and its habitat. Domestication is required to meet the market demand; however, it is currently limited by propagation techniques due to poor and slow germination and rooting periods, dioecism, and slow growth of the species. There is therefore need to develop proper asexual propagation methods that would allow the multiplication and selection of superior genotypes (Hamadeh *et al*., 2018).

In Sub-Saharan Africa, a number of native forest tree species of economic importance are dioecious and this poses particular challenges for management, which requires investigation of propagation strategies and regeneration potential (Cao *et al*., 2011a). Knowledge about plant propagation for many African trees of high economic potential such as *Milicia* species is scanty and often absent (Negash & Ababa, 2021). Considering the commercial importance of this tree, there is great need for improvement of this species and to develop propagation techniques suitable for cultivation and its regeneration in natural habitats. The findings of this study will provide authenticated alternative vegetative propagation strategies for development of materials to enhance regeneration potential of this threatened species.

1.6. Scope of the study

The study was carried out in the Agroforestry Tree Nursery at Egerton University in Nakuru County, Kenya. The study focused on vegetative propagation of *M. excelsa* stem cuttings which were collected from the Coastal and Western regions of Kenya.

1.7. Limitations of the study

Local language barrier during the collection of the cuttings in the two sites but this was solved by using a translator where possible. Poor accessibility of the tree species in Western and Coast region because they are under protection since they are endangered. Insufficient knowledge on the ages of some trees since most of them regenerate naturally on the farm.

1.8. Operationalization of terms

Vegetative propagation or Asexual propagation: Vegetative reproduction (also known as vegetative propagation, vegetative multiplication, or cloning) is any form of asexual reproduction occurring in plants in which a new plant grows from a fragment or cutting of the parent plant or specialized reproductive structures, which are sometimes called vegetative propagules.

Sexual propagation: Is the reproduction of plants by seeds. The genetic material of two parents is combined by pollination and fertilization to create offsprings that are different from each parent.

Stem cutting: a piece of a plant stem or branch including at least one node used in propagation.

Ecotype: In evolutionary ecology, an ecotype, sometimes called ecospecies, describes a genetically distinct geographic variety, population, or race within a species, which is genotypically adapted to specific environmental conditions.

Endangered species: a species of animal or plant that is seriously at risk of extinction.

Forest- Large area of land dominated by trees and other vegetation that influence the local climate.

Tree- A woody perennial plant with one erected trunk growing to a considerable height of at least above 3 meters above the ground bearing lateral branches.

Forest Conservation: is the practice of planning and maintaining forested areas for the benefit and sustainability of future generations.

Management: Forest management is the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, economic, social, and cultural objectives.

Physiological factors: These are factors that trees need to function; their actions are interrelated in a functional network involving all major processes of tree physiology in the ecological performance of trees.

Environmental conditions: Environmental factors that affect plant growth include light, temperature, water, humidity, and nutrition. It is important to understand how these factors affect plant growth and development.

Propagation material: all plant materials or vegetative parts of plants intended for the propagation and production of specific variety plants.

CHAPTER TWO

LITERATURE REVIEW

2.1. Occurrence and Cultivation of *Milicia excelsa*

African Teak is a hardwood tree of moist to wet tropical forests at low to medium elevations from sea level to 1,600 meters. It occurs in areas where the average annual temperature is 25-35 degrees Celsius and the average annual rainfall is 1,150-1,900mm. The tree may survive a six-month dry spell and grow in a location with annual rainfall as low as 700 mm if it has access to additional water from a perennial stream or underground source (Doumenge *et al*., 2003). African Teak succeeds on a large variety of soils so long as they are fertile, as it is especially sensitive to low levels of potassium and phosphorus. Its presence is said to indicate fertile soil that is suited for farming. It prefers well- drained soil and will die if the drainage is hindered (Fig 1).

Figure 1: ***M. excelsa*** **growing on farm in Taita Taveta County, Kenya**

African Teak is a pioneer species, demanding intense light and unable to survive deep shade (shade intolerant). Young trees grow continuously, but growth of mature trees is periodical. Trees are fairly fast growing - in a 6-year-old plantation some trees are over 6m tall, although the variability was large (Doumenge *et al*., 2003). On average it takes 130 years for a tree to reach a trunk diameter of 80cm. Male trees can start flowering within 10 years from seed, but females can take 15 years. It takes 5-6 weeks from fertilization to fruit maturation. Seed dispersal is mostly by birds, bats, and squirrels. Trees respond well to pruning and coppicing. In the dry season, African teak is deciduous for a short period, both male and female forms need to be grown if seed is required (Djagbletey *et al*., 2011).

Pests' population was impacted by mixed planting with other tree species and the usage of various shade settings, activity, abundance of galls and growth of *Milicia spp*, planting *Gliricidia sepium* (nitrogen fixing) together with Milicia reduced the damage caused by *Phytolyma spp*. and was related to increased nitrogen and/ or shading. Shade reduced the abundance of galls in different ways, with the lowest number occurring at the maximum level of shading of 82 % (Ofori & Cobbinah, 2007). In Kenya, African Teak referred to as "Mvule" occurs in the moist coastal forests at Buda, Mirima Hill, Shimba Hills, Witu, River Lumi riparian ecosystem and in the surrounding farmlands. The species can be found at Taveta on the Kenyan-Tanzanian border outside of coastal environments.

Seed can be kept for at least a year at room temperature (Ofori *et al*., 2001). It usually offers good germination rates of 90 % or more within two to four weeks when sown fresh. Seeds are collected in a seedbed three weeks after germination and transplanted to pots or nursery beds. To limit or prevent attacks by *phytolyma spp*., which impact seedlings at an early age, seedlings should be grown in the shade. About 4 months after sowing the seedlings are around 30cm tall and ready for planting out in the field (Babalola *et al*., 2013). Using stem cuttings obtained from 1-and 2-year-old trees have achieved successful propagation, however, cuttings from older trees should be taken from coppice branches or shoots, in most regions, root cuttings and regeneration rates are minimal (Ofori & Cobbinah, 2007).

2.2. Biology and Ecology of *Milicia excelsa*

African Teak is a deciduous forest tree species native to the Sudano-Zambezian super area that can be found in a variety of habitat ranging from Guineo-Congolian-East African forest belt linking species to riverine forest (Daïnou, 2017). Due to its light demand or light requirement, its population density rises from the moist, evergreen forest zone to the semi-deciduous forest zone or secondary forest. *M. excelsa* is a deciduous large tree with a potential to grow very large up to 50 m tall. It is dioecious with unclear differences in vegetative traits between males and females; however, when blooming occurs, flower size and toughness significantly differ according to gender. The species is pollinated by the wind (Daïnou, 2017). African Teak grows and attains a diameter of 2-10 m; bark thick, pale, ash grey to nearly black, then brown, usually fairly rough and flaking off in small scales, but rarely fissured; slash thick, fibrous, cream colored with brown spots, exuding white latex; trunk lofty, straight and cylindrical, up to 20 m or more to the 1st branches, usually with short, blunt buttresses; crown high, umbrella-like and growing from a few thick branches; branchlets thick, rather zigzag and angular, all more or less horizontal. Branches of female trees hang down but male individuals have upright branches (Daïnou, 2017). It is a valuable hardwood from the humid tropics of Africa, and is currently under threat of extinction because of over-exploitation and poor regeneration (Bosu *et al*., 2006).

Leaves in young trees and green above, paler and pubescent below; older leaves often becoming a bright yellow, serrate at the margin, simple and alternate, broadly elliptic or ovate, very shortly acuminate, usually unequally glabrous above and beneath except for minute hairs between the network of veins; about fifteen pairs thick parallel, upcurving, pale colored lateral nerves, very protuberant beneath and looped close to the margin; definitive veins thick and forming a highly characteristic, more or less rectangular network on the under surface; base sub-cordate; apex shortly acuminate; edge finely toothed; stalk 2.5-6 cm, stout, glabrous (Torrini *et al*., 2019). Flowers are dioecious, axillary, green in color, all floral parts in 4s; male flowers white, closely crowded on pendulous, slender catkins (spikes) 15-20 cm long, hanging from twigs of the outer crown. Female trees produce erect flower spikes about 5-6 cm long and 2 cm thick; female flowers are green, in shorter and much fatter spikes, the styles of each flower projecting so that the inflorescence appears hairy (Boyle & Bronstein, 2012).

Fruit is arranged along a longitudinal axis with 1 seed on each side, 5.0-7.5 x 2.0-2.5 cm, green, wrinkly, fleshy, and resembling a fat green caterpillar; no change in the color of the syncarp when it attains maturity, but the flesh between the actual fruit softens. Seeds are hard, small and lie in the pulp. Male and female flowers are found on separate trees, and *M. excelsa* flowers at slightly different times of the year depending on the area (Neuenschwander *et al*., 2015). The species is a secondary forest tree of wet savannah, rainforest, riverine, groundwater and low-altitude evergreen forests. It is sometimes found in formerly cultivated areas. The tree can tolerate a dry season of up to 6 months and can grow in areas with mean annual rainfall as low as 700mm provided it has access to extra water from a perennial stream or underground water source. It is intolerant to waterlogging (Daïnou, 2017). *M. excelsa* can be an agroforestry species, scattered trees grow on farmlands in Busia and Siaya Districts in western Kenya, concentrated around Malaba. Because of its high value as a timber tree, the species has been excessively exploited and is now endangered (Iralu *et al*., 2019; Maundu & Tengnas, 2005).

African teak is one of the most popular timber species in East Africa. The wood has an attractive brown color, which darkens on exposure and with greasing; the hard, dark heartwood is strong and durable on the ground, works easily, and is heavy, open grained and is resistant to termites (Neuenschwander *et al*., 2015). It resembles teak and is mainly used for outside construction work, furniture and other equipment, boats, cabinet work, paneling, frames, and floors. It plays important roles in preventing erosion and in enhancement of soil fertility since it is an agroforestry tree. It is one of the pioneer species of East Africa and is shade intolerant tree and occupies a successful pioneer niche on acid soils (Veenendaal *et al*., 1996). *M. excelsa* occurs in deciduous, semi-deciduous or evergreen, primary or secondary forest, with an apparent preference for drier forest types. It often occurs in gallery forests and on forest islands or as lone trees in savanna regions and is sometimes left as a lone tree in former cultivated areas. It is found up to 1200-1500 m altitude, even though it has been found at 4500 m altitude on Mount Kilimanjaro in Tanzania (Apetorgbor *et al*., 2004). In West Africa, *Milicia excelsa* occurs in regions with an average annual temperature of 25-35°C and an average annual rainfall of 1150-1900 mm. It is considered a pioneer species, demanding intense light and unable to stand deep shade. In young secondary forest, for example, it cannot compete with climbers and shrubs (Boyle & Bronstein, 2012).

2.3. Medicinal Importance of *Milicia excelsa*

African Teak is a medicinal plant recommended in tropical Africa as a cure for several ailments including amenorrhea. This is the hallmark of an ovarian lesion or a dysfunction of the hypothalamic-pituitary-ovarian axis which may lead to infertility, osteoporosis, or endometrial cancer. However, despite these long-held beliefs, no scientific information on emmenagogue characteristics has been published so far (Mvondo *et al*., 2017). African teak is commonly utilized in traditional African medicine. Chlorophin, a phenolic molecule found in plants, has been demonstrated to decrease melanin biosynthesis in studies. Hexahydrochlophorin, a more stable derivative, has the potential to be used in skin-whitening products and to treat pigmentation disorders. Two phenolic compounds (chlorophorin and iroko) have shown in-vitro anti-amoebic activity, a methanol extract of the stem bark has shown in-vivo anti-inflammatory properties (Udegbunam *et al*., 2013). A root decoction is taken to treat female sterility. A decoction of the root and stem bark is taken as an aphrodisiacal.

The bark is aphrodisiac, galactagogue, purgative and tonic used as a traditional cure to treat variety of ailments such as cough, asthma, heart disease, and lumbago, spleen pain, stomachache, abdominal pain, oedema, ascites, dysmenorrhea, gonorrhea, general fatigue, rheumatism, sprains. Bark preparations are externally applied to treat scabies, wounds, loss of hair, fever, venereal diseases, and sprains. They are also useful as an enema to cure piles, diarrhea and dysentery (Abiola *et al*., 2020). The latex is a galactagogue and is used to treat gastrointestinal disorders, hypertension, tumors, and obstructions of the throat. Externally, snakebites and fever are treated with leaf concoctions, and filariasis is treated with eye drops.

2.4. African teak wood properties

The heartwood is pale yellow in color, turning yellowish or greenish brown or even chocolate brown when exposed to light; it is distinguished from the sapwood by a 50-75mm wide strip of yellowish white sapwood. The grain is interlocked; texture medium to coarse; with stippled figure. The wood is somewhat greasy and it has no odor (Hans & Ndang, 2021). The wood is of medium weight, moderately hard, and of good durable property, being resistant to fungi, dry wood borers and termites. Hand and machine tool working properties are generally acceptable but varied, and the interlocking grain may make sawing and planing difficult. Due to the presence of hard deposits, the wood is quite abrasive (‘iroko stones’, mainly consisting of calcium carbonate), which can blunt cutting edges (Onuegbu & Olaide, 2018). Lacrimation in planing can be avoided by using cutting angles of 15° or less. The presence of good nailing in the wood nailing, screwing, bonding and adhering capabilities such as glue, as well as the ability to run readily. It finishes well, but filler is needed. Wood includes the stilbene derivative chlorophorin, which inhibits oil-based paints from fading and can cause metal to corrode when it comes into touch with it. It also has moderate steam- bending characteristics (Nichols *et al*., 1999).

Wood is one of the most highly valuable commercial timber in Africa, for which demand is increasing. It is used for construction work, shipbuilding and marine carpentry, sleepers, sluice gates, framework, trucks, draining boards, outdoor and indoor joinery, stairs, doors, frames, garden furniture, cabinet work, panelling, flooring and profile boards for decorative and structural uses (Sahromi & Yudaputra, 2015). It is also used artisanally for carving, domestic utensils, musical instruments, and toys. As it is resistant to acids and bases, it is used for tanks and barrels for food and chemical products and for laboratory benches. It is also used as sliced veneer but only rarely as rotary veneer. The wood is also used as firewood and for making charcoal (Onuegbu & Olaide, 2018). The tree is utilized for soil enhancement and soil conservation due to its leaf mulch. Within its native region, a natural pioneer species that produces high- quality wood. It could be a beneficial complement to native woodland restoration operations.

2.5. African teak ecotypes in Kenya

Kenya's forest cover is estimated to be 8.3%, below the internationally recommended minimum and constitutionally mandated of 10%. The country's low forest cover has contributed to a deterioration in environmental quality as well as a decrease in tree goods and services. Reduced forest cover has an impact on the coast area, which sustains 17% of Kenya population (Wasonga, 2019). The Coast region of Kenya comprises of six counties; Kilifi, Kwale, Lamu, Mombasa, Taita-Taveta and Tana- River, the forests in the coast region include mangroves, indigenous coastal forests, inland dry woodlands, and trees on farms. African Teak commonly referred to as Mvule is mostly found in Taita-Taveta, Mombasa and Lamu. *M. excelsa* can be an agroforestry species and scattered trees grow on farmlands in Busia and Siaya Districts in western Kenya, concentrated around Malaba. The species reduces soil erosion, provides building poles, timber, and fuelwood, and serve as a habitat for a variety of animals (Daïnou, 2017) .

Earlier studies by Mbuvi (2016) provides appropriate information on land capabilities for producing high value tree species in Kenya's Coast. In the Coast region, 96,075 ha is classified as an area of high capability (Table 1). It is utilized for furniture making, boat building, and other construction purposes in the area.

Table 1: Capable area for growing *Milicia excelsa* in the Coast region of Kenya

Capability	Capable area (ha)	Capable area excluding conservation areas (ha)
High Capability	96,075	80,844
Medium Capability	834,000	761,435
Low capability	1,023,238	1,003,841
Not capable	6,094,784	4,630,626

Source: Mbuvi *et al*. (2016).

On the north Kenya coast, flowering can be seen in January or February; at the south coast, flowers can be observed from January to March; in western Kenya from October to December as well as in January and February. Flowers appear a few weeks after the partial or complete shedding of leaves or with the new leaves. After pollination, the female flower ripens to some fruit within a month. Seeds are being transported and dispersed by birds, bats and squirrels after eating the fruits (Coenraets, 2019). The species does well at an altitude of 0-1400 m.a.s.l. and a mean annual rainfall of 100-2200 mm in well drained relatively fertile soils, red clay-loamy to sandy loamy soils. *Milicia* is also found in low lying areas with high water table and near water sources/ rivers (Seswa *et al*., 2018).

For on farm planting, it is recommended that the species be planted on boundary or scattered in the farmland as it found in Central and Western part of Kenya. Young trees need protection from termites and weeding is necessary at the initial stages of establishment. The distribution of endemic species within the area needs consideration. Both the Eastern Arc Mountains and the lowland Coastal Forest Mosaic have similar distribution trends, because of human activity, it implies habitat fragmentation and significant loss of habitats, as well as habitat continuity between natural fragments (loss of connectivity). When conservation initiatives are developed, this issue must be carefully considered (Critical Ecosystem Partnership Fund (CEPF), 2005). As a result, defining conservation goals is a bottom-up process in which species-level aims are established initially, based on species data, site-level conservation targets are identified. This data has been accumulating in the International Union for Conservation of Nature's (IUCN) Red Lists of Threatened Species, avoiding extinction means conserving the endangered species to make sure that its IUCN Red List status improves or at least stabilizes. As a result, information on population trends is required (Omondi *et al*., 2004).

African teak has been in decline for a long time because of overexploitation of its wood, which is great for wood and furniture. Despite this, no organized attempts have been made to grow this species in plantations (Iralu *et al*., 2019), and the country today has to import hardwoods (sometimes illegally) to meet the domestic needs for the furniture and timber industries. As a result, there is a pressing need and opportunity to adopt replanting of this species, both in their native habitats and on farms, where they can provide a source of income for rural residents. In addition, policies that support the replanting of this tree could also be adopted and implemented (Beentje, 1994).

2.6. Physiology of Vegetative Reproduction in African teak.

Vegetative regeneration can be both a natural process and an artificial process. The artificial process is used by agriculturalists, horticulturalists, and foresters to capture and multiply individual genotypes, and so to produce cultivars and clones (Monteuuis, 2017). Clonal approaches to forestry and horticulture have a history going back more than 800 and 3000 years respectively, originating from China. The clonal process is used to develop superior planting stock, although there are also many applications in research where clonal uniformity is a powerful tool in the separation of genetic effects from physiological and environmental impacts on growth processes in plants (Leakey, 2004). The level of understanding about vegetative regeneration using stem cuttings has developed enormously since the 1970s, the period when clonal forestry was becoming a reality in many parts of the world. Although the focus of this review is primarily on the physiology of root cuttings, other techniques include layering/marcotting, grafting/ budding, and different in vitro propagation methods (Leakey, 2004). The identification of underlying physiological principles determining successful rooting of stem cuttings. The problem that needs to be taken care of is the high level of interaction between the large number of factors perseverance, post severance, and in the propagation environment (Adams *et al*., 2016).

Stem cuttings can come in many forms but the two major groups are leafy softwood cuttings from relatively unlignified, young shoots (Fig.2), and leafless hardwood cuttings from older and more lignified shoots which typically have already shed their leaves due to the onset of winter or a dry season (D'Antraccoli *et al*., 2018). It is important to understand that the factors determining the rooting of these two types of cuttings are very different: leafy cuttings depend on current photosynthates produced in the propagation bed, while hardwood cuttings depend on the hydrolysis and availability of carbohydrates stored within the stem tissues. The most important aspect or feature of the propagation environment is that it encourages physiological activity (photosynthesis and transpiration) in the leaf to diminish the physiological stresses experienced by the tissues, from transpiration and respiration, and encourages meristematic activity (mitosis and cell differentiation) in the stem (Leakey, 2004). The transport of assimilates and nutrients from the leaf to the base of the stem, and the movement of water from the base of the stem to the leaf, are significant. Current physiological measurements confirm general experience that the duration of physiological shock arising from severing a cutting from its stock plant and inserting it in a propagator can be minimized or reduced by controlling the propagation environment. Minimizing this physiological issue enhances rooting (Leakey, 2004).

Figure 2: A rooted cutting of *Milicia excelsa*

2.7. Sexual and Asexual Propagation of African teak.

Plants are either propagated sexually or vegetatively or asexual propagation; sexual propagation by seed being important as it maintains genetic diversity and is also cheaper than asexual techniques (Ugwu & Omoloye, 2015b). However, from a farmer's perspective, relying on seed may not be the best approach because seed progeny can be very variable and have extensive emergence periods, resulting in a large time delay before harvesting useful products. On the other hand, vegetative propagation may result in minimal genetic variability but produces offspring that are highly precocious and allow farmers to acquire products quickly (Nyamukuru *et al*., 2014).

Seed can be kept for at least a year at room temperature. Seeds are sown in a seedbed and moved to pots or nursery beds three weeks after germination and for good germination rates of 90% or more within 2-4 weeks when sown fresh. Seedlings should be grown in the shade to avoid Phytolyma spp attacks and should also be 30cm tall and ready to planted out in the field around 4 months after sowing, immature plants transplant well (Luc, 2003). Seedlings and wildings can be used to propagate easily, but its seeds are susceptible to pests and diseases (Ofori *et al*., 1997; Ugwu & Omoloye, 2015b). Suckers are also produced, which can be used. However, the tree is not prolific seed producer, with delayed and poor germination. (Maundu & Tengnas, 2005). Normally the seeds mature before the syncarp is fully ripe, if the syncarps are not totally ripe they should be spread out in the shade for ripening. When the fruits are mature, they are soaked in water overnight and the seeds squeezed out. Sticky, greasy secretions surround seeds, which may cause seed treatment difficult. The presence of oily substances surrounding the seeds has been observed by many authors to impede seed (Ubani & Chukwunonso, 2017).

Although seedlings may be required for planting, determining sex of the seedlings raised or planted might be a problem as this species is dioecious meaning that it contains separate male and female plants. Seed germination is slow and might take place over a long period of time, therefore, strategies to improve seed germination are needed or developing methods that could enhance it. To address the slow and erratic seed germination and the dioecy phenomenon in the reproductive biology of the species, several reports indicated that vegetative propagation may be used to overcome this problem (Schmidt *et al*., 2019). Floating separates the seed from the pulp; then the seeds will sink. Before sowing, dry the seeds in the shade for a week, although, the seed loses viability quickly (Avana-Tientcheu *et al*., 2019). African teak is fast growing compared with other hardwoods. It may be pruned or coppiced. Regeneration rates are low in most areas. Occurs in plantations and mixed planting; young trees should be protected from browsing.

African teak is propagated mostly via seed. The weight of 1000 seeds are 1–4 g, for 1 kg of seeds, around 40 kg of fruits are required. Because the color of the infructescence does not change as they ripen, the only way to detect maturity is to cut the infructescence and examine if the pulp has softened. If unripe, infructescences are picked from the tree, and then left under shade for some days to ripen. Although it is easier to gather them from the ground, the seeds should be retrieved before the infructescence begin to ferment (Luc, 2003). After immersing the infructescence in water for roughly one day, the seeds can be separated by crushing them. Viable seeds sink in water and can be easily separated from floating unviable seeds. Fresh seeds normally germinate well; the germination rate may be more than 90% within 4 weeks. Because viability declines fast after 3 months, it is best to sow seed as soon as possible following collecting. Seeds that have been dried to an 80% moisture content can be stored for at least a year at 0–5°C (Abiyu *et al*., 2016).

Three weeks after germination, seeds are placed in a seedbed and moved to pots or nursery beds. To avoid *Phytolyma* spp. attacks, seedlings should be grown in the shade. About 4 months after sowing the seedlings are around 30 cm tall and ready for planting out in the field. Young plants transplant well (Ouinsavi *et al*., 2005). Seedlings planted during the lengthy rain season in Ghana have grown significantly better than seedlings planted during the short rainy season. The improved growth lasted for at least 9 years. Planting in a mixed stand with *Terminalia superba* Engl. & Diels (in equal proportions at planting) gave better growth than planting in pure stands. African Teak can be propagated vegetatively by stem and root cuttings, grafting, layering and invitro tissue culture. Successful propagation has been achieved using stem cuttings from 1- and 2-year-old trees, but from mature trees cuttings should be taken from coppice shoots. Stakes and posts made of branches may strike root like cuttings. The wide sapwood of this tree means that thinning in plantations are of little value, so it is recommended to plant at wide spacings (Ouinsavi *et al*., 2005).

2.8. Vegetative propagation

Vegetative propagation is a basic human activity that aims to create offsprings that are identical to the original plant. Naturally, a successful propagation method is the one that aids in the transmission of all the mother plants features to its offspring. The major activity that occurs in vegetative propagation is cell division by mitosis which involves division of tissues used for growth (Yeboah, 2015). Vegetative propagation can be utilized in a variety of ways to create offspring that are true-to-type to the parent plant. Some of the types of vegetative propagation which can be used in the Mvule to facilitate domestication and management are mainly rooted cuttings and stem cuttings.

2.9. Factors affecting vegetative propagation.

Vegetative propagation can be affected by a variety of endogenous and environmental factors such as tree species or varieties, the ability of cuttings to regenerate, carbohydrates, mineral salts, plant growth regulators and temperature, humidity, light and rooting medium in the rooting environment of cuttings (Hu *et al*., 2020a). The following paragraphs discuss the different factors affecting vegetative propagation.

2.9.1. Environmental conditions affect vegetative propagation.

Environmental factors seriously affect vegetative propagation on the responsiveness of the plant through absorption, translocation, plant developmental stage, nutritive conditions, and many others. Temperature plays an important role in hormonal availability (Yeboah, 2015). It is well known that maximal auxin effectiveness is obtained at high temperatures. Temperature and light conditions bear on the nutritional status of the plant. For rooting of cuttings, moderate to low temperatures (24-27^{o}C) can enhance cell processes whilst temperatures above 28^{o}C can retard development. Propagation by cuttings develops adventitious roots on the basal portion of stem material containing 2-4 axillary buds. Stem tissue is usually harvested from woody species' canopy or suckers, and the method remains entirely ex vitro. On greenhouse benches with mist or high humidity, adventitious roots are common. Cuttings are acclimated to greenhouse conditions for vegetative growth after sufficient rooting (Revord & Ronald, 2016; Yeboah, 2015).

2.9.2. Physiological factors influencing vegetative propagation.

The rooting of cuttings is influenced by several physiological factors found within stem cutting. Polarity, girdling, leaves, and buds are a few of them. Constriction of stem via girdling or any other means blocks the downward translocation of carbohydrates, hormones, and other substances responsible for rooting. The base where the constriction has been done accumulates high levels of these mentioned substances thereby promoting rooting (Yeboah, 2015). The presence of leaves as well as the age of material being used have strong influence on rooting of cuttings. The presence of rooting buds on stem has a strong promotive effect, if all the buds were removed from woody stem cuttings, rooting success was essentially non- existent. Auxins are produced in abundance by buds to aid grafts/ rooting success (Hu *et al*., 2020a).

2.9.3. Nutritional factors influencing vegetative propagation.

The two most important nutritional components are carbohydrates and minerals. The factors include carbohydrate levels as well as mineralization that influence vegetative propagation by rooted cuttings. Carbohydrate performs a lot of functions in the rooting of cuttings in a variety of ways. The carbohydrate pools of sugars (soluble carbohydrates) and storage carbohydrates (starches or insoluble carbohydrates) are important to rooting as building blocks of complex macromolecules, structural elements, and energy sources (NC State Extension Publications, 2018). Although stock plant carbohydrate content and rooting may sometimes be positively correlated, carbohydrates do not have a regulatory role in rooting.

A positive relationship between carbohydrate content and rooting may indicate that present photosynthate supplies are insufficient for optimal rooting (Hu *et al*., 2020b). High C/N ratios in tissues of cuttings promote rooting but do not accurately predict the degree of rooting response. Cuttings use stored carbohydrates in root regeneration, but only in small amounts. Differences in C/N ratios are mainly due to nitrogen rather than carbohydrate content. Nitrogen has been negatively correlated to rooting, which suggests that the correlation between high C/N ratios and rooting may be due to low nitrogen levels (Hu *et al*., 2020b).

2.9.4. Auxin effect on adventitious rooting

In forestry, vegetative propagation is commonly employed to increase selection of elite trees from natural populations or produced through breeding efforts or obtained in breeding programs. The formation of adventitious roots is an essential step in vegetative propagation and therefore if cuttings do not form roots, losses occur (Shekhawat & Manokari, 2016). Adventitious roots can arise naturally from stem tissue under stressful environmental conditions; they may also be induced by mechanical damage or following tissue culture regeneration of shoots (Li *et al*., 2009). Environmental and endogenous elements, such as temperature, light and hormones, influence and govern the production of adventitious (especially auxin), sugars, mineral salts, and other molecules. Auxin metabolism studies on adventitious rooting have been done on cuttings exposed for a prolonged period to auxin, but in other studies cuttings have been exposed to auxin for short periods. It was observed that apple micro cuttings cultured continuously on medium with auxin IAA (indole-3-acetic acid), IBA (indolic-3-butyric acid) or

NAA (1-naphthalene acetic acid) show the best rooting performance (a large number of roots is formed over a broad range of auxin concentrations) when cultured with IAA (Pop *et al*., 2011).

Many woody plants require the production of adventitious roots as part of their vegetative proliferation process, this is due to the presence of auxin. Although many researchers thought growth hormone treatment would promote rooting of cuttings, improve rooting number, and lower the rate of partial rooting, the rooting ratio decreased while the hormone concentration increased. High hormone concentrations or hormone levels that are too high have side effects on the root development (Kesari *et al*., 2009). The pattern of auxin action, despite its crucial role in adventitious root development, is still poorly understood. The process of adventitious root production or formation is quite complicated, but it is critical for the vegetative growth of genotypes that are difficult to root. Although auxin is widely known for its role in root development, it is not always effective, and the molecular mechanisms involved in the creation of adventitious roots are still unknown, despite the research efforts by researchers all over the world. For improving rooting conditions of economically important genotypes, scientists need to elucidate these molecular mechanisms through which auxins regulate adventitious rooting (Pop *et al*., 2011).

2.9.5. Factors influencing rooting of cuttings.

In a tree improvement program, vegetative propagation is beneficial because it increases genetic gain through broad sense heritability and allows genetic evaluation of genotypes and their interactions with the environment. The development of proper protocols for cloning requires investigation of factors playing and vital role in the rooting process (Vielba *et al*., 2016). Factors influencing the ability of leafy hardwood stem cuttings to induce adventitious root formation were revised by Leakey (2004). The propagation environment, post severance treatments (auxin application, cutting length, age of stem cuttings), and stock plant variables are all aspects to consider (cutting origin and environment), genetic variation which was accredited to between tree genetic change in morphology and physiology of cuttings.

In most tree species, the cuttings taken from juvenile (young) growth phase often root well than from adult phase (Iliev *et al*., 2010). This implies that the ability of cuttings to form adventitious roots decreases with the increase in the age of the plant. In hardwood cuttings, more roots are developed in the basal portion of the shoot than the cuttings taken mid or top of the shoot because the accumulation of the CHO and root promoting substances are in higher concentration at the basal parts. Cuttings taken from lateral shoots typically root better than those taken from terminal shoots. This is especially true of plum, spruce and pine trees (Iliev *et al*., 2010). It may be due to the reason that the lateral shoots have more stored food (CHO), which facilitates better rooting in the cuttings. Similarly, formation of some root initials in the basal portions probably under the influence of root promoting substances from bud and leaves may be responsible for it (Ngyete *et al*., 2020).

When leaves and buds are removed from cuttings, the root process is slowed in most species. The promoting effect of leaves and buds in root initiation is due to the fact that these are the primary source of carbohydrate and auxin synthesis and other root promoting co-factors in the plants, the leaves and buds carry these root-promoting co-factors to the cuttings basal area for root initiation (Henry *et al*., 1992). The effects of buds on rooting may vary with the time of the year. Growing buds usually encourage roots, while dormant buds prevent it. Rooting is stimulated by the presence of buds in easy-to-root species, but rooting is inhibited in difficult-to-root species. The promoting effect of buds on rooting during dormancy period may be due to the higher auxin and low inhibitor supply to the basal portion of the cutting. However, in some species, the leaves are removed to reduce the loss of water due to transpiration (Srikanth *et al*., 2016).

2.10. Perception on the constraints to propagation of African teak

Tropical rural populations have a long history of growing trees on their land to produce a variety of timber and non-timber forest products to support their way of life, the demands of the wood-based economy, and the environment (Ugwu & Omoloye, 2015a). It has been expected in tropical forestry that there will be a considerable change in the production of timber from natural forests to plantations, followed by the large-scale development of industrial fast-growing plantation forestry, especially on degraded areas. This trend towards a greater reliance on plantations as a source of industrial wood is acknowledged by FAO (2001). Problems with current forest management practices, but most importantly the necessity to meet the demand for forest products, have hastened this tendency.

African teak is a species that the International Union for Conservation of Nature (IUCN) has listed as endangered. Attacks by *Phytolyma lata* have severely restricted efforts to spread it. The study done in Nigeria on the constraints to propagation reported that in addition to the *Phytolyma lata* issue, the respondents mentioned additional barriers to Milicia cultivation success in the research location. Among these are the Milicia seedlings' sluggish development rate, the shortage of seeds for people who are interested in planting, bush burning, which usually results in the yearly extinction of the self-propagated plants in the wild, insects, lack of interest, and religious beliefs (spiritual factor) (Ugwu & Omoloye, 2015a). People avoid leaving Milicia on their farmland when they see the seedlings and avoid attempting to plant Milicia in their farmland because they believe it is connected to a particular spirit (Yliopisto *et al*., 2000).

Chemical pesticides have been shown to be inefficient for controlling phytolyma pests due to their covert nature. Numerous authors have suggested the use of companion crops or mixed planting as a potential technique for managing insect pests (Ugwu & Omolo, 2017). More diversified plant associations, especially those found in forests, are less vulnerable to insect damage, according to studies by Verheyen *et al*. (2016) and Castagneyrol *et al*. (2013). Tree diversity has the potential to lessen the effects of exotic forest pests at the stand level (Guyot *et al.*, 2015). According to Ofori and Cobbinah (2007b), growing Milicia with *Gliricidia sepium* reduces *P. lata*'s abundance and harm. According to earlier research, diversified planting gives natural enemies additional resources to grow, such as non-pest prey species, pollen, and nectar, strengthening their populations and impacts on pests (Ugwu & Omolo, 2017).

2.11. Physiographic and Nature Conditions of Busia District

Busia District falls within the Lake Victoria Basin. The altitude varies from 1130m above sea level on the shores of Lake Victoria to 1375m above sea level in the Central part. The district is in the Low Midland (LM) zone. It is divided into four agro-ecological zones LM1, LM2 and LM4 (NEMA, 2013a). There are two rainy seasons in the district, the long rains, and the short rains. The long rainy season starts in March and continues into May, while the short rainy season starts in late August and continues into October. The dry spells are from December through February and June/July. The mean annual rainfall for the district is 1500mm with most parts of the district receiving between 1270mm and 1790mm. The driest part of the district receives between 760mm and 1015mm of rainfall annually and is found along the lakeshore (NEMA, 2013a). The annual mean maximum temperatures range from 26^{o}C and 30^{o}C while the annual mean minimum temperatures vary between 14^{o} C and 18^{o}C. Due to the proximity of the district to Lake Victoria, the district records high rates of evaporation of between 1800mm and 2000mm per year. Thus, humidity is relatively high (Kebeney *et al*., 2014).

2.12. Physiographic and Nature conditions of Taita Taveta District

Taita Taveta District is one of the seven districts in the Coast Province. The district has a bimodal rainfall pattern with two rainy seasons. The long rains occur between March and May with a maximum in April. The short rains take place between October and December with a peak in November. The rainfall distribution varies depending on elevation and aspect. The annual potential evaporation (E0) ranges from 1200 to 2 100 mm. The mountainous zone serves as a rain catchment area with more the 900 mm of rainfall per annum. Descending the hills, rainfall becomes less (NEMA, 2013b). The temperature average 15-20^{o}C. The medium potential areas receive 700 to 900 mm, with higher temperatures, and evaporation. The annual average rainfall in Taveta is 350 mm to 750 mm. The temperature ranges between 21 to 38^{o} C and potential annual evaporation is 1950 mm. The lowlands receive a maximum of between 450-750 mm annually and rainfall is more unreliable in amount and distribution. The lower parts are hot with temperatures of about 30^{o}C. The potential annual evaporation rate is about 1800 mm. There is therefore a net water deficit (Kimori, 2020).

2.13. Interaction factors involved in vegetative propagation.

The propagation environment, post severance treatments (auxin application, cutting length, age of stem cuttings), and stock plant variables are all aspects to consider (cutting origin and environment), genetic variation which was accredited to between tree genetic change in morphology and physiology of cuttings (Han *et al*., 2017). In most tree species, the cuttings taken from juvenile (young) growth phase often root well than from adult phase (Iliev *et al*., 2010). This implies that the ability of cuttings to form adventitious roots decreases with the increase in the age of the plant. In hardwood cuttings, more roots are developed in the basal portion of the shoot than the cuttings taken mid or top of the shoot because the accumulation of the CHO and root promoting substances are in higher concentration at the basal parts (Arboriculture *et al*., 2010).

The study done by Savage *et al*. (2009) reported that cuttings are used to plant commercial willows, and it is well known that cutting length and diameter generally promote willow growth and survival. Most experts believe that the size of the carbohydrate storage pool that can be allocated to roots and shoots is what causes these beneficial benefits of cutting size (Carpenter *et al*., 2008; Woodruff & Meinzer, 2011).

In plant propagation process, the induction of roots is controlled by both external and internal elements, including temperature, light, hormones (particularly auxin), carbohydrates, mineral salts and other substances (Gehlot *et al*., 2014). The organization of the apical meristem (phyllotaxy), the branching of the plant's aerial parts (apical dominance), the formation of the main root, and the initiation of lateral and adventitious roots are all regulated by a group of signals called auxins that are derived from tryptophan (Gehlot *et al*., 2015). Auxins are important for controlling growth and development, early embryogenesis, main root formation, and lateral and adventitious to coordinate growth. Tree improvement must be pursued, which can only be done via vegetative proliferation of multiple superior genotypes (Hemantaranjan *et al*.,2017) But in other species, roots can be inconsistent, delayed, or scarce when reproduced through various stem cuttings, in this regard, the concept of mini-cutting propagation has encountered the drawback that the ability of stem-cutting to root declines with ontogenetic aging and may occur quickly than stated in the literature (Dhandapani *et al*., 2021).

For instance, the adventitious rooting ability in *Eucalyptus grandis* declined starting at the fourteenth node and took longer in *E. deglupta* (Fett-Neto *et al*., 2001). When handled in clonal hedges, clones of *E. saligna*, *E. grandis*, and *E. urophylla* that in vitro had an identical high proportion of stem-cutting rooting displayed varying degrees of rooting percentage reduction (Kendurkar & Rangaswamy, 2018). This suggested that the discrepancies may be caused by a clone growth factor that includes the six months between planting and cutting harvest (Luckman & Menary, 2002). Mini-cuttings have a considerably better chance of roots than stem-cuttings, albeit the advantages differ depending on the species and clones. When comparing stem cutting clones to mini-cutting clones in a species with poor rooting, rooting may typically increase by 40% (Rezende *et al*., 2014). The primary factors contributing to this rise are the tissues' excellent nutritional status and increased levels of juvenility, which enhance their rooting propensity and root initiation speed.

A more recent study done by Samarakoon and Faust (2022) reported that the entire clematis production cycle has been planned out over the course of a year. The availability of top-notch unrooted cuttings all year long is necessary for this timetable to be completed successfully. Due to low production costs and ideal growth environment, the majority of other floriculture crops cuttings are produced offshore (Kibbler *et al*., 2004). Unrooted clematis cuttings could be made abroad, and propagation would be handled by experts in the United States if stock plant production could be better understood. In order for propagators to increase this crop yield, rooting percentages of propagation must also be far higher than those now observed (Kreen *et al*., 2002)

2.14. Research gaps

Even though many studies have been done on vegetative propagation of the African teak, no information is currently available on the factors influencing rooting and sprouting abilities in this species. Studies conducted on vegetative propagation of *M. excelsa*, most of them focused on root cuttings, leafy stem cuttings and other factors. Table 2 summarizes the gaps that are in the study.

Table 2: Research gaps

Author(s) and year of publication	**Research topic**	**Research gaps**
Leakey, R. R. B., and Grace, J., Newton, A. C., Ofori, D. (1997)	Vegetative Propagation of *Milicia Excelsa* by Leafy Stem Cuttings	The study focused on the effect of maturity and node position with minimal consideration of losses due to leaf abscission and evapotranspiration
Apetorgbor, M. M., Cobbinah, J. R., and Ragazzi, A., Turco, E. (2004)	Potential factors limiting viability of *Milicia excelsa* (Welw.) C. C. Berg seeds in plantation establishment in West Africa	The study focused on limiting factors in plantation of Milicia by seed
Ouinsavi, C., Sokpon, N., and Bada, O. (2005)	Utilization and traditional strategies of in situ conservation of iroko (*Milicia excelsa* Welw. C.C. Berg) in Benin	The key question remains on how to use appropriate methods for propagation to promote conservation and its rehabilitation

Sahromi and Yudaputra (2015)	African teak (*Milicia excelsa*) as timber producers and its regeneration in Bogor Botanic Garden	The research and development ought to be conducted as an enrichment attempts on the types of timber-quality alternatives. The extensive research can be executed on stem cuttings propagation.

2.15. Theoretical and Conceptual Framework

2.15.1 Theoretical framework

Vegetative propagation of plants is their reproduction from vegetative organs: stems, roots, leaves, buds, and even single cells. Through vegetative propagation and cloning, exact copies of the mother plants are produced, a process that can in theory be repeated indefinitely (Jaenicke & Beniest, 2002). The phenomenon of vegetative propagation is based on the 'omnipotence' of plant cells meaning that any plants cell, unlike most animal cells has the potential to regenerate into functioning organism. Vegetative propagation as opposed to sexual propagation (by seed), offers a range of benefits in tree domestication as well as in conservation efforts (Hartmann *et al*., 1990).

For the domestication and conservation to be of benefit to the target species, it should be based on participatory approaches in decision making on both choice of species for domestication and the method to use. In this respect any domestication effort of a species must involve deciding as to whether to use sexual or vegetative propagation to achieve tree seedling production and improvement of tree. When Simons and Leakey (2004) advanced a definition of domestication used for agroforestry trees, they proposed that it should encompass both the socio-economic and biophysical processes involved in the identification and characterization of germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems (Cox, 2018).

The ecotype was originally envisioned by Turesson (1922) as the 'ecological unit to cover the product arising as a result of the genotypical response of an ecospecies to a particular habitat. Turesson proposed the more inclusive ecospecies to cover the Linnean species or genotype compounds as they are realized in nature and coenospecies for the total sum of possible combinations in a genotype compound. Ecophene was conceived as the reaction-types of the ecotypes arising through the modificatory influences of the combinations of extreme habitat factors given in nature (Quinn, 1978). In his early research, Turesson noted the conditions of various species in their natural habitats and collected seeds and plant materials which he planted in a uniform garden. By comparing such collections in a uniform environment, raising progeny from seed to check for retention of characters, and conducting breeding experiments in some cases, he was able to compile data substantiating the existence of many hereditary forms within several distinct species (Quinn, 1978).

Ecotype is not a helpful ecological unit, ultimately, whether an ecotype is an ecological unit depends upon a scientist's needs and criteria. From the point of view of Clausen in 1941, the ecologically important unit was the regional climatic race or ecotype. The local population is the only one which strictly may be specified as an ecological unit (Quinn, 1978).

2.15.2. Conceptual framework

The effect of stem size and planting orientation on sprouting in *Milicia excelsa* (Welw.) will be investigated. The results of vegetative propagation of *M. excelsa* are affected by different factors. The variables to be measured will include height, number of shoots produced per cutting and the cutting survival at the end of experiment. The rooting media used was river sand. The conceptual framework identifies how the variables are related (Figure 3).

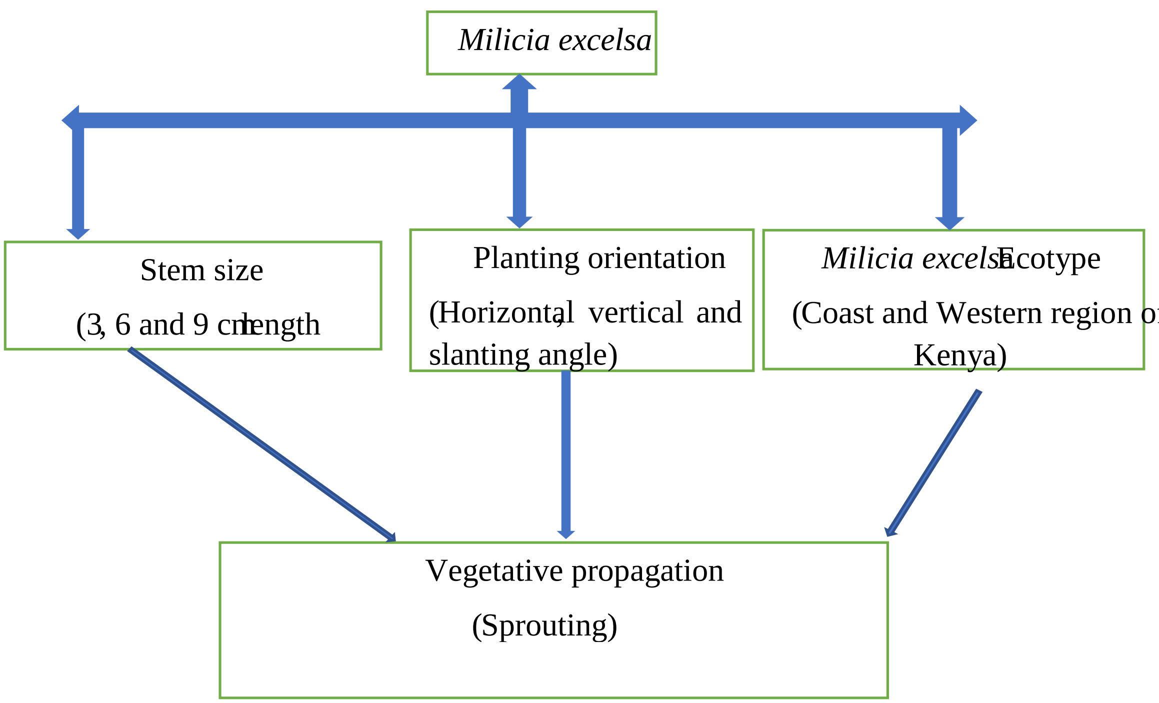

Figure 3: **Conceptual framework**

CHAPTER THREE

MATERIALS AND METHODS

3.1. Site Description

The study was conducted at the Agroforestry Tree Nursery, Egerton University, Njoro, Kenya. The University is in Njoro, a small community approximately 25 kilometers southwest of Nakuru town. This is located approximately 182 kilometers by road, northwest of Nairobi. The study site lies on a latitude 0°22'11.0"S, Longitude 35°55'58.0"E and an altitude of 2,238 m above sea level. The area falls in the agro ecological zone Lower Highland 3. The experimental site receives mean annual rainfall of 1200 mm. The rainy season is bimodal, with long rains from April to August and short rainfall season from October to December each year. The temperatures lie between 10.2 and 22.0°C while the soils are Mollic Andosols (Ngetich *et al*., 2014)

3.2. Experimental Materials

3.2.1. Preparation of Rooting Medium

Sand plays an important role in induction of roots from the cuttings. The rooting medium used in the whole experiment was composed of sand (approximately 2-3 mm diameter) which was collected from river Molo at Mogotio township, Baringo county. This was mixed thoroughly to distribute it uniformly to the growing cuttings and finally was filled into the nursery containers of 15 by10 cm in length and width respectively (Shekhawat & Manokari, 2016). The containers were positioned under a shade screen of other trees in the nursery and were covered by polyethene sheet to maintain humidity throughout the experiment (Figure 4).

3.2.2. Plant material

The propagation materials were collected from healthy mother trees from two different regions. The cuttings which were collected from Taita Taveta County, Coast province of Kenya in January 2022 from trees which were scattered on farms and were three to eight years old or coppice shoots based on farmers information. On the other hand, the cuttings were also collected from Busia County in Western part of Kenya in January 2022, the cutting lengths are 3, 6 and 9 cm, which were planted in three positions (horizontal, vertical, and slanting angle which was forty-five degrees) inside a polyethylene sheet measuring 1 by 1.5 m height and width respectively (Figure 4). The lengths of the cuttings were chosen based on node arrangement and to obtain maximum number of cuttings per cutting position on the shoot.

Figure 4: Polyethylene sheet tunnels for propagation of *M. excelsa* cuttings

To obtain cuttings, a cut in the base, or heading to the tip of the branches depending on the nature of each mother plant was done using sterile pruning scissors in the early morning as recommended by Gbadamosi (2013). The cuttings were misted with water and stored in the cooler boxes with ice inside for one day from the site of collection to the planting site prior to propagation. The shoots were severed into cuttings and the foliage was removed. The stem bases of the cuttings were dipped into a rooting powder ('Seradix No.2'with 0.6% IBA, Amiran ltd, Nairobi, Kenya) prior to insertion in the nursery containers and rooting medium (Atangana *et al*., 2006a).

3.2.3. Experimental design

The experiment was a factorial experiment with three factors as follows: cutting length, planting orientation and ecotype with three levels for length and orientation as well as two levels for ecotype. The experiment was laid down in Randomized Complete Block Design (RCBD). The two regions where the cuttings were sourced constituted the blocks. Three replicates were used in this experiment and were consisting of nine (9) treatments from two crossed factors; cutting length planting orientation, making a total of n=540 cuttings (3 cutting lengths (3, 6 and 9 cm) ×3 planting orientation (vertical, horizontal, and slanting angle) ×10 cuttings, since each treatment consisted of 10 cuttings (Figure 5). Simple random sampling was used for selecting trees where the cuttings were removed and five trees from each site were sampled from.

Coast region				**Western region**		
Rep1	**Rep2**	**Rep3**		**Rep1**	**Rep2**	**Rep3**
L6, S	L3, S	L9, V		L6, S	L3, S	L9, V
L6, V	L6, H	L9, S		L6, V	L6, H	L9, S
L9, S	L6, V	L6, H		L9, S	L6, V	L6, H
L9, V	L9, V	L6, S		L9, V	L9, V	L6, S
L9, H	L3, H	L3, V		L9, H	L3, H	L3, V
L3, H	L6, S	L6, V		L3, H	L6, S	L6, V
L3, S	L9, H	L3, S		L3, S	L9, H	L3, S
L6, H	L9, S	L3, H		L6, H	L9, S	L3, H
L3, V	L3, V	L9, H		L3, V	L3, V	L9, H

Figure 5: Experimental layout

L: Cutting lengths: 3, 6 and 9 cm Orientation: **H**: Horizontal; **V**: Vertical and **S**: Slanting angle

3.3. Data Collection

The cuttings having at least one shoot were considered for parameters such as number of sprouts and length of sprouts. The data on number of sprouts and height was collected monthly from seven cuttings per row while survival of cuttings was assessed at the end of experiment (150 days). A cutting sprouted when it has one or more sprouts, and their numbers were recorded. Cuttings were defined as dead when severely rotted (Cao *et al.*, 2011a). The length of sprout was determined by measuring from the base to tip using a ruler and the average height was worked out and expressed in centimeters.

3.4. Data analysis

Data collected was subjected to analysis of variance using General Linear Model for factorial design to obtain the effect of each treatment using GENSTAT 15th edition (Adams *et al.*, 2016). The treatments which were found to be significant were separated using Standard Error of Differences (SED) at $p \leq 0.05$ level of significance.

The Statistical model of this study was RCBD as shown below indicating how variables are related to each other.

$$Yijk = \mu + Li + Oj + \beta k + LOij + LOik + ALOijk + \varepsilon ijk$$

Where:

Y: Response

μ: Overall mean

Li: Effect of the ith level of factor L (Length of stem cuttings)

Oj: Effect of the jth level of factor O (Planting orientation of stem cuttings)

Bk: Effect due to the kth blocks (Ecotypes)

LOij: Effect of the interaction between the ith level of factor L and jth level of factor O

LOik: Effect of the interaction between the ith level of factor L and kth level of factor O

LOijk: Effect of the interaction between the ith of factor L, jth of factor O and kth level of factor O

Ɛijk: Random error.

CHAPTER FOUR

RESULTS

4.1. Distribution of number and height of sprouts due to Cutting Length, Planting Orientation and Ecotype

The distribution of number and height of sprouts due to cutting lengths was calculated by summing up the number of sprouts counted, and a summation of the heights measured in three levels of lengths. The number of sprouts increased from 30th to 90th day while the height increased from 30th to 120th day and reduced thereafter towards the 150th day of the experiment. The distribution is as indicated in Table 3 below.

Table 3: Distribution of number and height (cm) of sprouts per cutting length

	Number and height of sprouts				
	Interval of data collection				
Cutting length (cm)	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
3	38(30.7)	70(95.1)	97(178.2)	76(191.6)	54(172.5)
6	63(50)	98(149.9)	132(248.2)	107(299.5)	82(277.4)
9	82(74.3)	124(172.3)	158(285.5)	141(352.7)	111(337)

Note: The number of heights were expressed in centimeters and are indicated in brackets along with numbers of sprouts.

The number and height of sprouts observed due to planting orientation was calculated by summing up the number of sprouts counted, and a summation of the heights measured in three levels of planting orientation. The number of sprouts increased between the 30th and 90th day while the height increased between 30th and 120th day and reduced thereafter towards the 150th day of the experiment. The distribution is as indicated in Table 4 below.

Table 4: Distribution of number and height (cm) of sprouts per planting orientation

	Number and height of sprouts				
	Interval of data collection				
Planting Orientation	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
Horizontal	22(20.6)	56(71.5)	73(146.5)	67(178)	49(171.2)
Vertical	81(67.1)	117(173.7)	158(277.2)	128(311)	101(299.7)
Slanting	80(67.3)	119(172.1)	156(288.6)	129(354)	102(313.2)

Note: The number of heights were expressed in centimeters and are indicated in brackets along with numbers of sprouts.

The distribution of number and height of sprouts due to ecotypes were calculated by summing up the number of sprouts counted, and a summation of the height measured in two levels of ecotypes. The number of sprouts from the Coast increased from 30^{th} to 90^{th} day while the height increased from 30^{th} to 120^{th} day and reduced thereafter towards the 150^{th} day of the experiment. The number of sprouts from the West increased from 30^{th} to 90^{th} day while the height increased from 30^{th} to 120^{th} day and reduced thereafter towards the end of experiment. The distribution is as indicated in Table 5 below.

Table 5: Distribution of number and height (cm) of sprouts per ecotype

	Number and height of sprouts				
	Interval of data collection				
Ecotypes	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
Coast	168(130.8)	282(362.2)	422(703)	378(900.2)	282(795.4)
Western	198(179.2)	302(472.4)	352(720.8)	270(787.4)	212(778.4)

Note: The number of heights were expressed in centimeters and are indicated in brackets along with numbers of sprouts.

4.2. Effect of cutting length on the number and height of sprouts

The three length stem cuttings of *M. excelsa* responded differently after propagation. It took 28 days for the cuttings to start showing a sign of sprouts where the cuttings of 9 cm length showed high sprouting rate. The effect of cutting length had a significant effect on the number of sprouts of cuttings produced (Table 6) among different levels of length throughout the experiment, F=43.45, df=2, p-value= 0.001. The cuttings with 9 cm length and 6 cm length had high mean values of sprouts from 30 to 120 days while the cuttings of 3 cm length increased only from 30 to 90 days (0.30, 0.57 and 0.79) respectively. The cuttings of 6 and 9 cm length had reduced in the mean values of sprouts at 150 days (end of experiment) and the 3 cm length cutting reduced in the last 60 days of the experiment.

Table 6: Effect of cutting length on the number of sprouts

	Number of sprouts				
	Interval of data collection				
Cutting length (cm)	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
3	0.30c	0.57c	0.79c	0.74b	0.43c
6	0.56b	0.77b	1.07b	1.15a	0.65b
9	0.65a	0.98a	1.34a	1.39a	0.88a
CV	5.70	16.90	13.00	44.10	20.50
SE	0.056	0.130	0.14	0.48	0.13
P Value	<.001	<.001	<.001	0.001	<.001

Note: Means on the same column having different superscripts are significantly different (P<0.05)

The effect of cutting length was significant on height of sprouts produced by the cuttings throughout the experiment, df=2, F=48.25, p-value=0.001. The mean height of sprout of the cuttings in all three length levels increased from 30 days up to 120 days, 0.59, 1.37, 2.27 and 2.80 respectively and the mean height of the cuttings reduced (2.6746 cm) at the last 30 days of the experiment (Table 7).

Table 7: Effect of length of cuttings on the height of sprouts

	Height of sprouts (cm)				
Cutting length(cm)	Interval of data collection				
	30 days	**60 days**	**90 days**	**120 days**	**150 days**
3	0.24c	0.75c	1.43c	1.52c	1.37c
6	0.40b	1.19b	1.97b	2.38b	2.20b
9	0.59a	1.37a	2.27a	2.80a	2.67a
CV	5.70	5.90	12.80	15.00	12.90
SE	0.05	0.07	0.24	0.33	0.27
P Value	<.001	<.001	<.001	<.001	<.001

Note: Means on the same column having different superscripts are significantly different (P<0.05)

4.3. Effect of cutting length on survival of cuttings

The survival of stem cuttings was considered at the end of experiment after counting all dead cuttings, but the observation was made throughout the experiment on the survival performance of the cuttings (Figure 6). None of the cuttings obtained 50% though the highest survival percentage was obtained from 9 cm length cuttings with 48.1%. Cutting length was significant (p<0.05) on percentage of survival of stem cuttings at the end of experiment, df=2, F=26.58, p-value=0.001. Survival of cuttings obtained from 9 cm length reached 48.41 % followed by the cuttings obtained from 6 cm length at 41.27% and the cuttings obtained from 3 cm length attained 31.75% which showed lowest value at the end of experiment (Table 8).

Table 8: Effect of cutting length on survival of cuttings

Cutting Length (cm)	**Cutting survival (%)**
3	31.75c
6	41.27b
9	48.41a
CV	17
SE	6.88
P Value	<.001

Figure 6: ***M. excelsa*** **sprouted cuttings grown inside polyethene sheet tunnel.**

4.4. Effect of Planting Orientation on sprouting of cuttings

Stem cuttings were planted in three different planting orientations and showed different results after propagation. The good performance was obtained in the cuttings which were planted vertically and slanting orientation and these were higher compared with horizontal orientation (Table 9), df=2, F=117.93, p-value=0.001, this shows that there was statistically difference of planting orientation on sprouting since p<0.001. The high number of sprouts was found in cuttings from slanting position from 30 days up to 120 days of the experiment. However, the mean number of sprouts in all three positions reduced at the end of experiment.

Table 9: Effect of planting orientation on the number of sprouts

Planting orientation	Number of sprouts Interval of data collection				
	30 days	**60 days**	**90 days**	**120 days**	**150 days**

Horizontal	0.17b	0.45b	0.61b	0.65b	0.39b
Slanting	0.63a	0.93a	1.30a	1.34a	0.81a
Vertical	0.64a	0.93a	1.29a	1.28a	0.76a
CV	5.70	16.90	13.00	44.10	20.50
SE	0.06	0.13	0.14	0.48	0.13
P Value	<.001	<.001	<.001	<.001	<.001

Note: Means on the same column having different superscripts are significantly different (P<0.05)

The effect of planting orientation was significant (p≤0.05) on the height of sprouts produced by the stem cuttings throughout the experiment, df=2, F=82.48, p-value=0.001, this shows that there was statistically significant difference. The mean height of cuttings from the three positions increased from 30 days up to 120 days and reduced at the end of experiment (Table 10). The longest was obtained in cuttings which were planted in slanting positions.

Table 10: The effect of planting orientation on the height of sprouts

Cutting orientation	Height of sprouts (cm) Interval of data collection				
	30 days	**60 days**	**90 days**	**120 days**	**150 days**
Horizontal	0.16b	0.57b	1.16b	1.41c	1.36b
Slanting	0.53a	1.37a	2.29a	2.81a	2.49a
Vertical	0.53a	1.38a	2.21a	2.47b	2.40a
CV	5.70	5.90	12.80	15.00	12.90
SE	0.05	0.07	0.24	0.33	0.27
P Value	<.001	<.001	<.001	<.001	<.001

Note: Means on the same column having different superscripts are significantly different (P<0.05).

Planting orientation of stem cuttings was statistically significant, df=2, F=40.46, p-value=0.001 on survival of stem cuttings at the end of experiment (Figure5) with high number of survivals in cuttings planted vertically (46.8%) followed by cuttings planted in slanting angle position (46.03%) and horizontal with 28.57% although there were no statistical differences between vertical and slanting positions (Table 11).

Table 11: Effect of planting orientation on cutting survival.

Cutting orientation	Cutting survival (%)
Horizontal	28.57b
Slanting	46.03a
Vertical	46.83a
CV	17.00
SE	6.88
P Value	<.001

4.5. Effect of ecotype on sprouting of cuttings

The stem cuttings were collected from Coastal and Western region which comprises two ecotypes in the study. The ecotypes had a significant ($p<0.05$) effect on the number of sprouts obtained by stem cuttings at 30, 120 and 150 days after propagation (Table 12), df=1, F=6.99, p-value=0.012. The mean number of sprouts of cuttings from Coast had increased up to 120 days and dropped at the end of the experiment while those from Western had increased up to 90 days and then reduced until the end of the experiment. On the other hand, the coastal ecotype showed significantly higher number of sprouts at 120 (1.47) and 150 (0,75) days compared with the western ecotypes which showed 0.71 and 0.56 respectively. This shows the optimum period for sprouting was 120 days for the coast ecotype while for western was 90 days.

Table 12: Effect of ecotype on the number of sprouts

Ecotype	Number of sprouts Interval of data collection				
	30 days	**60 days**	**90 days**	**120 days**	**150 days**
Coast	0.44b	0.75	1.03	1.47a	0.75a
Western	0.52a	0.79	1.11	0.71b	0.56b
CV	5.70	16.90	13.00	44.10	20.50
SE	0.06	0.13	0.14	0.48	0.13
P Value	0.012	0.245	0.059	<.001	<.001

The ecotype was statistically significant df=1, F=17.38, p-value=0.001 on the height of sprouts from 30 to 60 days after propagation. There were no statistical differences on 90 days, but there were also statistical differences at 120 days of propagation (Table 13). However, at the end of experiment the mean height of cuttings from the two regions had reduced.

Table 13: Effect of ecotype on height of sprouts

Ecotypes	Height of sprouts (cm) Interval of data collection				
	30 days	**60 days**	**90 days**	**120 days**	**150 days**
Coast	0.35b	0.97b	1.87	2.38a	2.10
Western	0.47a	1.24a	1.91	2.08b	2.06
CV	5.70	5.90	12.80	15.00	12.90
SE	0.05	0.07	0.24	0.33	0.27
P Value	<.001	<.001	0.564	0.002	0.548

There was no statistical difference on percentage survival of stem cuttings from the two regions although the Coast region (41.27%) showed slightly higher survival compared with Western region at the end of experiment (39.68%). The low survival was contributed by fungal infestation of the cuttings during the experimental period (Figure 7).

Figure 7: **Wilted and dying *M. excelsa* cutting.**

4.6. Interaction effects on sprouting and survival of cuttings

4.6.1. Effect of Ecotype and Length interaction on sprouting of cuttings

There was interactive effect of ecotype and length on the height of sprouts at 30 days after propagation in both cuttings from the two regions, df=2, F=3.65, p-value=0.037. However, the mean height of the cuttings from the Coast had increased from 30 days to 120 days and reduced at 150 days at the end of experiment while the mean height of cuttings from Western had a slight increase up to 150 days in the 3 and 6 cm length and a slight decrease in 9 cm length at the end of experiment (Table 14).

Table 14: Interaction effects of ecotype and length on the height of sprouts

		Height of sprouts (cm)				
		Interval of data collection				
Ecotype	**Length**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
Coast	**L3**	0.23d	0.63	1.37	1.70	1.36
Coast	**L6**	0.34c	1.04	1.99	2.58	2.22
Coast	**L9**	0.47b	1.23	2.25	2.86	2.73
Western	**L3**	0.26cd	0.87	1.49	1.34	1.38
Western	**L6**	0.46b	1.34	1.95	2.17	2.18
Western	**L9**	0.71a	1.50	2.28	2.74	2.62
CV		5.70	5.90	12.80	15.00	12.90
SE		0.05	0.07	0.24	0.33	0.27
P Value		0.037	0.933	0.628	0.383	0.763

Note: Means on the same column having different superscripts are significantly different (P<0.05)

There was also no interactive effect of length and ecotype on the survival of stem cuttings at the end of the experiment, but the high percentage survival was observed from cuttings from Coast region from 9 cm length which is 49.20% and the cutting of 9 cm length from Western reached 47.62%.

4.6.2. Interaction effect of Length and planting Orientation on sprouting of cuttings

Length and orientation interaction was significant ($p \le 0.05$) from 60 days up to 90 days after propagation (Table 15), df=4, F=5.56, p-value=0.001. The number of sprouts tend to increase with increasing cutting length, the mean value was significantly higher in cuttings planted in vertical position than those planted in slanting and horizontal positions.

Table 15: Effect of length and orientation interaction on number of sprouts

Number of sprouts						
		Interval of data collection				
Length	**Orientation**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
L3	Horizontal	0.05	0.36g	0.62de	0.40	0.26
L3	Slanting	0.43	0.71d	0.88c	0.93	0.55
L3	Vertical	0.43	0.63d	0.88c	0.88	0.48
L6	Horizontal	0.21	0.44f	0.50e	0.71	0.38
L6	Slanting	0.67	0.98c	1.43b	1.37	0.79
L6	Vertical	0.62	0.88c	1.29b	1.36	0.79
L9	Horizontal	0.26	0.55ef	0.71d	0.85	0.52
L9	Slanting	0.81	1.10b	1.60a	1.72	1.10

L9	Vertical	0.88	1.29a	1.71a	1.60	1.02
CV		5.70	16.90	13.00	44.10	20.50
SE		0.05	0.13	0.14	0.48	0.13
P Value		0.274	0.001	<.001	0.917	0.067

Note: Means on the same column having different superscripts are significantly different (P<0.05)

The interactive effect of length and orientation showed significant from 90 days up to 150 days, df=4, F=3.31, p-value=0.001, (Table 16). The mean value tends to increase with increasing the length of stem cuttings and was high in cuttings which were planted in vertical position followed by the cuttings planted in slanting and horizontal position respectively. However, the mean value of all cutting in different orientations had reduced at the end of experiment.

Table 16: Interactive effect of length and orientation on the height of sprouts

		Height of sprouts				
		interval of data collection				
Length	**Orientation**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
L3	Horizontal	0.06	0.37	0.79f	1.11e	1.00e
L3	Slanting	0.36	0.96	1.75d	1.82d	1.49d
L3	Vertical	0.31	0.93	1.74d	1.63d	1.62d
L6	Horizontal	0.19	0.64	1.36e	1.48de	1.49d
L6	Slanting	0.47	1.44	2.25c	3.05b	2.59c
L6	Vertical	0.53	1.49	2.30c	2.60c	2.52c

L9	Horizontal	0.24	0.70	1.34e	1.65d	1.59d
L9	Slanting	0.77	1.69	2.88a	3.56a	3.38a
L9	Vertical	0.76	1.71	2.58b	3.19ab	3.05b
CV		5.7	5.9	12.8	15	12.9
SE		0.05	0.07	0.24	0.33	0.27
P Value		0.053	0.289	0.022	0.001	<.001

Note: Means on the same column having different superscripts are significantly different (P<0.05)

The interactive effect of length and planting orientation was not statistically significant on the survival of stem cuttings at the end of experiment. However, percentage of cutting survival was increased with increasing cutting length and vertical position and slanting obtained high percentage followed by horizontal with lowest value even though no statistical differences were observed, the high percentage of 57.14% was obtained in 9 cm length planted vertically.

CHAPTER FIVE

DISCUSSION

5.1. Effect of stem size on sprouting of *Milicia excelsa cuttings*

The different levels of cutting lengths had a significant effect on the sprouting of *M. excelsa* in this study. In propagation studies with a range of tree species, rooting and sprouting has been found to positively correlate with cutting lengths (Ambassa, 2021). This has been attributed to the fact that longer cuttings have larger reserves of carbohydrates and mineral nutrients which are required for root and shoot development. These agree with this study where the number of sprouts produced per cutting during propagation increased with increasing cutting length. The longer cuttings attained longer height of sprouts as well as the number of sprouts. This might also be explained by the fact that the cuttings may have used all the nutrient reserves available for both of them without competition (Meunier *et al*., 2016b).

The poor performance of shoot production in this study may have resulted due to the older cuttings because the tree age was not specifically known during the collection of cuttings from the two sites and this technique was not applied. Some researchers have revealed that the ease of adventitious root formation in stem cuttings declines with the age of ortet (Ambassa, 2021; Hartmann *et al*., 1990). This is an important problem because desirable phenotypic characteristics are generally not expressed until a plant has reached a considerable size or maturity. This also implies that by the time individuals which are genetically resistant to *Phytolyma lata* gall attack are identified, they may have lost their rooting ability (Djagbletey *et al*., 2011).

Contributory factors may be a reduction in the supply of endogenous auxin, carbohydrate or nitrogenous substances, or a decline in meristematic activity with increasing tree age, increasing sclerification as the tree ages may also be influential (Apetorgbor *et al*., 2004). When there is a high potential for rooting, a rooting hormone like IBA encourages rooting, but when there is a low possibility for rooting, it may have no effect or even become mildly inhibitive (Kesari *et al*., 2009).

The physiological state of the stock plant has an impact on its capacity to shoot as well as cultural factors and maturation (Ozel *et al*., 2005). Rooting hormones boost the proportion of cuttings that take root, speed up the process of roots forming, encourage more cutting roots, and improve the uniformity of cutting roots, but higher concentrations of IBA resulted in inhibition of shoot production and rotting on mature cuttings (Ozel *et al*., 2005). When compared to greenhouses or mist propagation chambers, the use of polyethylene sheet tunnels for Milicia cuttings propagation is a successful, less expensive method (Akakpo *et al*., 2014).

The bacterial and fungal infection may potentially be the cause of poor performance of shoot production which showed some symptoms of darkening of the lower portions of the cuttings, rotting and shedding of new sprouts, and this may have affected the performance of cuttings towards the end of experiment at 150 days after propagation. This observation corroborates with previous findings by De *et al*. (2017), who stated that bacterial and fungal diseases are frequent during the multiplication of rooted cuttings and can reduce the cuttings' survival and ability to root if not properly handled.

In this study the cuttings used were lignified at different degrees of maturity since the exact age of cuttings were not known, the less mature ones molded and died, the strongly lignified ones dried up. Indeed, the quality of the cuttings is very dependent on the stage of their development at the time of their collection (Daïnou *et al*., 2012). Lignified cuttings seem to contain few nutrients reserves to ensure their recovery, which could compromise the formation and development of roots and shoots and reduce the viability of budding buds. However, the rooting environment is one of the most important factors affecting the rooting success of cuttings (Daïnou *et al*., 2012). This is in accordance with previous works by Agbogan *et al*. (2014) who specified that temperature and water are external and important factors for germination in a medium.

The amount of water for irrigation regrettably seems to have been insufficient to induce good growth of the cuttings in this study. On the other hand, the plants resulting from the cuttings have genetic program as their mother stock and return relatively to production according to the cropping calendar of the stock of origin (Nguema *et al*., 2013) thus, the result obtained on the cuttings of *M. excelsa* would perhaps be of genetic origin. Several studies have demonstrated that the ability to root or to shoot are affected by the genotype (Bizoux *et al*., 2009; Ouinsavi *et al*., 2010). Previous research on the vegetative propagation of tropical tree species using stem cuttings has identified varying factors that can be optimized to increase rooting rate in tropical trees, including cutting length, cutting positions, auxin concentration and sowing media (Husen & Pal, 2006). The capacity of cuttings to root may also be impacted by cutting length, which will influence the depth of insertion into the rooting medium, another factor that affects a tropical tree's ability to take root successfully is the location of the cutting within the shoot (Agbo & Obi, 2007).

The cuttings have taken towards the tip of the branches in this study. The variation is a function of concentration of some factors that run from base to the apex of stem tissue in relation to the chronological age like leaf water potential, leaf carbon balance, stem lignification, carbohydrate content and respiration (Agbo & Obi, 2007). Rooting of stem cuttings with reproductively matured ortet or stockplant typically has the benefit of shortening the time it takes a plant to reach maturity in addition to providing genetic benefits (Olaniyi *et al*., 2021). Cutting length is an exogenous factor that affects sprouting activity in this study and can be explained by greater food (carbohydrate) reserves in the longer cuttings compared to shorter cuttings. Similar findings were reported in *Khaya ivorensis* (Tchoundjeu & Leakey, 1996) and *Picea abies* (Ou *et al*., 2015) where long cuttings rooted significantly better than short cuttings. These findings were also in agreement with (Naidu & Jones, 2009) who attributed large storage reserve and photosynthetic area of longer cuttings to rooting success of Eucalyptus hybrid clones.

5.2. Effect of planting orientation on sprouting of *M. excelsa*

Planting orientation had a significant effect on the number of sprouts and their heights, there was no statistical differences between the vertical and slanting orientations, but they had statistical difference on the horizontal position. This may be due to the fact that the cuttings planted in vertical or slanting receive more sunlight compared to those planted horizontally, hence the photosynthesis is high and the cuttings planted horizontally would decompose if placed too deep in the rooting medium (Cao *et al*., 2011b). Planting methods and preplanting treatments may play a key role in improving the success of stem cutting to develop roots and shoots (Volk *et al*., 2004).

Since the horizontally planted cuttings took longer to emerge than those that were slanting and vertically planted, the height of the shoots of the horizontally planted cuttings were smaller than the vertically and slanting planted cuttings. It has been suggested in the earlier studies that the differences between the two planting orientations may be caused by differences in the gravity orientation of the root hormones (Dieterich & Martin, 2008). Vertical or slanting positions allow the large area of cuttings to be in contact with the rooting medium for inducing roots, these positions help to expose more area of the cambium layer, which helps in more water absorption and callus formation (Hartmann *et al*., 1990).

Similar findings were earlier reported by Ofori *et al*. (1997), that the root cuttings displayed pronounced polarity. Shoots arose from the proximal ends of the cuttings while adventitious roots developed exclusively from the distal ends, when cuttings were inverted such that, their proximal ends were inserted into the medium, shoots always emerged from the proximal ends. Evidence of polarity in root segments has been reported in *Populus tremula* (Stenvall, 2006). Root cuttings in all species exhibit polarity with new shoot development occurring at the proximal end and root development at the distal end of cuttings, regardless of orientation at planting *(*Ede *et al*., 1997). This polarity results from the polar transport of auxin, basipetally from shoots to roots, coupled with the asymmetric distribution of auxin within each cell, with higher concentration of auxin promoting root development and inhibiting shoot development. The carbohydrate and nutrient status of cuttings also influences their regenerative capacity (Ede *et al*., 1997).

Despite planting positions, cultural practices such as pruning, fertilizing and watering during the dry season can encourage sprouting of shoots for cuttings (Byambadorj *et al*., 2021). The presence of auxins, enzymes and phenolic compounds in the mother plant affected rooting in cuttings. Whereas the physiological and biochemical quality could limit rooting in cuttings. Physiological conditions are affected by environmental conditions such as light, temperature, water and nutrients (Byambadorj *et al*., 2021). Endogenous auxin, carbohydrate content, mineral nutrients, and other biochemical components such as phenolics which act as auxin transport modulators may be affected by environmental factors.

5.3. Effect of Ecotypes on sprouting of *M. excelsa* cuttings

Genetic potential, as well as propagation environment, postseverance treatment, cutting origin and environment, stockplant physiology and management have been reported to influence rooting and sprouting (Choungo *et al*., 2021; Leakey, 2004). The results in the present study showed that ecotype had significant effects on the sprouting of *M. excelsa* towards the end of the experiment. The trends observed in this study might have been influenced by environmental factors. Several studies have indicated that morphological variation is apparently the result of an adaptive response to the environment; for example, variation in growth traits and phonological traits is associated with a latitudinal and altitudinal range or by contrasting climatic conditions (Atangana *et al*., 2006b; De *et al*., 2017).

The greater discrimination power of adaptation micro edaphic conditions compared to the geographical regions of origin of accession was found in the study done in morphological variation and ecological structure of African teak in Benin and the results clearly indicated the greater importance of environmental factors (soil texture, soil chemical characteristics, and annual rainfall than geographical location in discriminating populations (Ouinsavi & Sokpon, 2010; Wilson & Provan, 2003). The differences and variations shown in the present studies between the two ecotypes might have resulted due to changes in environmental conditions and other climatic conditions. Water stress, together with soil nutritional deficiencies, have led to the development of adaptation aptitudes and hence morphological variation in tree populations (Atta-Krah *et al*., 2004).

Dioecious plants are vulnerable to change in population size and structure, thus sensitive to habitat fragmentation through human or livestock encroachment (Wilson & Provan, 2003) but the presence of caterpillars which were eating young sprouts and leaves might have caused some changes in this study. Male plants of perennial species are either larger, grow faster, have more ramets or have higher biomass than female plants though the growth rate could be habitat dependent. Hossain *et al*. (2019) also reported that climatic sensitivity in male and female trees of dioecious species is different, yet this difference is not stable through time. However, the current study was conducted in a mild environment of the great rift valley and the female and male trees were not separated, hence this could account for some differences in the findings.

Species with wide distributions tend to exhibit large intraspecific variation in most functional and phenotypic traits. This geographical variation in biotic and abiotic factors across species distributions can lead to the evolution of morphologically and functionally different ecotypes (Atkin *et al*., 2006; Bakhtiari *et al*., 2019). Ecotypes are genetically distinct populations of a given species, displaying phenotypic traits that maximize fitness within particular local abiotic and biotic conditions (Bakhtiari *et al*., 2019). Along environmental gradients, trait-mediated local adaptations of plant ecotypes are the result of selection for fitness maxima under local conditions (Wadgymar *et al*., 2017). The study of plant adaptation and species interactions along elevational clines comes with several advantages compared to studies along latitudinal gradients (Körner, 2016). In particular, plant adaptation to habitat-specific abiotic and biotic factors can be studied along elevations transects with homogenous macroclimatic conditions, minimizing the effect of biogeographical history and barriers to gene flow (Körner, 2016). Plant growth and defense have been shown to vary in response to different abiotic and biotic conditions, furthermore, growth and defense traits can be subjected to resource allocation trade-offs, and the correlated expression of these traits should serve to maximize plant fitness within a given herbivory and climatic environment (Agrawal *et al*., 2010).

Plant functional traits often vary across space, particularly when species encounter contrasting environmental conditions throughout their range. Such phenotypic variation is determined by both genetic and environmental effects. Understanding their relative contribution to trait variation and how they influence plant adaptation are central questions in evolutionary ecology (Albert *et al*., 2011). In the classical Darwinian paradigm, plants accommodate environmental variation primarily through natural selection. Differential selection pressures across contrasting conditions drive the evolution of functional traits, resulting in genetic differentiation among populations and the formation of ecotypes (Matesanz *et al*., 2020).

In the present study, the poor performance was slightly affected by the environmental conditions experienced during the specific propagation season when the experiment was performed. Water stress can injure and kill cuttings, at the initial stage of propagation, water deficit can cause prolonged permanent wilting that usually kills cuttings (Appiah, 2013). In addition, stressed cuttings are more vulnerable to insect and disease pests and in present study, the cuttings were eaten by small caterpillars and the cuttings became stunted and died while they were still small sprouts.

Since *M. excelsa* is distributed across a wide precipitation gradient, the populations are likely to produce ecotypic variation in drought tolerance and potentially, local drought adaptation. Thus, the populations of *M. excelsa* could exhibit differences in morphological and/or physiological responses to environmental stresses (Appiah, 2013) . These variations may reveal the competitive abilities and physiological tolerance of the populations to promote or worsen the species' survival under environmental variability. Ecotypic variations in drought tolerance have been studied in many tree species (Bachofen *et al*., 2021). However, they are mostly on exotic and temperate trees. The effect of an extended period of water deficit on seedlings of tropical forest trees has for the most part remained uninvestigated (Aguirre-Gutiérrez *et al*., 2020), especially for local tree species such as *M. excelsa* that are native to Africa.

The study done by Moe *et al*. (2016) reported that termites can cause considerable damage to tree plantations, and plant susceptibility to termites, perhaps related to co-evolution between local tree ecotypes and associated termite species producing resistance to termite attack (Suganthy & Pretheepkumar, 2019) but Milicia was reported to have lower survival when exposed to termites. In the present study there was presence of termites in short time and had eaten small sprouts of cuttings which caused some of them to die, may be the termites were coming from the surrounding tree species in the nursery where the experiment was established. Some studies showed that termites feed preferentially on native species (Moe *et al*., 2016).

5.4. Interaction effects on sprouting and survival of cuttings

There was significant interactive effect between ecotype and length at 30 days after propagation, and this might be due to the early adaptation of cuttings to the new environment and rainfall patterns, ecotypes have varying strategies and adaptations that may translate into stress resistance and productivity in varying environment (Griffiths *et al*., 2022). The cuttings from

Western regions were observed to grow more compared to the Coastal regions, and this might also be driven by a reduction in growth and photosynthate availability, followed by also an interactive effect of length and orientation. Due to the diversity of the ecotypes, each has a unique potential for beneficial breeding with varying environmental adaptability and pathogen resistance (Milano *et al*., 2016). Ecotypes adapted to more mesic habitats are often larger in size and flower later than ecotypes from drier environments. This difference in soil water availability across habitats is a frequent driver of ecotype creation.

The study done by Von and Schmid (2008) reported that the cuttings planted with proximal and above soil had greater sprouting percentage than the cuttings planted horizontally. Since the shoot emerges from the proximal end of cutting and the roots from distal end, there was no hinderance from rooting medium in shoot emergence in vertically placed cuttings. In horizontal planting the cuttings were placed in polyethene bags and covered with sand which make the shoots difficult to emerge on the rooting media surface. This might be the cause of poor performance of cuttings with 3cm length which were planted horizontally. Earlier studies by Han *et al*. (2017) reported that shallow planting with a longer portion of the cutting protruding above ground level has the potential to result in the production of a greater number of shoots since number of shoots per cutting increases with cuttings length, in present study the longer cuttings planted vertically, and slanting were observed to perform better.

Ecotypic differentiation, with the prediction that ecotypes adapted to one environment should change their phenotypes when placed in a novel environment. Two reasons have been put forward for plants to reduce growth at high elevation. First, a decrease in the general metabolic activity as a function of colder temperature inhibits photosynthetic rate and biomass production (Doumenge *et al*., 2003). Secondly, it has been proposed that because plants growing at higher elevations typically receive direct sunlight and higher ultraviolet radiation, and ultraviolet radiation destroys the auxins content at the apical shoots, they tend to grow much slower than lowland plants (Keller *et al*., 2004) and this might have encountered some changes in the findings since the cuttings were collected from the two sites which are hot and moved to colder environments.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

i. The study concluded that the different length sizes had a significant effect on the number and height of sprouts obtained on the cuttings of *Milicia excelsa*. This therefore means that before planting *M. excelsa* cuttings, there is consideration of length of cuttings suitable for planting as in this study showed that the 9 cm length performed better compared to other shorter lengths in the experiment.

ii. Planting orientations had a significant effect on the number and height of sprouts produced of Milicia excelsa cuttings hence cuttings which were planted vertically, and slanting positions performed better compared with those planted horizontally. This implies that there is consideration of orientation before planting them.
iii. The ecotype was significant in the beginning of the experiment in this study on the sprouting of *Milicia excelsa* and towards the end of the study. This therefore means that the ecotype should also be considered before planting the *M. excelsa* cuttings.

6.2. Recommendations

Upon completion of this study, the following recommendations were formulated:

(i) This study recommends that planting orientation like vertical and slanting can be used since they have performed better than horizontal position.

(ii) The recommended cutting length is 9 cm length, since it gave the best sprouting performance. The Western ecotype performed slightly better than the Coastal ecotype and is also recommended.

(iii) Further research is required on the propagation of the taller cuttings, the best age of cuttings, appropriate period of propagation, control of watering, planting depth and rooting media.

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APPENDICES

Appendix A: Analysis of variance for the number of sprouts after 30 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.091785	0.045892	14.80	
Rep.*Units* stratum					
Ecotype	1	0.021689	0.021689	6.99	0.012
Length	2	0.269498	0.134749	43.45	<.001
Orientation	2	0.731481	0.365741	117.93	<.001
Ecotype.Length	2	0.010927	0.005463	1.76	0.187
Ecotype.Orientation	2	0.000101	0.000051	0.02	0.984
Length.Orientation	4	0.016683	0.004171	1.34	0.274
Ecotype.Length.Orientation					
	4	0.004625	0.001156	0.37	0.826
Residual	34	0.105446	0.003101		
Total	53	1.252235			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.05049	5.2
Rep.*Units*	34	0.05569	5.7

Appendix B: Analysis of Variance for number of sprouts after 60 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.02813	0.01406	0.84	
Rep.*Units* stratum					
Ecotype	1	0.02359	0.02359	1.40	0.245
Length	2	1.50976	0.75488	44.87	<.001
Orientation	2	2.78504	1.39252	82.77	<.001
Ecotype.Length	2	0.00228	0.00114	0.07	0.935
Ecotype.Orientation	2	0.05579	0.02789	1.66	0.206
Length.Orientation	4	0.37416	0.09354	5.56	0.001
Ecotype.Length. Orientation					
	4	0.02723	0.00681	0.40	0.804

Residual	34	0.57201	0.01682		
Total	53	5.37798			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.02795	3.6
Rep.*Units*	34	0.12971	16.9

Appendix C: Analysis of variance for number of sprouts after 90 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.03250	0.01625	0.84	
Rep.*Units* stratum					
Ecotype	1	0.07407	0.07407	3.81	0.059
Length	2	2.69917	1.34958	69.38	<.001
Orientation	2	5.65608	2.82804	145.38	<.001
Ecotype.Length	2	0.03704	0.01852	0.95	0.396
Ecotype.Orientation	2	0.03250	0.01625	0.84	0.442
Length.Orientation	4	1.19879	0.29970	15.41	<.001
Ecotype.Length. Orientation					
	4	0.16931	0.04233	2.18	0.093
Residual	34	0.66138	0.01945		
Total	53	10.56085			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.03005	2.8
Rep.*Units*	34	0.13947	13.0

Appendix D: Analysis of variance for the number of sprouts after 120 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00819	0.00409	0.23	
Rep.*Units* stratum					
Ecotype	1	0.30697	0.30697	17.11	<.001
Length	2	3.82710	1.91355	106.67	<.001
Orientation	2	6.85771	3.42885	191.14	<.001

Ecotype.Length	2	0.05159	0.02579	1.44	0.252
Ecotype.Orientation	2	0.00510	0.00255	0.14	0.868
Length.Orientation	4	0.95805	0.23951	13.35	<.001
Ecotype.Length. Orientation					
	4	0.09637	0.02409	1.34	0.274
Residual	34	0.60991	0.01794		
Total	53	12.72099			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.39868	36.5
Rep.*Units*	34	0.48163	44.1

Appendix E: Analysis of variance for the number of sprouts after 150 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.08587	0.04294	2.19	
Rep.*Units* stratum					
Ecotype	1	0.57778	0.57778	29.53	<.001
Length	2	5.80492	2.90246	148.33	<.001
Orientation	2	8.26252	4.13126	211.13	<.001
Ecotype.Length	2	0.20930	0.10465	5.35	0.010
Ecotype.Orientation	2	0.11271	0.05635	2.88	0.070
Length.Orientation	4	1.42277	0.35569	18.18	<.001
Ecotype.Length. Orientation					
	4	0.10636	0.02659	1.36	0.269
Residual	34	0.66528	0.01957		
Total	53	17.24752			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.04849	7.4
Rep.*Units*	34	0.13386	20.5

Appendix F: Analysis of variance for the height of sprouts after 30 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.000943	0.000471	0.16	
Rep.*Units* stratum					
Ecotype	1	0.050020	0.050020	17.38	<.001
Length	2	0.277739	0.138870	48.25	<.001
Orientation	2	0.474791	0.237395	82.48	<.001
Ecotype.Length	2	0.021021	0.010510	3.65	0.037
Ecotype.Orientation	2	0.008106	0.004053	1.41	0.258
Length.Orientation	4	0.029968	0.007492	2.60	0.053
Ecotype.Length.Orientation					
	4	0.008014	0.002003	0.70	0.600
Residual	34	0.097857	0.002878		
Total	53	0.968459			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.00512	0.5
Rep.*Units*	34	0.05365	5.7

Appendix G: Analysis of variance for the height of sprouts after 60 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.058141	0.029070	5.39	
Rep.*Units* stratum					
Ecotype	1	0.147548	0.147548	27.35	<.001
Length	2	0.576062	0.288031	53.40	<.001
Orientation	2	1.344992	0.672496	124.67	<.001
Ecotype.Length	2	0.000754	0.000377	0.07	0.933
Ecotype.Orientation	2	0.004562	0.002281	0.42	0.659
Length.Orientation	4	0.028059	0.007015	1.30	0.289
Ecotype.Length.Orientation					
	4	0.023232	0.005808	1.08	0.383
Residual	34	0.183401	0.005394		

Total	53	2.366751			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.04019	3.2
Rep.*Units*	34	0.07344	5.9

Appendix H: Analysis of variance on the height of sprouts after 90 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00531	0.00266	0.05	
Rep.*Units* stratum					
Ecotype	1	0.01986	0.01986	0.34	0.564
Length	2	6.50980	3.25490	55.48	<.001
Orientation	2	14.25028	7.12514	121.44	<.001
Ecotype.Length	2	0.05532	0.02766	0.47	0.628
Ecotype.Orientation	2	0.38271	0.19136	3.26	0.051
Length.Orientation	4	0.77628	0.19407	3.31	0.022
Ecotype.Length. Orientation					
	4	0.28909	0.07227	1.23	0.316
Residual	34	1.99486	0.05867		
Total	53	24.28351			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.01215	0.6
Rep.*Units*	34	0.24222	12.8

Appendix I: Analysis of variance on the height of sprouts after 120 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.7572	0.3786	3.39	
Rep.*Units* stratum					
Ecotype	1	1.2022	1.2022	10.77	0.002
Length	2	15.2781	7.6391	68.43	<.001
Orientation	2	19.1456	9.5728	85.75	<.001
Ecotype.Length	2	0.2207	0.1104	0.99	0.383

Ecotype.Orientation	2	0.0498	0.0249	0.22	0.801
Length.Orientation	4	2.6326	0.6582	5.90	0.001
Ecotype.Length. Orientation					
	4	0.6863	0.1716	1.54	0.214
Residual	34	3.7958	0.1116		
Total	53	43.7682			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.14502	6.5
Rep.*Units*	34	0.33413	15.0

Appendix J: Analysis of variance for the height of sprouts after 150 days

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.03531	0.51766	7.16	
Rep.*Units* stratum					
Ecotype	1	0.02667	0.02667	0.37	0.548
Length	2	15.72463	7.86232	108.72	<.001
Orientation	2	14.17010	7.08505	97.97	<.001
Ecotype.Length	2	0.03948	0.01974	0.27	0.763
Ecotype.Orientation	2	0.25796	0.12898	1.78	0.183
Length.Orientation	4	2.64192	0.66048	9.13	<.001
Ecotype.Length. Orientation					
	4	0.15841	0.03960	0.55	0.702
Residual	34	2.45884	0.07232		
Total	53	36.51332			

Stratum standard errors and coefficients of variation

Stratum	d.f.	s.e.	cv%
Rep	2	0.16958	8.1
Rep.*Units*	34	0.26892	12.9

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The influence of planting orientation and ecotype on sprouting and survival of stem cuttings of African teak (*Milicia excelsa* (Welw.) in Kenya

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Abstract

African teak (*Milicia excelsa* (Welw.) is a giant deciduous forest tree which belongs to the Moraceae family and is now threatened by extinction due to over exploitation. This study determines the influence of planting orientation and ecotype on sprouting and survival of cuttings of African teak. The cuttings were collected from the Coastal and Western regions of Kenya. A Randomized Complete Block Design was used. The cuttings were planted in three positions (horizontal, vertical, and slanting angle) in the nursery containers covered with the polyethene sheet and the planting

Appendix M: The 2nd publication from this thesis

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Stem cutting size influence on sprouting and survival of stem cuttings of African teak (*Milicia excelsa* (Welw.) in Kenya

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African Teak (*Milicia excelsa* (Welw.) belongs to the Moraceae family. Vegetative propagation has been proposed to overcome some of the reproductive biology challenges in the species. The study was to determine the influence of stem size on sprouting and survival of stem cuttings of African teak. The experiment was conducted at Egerton University, Njoro, Kenya. The propagation materials were collected from healthy mother trees from the Coast and Western regions of Kenya. A Randomized Complete Block Design was used. The cutting lengths were 3, 6 and 9 cm. The planting medium was composed of river sand. Data were collected monthly on the number and height of sprouts and the cutting survival at the end of 150 days. Data were then subjected to analysis of variance (ANOVA) using GENSTAT 15th Edition. Separation of means was performed using the SED. The results showed that the cutting length had a significant effect on the number of sprouts, F=43.45, df=2, p= 0.001 and height of sprouts produced, F=48.25, df=2, p=0.001. None of the cuttings obtained 50% of survival though the highest survival percentage obtained was 48.1% from cuttings with 9 cm length. The survival of cuttings obtained from 6 cm length reached 41.27% while 3 cm length attained 31.75%. It was concluded that cutting length positively influences the sprouting of cuttings; hence longer cutting should be selected for propagation. Further studies should take into account the optimum cutting length and the factors which influence the shoot formations and cutting survival including diseases prevention and age of cuttings.

Key words: *Milicia excelsa*, stem cuttings, vegetative propagation.

INTRODUCTION

Milicia excelsa (formerly known as *Chlorophora excelsa* (Welw.), is an economically significant timber species of

2020). Most of the timber for this species comes from natural forests and currently, only a few commercial