CLONAL PROPAGATION OF Melia volkensii (GÜRKE) TREES FOR SEED ORCHARD ESTABLISHMENT IN KIAMBEERE, EMBU COUNTY, KENYA

By

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MAY, 2018
DECLARATION

This thesis is my original work and has not been presented for a degree in any other Institution, School or University. No Part of this thesis should be reproduced without prior permission from the author and/ or Kenyatta University.

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DEDICATION

This work is dedicated to my loved ones and friends that stood by me all along. To Mr. Samson Nturibi and Mrs. Priscilla Makena Nturibi (my parents) for their financial commitment/sacrifice and moral support towards my education and life; my beloved favoured child Moses Munene; my Supportive sisters Betty Mwendwa and Sharon Karwirwa for their capacity to love, encourage and care for me.
I would like to express my deepest appreciation first to God for His mercies, faithfulness and Favour over my endeavours of life especially in line to the effective completion of this thesis. I wish to also recognize the following persons who made the completion of this thesis a success. Firstly, to my supervisors: Prof. James B. Kungu and Dr. Theresa C. Aloo for their competent and persistent guidance throughout this thesis compilation. Special thanks go to Dr. Felix Ngetich for his useful scientific input and unfailing assistance accorded upon request. Secondly, I would also like to thank Better Globe Forestry Ltd through the Executive Director Mr. Jan Van Den Abeele for their financial support granted to me during the data collection. Special appreciation to the Better Globe Forestry (BGF) staff (Mr. Samuel Nakhone, Mr. Njeru, Mwanzia and the rest of the staff) stationed at Kiambeere Nursery for going out of their way to make my data collection in all the phases successful.

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<tr>
<td>IBA</td>
<td>Indole-3- Butyric Acid</td>
</tr>
<tr>
<td>DBH</td>
<td>Diameter at Breast Height</td>
</tr>
<tr>
<td>Genstat</td>
<td>General Statistic Software</td>
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<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
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<tr>
<td>GPS</td>
<td>Geographical Positioning System</td>
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ABSTRACT

*Melia volkensii* (Melia) is an indigenous tree species belonging to the plant family Meliaceae. In Kenya, the tree is commonly known as “Mukau”. Melia grows naturally in the arid and semi-arid zone of Tanzania, Ethiopia, Somalia, and Kenya. It’s highly valued for its timber which is termite resistant and so imperatively durable. Despite its popularity, its domestication efforts have been minimal, as a result of poor access to quality planting material and lack of a comprehensive viable propagation protocol. Seed propagation has been hectic due to difficulties in extraction, poor germination and high post-germination mortality which has hindered its wide scale cultivation. The study therefore sought to investigate the potential of establishing *Melia volkensii* seed orchards by use of high quality vegetatively propagated seedlings in Kiambeere, Kenya. The hormone Indole-3- Butyric Acid (IBA) at various concentrations (0.25 %, 0.5 % and 0%) was used to determine the effect on rooting and shooting of cuttings of different lengths, diameters and positions (top, bottom and full). The effect of merchantable heights on the production of ideal cuttings was also investigated. A complete block design of five blocks (IBA concentration, cutting diameter, cutting length, cutting section and cutting portions) was used. Cuttings were obtained from selected healthy plus trees from fields and raised in non mist propagators where number of roots and shoots that sprouted were observed and recorded. The data was analysed for significance by use of GENSTAT version 14 computer software, where significant treatments were separated by Least Significant Difference at p=0.05. Results showed significant improvements in shooting and rooting percentage both of stem and root sections (p<0.001) with 0.25 % IBA concentration having highest grand rooting percentage of 15.19 %, and root sections developing more morphologically than stem sections in all IBA concentrations. Diameter of cuttings also significantly affected rooting (p= 0.031), with smaller diameter (diameter of ≤ 0.5 cm) exhibiting more rooting potentials than wider cuttings ≥0.5cm. Cutting lengths of ≤ 12 cm had a higher rooting ability than long ones of ≥12 cm. Portions obtained from basal points (bottom portions) gave the best rooting percentages compared to those from apical points of cuttings (top portions). Moreover, donor/plus trees with merchantable heights of 2 - 5 m provided the best cuttings which gave the best rooting (17.5 %), thus proving to be the ideal height from which planting material need to be harvested. The research therefore recommends that propagation programmes utilize cuttings of short lengths ≤ 12 cm, with diameters below 0.5cm from basal points harvested from maintained Melia plus trees of merchantable heights of 2 - 5 m while establishing future seed orchards.
CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

In East Africa, there’s heavy reliance on trees and shrubs by pastoralists living in the dry savannahs. Milimo et al. (1994) maintains that this overreliance is for the important supply of firewood, poles, posts (wood) and other (non-wood) products such as gums, fodder, browse, resins, fruits, food, medicines and for soil fertility retention. In tourist trade, the black decorative woods particularly Diospyros spp. and Dalbergia melanoxylon, have emerged of great commercial importance as carvings (Milimo et al., 1994). However, in Agroforestry a majority of the tree improvers have their judgement clouded as to whether single or multipurpose characteristics of these trees and shrubs should be selected when breeding or selecting superior lines of multipurpose trees (Milimo et al., 1994). Hence to address this, Atangana et al. (2002) proposes an emphasis on tree domestication that utilises the variability within species. This according to Atangana et al. (2002) can be achieved through the selection and maintenance of superior trees then propagating them sexually or asexually, depending on the appropriate strategy for the species and the products, while ensuring that a broad genetic base through gene banks has been heightened. Therefore, domestication of trees conceptualizes horticultural approaches focused on producing quality germplasm for a wider culture to meet the needs of small farmers for common tree improvement practices based on the selection of conventional forest trees.

Amongst the recommended conservation strategies is the domestication of a species in agroforestry systems (Milimo et al., 1994; Kariuki et al., 2008). This is because the genetic diversity conservation is guaranteed. Genetic variation provides better opportunities in adaptation, allowing assortment and the diminution of risks in inbreeding of the future generations. Due to the gene flow establishment therefore, the superior genotypes captured ascertain intended use appropriateness among other desirable characters (Mbora et al., 2009). Additionally, tree users enjoy selecting from a wide array of genotypes as genotypes vary in their attractiveness to others. Moreover, genes resulting to trees with outstanding phenotypes are preferred, such as, those that augment superior production (yield) and product quality.
*Melia volkensii* (Melia) is an indigenous tree species belonging to the plant family Meliaceae- Mahogany family (Albrecht, 1993; Beentje, 1994; Orwa *et al*., 2009). Some of the familiar names used to its reference include Mukau (Kamba/Mbeere/Embu/Tharaka/Meru), Mpendabure (Swahili), Kirumbutu (Taita and Digo), Bamba Barnha (Boran) and Boba (Somali). Melia grows naturally in the arid and semi-arid zone of Ethiopia, Somalia, Tanzania and Kenya (Mulatya, 2000). The species in close relations with Acacia-Commiphora vegetation is commonly found in deciduous bush land within Agro-ecological Zones IV —V (arid and semi-arid) (Muok *et al*., 2000). In Kenya, Melia grows mostly in Mbeere, Tharaka, Mutomo, Kitui, Mwingi, Makueni and Taita Taveta, where it occurs as remnant of natural stands, woodlots, scattered trees in cropland, and homestead compounds (Wekesa *et al*., 2012).

*Melia volkensii* is a highly sought after multipurpose tree species. Its timber is greatly valued for its durability and termite resistance (Mulatya, 2000; Muchiri and Mulatya, 2004). The easy to work wood used for construction of log hive and its locally available timber used for construction and furniture has made it to fetch a price that is four times higher than other local hardwood tree species (Muok *et al*., 2010). Moreover, Muok *et al.* (2010) estimated the timber related income from a 10 to 15 year plantation of *M. volkensii* to be Ksh 3 million (US$ 35,294) per hectare. In fact in the dryland afforestation projects, Melia is favoured over the exotics like *Eucalyptus camaldulensis*, *Grevillea robusta*, *Prosopis juliflora*, *Senna siamea*, and indigenous ones like *Acacia polyacantha* and *Brachyleana huillensis* (Mulatya, 2000). In the farm, the good form Melia trees found presumably due to management practices are heavily being exploited for timber leaving behind the bad quality trees. This is a great contrast to the farmers’ desire to plant more of the superior qualities as the economic importance dictates them to (Kyalo, 2004). Consequently, genetically diverse and superior trees are required to be conserved in whatever form and propagated in large populations.

*M. volkensii* is a valuable asset to the ASALs for its fast growth and coppicing, providing valuable fodder for goats, cattle and sheep particularly during the dry season (Tedd, 1997). The flowers provide excellent bee forage (Salim *et al*., 1998) and can be made into powder and used as an insect repellent (Rajab and Bently,
It also contributes fuel-wood (the branches) to the locals as well as playing a role in environmental protection and conservation. As a result, its heavy exploitation without replanting has led to rapid depletion of this species. This trend of exploitation has worsened in the past two decades owing to the lack of an alternative quality hardwood species. This is currently of great concern as its continued heavy usage has resulted into serious population deterioration that urgently calls for interventions such as intensive cultivation and conservation programmes (Rajab and Bently, 1988). However, in recent times (KEFRI) in conjunction with Japan International Cooperation Agency (JICA) have made several strides in improving *Melia volkensii* species genetically thus conserving the good form superior trees for future (Kamondo *et al.*, 2016).

“Mukau” -local name- (Albrecht, 1993) experiences propagation limitations associated with its seed dormancy nature. As a result, in spite of the ecological and economical potentials of *M. volkensii* tree for ASALs areas, it is yet to be massively propagated for plantation establishment, especially by farmers. In addition complications in seed extraction, coupled with poor germination and high post-germination mortality has hindered its mass propagation by seeds. Among other factors, seed extraction has been regarded as a major hindrance to propagation as the common seed extraction method from the hard stony nut is by use of a sharp kitchen knife and a hammer, which is slow and injurious to the operator (Lugadiru, 2004).

Vegetative propagation of *Melia volkensii* by cuttings has had its own share of challenges when compared to other species (Kyalo, 2004) with the rooting of cuttings varying from species and provenances (Pijut *et al.*, 2011). Stewart and Blomley (1994), reported rootability of Melia stem cuttings to be difficult and erratic and produced melia trees that were unstable due to shallow rooting. Other studies using other tree species established from cuttings, identified shallow rooting –a root architectural (i.e. depth of the rooting and the number of roots) problem further giving an indication that the technique of propagation and transplanting can have an extensive effect on the root architecture (Bell *et al.*, 1993 in Mulatya *et al.*, 2002).

The development of a right root system is imperative for anchorage and adaptation to harsh weather conditions. Adventitious root formation studies have increased in
number as the economic relevance has been realised by many plant scientists (Hartmann et al., 2002). Adventitious roots and buds formation is dependent on plant cells to dedifferentiate and develop into either a shoot or root system. The rooting requirements of cuttings can be very species specific (Rahman et al., 2007). Nonetheless, the cutting material traits have been associated with adventitious root development (Hartmann et al., 1997) but with variations from species to species (Harrison- Murray and Knight, 1997).

Auxins significantly influence root morphology, inhibit root elongation, increase lateral root production, and induce adventitious roots (Palmer, 2000). Over time, IBA has emerged as the most extensively used auxin for commercial rooting (Kaushik, 2017) due to its efficiency in inducing lateral roots at concentrations that only minimally inhibit root elongation (Zolman et al., 2000). All in all, for successful propagation other than the universal condition of light, temperature, humidity and air the following have to be taken into consideration: the selection of the cuttings; health, age, growth stage, maturity of the stock plant, type of cutting and time of the year (Woodward and Bartel, 2005).

It is anticipated that promoting sustainable cultivation and conservation of *M. volkensii* can easily be carried out if proper vegetative propagation methods have been developed. Thus, it is for this backdrop that the selection and identification of an appropriate sustainable propagation protocol of *M. volkensii* should be given priority in the ASALs. Consequently to ensure desired superior genetic qualities are captured and rapidly multiplied, vegetative propagation of stem and root cuttings using IBA rooting hormone was adopted as a highly potential viable option for a comprehensive Melia propagation study. Vegetative propagation allows duplication of the mother plant genome in the new plants which may otherwise be diluted when using sexual propagation.

1.2 Statement of the Problem

*Melia volkensii* is an indigenous multipurpose tree species endemic in semi-arid areas of Eastern Africa. Compared to other hardwood species, it has been heavily exploited for its highly valued timber further threatening its future due to the depletion of the genetic composition occasioned by harvesting of trees of good
quality with the remnants- inferior genotype-being used for seed collection meant for future breeding. Additionally, the plant domestication efforts are minimal despite its popularity and multipurpose nature. For this reason, *M. volkensii* wide scale cultivation has been constrained by lack of quality planting material due to problems associated with seed quality and seed availability.

The species propagation has been very problematic more so due to seed difficulties in extraction, poor germination and high post-germination mortality. Mulatya (2000) investigations asserted that the majority of farmers (60%) in Mbeere sub-county and Kitui county of Kenya, who had intercropped *M. volkensii*, depended on natural regeneration for seedlings. Of the remainder 34%, used transplanted saplings while the rest 6% utilized either root cuttings or nursery raised seedlings, where these were accessible. Nevertheless, natural growth dependence is a noteworthy limitation to the expansion of use of this species as the low germination rate (<5%) obtained by farmers (Stewart and Blomley, 1994) simply means it can be applicable where the trees are already in abundant (Mulatya *et al.*, 2002).

Vegetative propagation plays a key role in tree improvement programmes as a means of large scale multiplication of superior genotypes. Research by Kenya Forestry Research Institute (KEFRI) has shown that *Melia volkensii* - crop interactions with agricultural crops have little or no significant effects on yields; thus it qualifies as an agroforestry species at large plantations. In addition, its performance when grown in a plantation has shown encouraging results in terms of good tree form. The high preference of *M. volkensii* timber is due to its sturdiness coupled with its resistance to borers and termites that make it suitable for furniture and door frames especially in dryland areas where subterranean termites are a major problem.

*M. volkensii* has a great potential for improving and conserving the forest cover of the region if embraced in the concept of dryland forestry that has for a long time been neglected. In fact, one of its multipurpose uses as a high value dry season fodder for goats (Tedd 1996, Tedd, *et al.*, 1997) as well as its poor management by the fast expanding and encroachment of human population in semi-arid areas, are the main threats for *M. volkensii*. *M. volkensii*'s outstanding ability to withstand long
periods of drought, has qualified its use as a mitigation tool in the struggle against
the expanding desertification that threatens these regions, further leading to its
adoption in afforestation and re-forestation programmes in the climate change
affected lands.

These worrying trend cultivated by the high demand and challenges in its
propagation experienced in seed availability and seed quality have dictated the
urgent rapid need to conserve the genetic material that will ensure the future survival
of this tree species. One way to achieve this is through running more meticulous
critical experimental studies that will create a sustainable supply of the *Melia
volkensii* products and in particular timber through increased plantation
establishment and on farm planting.

This study therefore sought to provide the much needed information on conservation
and sustainable utilization of the species by providing the most suitable method to
catalyse rooting on *M. volkensii* stem and root cuttings that would contribute to the
mass propagation of high quality trees. To address this challenge, vegetative
propagation by stem and root cuttings, was chosen to determine which vegetative
part from the plus mother tree (root or stem) has the highest potential for rooting.
Further if the cuttings are differentiated, to ensure desired genetic qualities are
captured to determine whether the top, bottom or full portions can influence the
rooting due to the endogenous root hormones (inducing and inhibiting) imbalances.
The direct and or indirect influence of exogenous treatments through the use of IBA
rooting hormone at varying levels of the auxin concentrations on the rooting of these
sectional cuttings needed also to be determined and predicted. This was
predetermined by the need to collect and conserve the genetic diversity of *M.
Volkensii* species (Runo et al., 2004) as it was important to determine the best
section of the tree for obtaining the cuttings and the best hormone concentration.
This would ultimately lead to increased Melia numbers on farms and in the wild
hence meet the increased demand of the species both locally and regionally.
1.3 Research Questions

The study was guided by the following research questions;

1. Which IBA concentrations (0.51% and/or 0.25%) - best allows the *Melia volkensii* cuttings to root and shoot?
2. Does the diameter and the length from the (top, bottom and full) portions have any effect on the rooting ability of *Melia volkensii* stem and root cuttings?
3. Do *Melia volkensii* cuttings obtained from the stem have a higher chance in producing higher rooting percentage as compared to the cuttings obtained from the roots?
4. Does the plus tree merchantable height have any influence on the rooting capacity of the harvested cuttings?

1.4 Research Objectives

The broad objective was to investigate the potential of establishing *Melia volkensii* seed orchards by use of high quality vegetatively propagated seedlings in Kiambeere, Kenya. To achieve this broad objective, the study sought to address the following specific objectives:

1. To investigate the effects how the IBA hormone concentrations (0.25%, 0.5%) on the rooting and shooting of *Melia volkensii* cuttings.
2. To assess the effect of the cutting diameter and length -from different portions (top, bottom and full) of melia stem and root cuttings -on the rooting percentage.
3. To determine the most suitable sectional cuttings (root or stem) from the plus mother tree for establishing a stable seed orchard.
4. To indentify the ideal plus tree merchantable height that can produce cuttings with the highest rooting percentage.

1.5 Hypotheses

The study sought to test the following hypotheses:

1. There are significant differences in the level of concentrations used of IBA rooting hormone on the rooting and shooting percentages of melia cuttings.
2. There are significant differences in rooting percentages of long cuttings with large diameters to those of short cuttings with a small diameter.
3. There is a significant difference in the rooting percentage of cuttings obtained from stem to those obtained from roots of *M. volkensii* plus trees.
4. Cuttings from longer bole mother plus trees have a significantly higher rooting percentage than those from shorter bole mother plus trees.

**1.6 Significance of the Study**

The study was to further help develop a high quality source of seedlings for the establishment of an improved Melia plantation/seed orchard. This was geared in the improvement of the existing propagation methodology that would allow massive multiplication of *Melia volkensii* through cuttings in areas with similar climatic conditions as Embu County.

The findings of this study was to provide the needed protocol on propagation of *M. volkensii* cuttings, disseminate information to the local farmers on better management of the tree so as to achieve its full potential in terms of the important resources it offers to alleviate poverty. It was also to provide an opportunity to highlight the local importance of *Melia volkensii* and the impact the tree species has on the farms, livelihood and on minimizing the extensive effects of climate change /drought in these dryland areas to the academia fraternity, policy makers, Community Forest Associations, local investors.

**1.7 Limitation of the Study**

The research was limited to the farmers’ fields where tree growth is largely as a result of silvicultural management and less because of the genetic composition. The availability of dense population of Melia plus trees that were accessible further dictated the sampling procedure to largely be undertaken in the fields than the wild regions of Mbeere in Embu County.
1.8 Definition of Significant Terms

ASAL: Arid and Semi Arid Land

Bole Length: The length in feet of merchantable bole of trees 5.0” D.B.H. (diameter breast height). Unless otherwise specified, it’s usually larger in between the top of a 1 foot stump and 4.0” diameter outside bark (D.O.B.)

Breast height: It’s commonly defined as the standard height for measuring the girth, diameter and basal areas of the standing tree. Usually a height of 1.37m above the floor of the forest (sometimes comprising of the duff layer with the exclusion of unincorporated woody debris that may rise above the ground line) on the uphill side of the tree is adopted

DBH (Diameter at Breast Height): Refers to the tree/trunk diameter at breast height. It’s traditionally known to be the "sweet spot" on a tree (usually at human breast height) where measurements are taken and a multitude of calculations are made to determine several things like age of veteran trees, growth, volume, yield and forest potential

Deciduous: Perennial plants that naturally shed their leaves for sometime once a year

Genetic Diversity: Total number of genetic characteristics in the genetic makeup of a species

Germplasm: Refers to the collection of genetic resources of an organism

Hardening up: Preparing tree seedlings for planting out by gradual reduction of water, shade and shelter intensity just before out planting in readiness for the harsh field conditions

Merchantable height/length: Refers to the length of its trunk/bole up to which a particular product like timber can be acquired, usually minus
a one-foot stump height. Also known as the usable length of the tree - that is factored from the height of the tree

**Potting:** Process of containerizing growing media for germinated seedlings

**Provenance:** Refer to known sources of propagation material

**Prick out:** To individually transplant small seedlings from the propagators into the nursery beds or containers/boxes

**Seed Dormancy:** It’s typical a barrier to the completion of germination of an intact viable seed under favourable conditions

**Seed Orchard:** A plantation consisting of an aggregation of trees intensively managed for the mass production of genetically improved seeds to create plants, or seeds for the establishment of new forests

**SSO:** Seedling Seed Orchard – a seed orchard established from seedlings

**CSO:** Clonal Seed Orchard - a seed orchard established from clones

**Silviculture:** The growing and cultivation of trees

**Stock-plant:** A plant used to obtain propagating material, whether seed or vegetative material

**Wildings:** Naturally growing seedlings, as opposed to nursery grown one, used in forest planting.
CHAPTER TWO: LITERATURE REVIEW

2.1 Dry land Forests of Kenya

Kenya has been listed as one of the countries with a low forest cover internationally. The existing 6.99% forest cover of the country’s’ land area is still below the constitutional requirement of 10% (GoK, 2014). The forest cover has been shrinking speedily over the last twenty years due to population pressure and development related activities such as excisions, over harvesting, illegal settlements and agricultural expansion (GoK, 2009). Earlier on in this decade the Kenyan government banned tree harvesting in state forests. Ever since, the country has been outsourcing industrial wood from farms (supplemented with timber) in the neighboring countries (GoK, 2009). This has resulted to the depletion of farmland wood stock ultimately creating serious challenges in restocking trees that have been cut on farmlands. In the end, the potential of these forests to supply products, to serve as water catchments, as biodiversity conservation reservoirs, wildlife habitats and carbon sinks has diminished (Leach and Mearns, 2013).

The contribution of forestry to the Kenyan economy is currently undervalued in terms of Gross Domestic Product contribution (GoK, 2008; Ogechi, 2016). For instance, the contribution of the forestry sector at the national level is about 1% (monetary economies) and 13% to the non-monetary economies as (2008) GoK report highlights. At national level, the output from direct utilization value of forests in terms of fuel wood, timber and poles is estimated per annum to be KES 3.64 billion. Further reports by GoK, (2008) regard farmlands as reliable sources of fuel wood materials -around 24 million m³ - that are annually approximated at KES 4.8 billion.

After the Kenyan government ban on harvesting of forest industrial plantations, the demand for wood has escalated with private farms becoming the key sources of materials for mobile benches and sawmills (Ng’ang’a, 2012). This change has exerted great pressure on the available forest resources, positively impacting farmers’ outlook towards the commercial value extent of trees, resulting in high demand for seedlings to plant. A study by Thorlakson and Neufeldt, (2012) maintains that farmers have acknowledged the benefits of growing trees to improve
productivity demonstrated by increased tree cover present on farms and most particularly in higher agricultural (more densely populated) potential regions. This demonstrates that farmers recognize the benefits of tree growing in improving land productivity. Whereas in the lower rainfall areas the challenges in tree growing are greater, a range of species perfectly fit in their potential to make tree growing in these areas profitable.

As a result, major afforestation efforts will need to be put in place through farm forestry that revolves in the community and private lands to achieve the asserted 10% that’s the national wide forest land area cover targets (GoK, 2014; Appiah and Pappinen, 2010). Farm forestry incorporates natural occurring trees or those introduced/planted into the farmlands as intercropping, small scale woodlots and nurseries, shade trees, scattered trees in the towns and along the roads, shelterbelt plantings, ornamental and boundary tree populations (Mbora et al., 2009). It’s a practice usually undertaken outside state forests /gazetted government forests for the aim of meeting the fundamental needs of the rural populations which may include in part as timber, fuel-wood, shade, medicine, fodder and fruits for the livestock, and soil improvement.

The country’s arid and semi-arid (ASALs) areas cover about 80% of Kenya’s land total surface (Mganga, 2010). This forms home to close to 10 million people roughly, as 25% is occupied by the human population (Mganga, 2010). The uniqueness of the ASALs necessitates special attention to strengthen the country’s economy as well as the economic base of the populace. The Forest policy of 2014 confirmed that the ASALs also offer the greatest potential for intensified afforestation geared towards realizing the nationwide objective of 10% tree cover. Despite of constraints by drought, their richness in biodiversity with the potential to sustainably supply profitable commodities such as gums and resins, aloe, charcoal, essential oils, silk, edible oil, commercial juices, frankincense, indigenous fruits, thatching materials, honey and timber has fascinated many alike (GoK, 2014). However Schwilch et al., (2014), acknowledged that the forest resources in ASALs are being degraded due to the migration of people living in the high and medium potential areas where population pressure is a scourge. This is because these ASALs support pastoralist and agropastoralist lifestyles by their woodlands that serve as a
major source of charcoal - a commodity with a ready market- for domestic energy in rural and urban settlements all over Kenya (Nyakiri et al., 2005). This woody vegetation also provides useful cover to the fragile and highly erodible soils, shelter for people and livestock in the harsh environment and habitats for wildlife.

2.2 *Melia volkensii* as a Solution to the ASALs

Mahoganies (Meliaceae) are among the most economically important tropical timber species, accounting for a significant proportion of world trade in tropical hardwood (Newton et al., 1994). The timber obtained from mahogany is predominantly used for furniture and veneers; as it is easy to work on and strong for its weight (Newton et al., 1994). Other purposes apply in agroforestry systems (e.g. in Central America and parts of Indonesia), where they may provide shade for crops and fuelwood. Other non-wood products derived from Meliaceae include oil (derived from the seed of *Carapa* spp. (Prance, 1998; Campbell et al., 2011), biological insecticides (such as neem, obtained from *Azadirachta indica*) and medicinal products, such as treatments for whooping cough, rheumatism and lumbago, derived from *Khaya* spp. (Abbiw, 1990). Products such as these could potentially be derived from other meliaceous species by appropriate selection programmes. Despite this fact, the mahoganies largely remain undomesticated: the extent of the information on genetic variation in wild populations is scanty with very few attempts being made towards genetic improvement (Miller, 2013).

*Melia volkensii* (of Meliaceae family) serves as a multi-purpose indigenous dryland tree species that has enormous potential in the ASALs (Esilaba et al., 2011). *M. volkensii* greatest utilization is in agroforestry in the production of wood products (easily workable high quality timber, firewood, posts, poles) and non-wood products (fruits, medicine- insect repellents, fodder, gums and resins, essential oils that should be tapped into through the tree domestication (Nyariki, 2011). Melia tree also maintains soil fertility (Njenga and Eckert, 1990) through heavy leaf fall (Kimondo, 1992), which disintegrates enriching the soil with nutrients. Farmers consider *Melia volkensii* to be a weaker competitor and thus compatible with agricultural crops (Tedd, 1996; Kidundo, 1997). *Melia volkensii* easily workable high quality timber has rendered it almost extinct as the exploitation targets mature trees of good form, leaving trees of poor form behind (Muchiri and Mulatya, 2004). Despite the
potential of the tree for semi-arid areas, it is yet to be massively propagated for plantation establishment, especially by farmers. This has been due to difficulties experienced in seed extraction, germination, and propagation through cuttings when compared to other species (Kyalo, 2004).

### 2.3 Taxonomy and Botanic Description of *M. volkensii*

The tree, *Melia volkensii* is in the group family Meliaceae. It has an open, deciduous and laxly branched crown with a total tree height at maturity varying from 6 - 20 m tall (Orwa *et al.*, 2009). Trees with diameters breast height (Dbh) of 25 cm are widespread (Beentje, 1994). The bark is moderately smooth, with a grey coloration furrowing with age. The foliage has a bright yet light green shade, with bi-pinnate leaflets each consisting of 3 - 7 pinnule that are up to 35 cm long, and in their youth appear heavily haired (Mfahaya, 2008). The oval to lanceolate shaped leaflets tapers to the apex with entire or serrated margins closely becoming glabrous when fully grown within a range of between 4 cm and 7.5 cm long (Beentje, 1994). Its white and scented flowers appear small in loose sprays. The tree is andromonoecious with the female and male flowers occurring on the same tree. On young and (auxiliary) adult branchlets the inflorescence crowds up to 12 cm long. The Petals have white coloration, and are tetra- to pentamorous, free - curling backwards sometimes; with similar numbers of stamens and petals, occasionally appearing twice, integrated in a tube-like structure (Beentje, 1994). The fruit size is 4 cm lengthy with an endocarp that’s very thick and bony (Albrecht, 1993). As the drupe-like, oval fruit matures the colour changes from green to yellow (Beentje, 1994). The generic identification Greek melia (the ash) is derived from the divided nature of the leaves.

### 2.4 Ecological Distribution and Reproduction of *Melia volkensii*

*Melia volkensii* is widely linked to Agro-ecological Zones IV-V (Arid and semi-arid) (Muok *et al.*, 2010) growing in deciduous acacia-commiphora bushlands, every so often fringing seasonal watercourses or emerging on rock outcrops. Melia tree is by nature deciduous. More often than not, it sheds its leaves early in the dry season having been triggered by reduced availability of soil moisture, which gives room for the emergence of new leaves two to three weeks before the onset of rains (Kimondo *et al.*, 2008). On the contrary, on farm lands in accordance to Bloomley (1994), the
leaves are normally shed late into the dry season. It’s rapid growth within a rotation period of 10-15 years has achieved a record of 6 to 20 metres height with diameters breast heights of around 25 cm. Bigger trees are however common in suitable environments as regions vary in abiotic and biotic factors (Kimondo et al., 2008).

The tree is native to Ethiopia, Kenya, Somalia and Tanzania growing in altitudes ranging from 350-1680 m, with an yearly mean rainfall range of between 300 - 800 mm coupled with temperatures of 22.0 to 28.6°C (Muok et al., 2010). In the warmest month, melia grows well under a mean maximum temperature of 30°C. The species in Kenya grows mostly as remnants of natural stands, woodlots, scattered trees on cropland and homestead compounds in the following regions; Tharaka, Mutomo, Kitui, Mwingi, Makueni, Taita Taveta, and Mbeere (Juma et al., 2004). As asserted by Wekesa et al. (2012) the species has been introduced in the Kenyan Coast in Kilifi, Kwale and Lamu County towns (Kinango, Malindi, Ganze and Lamu west). In its natural range, the physical qualities of the soil have to be clay, sandy and shallow stony. A suitable drainage is a familiar attribute, even though ICRAF (1992), have reported of Isiolo and Tharaka-Nithi parts of Kenya as sites/locations categorized as poorly drained soils.

*Melia volkensii* tree flowers early with reports indicating flowering starting off as early as 2-3 years (Bloomley, 1994; Muok et al., 2000). The shedding of its leaves is twice yearly, with the flushing of new foliage coming just before the closing stages of the dry season. Fruits and flowers are biannual, with the fruits ripening at the close of the low rainfall season when the leaves emerge (Muok et al., 2010). Reports by Salim et al., (1998), give an indication of insect pollination as the flowers are visited by bees. The development of fruits and their stages follows an unseasonal pattern that normally takes a year to 13 months from the beginning of flowering to maturity. It’s rare to have Melia trees on the similar site fruiting and flowering at diverse times of the year a reason why you might get fruits at different stages of growth occurring on the same branch. This makes it difficult for the tree users to differentiate mature from immature fruits, except for the colouration (Milimo, 1994; Muok et al., 2000). The dispersal agents apart from human beings include the kudu, giraffe and the domestic goat who mainly consume the fleshy fruits (Kimondo, 2005).
2.5 Propagation and Management of M. volkensii

A rapid appraisal study undertaken by Juma et al. (2004) of the management and utilization of M. volkensii by farmers in Kibwezi, Makueni district identified the use of seeds to raise seedlings, coppicing and injuring of roots - deliberately or accidentally - to promote suckering as the most widespread propagation methods (Mfahaya, 2008). Other regularly used methods of propagation include transplanting from wildlings, transported in the wet season from either the arable land or from the bush. Farmers who do not have access to seedlings use vegetative propagation (Kimondo and Kiamba, 2004).

Juma et al. (2004) made the following general observations on M. volkensii tree management: Agroforestry or integration of M. volkensii into farming system is the viable option, pruning undertaken during the dry season produces fodder while pruning done just before the rains is to reduce tree-crop competition and improve timber quality and finally tree weeding is an inferred management practice particularly in tree crop interactive systems. Among the farmers interviewed by Juma et al. (2004), timber use ranked the highest with pole and fodder functional use following.

Vegetative propagation using root cuttings entails injuring the roots to initiate sprouting of shoots from the roots (Mfahaya, 2008). However, a majority of Kenyan farmers do not prefer root cuttings because of the resulting trees that are unstable even though it’s reported that the Melia tree grows faster through this means (Kimondo, 2002). As further corroborated by Kidundo (1997), vegetative propagation using stem cuttings has had little success. Moreover, literature on air-layering is lacking, suggesting that it has not been tried on Melia Volkensii substantively (Muok et al., 2000).

Propagation by seeds has proven problematic because the epigeal sprouting (appendages) of M. volkensii seed is very hard to germinate (Milimo, 1989). Even in well organized nurseries it is very difficult to achieve germination rates above 40% (Maundu and Tengnäs, 2005). Placing the seeds under favourable conditions of moisture and temperature is not enough. Milimo (1986) witnessed that sprouting started after seeds with damaged integuments absorbed over 60% water and
concluded that dormancy is imposed by the integuments because they don’t allow water absorption hence mechanically preventing the ridicule to emerge. Subsequent to dispersal, seed dormancy can take 2-5 years prior to germinating naturally for maturation of seeds takes 11 to 13 months and more so lack seasonal patterns (Orwa et al., 2009).

Despite the potential of the tree for semi-arid areas, it is yet to be massively propagated for plantation establishment, especially by farmers. This has been due to difficulties experienced in seed extraction, germination, and propagation through cuttings when compared to other species (Kyalo, 2004). Among factors that hinder mass propagation is seed extraction from the hard stony nut (Kyalo, 2004). Indeed; nurseries have had trouble with seed extraction, where the only known method of extraction is by splitting the nut into two using a hammer and a sharp kitchen knife. This slow and cumbersome method often leads to injury to the seed, and toes injury to the operator (Lugadiru, 2004). A nut cracker was developed in the 1990s to support the expanded tree planting programme under KEFRI/JICA social forestry training programme (Muok et al., 2010; Luvanda et al., 2015). When extracting seeds using the cracker, to ensure quality seeds are obtained, sorting of seeds into uniform size classes by visual means is necessary. These are then placed into the nut rest slot with the nut’s long axis perpendicular to the knife then cracked using optimal force. The seeds are gently eased out from the cracked nut (Lugadiru, 2004).

*M. volkensii* propagation using seed and cuttings has given variable results among different researchers which need to be harmonized (Hanaoka et al., 2016). Using seed, a germination of 80% within 5-7 days and successful seedling production was achieved (Kyalo, 2004) by collection of mature nuts (yellowish green to yellow) and de-pulping. Care should be taken to ensure extraction of seeds from the nut is done without injury. Pre-treatment of the seed through careful nipping, soaking in cold water overnight, slitting to break the inner and outer seed coat using a razor blade is done before sowing them in sterilized or fumigated medium such as sand or vermiculite in germination chambers where ambient temperature is maintained between 30°C to 38°C (Kyalo, 2004; Abwao, 2011).
Indieka and Odee (2004) have reported that the propagation methods of using seed and asexually using root cuttings are quite problematic and hence not amenable for mass production of planting materials. The rationale was that the methods are labour intensive, difficult to optimize and incapable of meeting the growing demand of planting stock (Abwao, 2011). Moreover, studies conducted on macro and micro propagation using leafy stems from mature trees show a potential for the method in mass propagation. The same results were achieved using invitro multiplication of juvenile tissue. In many experiments conducted on in vitro rooting, multiplication and acclimatization using Meta topolin derivates (mTR and MemTR) good multiplication results were obtained, but with moderate rooting (Acker, 2012, Chiruvella et al., 2014). This is in line to the recommendations made by Indieka & Odee (2004) who observed limited rooting while using invitro method for mass propagation of Melia.

Kyalo (2004) through cuttings achieved a success rate of 40% seedling production when root cuttings were subjected to the following treatments: obtaining fresh root cuttings measuring 8-12cm, sterilizing the cuttings and waxing the upper end, inserting the cuttings in sterilized rooting medium such as sand or vermiculite in germination chambers where ambient temperature is maintained between 30°C to 38°C. Attempts to establish seedlings using stem cuttings using the above procedure failed. In these two methods, Kyalo recommended the sustenance of high ambient moisture using polythene sheets cover on the propagation chambers.

For healthy seedling production, pricking out should be done as soon as the seedlings emerge (usually 2 - 3 days after germination) (Abwao, 2011). Seedlings from cuttings should be transplanted into the pots kept under shade after several flushing leaves are fully developed which takes about two weeks. To avoid post transplanting losses, the potting media should be well drained and watering intensity and frequency should be well maintained to steer clear of water logging. Seedlings from their onset, should be sprayed on a regular basis with a fungicide to circumvent losses associated with fungal infections like damping off disease that is common with Melia volkensii (Hanaoka et al., 2012).
A larger fraction of the growers’ have irregularly dispersed *M. volkensii* within crops, usually at a spacing exceeding 10-15 m. Boundary plantations has been preferred by only a few of the farmers’ but hardly ever close to homes that have a tendency to break branches during rainstorms (ICRAF, 2012). The growth of *Melia volkensii* in well-managed plots in arid and semi arid lands far exceeds those of other indigenous tree species (Kimondo, 2002). Over time, KEFRI in their endeavour of dryland afforestation has embarked in projects geared in the improvement of melia species and offered management guidelines for tree growers and farmers to use to (Muok et al., 2010). However, most *M. volkensii* farmers have adapted to pruning the tree from its 1st year onwards to maintain a clear straight bole (Orwa et al., 2009). This has been prompted by the tendencies for the tree to develop heavy lateral branching. Thinning on the other hand is normally intensified annually - as soon as the crown is fully developed- to lessen shading on under planted crops such as sorghum and millet (ICRAF, 2012). This procedure is usually done during the low rainfall season to provide lucid conditions at planting time. In practice, farmers conduct pruning of new foliage and fruits to coincide with the time when feed for the animals is limited and for fuelwood during drought (Blomley, 1994). A few of the Melia farmers believe in pollarding their trees to induce an increase in diameter while the majority of them, however, consider pollarding as counterproductive practice that encourages rotting (Kidundo, 1997). Recently KEFRI has made great milestones in providing guidelines that touch on marketing of the improved melia seed and seedlings to promote adoption and subsequent production of better quality timber (Kamondo et al., 2016).

The behaviour of Melia seed at storage is conventional, and at room temperature with a moisture content of 11 -15% its viability - in hermetic storage- can be sustained for several years (Kidundo, 1997). Initial germination trials at the Kenya Forestry Seed Centre (KFSC), using seeds stored for 3 months at -30°C resulted to a mean germination percentage of 3% (Kidundo, 1997). Further research findings from the centre confirmed that mature and properly dried 'stones' can be stored in air-tight containers at a temperature of 3⁰C for several years without damage. The seed extraction was with a seed extractor or a pocket knife. Studies by Albrecht (1993) and Muok et al (2010) noted that on average one can obtain 200 extracted
seeds per kg, depending largely on the climatic conditions of the ripening year and the provenance.

2.5.1 Propagation of Melia Volkensii by Seeds
In Africa seed propagation is the main method of plant multiplication, nonetheless the availability of quality seeds constrains planting of Melia volkensii (Milimo et al., 1992). The difficult to root nature of melia has further discouraged its massive propagation by most farmers (Kyalo, 2004).

Seed collection and processing
Mature yellowish brown fruits are collected from the crown by spreading a net, canvas or any other appropriate material under the tree and climbing the tree to select the fruits or shaking the branches to release the fruits. Seed collection according to Mfahaya (2008) ought to be further improved on cleaning, processing and storage of the seeds. The use of sieves with different perforators would sieve the small damaged nuts from the wholesome large desirable nuts.

Ripeness, period of collection, location and quality of the parent trees are crucial in obtaining quality seedlings (Kimondo and Kiamba 2004). Mature ripe fruits are depulped using a mortar and pestle. The nuts are then washed thoroughly under running water (Kamondo et al., 2006; Muok et al., 2010). Alternatively, de-pulped nuts are collected from goat shed where they are regurgitated during the chewing of cud.

Successful extraction of the seeds is by means of cracking the hard nut. It’s achieved by either use of a knife and hammer or the seed extractor, a machine developed by KEFRI (Lugadiru, 2004). The extracted seeds are then cleaned by hand sorting. However, when seed is required for subsequent seasons, it should be noted that Melia seeds are better stored unextracted to avoid significant loss of viability (Muok et al., 2010; Luvanda et al., 2015).

Seed germination
Propagation of M volkensii has been hampered by low seed germination. Seed dormancy, has contributed to the low seedling production in tree nurseries. This is because the epigeal sprouting seeds of the Mukau (Milimo, 1989) are very hard to germinate. The seed coat dormancy common in family of meliaceae renders all
exchanges of gases and water/moisture impossible. According to Hidayati et al. (2001), the nature of seed coat differs between legume species; in others the nuclear membrane appears to be the structure, which restricts gas exchange. Impermeability is based on the physical and chemical properties of cells in various layers of the seed coat. Maturation of seeds takes 11 to 13 months and lack seasonal patterns (Muok et al., 2010).

Hence to improve germination, effective pre-treatment methods to increase water imbibitions for germination success without injury to the embryo should be predetermined. Muok et al., (2010) and Milimo (1989) recorded that it is necessary to nip the tip of the seed, leave it to soak for 24 hours in cold water, and slit longitudinally through the inner and outer seed coats.

After pre-treatment, seeds are sown in a sterilized or fumigated germination medium such as sand or vermiculite in germination chambers where ambient temperatures of between 30-38°C and high humidity are maintained (Kyalo, 2004). In practice, such conditions are maintained under non-mist propagators similar to green house conditions. Under such conditions, germination takes 4-10 days. Pricking out is done 1 – 2 days after germination. This is in contrast to (Kyalo, 2004) that cited that germination takes place after 5-7days under such conditions. Moreover, melia is prone to high mortality after pricking out, during seedling rearing, and even during seedling establishment in the field (Muok et al., 2010).

Fundamentally, germination consists of three overlapping processes namely (i) absorption of water by imbibition, causing a swelling of the seed and eventual splitting of the seed coat, (ii) translocation of stored food to growing regions (Young and Young, 1992), (iii) cell enlargement through enzymatic activity and increased respiration and assimilation rates which signals the use and divisions resulting in emergence of radicle and plumule (Tiffney and Mazer, 1995).

**Seed Dormancy**

Milimo (1989) concluded that Melia volkensii seed dormancy is imposed by the integuments because they don’t allow water absorption and mechanically preventing the ridicule to emerge. Seed dormancy in Melia volkensii propagation has proven a great challenge. However, on the flip side dormancy preserves the seed against
temporarily unsuitable conditions such as it may occur during the period between
seed collection and planting (Wambui, 2014). It also provides an insurance against
the loss of viability during transport and processing which can easily occur in non-
dormant seeds in less than ideal conditions (Willan, 1985).

There are two main types of dormancy i) Embryo dormancy where the embryo is
morphologically under developed and ii) Seed coat dormancy where the seeds have
cutinized seed coat that completely prevents the imbibitions of water and sometimes
also the exchange of gasses (Wambui, 2014). The former is not common in the
tropics while the latter occurs frequently in species adapted to dry conditions
(Willan, 1985).

To break the seed dormancy for improved seed germination and mass dissemination,
scarification that involves the seed extraction from the hard stony nut of melia is
important (Wambui, 2014). Since melia seed are sensitive to fungal attack, it is
important to maintain a sterile environment during the scarification process using
conventional methods like the nut cracker developed in the 1990s by KEFRI
(Lugadiru, 2004).

There are other traditional methods of breaking seed dormancy. One is scarification
by burning where the seed is scarified by means of fire ignited through (fast fires or
dry grass dung) prior to planting. Mwamburi et al ( 2004) reported traditional
methods of breaking seed dormancy of M.volkensii in six districts (Kitui, Mwingi,
Taita Taveta, Makueni, Tharaka and Mbeere) as scarification by burning (39
farmers) followed by splitting/cracking of the nuts (15 farmers) and sowing of nuts
in troughs (11 farmers). Burning was common in all the districts except Taita-Taveta
district (Mwamburi et al., 2004).

A study at Kitui- Kenya discovered a new scarification method that is able to give
up to 64% germination rate (Slabbert et al., 2014). This particular technique
systematically involves: breaking the caruncle at the micropyle end, cutting
longitudinally through the integuments, perisperm and endosperm from the centre to
the micropyle end, then soaking the seeds in water at ambient temperature for 6
hours (Slabbert et al., 2014). Melia volkensii being a prolific species produces a
seasonal yield of between 600 and 10,000 viable seeds per tree. Each kilogram holds
an approximate 200 stony endocarps, from which 4,000-5,000 intact seeds can be obtained, assuming they are not damaged during extraction (Kamondo et al., 2016).

2.5.2 Vegetative Propagation of Melia

Vegetative propagation plays a key role in tree improvement programmes as a means of large scale multiplication of superior genotypes (Mfahaya, 2008). The paradigm of vegetative propagation is viable in plants only, – unlike animals or humans, – because plants have meristematic, undifferentiated cells that can differentiate to the various organs necessary to form a whole new plant (ICRAF, 2012). Additionally this science, as ICRAF (2012) defines, targets the replication of the genome of a mother plant into new individuals. A section of a plant leaf, root or shoot, can consequently, develop into a new plant that contains the exact genetic information of its source plant.

Asexual (vegetative) propagation is the best way to maintain some species, particularly an individual that best represents that species. Clones are groups of plants that are identical to their one parent and that can only be propagated asexually. The Bartlett pear (1770) and the Delicious apple (1870) are two examples of clones that have been asexually propagated for many years (University of Arizona, 1998).

The major methods of asexual propagation are cuttings, layering, division, budding/grafting and micro propagation (Mfahaya, 2008). Cuttings involve rooting a severed piece of the parent plant in a suitable rooting media that’s maintained under high moisture content until the development of shoots and roots is attained. Layering is similar to cuttings but the propagules are only separated from the mother plant after the roots have formed (Palzer, 2002). Budding and grafting are joining two plant parts from different varieties (University of Arizona, 1998). Grafting allows a combination of two or more desired characteristics into one plant. Micro propagation on the other hand is a high investment and intensive technique whereby the development of plants stems from a single cell that is grown into a septic culture media (Jaenicke and Beniest, 2003). It’s mainly used for high valued trees like Eucalyptus (Wakhusama and Kanyi, 2002) for commercial purposes.
Palzer (2002) states that the main reasons for using vegetative propagation could be (i) having seeds with problems of seed germination (ii) successful nursery technique for a given species not having been developed or (iii) trying to maintain the superior genotype of a mother tree, by combining desirable characteristics of two plants by grafting into a single plant or when production of a uniform plantation is desired.

In forestry and agroforestry, vegetative propagation is becoming increasingly important as an optimal solution to the multiplication of limited seed material and for the production of genetically homogenous stocking plants. The main aim of vegetative propagation is to multiply selected planting material and to capture the genetic potential that has long been known (Leakey, 1987; Hartmann et al., 2002). The tree improver in vegetative propagation has an added advantage as he’s given the ability to select from, test, multiply and utilize the vast presence of genetic diversity in a great number of tree species. By this way selected, highly productive but unrelated clones can be used commercially for reforestation and agroforestry (Leakey, 1991).

**Cuttings**

Vegetative propagation of *Melia volkensii* could be an alternative propagation method since seed germination is low. Vegetative propagation technique using cuttings offers potential to grow more trees with desirable traits. The method is cheap, rapid and simple and does not require special technique as in grafting, budding and micro propagation (Palzer, 2002). Trees selected for cuttings should be superior in terms of height, diameter breast height and straight bole (Kijkar, 1992).

Root cuttings propagation technique involves plant roots being severed into individual pieces, segments or cuttings, each of which is capable of developing adventitious buds and roots and, therefore, of regenerating into complete plants (Macdonald, 1990). The newly formed plants thus are known as ‘rootlings’ (Hall et al., 1989, Snedden et al. 2010). The technique has been used for propagating some forest trees species, such as poplars (Snedden et al., 2010), with varying success. In essence therefore, an understanding of the main factors affecting the regeneration vigor of root segments, such as cutting size (length, diameter), the original location of the segment in the root system and growing conditions is quite crucial (Hartmann et al., 2002). Stem cuttings on the other hand has been the most commonly used
means of vegetative propagation in agroforestry. Many internal factors such as auxins, rooting cofactors, carbohydrate and nitrogen levels have been shown to influence rooting of stem cuttings (Hartmann et al. 2002). The main problem in vegetative propagation is poor rooting of stem cuttings and this has been indicated by inclusion of *M. volkensii* in the Royal Botanic Garden Kew list of species whose seeds are most difficult to handle, store and even germinate (Royal Botanic Garden Kew, 2012). For this reason, clonal propagation techniques through the use of stem cuttings can offer the opportunity to produce a reliable and adequate supply of superior planting stock locally, in a timely and quickly manner as it has been done to other plants (Baul et al., 2011). Many economically and ecologically important tree species have indeed been known to have low capacity for the formation of adventitious roots however, and as such have been found to be unsuitable species for efficient large-scale commercial propagation through stem cuttings (Bellini et al., 2014). The use of stem cuttings thus has had different success and failure stories in different tree species.

Successful propagation by cuttings is influenced by rejuvenation of stock plants used, wood section, water selection and application of hormones and plant growth regulators (Jaenicke and Beniest, 2003). For purpose of propagation, biological age (age of tissue within a plant) is more important than chronological age. The more juvenile the tissue is from which cuttings are made, the greater the success the propagator has in getting those cuttings to root (Hartmann et al., 1990). The section of plant parts used for cuttings also affects the amount of success in rooting of cuttings. The base of the plant always tends to be juvenile than the actively growing parts of the plant. There is an increase in rooting from the apex moving down to the base of the stem parts (Salimini, 2003). This is in accordance with Mfahaya (2008) whose studies recorded a high rooting percentage of 73% cuttings from the bottom section under the treatment of 0.33% IBA hormone.

Cutting morphological Characteristics

The ability to form adventitious roots has also been associated with the characteristics of the cutting material (Hartmann et al., 1997). However, the effect of cutting characteristics on the formation of roots varies from species to species (Harrison- Murray and Knight, 1997). It is unclear whether the characteristics of
Cuttings are associated with genetic differences in rooting ability or simply an expression of growth and the condition of the stock plant. Among the characteristics identified to influence the ability of cuttings to form adventitious roots are; size and age of leaves (Wilson, 1993; 1994), presence of active buds (Kibbler et al., 2004), proximity of nodes to the base of the cutting (Hansen, 1986), size of the stem (Howard, 1991, Wilson, 1994) and position of cutting on the stock plant (Howard and Ridout, 1991).

**Cutting diameter and Lengths**

In the view of Beyl’ et al. (1995), physical elements such as the cutting diameter and cutting size have received comparatively little consideration in propagation literature. Habitually, the focus is on the cutting position from the mother plant, the type of cutting and hormonal and environmental treatments to enhance rooting—not on the relationship between factors, such as size of the cutting and or nodal positions on successive performance with respect to formation and development of roots.

In *Prunus persica* (L.) Batsch (peach plant), a positive correlation between stem diameter and rooting was noted (Marini, 1983). A 50% rooting success was achieved using terminal cuttings that were 3.5mm in diameter. As for ‘Pixy’ plum (*Prunus insititia* L.), the rooting percentage decreased with increasing cutting diameter when the medium was rapidly draining sand rather than granulated bark (Howard and Ridout, 1991). From data collected in three experiments over 2 years, Howard and Ridout (1991) were able to conclude that shorter, thinner shoots collected from hedges had the highest rooting potential. Further studies by Avery and Beyl (1986), established that the diameter of the cutting had a profound effect on successful rooting using semi-hardwood cuttings of *A. deliciosa* that contained one bud and one leaf. Cuttings that had diameters ranging from 2.0 to 3.9 mm recorded a rooting of 90% while those with diameters >8.0 mm produced a 10% rooting. Stenvall (2006) studies on hybrid aspen recognized that the diameter of the cuttings had a significant effect on the rooting of the cutting but not on the sprouting efficiency.

A study by Zhang et al. (2010) on rooting success of *Feijoa sellowiana* cuttings from 4 year old stock plants, recorded a significant influence on the rooting capacity and sprouting rate after 60 days of evaluation. The results showed that cutting
diameter has a remarkable influence on the rooting rate, rooting traits (sum of adventitious roots and average length of roots). The cuttings characteristics included two to three nodes and two pairs leaves (half-leaf pruned) measuring 8-12 cm long with diameters ranging from 0.20-0.30mm. Root length, root number and rooting rate increased gradually with increase in diameter of the cuttings. The thickest (in diameter) cuttings had a higher rooting capacity as compared to the medium cuttings. The stouter (short in length) cuttings recorded better rooting capacity. For the sprouting, the thin (1.5-2.0 mm) cutting’s sprouting rate was 6% higher than the thick (2.5-3.0 mm) and medium (2.0-2.5mm) cuttings (Zhang et al., 2010).

With respect to how cutting characteristics influenced rooting, Beyl’ et al. (1995) observed in Actinidia arguta cultivars that cuttings that had eight to nine buds -with three to four actively growing - measuring >10 cm long and <2 mm in diameter gave the highest percentage of rooting. Nevertheless a superlative overall development of root, as far as the number of roots formed, root length, and root grade is concerned, was attained with cuttings >8 cm long and 2 to 8 mm in diameter, with five to seven buds where 1-3 were actively developing. Therefore cutting slips of greater than 3.0mm in diameter are ideal for seedling growth (Zhang et al., 2010) additionally shorter lengths produce higher rooting potential (Howard and Ridout, 1991).

Propagation from Adventitious organs

The adventitious organs include new roots and buds that are formed from cells and tissue of previously developed shoots and roots. These organs arise from the dedifferentiation of parenchyma cells; when they originate from callus (also composed of parenchyma cells) their organogenesis is termed indirect (Hartmann et al., 2002). Propagation by stem cuttings requires only that a new adventitious root system be formed, because a potential shoot system (a bud) is already present. Root cuttings on the other hand must initiate both a new shoot system— from an adventitious bud—as well as new adventitious roots.

The formation of adventitious roots and buds is dependent on plant cells to dedifferentiate and develop into either a root or shoot system. The process of dedifferentiation is the capability of previously developed, differentiated cells to initiate cell divisions and form a new meristematic growing point (Hartmann et al., 2002). Hartmann et al. (2002) further advices that the propagator conditions must be
manipulated to provide the proper conditions for plant regeneration, since this characteristic is more pronounced in some cells and plant parts than in others.

**Root Development**

The Rooting requirements of cuttings can be very species specific (Woodward and Bartel, 2005). Nonetheless, in general root formation demands a high respiration rate where oxygen is consumed and carbon dioxide produced. Consequently the medium should be sufficiently porous, easy to wet but yet firm enough to hold the cuttings, free from pest, low salinity, high Cation Exchange Capacity, economical and readily available (Hartmann *et al.*, 2002).

Studies that correlate the stem structure to rooting ability of the cutting have circumvented to sclereids. Sclereids and fibers are impregnated with lignin, which provides structural support to the stem and mechanical barriers for pest resistance. Sclereids occur in difficult-to-root species such as olive stem cuttings, mature English ivy (*Hedera helix*) (Geneve, 1991), and creeping fig (*Ficus pumila*) (Davies, 1984). In some rare occasions these cells may impede the rooting process.

Hartmann *et al.* (2002) regards rooting to be related to the genetic potential and physiological conditions for root initials to form, rather than to the mechanical restriction of a sclerenchyma ring barring root emergence (Davies *et al*., 1984; White and Lovell, 1984). The indirect adventitious root formation for the difficult to root species emerges where there is nondirected cell division, including callus formation. They occur for an interim period before cells divide in an organized pattern to initiate adventitious root primordia. See the flow diagram of adventitious root formation in Figure 2.1 (Lovell& White, 1986; Geneve, 1991; Hartmann *et al*., 2002).
Adventitious roots are of two types 1) Preformed roots (preformed root initials and primodia and preformed or latent root initials) 2) Wound induced roots (Hartmann et al., 2002). The preformed roots initials and primodia develop naturally on stems while they are still attached to the parent plant and roots may or may not emerge prior to severing the stem piece. In poplar plant (Populus xrobusa), the root initials form in stems and lie dormant in midsummer to later emerge from cuttings made the following spring (Schroeder and Walker 1990). These referred to as preformed or latent root initials generally lie dormant until the stems are made into cuttings and placed under environmental conditions that are favourable for further development and emergence of the primordia as adventitious roots (Mulanda, 2016). Wound induced roots on the other hand, develop only after the cutting is made, in response to wounding in preparing the cutting. In effect, they are considered to be formed de novo (anew). Any time plant living cells at the cut surfaces are injured and exposed, a response to wounding begins.

According to Hartmann et al. (2002), the stages of de novo adventitious root formation are; (1) Dedifferentiation of specific differentiated cells, (2) formation of root initials from certain cells near vascular bundles or vascular tissue, which have become meristimatic by dedifferentiation, (3) subsequent development of root initials into organized root primordial and (4) growth and emergence of the root primordia outward through other stem tissue, plus the formation of vascular tissue.
between the root primordia and the vascular tissue of the cutting. The development of the right root system architecture is very imperative; it allows a plant to survive periods which it is meant to overcome. The number, the direction of growth of each root and its placement are highly variable, even when plants have identical genomes.

During rooting, starch is converted to soluble carbohydrate. In the development of adventitious roots on IBA-treated plum cuttings, as soon as callus and roots started forming, pronounced carbohydrate increases of sucrose, glucose, fructose, sorbitol and starch losses occurred at the base of the cuttings where rooting occurs (Mulanda et al., 2012; Mulanda, 2016). While soluble carbohydrates are not the cause of rooting, developing callus and roots at the cutting base act as a “sink” for the movement of soluble carbohydrates from the top of the cutting to other parts of the plant.

Root architecture that refers to the depth of roots and the root numbers is thus influenced by the following two categories (1) pathways that are essential for organogenesis and growth, (2) pathways that determine how plants respond to external signals (Malamy, 2005). Malamy and Ryan (2001) observed that a high ratio of sucrose to nitrogen in the plant medium, inhibits lateral root initiation with A. thaliana and so does a high sulphate content. Sulphate deprivation triggers a response pathway that leads to increased formation of IAA (Kutz et al., 2002; Malamy, 2005). It seems logical, but also water stress inhibits lateral root initiation with A. thaliana (Van der Weele et al., 2000).

Indieka et al. (2007) observed that callus forms at the base of M. volkensii cuttings. Callus is an irregular mass of cells in different stages of lignifications that develop at the basal end of a cutting that is placed under environmental conditions favorable for rooting. In some species, callus is a precursor for root formation (Hartmann et al., 2002) while in other species excess callusing may hinder rooting. Origin of adventitious roots from callus tissue has been associated with difficult to-root species such as pine (Pinus radiata), Sedum and the mature phase of English ivy (Hedera helix) according to Hartmann et al. (2002).

**Shoot Development**

Shoot organogenesis of adventitious bud differentiation and subsequent adventitious shoot formation may also be obtained by direct organogenesis or via secondary
organogenesis from disorganized calli (Garcia-Luis et al., 1994). Moreira-Dias et al. (2000) study on Troyer citrange cuttings reported that shoot formation occurs by direct morphogenesis when the apical ends of epicotyl micro-cuttings are inserted vertically in a solid medium at the basal end; conversely shoot formation occurs by indirect organogenesis through callus formation. When epicotyl explants are placed horizontally on the medium, shoot regeneration at both ends occurs by indirect organogenesis through callus formation.

2.5.3 Propagation Environment

To enhance the propagation of plants, commercial producers’ manipulation of the environment of propagules (cuttings, seeds) is key (Ochora et al., 2012). The conditions that need to be managed include microclimatic conditions/environmental factors (temperature, relative humidity, light, gases), edaphic factors those that are influenced by the propagation medium or the soil, mineral nutrition, water and biotic factors involving the interaction of propagules with other organisms (such as beneficial bacteria, mycorrhizal fungi, pathogens, insect pests, etc. (Hartmann et al., 2002). The environmental conditions that are optimum for plant propagation are frequently conducive for pests (pathogenic fungi, viruses, bacteria and insect/mite development).

Structures, facilities and procedures play a great role in the growth and development of the plant as they optimize the response of the plant to the environmental factors applied (Hartmann et al., 2002). Research studies to establish the best propagation environment for semi-arid species have indicated that a non-mist propagation system is generally more effective than conventional mist propagation (Milimo et al., 1994). Most particular, enhanced rooting of cuttings in non-mist propagators seems to be related to a lower susceptibility to rotting and consequent mortality. This flexible and low technology design needs no electricity or piped water, and is thus predominantly suitable for rural areas, in the tropics and in this case Kenya.

In edaphic factors various substrates and mixtures of materials are used for germinating seeds and rooting cuttings but the following medium characteristics are required; the medium must be sufficiently firm and dense, must be easy to wet but sufficiently porous, must be free from pests and pathogens, must have a low salinity
level, must have a high cation exchange capacity (CEC), consistency in quality and finally must be readily available and economical to use (Hartmann et al., 2002).

High standards of hygiene should be maintained during propagation to avoid the introduction and spread of pests and diseases to the propagules (Hartmann et al., 2002). A goal in propagation is to keep stock plants and propagules as clean and pest-free as possible and to suppress pathogenic fungi, viruses, nematodes, and weed seed from the propagation media. Use of disinfectants such as chlorine that’s easily accessible is advised to control pathogenic fungi, algae among other pests (Hartmann et al., 2002; Ochora et al., 2012).

In general, the critical environmental factors to manage during rooting are: controlling light intensity; providing adequate mist; maintaining high relative humidity; maintaining desirable air and media temperatures; and limiting air flow around leaves (to minimize desiccation and maintain a low vapor pressure deficit between leaves and surrounding air) (Lopez and Runkle, 2008).

In addition to the basic conditions that favour plant growth, other key factors that may influence successful propagation include- the selection of the cuttings, health, age, growth stage, maturity of the stock plant, time of the year and type of cutting that have to be taken into consideration (Woodward and Bartel, 2005).

### 2.5.4 Clonal Selection in Propagation of Melia

This follows the concept of clonal forestry that refers to the whole process of forming a clonal forest plantation from selecting trees for cloning, vegetatively multiplying their propagules, evaluating trees in field tests, and establishing and managing the most productive clones in plantations (Wendling et al., 2014). Clonal forestry is employed in many countries to reduce harvest age, increase timber yield or improve wood quality (Weng et al., 2012).

Over time, exotic fast-growing species have been preferred when selecting trees of semi-arid lands in Kenya (Milimo et al., 1994). Conversely, the concerted efforts of the Government of Kenya (GoK, 2005) in supporting the replanting of indigenous rather than exotic tree species have not only been a accomplishment but have made the campaign a part of the government policy in Kenya. In order to facilitate domestication, it is necessary to determine the tree characteristics desired by a
particular community and to identify genetically outstanding natural populations and individuals for propagation by vegetative techniques or by seed (Milimo et al., 1994). In semi-arid areas, according to Milimo et al. (1994), there is significant variation in rainfall (quantity, frequency, duration of low rainfall season, reliability etc), soil types, proximity to water table, pH, salinity and topography. Thus, there is a likelihood that wild tree populations will have adapted to their environments on a local scale.

Observations of melia in the nursery and field have shown differences in: bark and leaf colour; tree form; growth rates and branching habits (Kimondo and Kiamba, 2004). Both genetic composition and the management have generally influenced trees growth and form on the farms while those in the wild are mainly influenced by genetic composition. These observed differences however, require investigations to determine whether they have a genetic basis and their effect on growth as some traits in *M. volkensii* maybe genetically controlled and other traits may be as a result of proper and timely silvicultural management practices (Kimondo and Kiamba, 2004).

2.5.5 Rooting Hormones in Propagation

Rooting hormones are very necessary for easy to root and difficult to root plants for its role in improving the quality of root system developed, decreasing the rooting time and improved percentage of the cuttings rooted (Salman, 1988). Hartmann *et al.* (2002) states that treating cuttings with Auxins increases the percentage of cuttings that form roots, hastens root initiation and it is useful in propagating plants, and can increase production efficiency time from propagule to rooted liner. In contrast, too much rooting hormone can hinder root growth, so care has been taken to find the right concentration to use (Ruchala, 2002). Hammo *et al.* (2009) found that an increase of IBA concentration from 750 to 3000 ppm causes a significant increase in rooting percentage of shoot tip cutting of *Myrtus communis* when compared with other treatment, while an increase of IBA from 2250 to 3750 ppm significantly increases total roots length, roots dry weight and shoots number. Alsup and Cole (2000) noted that optimum rooting for Caddo Sugar Maple (*Acer saccharum* ‘caddo’) was obtained with shoot tip cuttings taken at the green softwood stage and treated with 5000 ppm IBA, and the average number of roots per cutting
increased as IBA concentration increased. The Root length was greatest with the 5000 ppm IBA treatment.

**Auxins**

Auxins are Plant Growth Regulators (PGR’s) well known to stimulate the rooting of cuttings (Hartmann *et al.*, 2002). The best-known auxins are naphthalene acetic acid (NAA) and indole-3-butyric acid (IBA). They are extensively used in the nursery industry and in creating substances like the well-known herbicides 2, 4-D and 2, 4, 5-T (Hartmann *et al.*, 2002). PGR’s have gained wide acceptance for optimizing the yield of plants by modifying growth, development and stress behaviour (Shukla and Farooqi, 1990). According to Salisbury and Ross (1992), IBA natural occurrence in plants has made it to be regarded as a hormone.

Plant hormones have a set of events that occurs during hormone-induced growth and development as follows: 1) Biosynthesis of the hormone 2) Transport or distribution to its site of action 3) Perception of the hormone signal by its cellular receptor and 4) Signal transduction leading to downstream events often at the molecular (gene expression) level (Hartmann *et al.*, 2002; Arteca, 2013).

Auxins often glycosylated or bound to proteins promote elongation, stimulation differentiation and branching (Palmer, 2000). The main effects of auxins on plant growth and development are as follows: initiate root development and meristematic activity, inhibit dormant bud development, have a role in leaf, flower, and fruit abscission, stimulate cell division, responsible for phototropism, stimulate ethylene production and loosen cell wall binding. PGRs (Auxins) profoundly contribute to root morphology, inhibit root elongation, increase lateral root production, and in the inducing of adventitious roots (Woodward and Bartel, 2005).

In comparison, the auxins that are hormonal are easily biodegraded not only by the tree's metabolism but by also other organisms (Arteca, 2013). They are quickly and easily degraded by light. In disparity, PGR auxins are much more stable and, as a consequence, can be prepared and utilised for long. Use of synthetic auxin on the base of cuttings tends to aid in stimulation of production of adventitious roots. Indole acetic acid (IAA), a type of auxin, can have this effect over only a certain concentration range. When the concentration is increased the auxin inhibits cell
elongation (Palmer, 2002) hence there is need for a study to know the best concentration required in specific species.

However, Rahman et al. (2007) disputes this listing down Auxins like 2, 4-D and NPA as auxins that inhibit root growth by reducing the cell production rate. It has been also established by various studies poor/low rooting percentages and delayed time for rooting resonates with the use of auxins (Ullah et al., 2013). In comparison with NAA trials for root regeneration IBA was more responsive than NAA.

The broadly used auxin for commercial rooting is IBA (Nickel, 1990). IBA, formerly a synthetic auxin, is in fact an endogenous plant compound (Ludwig-Müller, 2000). However, in accordance to Hartmann et al., 2002, IBA occurs naturally, but in less abundance amounts compared to IAA and further stated that for IBA to function it must be converted by plant tissue into IAA. At lateral root induction IBA is more effective than IAA, conceivably because, unlike IAA, IBA efficiently induces the development of lateral roots at concentrations that only minimally inhibit root elongation (Zolman et al., 2000); IBA is employed commercially for this purpose (Hartmann et al., 1990).

Auxin is produced largely in shoot apical regions, historically identified as the shoot apical meristem (Woodward and Bartel, 2005). However, application of auxin transport inhibitors such as NPA (Jensen et al., 1998) hinders the accumulation of IAA in the shoot apex, suggesting that apical auxin is transported from other regions, probably young leaves and developing leaf primordia (Avsian-Kretchmer et al., 2002). Ethylene gaseous hormone intimately interlinked to auxin may also inhibit auxin lateral transport (Suttle, 1988). Antiauxins which consist of the following compounds; triiodobenzoic acid (TIBA) and naphthylthalamic acid (NPA) interfere with the transport of auxin (Salisbury and Ross, 1992).

Other hormones that indirectly affect root initiation, but merely because of their effect on auxins include Brassinosteroids, Abscisic acid and nitric oxide. They have been known to influence either the transport of auxin, or it’s signalling (Malamy, 2005).

Auxin transport in plants is linked to polarity. The general explanation of polarity is that when tissue segments are cut, the physiological unity is disturbed. This must
cause a redistribution of some substance, probably auxin, thus accounting for the different growth responses (Hartmann et al., 2002). The correlation of polarity of root initiation with auxin movement has been noted in several instances (Haissig and Davis, 1994). It is also known that the polarity in auxin transport varies in intensity among different tissues. The polar movement of auxins is an active transport process, mediated by a membrane transport carrier, which occurs in phloem parenchyma cells (Woodward and Bartel, 2005). Cellular auxin movement and the subsequent polar gradient established between cells are important for normal development of the plant embryo as well as the shoot apical meristem. Some of the many chemical and genetic studies that validate this plant development include Reed et al. (1998) and Bhalerao et al. (2002) who identified IAA transport to be necessary for proper lateral root development, phyllotaxis (Reinhardt et al., 2003), vascular development (Mattsson et al., 2003) and embryonic axis development by Friml et al. (2003).

Auxin interactions with other hormones results to reduced auxin transport. The Auxin/cytokinin ratios have been implicated in many root development processes (Malamy, 2005). Whenever a tree is ruthlessly pruned (or worse, lopped) the growing tips and most, if not all, of the leaves are removed an internal hormonal imbalance is considerably created. The hormonal imbalance is because the auxins are removed even as moderately high levels of cytokinin are still produced from the roots. Generally, an increase in auxin content to decreased cytokinin content favors adventitious formation of roots whereas a decreased auxin to an increased cytokinin ratio favors adventitious bud formation (Bouza et al., 1994).

Various sources (Ljung et al. 2005; Malamy 2009) report that high endogenous IAA content and low cytokinin content is needed for good rooting. Malamy (2005) found that Arabidopsis thaliana plants, engineered to have lower cytokinin levels, have a larger number of lateral roots. Cytokinin and Auxin levels are inversely correlated in vivo (Shakirova et al. 2010) and auxin treatment can rapidly inhibit cytokinin biosynthesis (Nordström et al., 2004).

Variability in forming adventitious roots has been attributed to differences in auxin metabolism (Salamini, 2003). Comparatively IBA enhances rooting to IAA. This has been attributed to differences in receptor binding, compartmentalization, greater
stability and differences in tissue sensitivity between the two auxins (Woodward and Bartel, 2005).

Over time auxin has repeatedly been confirmed crucial for the initiation of adventitious roots on stems and indeed, it has been shown that divisions of the first root initial cells are dependent upon either applied or endogenous auxins (Gaspar et al., 1990). The development of root primordium cells is dependent on the endogenous auxins in the cutting and on a synergic compound such as a diphenol. These compounds lead to the synthesis of ribonucleic acid (RNA), which are prompted by the root primordium initiation (Hartmann et al., 2002). The employment of some plant growth retardants, together with auxin, to improve the rooting capacity of cuttings in some species has been a great milestone (Davis and Haissig, 1990; Pan and Zhao, 1994).

2.5.6 Seed Orchard Production

By definition, seed orchards are plantations of trees exclusively and intensively raised for the sole production of high quality seeds. They are founded from selected plus trees, with a broad genetic diversity (many seed mother trees), generally based on phenotypic appearance where seed sources termed as “selected” (Mbora et al., 2009) are produced. Or else in case of advanced generation seed orchards with genetic tests available (Hansen, 2008), where genotypic selection is established producing “tested” seed sources (Mbora et al., 2009). These seed sources’ (seed orchards) are designed to meet the so more often goal of production of superior seeds (Nikles, 2006). Seed orchards established by seeds are Seedlings Seed Orchard (SSO) and those established by clones are Clonal Seed Orchards (CSO). In general the product in both cases is seed.

Every so often genetic experiments form an incorporated portion of the seed orchards where the tests are preserved at an alternative site. Each generation number typically connotes a highly developed generation seed orchard assuming the order 1st, 2nd, 3rd that refers to seed orchards established after 1, 2 and 3 selection and breeding generation (Talbert and Marshall, 2005). The significance of tree domestication in capturing an array of genetic potential is lost if, when the selected germplasm of multipurpose trees is out planted in the field
and does not either establish or tends to grow poorly (Indieka et al., 2007). These struggles have been encountered in the dryland reforesting programmes where low rainfall is experienced and the soil nutrients are limiting or whenever the seedlings have been left exposed to the grazing animals. The environmental changes experienced by the plants during transplanting may be severe if inadequately prepared, and may result in severe droughting of the plants, which can be at least partly alleviated by irrigation (Newton et al., 1993).

*Melia volkensii* trees are currently heavily exploited for timber in the drylands leading to high erosion of their genetic variability. This selective tree cutting has exacerbated the removal of best trees from existing sources necessitating for the need to identify more *M. volkensii* seed sources like the seed orchard development. However, surveys done in 2004 have shown that some superior trees still exist in those areas that are not easily accessible (Kimondo and Kiamba, 2004). As a result, it is necessary to identify such trees and conserve their genes insitu in order to capture a larger gene pool. The selection for improvement should focus more into the natural range (influenced by genetic pool) rather than on the farms where tree growth is influenced by both the genetic composition and the management of the trees.

In provenance trials in the southern drylands of Kenya *Melia volkensii* demonstrated superior growth compared to both fast growing species such as *Eucalyptus* and *Senna* and indigenous species like *Croton megalocarpus* and *Acacia polyacantha* that are commonly grown and promoted by researchers in the drylands (Mulatya and Misenya, 2004). Siakago (Mbeere) and Kitui provenances of *M. volkensii* reportedly had superior growth as compared to those from Kibwezi and Ishiara (not geographically far) hence the need to optimize Mbeere provenance growth through appropriate selection and ultimate domestication through seed orchard establishment (Kimondo and Kiamba, 2004).

### 2.6 Functional Uses of Melia volkensii

**Fodder:** To most farmers the leaf fodder is of high nutritional value to both goats and cattle. As the dry season closes, a time when the fodder is scarce, the tree is pruned to the benefit of some domestic animals that consume the fleshy drupes once
they fall (Wekesa et al., 2012). It is reported that the fruit pulp contains an approximate unrefined fat and protein content of 10% and over 12% respectively; as the matured leaves contain more than 5% and 21% crude fat and protein content correspondingly (Stewart and Blomley, 1994).

**Apiculture:** *Melia volkensii* is among the top species used to make log hives in light of the fact that the wood is effectively formed since its easily workable. The exceptional bee forage produced by the flowers heightens its practical preference (Otiato et al., 2008).

**Fuel:** The branches severed amid routine management to give feed are frequently air/sun dried in the field before being utilized as fuel. However, fuelwood from *Melia volkensii* is unfavourable due to the production of unpleasant smoke terming it as a poor quality charcoal tree (Mfahaya, 2008).

**Timber:** The heart shaped coarse-textured melia wood with 0.62 density is easily worked on, planes well and is durable. It’s extremely drought, termite and decay resistant property thus sets it far ahead of other species like *Vitex keniensis, Khaya species* and *Ocotea usambarensis* (Orwa et al., 2009). Locally, the timber is valued for poles and furniture, door and window frames, doors shutters, rafters; good for making containers, acoustic drums and mortars (Runo, 2012).

**Poison:** Preparations of the leaf are effectively utilized as insect and anti-fly agents on goat kids. Further applications of these preparations have combated organisms such as *Schistocerca gregaria* -against its anti-feeding activity and mosquitoes - against its larvicidal and developmental inhibitory effects (Isman, 2006).

**Soil improver:** The influence of the overwhelming shedding of leaves of *M. volkensii* -amid the later stages of crop growth- on the enhancement of crop yields has not been acknowledged by many farmers (Orikiriza et al., 2009).

**Inter-cropping:** Under good consistent farm-management practices of lessening the canopies shade effect, *M. volkensii* has passed the compatibility test as an intercrop by most farmers. This would otherwise adversely affect the light-demanding crops. Melia’s character of being deep rooted has led to minimal interference with ox-plough cultivation adding to its great advantage for intercropping (Stewart and Blomley, 1994).
2.7 Pest and Disease Management for Melia volkensii

*Melia volkensii* has suffered from recent incidences of disease attacks in the field – based on increasing reports from farmers and at the nurseries where high post germination mortality has been recorded (Njuguna *et al.*, 2004). The damping–off disease common at the nursery is a function of the soil moisture, pathogenic materials in the soil, seed defects and temperature extremes. Normally, cool wet soils favour the development of this disease hence a correct diagnosis is key to effective control measures (Pfleger & Gould, 1994). Njuguna *et al.* (2004) identified a host of fungi, (*Fusarium* spp, *Colletotrichum* spp, *Alternaria* spp, powdery mildews and *Phomopsis* spp) as being the causal agent right from the seedling in the nursery to the mature trees in the field. Other form of harm occurs especially during the juvenile phase where the animals afflict the sensitive trees through trampling and browsing. In its natural untamed habitat, however, the tree has been reported in a number of cases to suffer damage from larger animals like elephants (Lennah, 2014).

2.8 Significance of Melia volkensii

2.8.1 Impact of Melia on the Farmland

Agroforestry represents varying combinations of woody, agricultural, and animal production systems. For millennial agriculturalists–on their pasture lands, farms, and homesteads–have created and overseen agroforestry frameworks for nurturing trees (Roshetko *et al.*, 2007). By convention these frameworks have delivered a wide assortment of items, for example, fuelwood, timber, organic products, vegetables, spices, tars, and prescriptions, essentially to address family unit issues yet additionally to create some income generating projects through sales in the regional markets (Roshetko *et al.*, 2007). Regardless of how agroforestry is practiced its overall purpose is to attain ecological stability and at the same time provide sustainable benefits to the users of the land (Mbow *et al.*, 2014).

The Forest Policy of 2014 emphasizes the development of farm forestry as a way of increasing the deteriorating forest cover, diversifying subsistence products and incomes while contributing to the protection and conservation of soil and water resources (Larson and Dahal, 2012). This policy underscores the need to support
farmers with sound management and utilization principles, incentives, information, better germplasm and marketing strategies. Farmers are advised to make and commit to a list of priority products from multipurpose trees in order to optimise production. Vision 2030 has also stipulated similar emphasis on the contribution of forestry towards conservation of water resources (GoK, 2007).

Farmers in the drylands generally have larger tracts of land than in other areas (Kioko and Okello, 2010). This land, if put under appropriate high value trees; can earn income for the farmers besides protecting the environment. Tree farming is also an avenue for diversifying investment activity at farm level. *Melia volkensii* is an indigenous tree species found in the drylands of East Africa east of Mt. Kenya to southern Tanzania (Hanaoka *et al*., 2012). It is a fast growing tree, drought tolerant and produces high quality hardwood timber used to make furniture, door and window frames (Runo, 2012).

*Melia volkensii* large genetic variation in seedling population can be a drawback for agroforestry because there is no place for inferior seedlings (Hanaoka *et al*., 2012). However, its deep tap root system ensures seedlings survival in the dry season in the tropical drylands (Ong *et al*., 2006). Disease resistant, elite trees with good growth characteristics can be cloned by means of shoot or root cuttings. However, the rooting percentage is rather poor (Mulanda, 2016). Moreover, the trees produced through vegetative propagation have superficial rooting. Where tree roots are shallow, they occupy the same soil layers as crops and compete for water with crops, which leads to considerable yield reductions in mixed plantations (Wekesa *et al*., 2012).

*Melia volkensii* is a tree species that grows rapidly, reaching over 1 m height in one year. Even with this fast growth, Melia in its initial stages does not compete with crops as it has a light crown and the root system is not extensive (Muok *et al*., 2010). It is therefore possible to intercrop the tree with most agricultural crops. However, under plantation, it is recommended that only short crops such as beans are planted in the first year since taller crops such as maize shadow the tree. After four years the tree canopy does not favour intercropping due to shading effect on the crops (Muok *et al*., 2010).
However according to Mulatya et al. (2002), full grown melia trees compete for resources with crops leading to yield losses of up to 50% because of canopy shading and root competition. The effects of shading alone suppress crop yields at rates greater than that caused by 50% artificial shading. Canopy and root pruning on the melia trees has been recommended to reduce competition (Ong et al., 2007). Besides, trees without a tap root are easily uprooted by the destructive power of tropical wind storms.

Growing of *Melia volkensii* has the potential to increase the income of farmers in the drylands (Muok et al., 2010). KEFRI through its Dryland Forestry Programme has over the years developed technologies to optimize the growing of *Melia volkensii*. The knowledge on propagation, establishment and management of Melia accumulated over the years of research has led to the birth of several technologies in weeding, protection, pruning and pests and diseases management (Wekesa et al., 2012) and recently Melia seed and seedling production and distribution strategies (Kamondo et al., 2016).

### 2.8.2 How Melia can Improve Livelihoods in Mbeere

In accordance to the Welfare Monitoring Survey of 1997, the number of people in absolute poverty in Mbeere was 102,327, which translates to 56% of the total population. Rural poverty stood at 57.42% while rural hardcore poverty in the district was 42.38 % (GoK, 2002). This implies that more than half of the total population of Mbeere live below poverty line (NEMA, 2009). The 2005 strategic plan for Mbeere identified the causes of poverty as poor access to water due to unreliable and low rainfall levels, inadequate infrastructure, the semi-arid state of the district characterized by persistent drought, unemployment of the youth which increases dependency, inaccessibility to credit facilities etc. Diseases such as HIV/AIDS have also made people poorer as most children are orphaned after their parent’s death. In 2002, Mbeere District development plan cited population growth as an additional key development challenge in the district (GoK, 2002).

The poverty level in Mbeere district stands at above 60%, while dependency ratio is 100:97.8 (GoK, 2005). High poverty levels can be attributed to over reliance on agriculture, persistent drought, poor soils and erratic rainfall. High dependency levels are as result of large household size with majority of the population consisting
of the young and non-working persons. Charcoal making has been a very common way of survival during the harsh conditions among the poor (Luvanda, 2016). Charcoal making has on the other hand been one of the main causes of vegetation degradation and land conversion due to selective cutting of the big trees. Poverty has led to subdivisions of the already small pieces of land for reselling (Muchena et al., 2005).

The current emphasis of afforestation in arid and semi arid lands is based on the planting of high value trees and shrubs (Wekesa et al., 2011). Such trees species provide the farmers with valuable products and services to meet their indispensable needs in terms of shelter, food, and clothing. This move has been found to act as an incentive to farmers to plant trees on their farms. For the past two decades, research work has attempted to identify such tree and shrub species, both indigenous and exotic. In most trials, Melia volkensii has outperformed a great number of other dryland species (Kidundo, 1997) by providing high valuable durable termite resistant timber, fodder and forage to livestock and apiculture to mention a few. Melia can thus be a viable option in improvement of livelihoods and reducing the poverty levels in the area if propagated as an investment.

2.8.3 Impact of Melia on Sustainable Development

Dryland forestry plays a vital role in maintaining an ecological balance as well as increasing the national forest cover. Dryland forestry is concerned with the establishment of trees and shrubs for conservation and sustainable development through harnessing the enormous potentials in the woodlands cover that constitute over 50% charcoal source for the urban energy requirement and 80% rural woodfuel (Wekesa et al., 2011). Dryland forestry Programme is geared towards contributing to the harnessing and development of dryland resources by generating technologies to improve woodlands management and conservation, thereby contributing to poverty alleviation at local and national levels (Kioko and Okello, 2010). This plan is broad enough to facilitate the implementation of the global objectives expressed in multilateral environmental agreements (MEAs) to which Kenya is a signatory.
2.8.4 Impact of Melia on Climate and Environment

*Melia volkensii* being a multipurpose dryland species seeks to positively impact the environment. It provides numerous meaningful functions simultaneously. It aids in combating the devastating effects of desertification by modification of local microclimate, that is, acting as a micro-climate regulator. Acts as a wind break planting (wood lots) that increase agricultural production and water use efficiency through stabilizing the soil and preventing soil erosion (Muok *et al.*, 2010). As linear plantations that offer protective buffer systems along roads and waterways stabilizing channels and providing wildlife habitats and shade. Furthermore as scattered plantings that enriches the soil through the addition of manure from decomposition and mineralization (Kariuki *et al.*, 2008).

In the context of agroforestry, *M. volkensii* tree domestication can increase productivity, resilience and value alongside providing mitigation and adaptation opportunities to combat climate change (Verchot and Noordwijk, 2007), enhancing nutrient cycling and soil formation, preventing soil erosion and siltation and it is also able to help prevent deforestation and biodiversity loss (Budiani and Viii, 2009).

2.9 Domestication of Melia as a Multipurpose Tree

By description, Tree domestication alludes to how (people included might be researchers, common experts, business organizations, timberland tenants or ranchers) select, oversee and proliferate trees (Simons and Leakey, 2004). The concept behind tree domestication takes after the reception of plant approaches concentrated on quality germplasm generation for more extensive development to serve the requirements of smallholder agriculturists from the typical concentrate on tree change in view of rearing and ordinary woodland tree choice. Domestication utilises the variability within species, by selecting trees with desirable traits (Atangana *et al.*, 2002) and propagating them sexually or asexually, depending on the appropriate strategy for the species and the products, while keeping a broad genetic base through gene banks.

In East Africa, there’s heavy reliance on trees and shrubs by pastoralists living in the dry savannahs. Milimo *et al.* (1994) maintains that this overreliance is for the important supply of firewood, poles, posts (wood) and other (non-wood) products
such as gums, fodder, browse, resins, fruits, food, medicines and for soil fertility retention. Further on in tourist sector, the black decorative woods particularly *Diospyros* spp., and *Dalbergia melanoxylon*, have emerged of great commercial importance as carvings (Milimo et al., 1994). However, in Agroforestry, amidst all this benefits, a majority of the tree improvers are facing great decision making challenges as to whether single or multipurpose characteristics of this trees and shrubs should be selected when breeding or selecting superior lines of multipurpose trees (Milimo et al., 1994) for future generations.

Muchiri and Mulatya (2004) documented that in the eastern and coastal regions of Kenya, *Melia volkensii* is heavily exploited for its high quality timber. Exploitation targets mature trees of good form, leaving trees of poor form. The trend is likely to worsen considering the prevailing shortage of alternative hardwood species in high potential areas. To cope with this challenge, most of the dryland afforestation projects have embarked on aggressive Melia afforestation programmes. *M. volkensii* is a rapidly growing species delivering quality timber in 10 to 12 years (Mulatya, 2000; Kimondo, 2002; Muturi et al., 2003). The growth on the farm is even faster than in the wild, suggesting tremendous potential gains through domestication. Most farmers sell their Melia trees as standing trees. It is however much more profitable to harvest and sell processed timber than the standing tree because timber fetches higher prices in the market. One hectare for instance can accommodate 400 melia trees at 5 m by 5 m spacing and by maturity time, some trees could be lost naturally through animal damage or planned management procedures such as selective thinning (Muok et al., 2010). Others may also be of poor form for timber. One Melia log from a mature tree can produce 300 running feet of 6 x 1 inch timber and considering a harvest of 250 trees of good quality at maturity, one hectare can yield a potential of 75 000 feet (250 trees x 300 feet) of 6 x 1 inch timber, of which if a price of Ksh. 40 for one foot of 6 x 1 inch timber is assumed it can earn a farmer Ksh.3,000,000 at the end of the rotation period (Muok et al., 2010).

A major impediment to successful domestication programme is the source of good germplasm (Njuguna, 2010). Unfortunately, it has been observed that the local communities in most areas have cut the best and mature plus trees for their own
local use. This selective cutting of the best trees has ultimately caused the seed collectors to sample from the presumed existing superior stands undermining the value of domestication.

2.10 Literature Gap

The future of forestry in Kenya is leaning towards the marginal areas. Kenya ASAL regions possess great capacity for a number of dryland afforestation and reforestation projects all aimed at attaining the constitutionally targeted tree and forest cover of 10%. The indigenous *Melia volkensii* exclusively stands as the most valuable species to sustain these projects and to cater for other Agroforestry purposes for the inhabitants. Despite its great ecological and economic potentials in agroforestry its domestication efforts still need to be upgraded through vegetative propagation to ascertain the vegetative part from the plus tree that would produce great rooting potential contributing to the mass propagation of high quality trees. Further on gaps to ensure desired genetic qualities are captured through differentiation of the cuttings into top, bottom and full portions that could influence rooting compounded by the endogenous root hormonal imbalances need to be investigated. Moreover the ideal merchantable heights (synonymous to the age of the donor tree) from which to obtain planting materials for high quality timber production need also to be established. IBA rooting hormonal influences at optimal concentrations (both direct and indirect) on the rooting of Melia sectional cuttings of different diameters and lengths need to be determined and expounded on for the sustainable utilization of the species.

Therefore, investigation on the visual parameters such as the cutting size, sections and portions would further enhance the efficiency of melia propagation for Kiambeere provenance and help to provide truthful information on the conservation and sustainable utilization of the species.
CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Study Area

The research was carried out in Kiambeere/Mbeere south Sub-County (Gachoka Division) in Embu County as shown in Figure 3.1.

![Map showing the study area](source.png)

**Figure 3.1:** Map showing the study area

*Source: (ILRI, 1998)*

Mbeere South sub-county lies in the Agro ecological zones Lower midland (LM 3, 4 and 5) (Jaetzold *et al.*, 2006) at an altitude of approximately 500 m-1200 m above sea level. It has an annual temperature range from 20 °C to 28 °C with an average of
about 24 °C and average annual rainfall ranging from 700 mm to 900 mm (Jaetzold et al., 2006). The population density is 105 persons per Km² with an average farm size of slightly less than 5.0 ha per household (GoK, 2010). The rainfall is bimodal with long rains (LR) from mid March to June and short rains (SR) from late October to December hence two cropping seasons per year. The soils are predominantly Ferralsols and Acrisols (Jaetzold et al., 2006).

3.2 Experimental Design and Treatment Combinations

To facilitate domestication it was important to identify the desired tree characteristic by the community. Therefore timber use among other multipurpose functions was identified for the domestication of Melia. The biophysical and ecological dimensions of agroforestry captured in this study were measured quantitatively to provide the empirical evidence needed in realization of the objectives of the study. A complete block experimental design (CBD) was used with three replications for mass propagation of Melia volkensii. The blocks were five as follows: IBA concentrations (0.25%, 0.51%, control) with the control having been treated with solely tap water. Secondly, cutting sections (stem, root) which represented cuttings obtained from the stem and from the roots. Thirdly, cutting portions (bottom, full, top) where each section was further differentiated to obtain distal (top) cuttings, proximal (bottom) cuttings that occurred at the proximal end attached to the mother main stem prior to severing and uncut (full) cuttings which consisted of the top and bottom portions undifferentiated. Lastly, diameters of cuttings (≤ 0.5 cm and ≥ 0.5 cm) and cutting lengths (≤ 12 cm and ≥12 cm) all totalling to the initial five blocks. The number of treatments was 9. Cutting preparations top, bottom and full, three IBA hormone concentrations (0.51%, 0.25% and 0% control) in the root and stem sectional cuttings. Hence the overall treatments were 18 (9 from stem and 9 from roots) as illustrated in the Table 3.1. Further on, literature review was undertaken to complement the quantitative approach adopted for this study.
Table 3.1: The treatment combinations

<table>
<thead>
<tr>
<th>Cutting</th>
<th>Part Differentiated</th>
<th>IBA Hormone conc.</th>
<th>Treatments Code</th>
<th>Diameter classes of cuttings (cm)</th>
<th>Length classes of cuttings (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM</td>
<td>Top</td>
<td>0.25</td>
<td>ST 0.25</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Top</td>
<td>0.51</td>
<td>ST 0.51</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Top</td>
<td>Control / 0</td>
<td>ST C</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Bottom</td>
<td>0.25</td>
<td>SB 0.25</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Bottom</td>
<td>0.51</td>
<td>SB 0.51</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Bottom</td>
<td>Control / 0</td>
<td>SB C</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Full</td>
<td>0.25</td>
<td>SF 0.25</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>STEM</td>
<td>Full</td>
<td>0.51</td>
<td>SF 0.51</td>
<td>&lt;0.5</td>
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<tr>
<td>STEM</td>
<td>Full</td>
<td>Control / 0</td>
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<td>&lt;0.5</td>
<td>&lt;12</td>
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<tr>
<td>ROOT</td>
<td>Top</td>
<td>0.25</td>
<td>RT 0.25</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
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<tr>
<td>ROOT</td>
<td>Top</td>
<td>0.51</td>
<td>RT 0.51</td>
<td>&lt;0.5</td>
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<td>ROOT</td>
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<td>Control / 0</td>
<td>RT C</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>ROOT</td>
<td>Bottom</td>
<td>0.25</td>
<td>RB 0.25</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
<tr>
<td>ROOT</td>
<td>Bottom</td>
<td>0.51</td>
<td>RB 0.51</td>
<td>&lt;0.5</td>
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<tr>
<td>ROOT</td>
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<td>Control / 0</td>
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<td>ROOT</td>
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<td>ROOT</td>
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<td>ROOT</td>
<td>Full</td>
<td>Control / 0</td>
<td>RF C</td>
<td>&lt;0.5</td>
<td>&lt;12</td>
</tr>
</tbody>
</table>

3.3 Sources of data

The study utilized Better Globe Forestry Ltd nursery at Kiambeere that was located near the Kiambeere dam but on a level ground. This ensured continuous reliable supply of water for the seedlings. The area was heavily guarded by human guards.
with all round fencing from animal intrusions hence further making the environment for domestication of Melia conducive.

The purpose of this study was to establish an ideal nursery methodology that would catalyse rooting on the superior *M. volkensii* (stem and root) cuttings for its mass propagation. As a result a comprehensive survey was conducted where primary and secondary data was collected. Primary data was obtained from the study sites through observation walks and interviews with the farmers to access information on the selected trees in their farms. The information included the age of the tree and reason for planting mukau tree. Secondary data comprised of a review of published information such as thesis, reports, conference proceedings, text-books, journals extracted from the library and from the internet.

3.4 Sampling design

Clustering sampling method was used where each cluster consisted of a number of individual Melia trees with the group of sample plots located close to one another. The six provenances (Kathiani, Ngungani, Kasyongo, Mutanda, Musyosia, Kamuthale) represented the sample plots. Further snowballing sampling technique was used to identify individual farmers with outstanding Melia trees in their farms.

3.4.1 Stockplant selection and sample size

Initially 50 *Melia volkensii* plus trees were selected across six provenances (Kathiani, Ngungani, Kasyongo, Mutanda, Musyosia, Kamuthale) as the base population for the propagation programme. The guiding factor in the selection was identification of healthy trees that could enhance timber production. Stem straightness was measured by clear straight boles. The crown nature/ number of branches were attained by actual counting of the branches- densely crowned trees were omitted. The straight boles assessment was in relation correlated to the number of branches as naturally a heavily crowned *M. volkensii* tree would appear slanted /bent due to the weight. A tree was assumed healthy/non-diseased for collection of cuttings where visible pests were not observed on the bark of the trees. The accepted tree heights attained by the suunto hypsometer gadget ranged from 9 m and above while the merchantable length was > 7 m. The DBH was attained by the help of a diameter tape at starting measurements of 25 cm and above. A tree data collection
sheet (Appendix I) was used to fill in the above tree characteristics details guaranteeing an accurate refined selection procedure and hence *M. volkensii* plus trees. Plate 3.1 shows one of the plus trees that were selected.

![Plate 3.1: Straight boled plus tree of Melia in farmer’s fields](image)

The data collected as afore detailed followed the following steps. It was first run through excel programme coded and a selection criterion that clearly displayed the traits that were indicative of good log/timber production established. The said selection criterion was based on the following key parameters; tree form (branching habit, bark/tree health, stem straightness), merchantable length and the tree height all orientating on identifying the best for timber use. Finally, a guide list consolidating the following elements was compounded. Branch diameter in three group levels small (≤ 4cm); medium (5-8 cm); large (≥ 8cm). Four level of classes in decreasing order of the best to the least preferred to measure tree form (class 4- straight and lightly branched; class 5- straight and moderately branched; class 6-slightly bent and lightly branched; class 7- slightly bent and heavily branched). Merchantable lengths were also measured in three levels (tall > 10-12 m; medium 7-9 m and short 4-6 m). For the branching habit, lightly branched plus trees had 2-9 branches count;
moderately branched tree had 10-20 branches and the heavily branched trees were those that had greater than 20 branches. This index consequently formed five categories to go on record as the guide for the selection of the 25 *M. volkensii* superior plus trees. Trees in class A had (straight clear boles, Tall, lightly branched, small-medium branch size, straight grains); class B had (Straight, Tall-medium heights, boles with minor defects, light- moderately branched, small-medium branch size, straight grains); class C had (Straight, with medium – short heights, boles with minor defects, light- moderately branched, small-medium branch size, straight grains); class D that had (Straight, medium- short heights, boles with minor defects, light- moderately branched, large branch size, straight grains); class E trees (bent, short, boles with major defects, light-heavily branched, large branch sizes, spirally grained). The last class (E) had poor qualities and hence was out rightly rejected for the selection. Sources of defects included either natural (resin), man-made (badly pruned with dark large notches) or animal disturbances to the bark of the tree.

They were however re-evaluated through the help of MS-Excel computer programs where the trees that failed to achieve the superior traits standard of plus trees in terms of their good tree form (stem straightness, branching habit, apparent resistance to disease and pest), growth vigour, diameter breast height, merchantable height and tree height were dropped and replaced. A sample size of 25 with superior pronounced features (straight bole, tree height, merchantable length and DBH) and within an age bracket of (4-28 years) was identified and selected to reproduce their clones asexually through cuttings by initiating root suckers and shoot coppices. This would later form root and stem cuttings respectively (Indieka and Odee, 2004). They occurrence was in the farms (a large percentage) and in the wild at Kiambeere.

### 3.4.2 Equipment used

All the materials for the efficient propagation were congregated. They included the rooting media which included (sun-baked sand), thermometer, hygrometer, Vernier calliper, a cooler box, pruning shears, IBA powder rooting hormone (0.51% and 0.25% ), scalpels, secateurs, paper labels, cups, non-water soluble marking pen, clear polythene papers, pen knife, propagator beds, hydrochloric acid (HCL), and rubber bands.
3.5 Clonal propagation procedure

For effective “mukau” clonal propagation, the study was divided into three phases as follows.

**Mapping out Phase**

This first phase (that was succeeded by a reconnaissance survey) took three weeks in August 2011. It entailed mapping out; that is identification, selection and labelling based on the following tree parameters- tree height, diameter breast height, merchantable height and the number of branches. Under this phase, accuracy was top priority hence proved the most crucial stage of the experiment since it formed the foundation for the success of the succeeding stages and ultimately the whole research.

**Wounding Phase**

The second stage (that took two weeks in November 2011) involved injuring of the 25 plus trees selected to initiate root suckers and shoot coppices. The wounding applied for the root cuttings that were obtained by injuring the roots using trenches dug at a depth of 30cm and at a distance of 0.5m from the mother plant.

**Harvesting Phase**

The harvesting of the coppices/shoot suckers and the successful planting into the non-mist propagators-the last stage- took place from (April-July 2012). Healthy cuttings were harvested and taken to the nursery which was 40km away. The harvesting of the stem cuttings involved climbing to the crown of the plus tree and the use of the secateurs to cut off the branch with the most juvenile cuttings. This was because none of the epicormic shoots coppiced as anticipated. Branches with berries and flowers were avoided. Great focus was made on the growth direction of the branches- it had to be stems vertically growing on the primary axis -and on the juvenility aspect (visual assessment in terms of the size/diameter of the shoot) where smaller sized leafy shoots were taken into consideration. After the branches were felled they were placed on the clear sterilized large polythene under a shade. The pruning shears were used to trim off excess branches and leaves to achieve a manageable outlook.
On the other hand, harvesting of root cuttings that occurred on the ground, involved excising them from the selected mother plus trees and washing the dirt on them with clean tap water. They were then placed on sterilized polythene under shade. The same procedure as for the aforementioned stem cuttings was followed. Due to the distance of the plus trees to the nursery, a cooler box was used to ferry the sensitive shoots wrapped in moist plastic paper bags cushioning them from the hot dry temperatures that characterises the area.

Unforeseeable climatic factors- such as erratic/heavy rains that suffocated many coppices, physiological stage of the plus tree and human interruption as it was during the planting season for the farmers contributed to reduced root cutting numbers.

3.5.1 Raising of cuttings

Propagators assembly and the rooting media

Four large non-mist propagators were constructed. The first pair of non-mist propagators with polythene and their replicates allowing 30% sunlight (2 m by 1 m and 1.2 m by 0.6 m - 8” at the front and 10” at the back) were filled with sun-baked river sand at a height of 3 inches. The use of river sand that had been in the sun for two months was to provide a sterilized inert substrate free of any microorganisms. The river sand again complimented the *M. volkensii* fragile cuttings as the air and water holding capacities are in tandem with the required amount and also because water-logging attracts damping off disease. Sterility was crucial so HCL diluted water was used to wipe off the surfaces of the propagators after assembling. Additionally, fungicides such as Bavistin and Ridomil systemic fungicides were applied interchangeably to avoid a build-up of a fungi resistance hence zero fungi attacks.

Preparation of cuttings

To determine how the morphological characteristics of the cutting influence the rooting success of *Melia volkensii* cuttings from the stem and roots, the cutting diameter and the corresponding length was investigated.
An indoor location within the nursery was chosen as an ideal place for the preparation. The long branches were severed into smaller convenient sizes. Thirty leafy cuttings of 2–4 nodes (lengths ≥8 cm but <16 cm; diameters ≥3mm but <20 mm) were prepared for each sectional treatment. The lengths and diameters measured and recorded as per the objective of the study were dictated by the amount of wood on the vine. Further, the long branches were made smaller pieces, differentiating them into top, bottom and full parts with the basal end at a 45° angle whilst the tip at slanted angle. This was to avert water stagnation at the tips and hence rooting concentration at the base of the cuttings. Moreover polarity was observed as the rooting part was clearly distinguished because upside down cuttings will not root.

Two to four leaves (depending on leaf size) were left attached to each cutting, and all other basal leaves were removed. Terminal buds and leaves that were too soft were discarded. Leaves that were larger were trimmed to approximately 30 cm each. The prepared cuttings were then put in sterile polythene bags containing the labels marked with; the plus tree number, the section of the cutting and the percentage of IBA rooting hormone to be applied. Proper safety and sanitation procedures meticulously followed included but not limited to; using HCL water to sterilize equipments as well as cleansing of the hands before handling the cuttings, removal of foreign bodies as well as the dead cuttings to avoid spread of infections.

**Planting into propagators**

A non-misting cutting propagation was adopted. Fungicide bavistin df (5 ml put in 9 litres of water) was sprayed into the propagators prior to any insertion of the cuttings that was done sporadically as per the distance of the plus trees to the nursery. After all details were recorded, the insertion began one at a time based on the number of cuttings that were available at hand, since the cooler box couldn’t hold them for long. This was done to avert high mortality of the cuttings. A small portion of the rooting powder was set apart in a different small container so as to avoid contaminating the content in the stock container. The basal dry dipping method was used where the ¾ inch of the basal wounded end of the cutting was wet and dipped into the IBA rooting powder for about 5 seconds before planting. Excess powder was tapped off and care was made to ascertain that no rooting powder came into
contact with other parts of the plant. Each portional cutting (top, bottom and full) from the roots and stem section underwent the aforementioned IBA rooting powder dipping procedure just as their individual labels dictated and the cuttings inserted into the rooting medium to a depth of 2-3cm. The date of the setting and the treatments applied were visibly labelled in the propagators (Plates 3.4) and recorded.

The propagators were maintained under the following standard range of conditions; temperatures 22-28\(^0\) C and humidity 70-90%. The watering regime followed after every five days as per the weather effect on the rooting media. The polythene sheet used to construct the propagators was weekly wiped off dust to allow sufficient lighting for proper rooting. The assessment and removal of infected cuttings was after every 15 days while the removal of foreign bodies and dead leaves was after every 3 days as this would otherwise introduce fungal infections.

Plate 3.2: Well planted cuttings in the furrows

From the third month, assessment was done twice weekly for each cutting basing on the number of roots, total root length, leaf abscission, leaf regeneration and cutting death, until the completion of 120 days counted planting into the propagators. The proportion of deaths was calculated as the percentage of cuttings with a completely brown rotting/peeling stem. A root was described as the emergence of any rounded growth with a minimum length of 1 mm from the cutting. New sprouts, roots (>1mm) and shoots were recorded when they could be clearly identified.
3.6 Data analyses

Analysis of variance (ANOVA) using GENSTAT version 14 (VSN International, 2011) was used to test levels of significance in the means of treatments. Significant differences between treatment means were separated using Least Significant Difference Test (L.S.D) at $P=0.05$. T-tests tested hypotheses and correlations were done to assess the relationships between varieties.
CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Effect of IBA rooting hormone on the Rooting and Shooting of Melia cuttings

4.1.1 Effect of IBA concentrations on shooting of root and stem cuttings

IBA Concentration of 0.25% recorded a significantly high shooting percentage than the counterpart 0.5% concentration with root sectional cuttings recording highest of (53.8 %). Similarly in the stem sectional cuttings, 0.25% gave the highest shooting occurred at (32.4%) followed by IBA 0.5% (30.16%) then the control IBA treatments (27.55%). This gave the indication that root sectional cuttings performed better in shooting than the counterpart stem sections as it’s evident in Table 4.1. The low shooting under control treatments for both the stem and root sectional cuttings therefore showed that IBA hormone enhances the sprouting percentages of cuttings. The differences in mean shooting percentages of the root and stem cutting sectional were ultimately found to be highly significant (p< 0.001).

Table 4.1: Shooting percentages for stem and root cuttings under varying IBA concentrations

<table>
<thead>
<tr>
<th>IBA concentration</th>
<th>df</th>
<th>Root Sectional cuttings (%)</th>
<th>df</th>
<th>Stem sectional cuttings (%)</th>
<th>Grand mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>54</td>
<td>53.8</td>
<td>123</td>
<td>32.4</td>
<td>39.15</td>
</tr>
<tr>
<td>0.5</td>
<td>37</td>
<td>45.56</td>
<td>103</td>
<td>30.16</td>
<td>34.99</td>
</tr>
<tr>
<td>control(0)</td>
<td>4</td>
<td>33.12</td>
<td>22</td>
<td>27.55</td>
<td>29.3</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td>*&lt;0.001</td>
<td></td>
<td>*&lt;0.001</td>
<td>0.412</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>20.52</td>
<td></td>
<td>20.5</td>
<td>14.01</td>
</tr>
</tbody>
</table>

*Denotes significance at p=0.05

4.1.2 Effect of IBA concentrations on shooting of different portions (top, bottom, full) of stem and root sectional cuttings

The highest shooting percentages were realized in the root portions. Root full portion cuttings with IBA 0.25 % (RF 0.25) gave the highest shooting percentages at (66.78 %). Root top portions with IBA 0.25% (RT 0.25), IBA 0.5% (RT 0.5) and IBA 0% (RT 0) followed at 66.67%, 56.39 %, 56.25% respectively (Table 4.2). In the stem portions however, the highest shooting once again was realized in stem full
portion with IBA 0.25% (SF 0.25) at 44.44 % followed by stem full portion with IBA 0.5% (SF 0.5) at 37.94 % then stem bottom with IBA 0.5 % (SB 0.5) at 35.5% shooting percentage. The lowest shooting percentages were realized for stem portions under 0% IBA, where only the bottom portions (SB 0) showed shoot development, with a shooting percentage of 21.43%, with inconsiderable shooting development under stem full portions (SF 0) and stem top portions (ST 0). In the root sections, only the full portions under IBA 0% (RF 0) did not show considerable shooting development. The differences in means of the shooting percentages for both stem and root portions were found to be statistically significant (Table 4.2).
Table 4.2: Shooting percentages of different portions of stem and root cuttings under varying IBA concentrations

<table>
<thead>
<tr>
<th>IBA Rooting Hormone %</th>
<th>Treatment</th>
<th>Stem (S) Cuttings (%)</th>
<th>Root (R) Cuttings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>Top (T)</td>
<td>df</td>
</tr>
<tr>
<td>0.25</td>
<td>40</td>
<td>33.38</td>
<td>47</td>
</tr>
<tr>
<td>0.5</td>
<td>36</td>
<td>22.77</td>
<td>33</td>
</tr>
<tr>
<td>0</td>
<td>11</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>p</td>
<td>*0.044</td>
<td>*0.044</td>
<td>*0.04</td>
</tr>
<tr>
<td>LSD</td>
<td>11.41</td>
<td>11.41</td>
<td>11.41</td>
</tr>
</tbody>
</table>

*Denotes significance at p=0.05
4.1.3 Effect of IBA Concentrations on rooting percentage of root and stem cuttings

In general IBA concentration of 0.25 % had the highest influence on rooting percentage of both root and stem sectional cuttings (Grand mean = 15.19%) compared to 0.5% concentration (14.24%) which was the lowest in rooting of the cuttings (Table 4.3). Moreover, the IBA concentration had a significant influence on the rooting of both stem and root sectional cuttings as shown by ANOVA ($p<0.001$) and t-test ($t (37.66) = 5.64, P<0.001$). Root sectional cuttings gave the best performance in rooting with IBA concentration of 0.25 % producing the highest rooting percentage at (27.22%) followed by 0% control (24.38%) and the least was IBA 0.5% (22.33%). In the stem sections however, the highest rooting occurred under IBA 0.5% (10.78%) followed by 0.25 % IBA and lastly 0% IBA concentrations (9.63 % and 9.39 % respectively) as shown in Table 4.3. The differences in mean rooting percentages of both stem and root sectional cuttings were found to be statistically significant.

Table 4.3: Effect of IBA hormone on rooting percentage of stem and root cuttings.

<table>
<thead>
<tr>
<th>IBA Rooting Hormone concentration</th>
<th>Root sectional cuttings (%)</th>
<th>Stem sectional cuttings (%)</th>
<th>Grand Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>27.22</td>
<td>9.63</td>
<td>15.19</td>
</tr>
<tr>
<td>0.5</td>
<td>22.33</td>
<td>10.78</td>
<td>14.24</td>
</tr>
<tr>
<td>Control (0)</td>
<td>24.38</td>
<td>9.39</td>
<td>14.84</td>
</tr>
<tr>
<td>$p$</td>
<td>*&lt;0.001</td>
<td>*&lt;0.001</td>
<td>0.87</td>
</tr>
<tr>
<td>LSD</td>
<td>3.67</td>
<td>3.67</td>
<td>5.298</td>
</tr>
</tbody>
</table>

*Denotes significance at $p=0.05$

Further on when the parameter of root architecture in terms of the root length for both stem and root sectional cuttings was investigated, IBA concentrations of 0.5 % in the study gave more pronounced results. The control IBA treatments with 0% concentration exhibited the least length of roots (1.5 cm for stem and 1.25 cm for root cuttings) as in Figure 4.1.
Figure 4.1: Root length and number variations for stem and root cuttings under different IBA concentrations

4.1.4 Effects of IBA on the rooting percentage of different portions (top, full and bottom) of stem and root sectional cuttings

As shown in Table 4.4 root portions gave the best rooting percentages compared to stem portions. The highest rooting percentages were realized for root top portions at 0% IBA (RT 0) at 31.25 % followed by root full portion at IBA 0.25 % (RF 0.25) 31.11 % then root full portion at IBA 0.5 % (RF 0.5) at 29.17 %. For the stem cuttings on the other hand, the highest rooting was realized in the full portions at 0.5 % IBA (SF 0.5) at 11.9 % followed by SB 0.5 (11.3%) and then SF 0.25 (11.1%). Full portions did not root for both stem and root cuttings under 0% IBA (SF 0 and RF 0). The lowest rooting percentages were for ST 0 (7.14%) and RB 0 (17.5%). The differences in means of the rooting percentages were also found to be statistically significant, as evidenced by p values of less than 0.05 (P<0.001) as illustrated in Table 4.4.
Table 4.4: Influence of IBA Hormone on rooting of different cutting portions in stem and root sections

<table>
<thead>
<tr>
<th>IBA Rooting Hormone</th>
<th>Stem (S) Cuttings (%)</th>
<th>Root (R) Cuttings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top (T)</td>
<td>Bottom (B)</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>8.44</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>9.73</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>7.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>*&lt;0.001</th>
<th>*&lt;0.001</th>
<th>*&lt;0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSD</td>
<td>4.55</td>
<td>4.5</td>
<td>4.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>*&lt;0.001</th>
<th>*&lt;0.001</th>
<th>*&lt;0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSD</td>
<td>4.55</td>
<td>4.5</td>
<td>4.54</td>
</tr>
</tbody>
</table>

*Denotes significance at p=0.05
4.1.5 The effect of application of IBA hormone on the cutting diameter of stem and root section in influencing rooting percentage

The induction of IBA hormone on the different cutting diameters did not have any significant rooting effect on the stem and root sectional cuttings \((p=0.86)\). Using 0.25% IBA concentration on small diameter \((\leq 0.5 \text{ cm})\) root cuttings gave the best rooting percentage of 37.5% followed by diameters of \(\geq 0.5 \text{ cm}\) under 0.25% IBA at (25.17%) and the same diameter \((\geq 0.5 \text{ cm})\) under 0% IBA at (22.38%) as in Table 4.5. The lowest rooting was realized for the Stem sectional cuttings with 0% IBA (7.14%) for small cuttings of less than 0.5 cm while in the wider cuttings of greater than 0.6 cm, the lowest rooting was under stem cuttings treated with 0.25% IBA at 9.72%. Root sections with small diameters at IBA concentrations of both 0.5% and 0% \((\leq 0.5 \text{ cm})\) however did not root at all (Table 4.5). All the stem cuttings on the contrary rooted for both the diameter groups in all the IBA concentrations.

Table 4.5: The effect of application of IBA hormone on the cutting diameters of stem and root section in influencing rooting percentage

<table>
<thead>
<tr>
<th>Treatment</th>
<th>IBA Rooting Hormone in %</th>
<th>Stem Cuttings (%)</th>
<th>Root Cuttings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter Group</td>
<td>df</td>
<td>%</td>
<td>df</td>
</tr>
<tr>
<td>Group 1 (≤0.5 cm)</td>
<td>11</td>
<td>0.25</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group 2 (&gt;0.5 cm)</td>
<td>57</td>
<td>0.25</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>0.5</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>p</td>
<td>0.857</td>
<td>0.857</td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td>11.54</td>
<td>11.54</td>
<td></td>
</tr>
</tbody>
</table>

4.1.6 The effect of application of IBA hormone on the rooting percentage of cutting diameters of (top, bottom, full) portions obtained from Melia stems and root (sectional) cuttings

Results showed that the top portions of both root and stem sectional cuttings performed poorly in rooting for small diameter cuttings of less than 0.5 cm. Only ST 0.25 and RT 0.25 rooted (7.14% and 31.25% respectively) under this diameter
Group (Group 1) as shown in Table 4.6. Root full portions at 0.25 % IBA concentration (RF 0.25) however gave the highest rooting percentage of 50% for the small diameter cuttings of less than 0.5 cm. Bottom portions gave higher rooting percentage followed by full portions and then the top portions under larger diameter cuttings (≥ 0.5 cm) in all concentrations of IBA while the control concentration of IBA (0 %) performed the least overall in both the diameter groups for all portions (Table 4.9). Root top, root bottom and root full portions under small diameters group of ≤ 0.5cm with IBA concentrations of 0.5 % and 0% however did not root at all, same to stem top at 0.5% and 0% IBA (ST 0.5 and ST 0), stem full at 0% IBA (SF 0) . In the wider diameter category (≥0.5 cm), ST 0 and SF 0 and RF 0 did not root. This was an indication that IBA hormone increases rooting of cuttings and the low and nil rooting of portion under 0% IBA was a testament. The differences in mean rooting percentages of the portions for the small and wider diameter categories were however not significant (p=0.92).
Table 4.6: Effect of application of IBA hormone on the rooting percentage of cutting diameters of (top, bottom, full) portions obtained from Melia stems and root sections

<table>
<thead>
<tr>
<th>Diameter Group</th>
<th>IBA Rooting Hormone in %</th>
<th>Stem (S) Cuttings (%)</th>
<th>Root (R) Cuttings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Top (T)</td>
<td>Bottom (B)</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------------</td>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>Group 1 (≤ 0.5cm)</td>
<td>0.25</td>
<td>df</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group 2 (≥ 0.5cm)</td>
<td>0.25</td>
<td>10</td>
<td>0.502</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>15</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>p</td>
<td>0.92</td>
<td>0.92</td>
<td>0.92</td>
</tr>
</tbody>
</table>


4.1.7 The effect of application of IBA hormone on the cutting lengths of Melia stem and root sections in influencing the rooting percentage

The highest rooting was achieved for short root cuttings (of ≤ 12 cm in length) induced with 0.25% IBA concentration (35.12 rooting %) while the lowest rooting was realized under long stem cuttings (≥12 cm in length) under 0 % IBA (7.14 rooting %) as in Table 4.7. Root cuttings both long (≥12 cm) and short (≤12 cm) performed better than the stem cuttings in all the three tested IBA hormone concentrations. General rooting trends showed that when IBA concentration was increased from 0.25 % to 0.5%, the rooting percentages decreased in short root sectional cuttings and increased in the long root cuttings. In the stem sections however, the variations were not consistent. Ultimately, IBA hormone did not have any significant effect on the rooting percentage of both long and short length diameter sectional cuttings (p=0.496).

Table 4.7: IBA Hormone concentration influence on the cutting length of root and stem cuttings and the impact on rooting

<table>
<thead>
<tr>
<th>Treatment</th>
<th>IBA Rooting Hormone in %</th>
<th>Stem Cuttings %</th>
<th>Root Cuttings %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Group</td>
<td>df</td>
<td></td>
<td>df</td>
</tr>
<tr>
<td>Group 1 (≤ 12cm)</td>
<td>0.25</td>
<td>12</td>
<td>9.26</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>13</td>
<td>10.61</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3</td>
<td>11.07</td>
</tr>
<tr>
<td>Group 2 (≥ 12cm)</td>
<td>0.25</td>
<td>25</td>
<td>9.67</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>22</td>
<td>10.88</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>2</td>
<td>7.14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>p</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.496</td>
<td>7.5</td>
</tr>
</tbody>
</table>

4.1.8. The effect of IBA hormone on the rooting percentage of the cutting lengths of (top, bottom, full) portions obtained from Melia stem and root sections

Table 4.8 shows how different root and stem sectional cutting portions lengths rooted when induced with IBA at different concentrations. From the table, bottom
and full portions with long lengths of ≥12 cm rooted dismally under control (0%) treatment. Only the root top portion (RT 0) (31.25%) and the stem bottom portion (SB 0) (7.14%) rooted for the long cuttings (Length group 2). Moreover, full portions of short lengths (≤ 12 cm) had the least rooting percentage in both root and stem sections with only SF0.25 (10%) and SF 0.5 portions (10 %) rooting. No rooting was realized for the RF 0.25, RF 0.5 and RF 0 portions with short lengths of ≤ 12 cm; and in ST 0, SF 0, RB 0 and RF 0 with long lengths (≥12 cm) as shown in Table 4.8. The bottom portions however recorded the best rooting percentages for both the root and stem sections of short lengths (≤12 cm) in all tested IBA concentrations, posting the highest rooting achieved at 36.11 % for root bottom under 0.25% IBA (RB 02.5). However, the differences in means of top and bottom portions were not statistically different from each other (p=0.962).
Table 4.8: Effect of IBA hormone on the rooting percentage of the cutting lengths of (top, bottom, full) portions obtained from stem and root sections

<table>
<thead>
<tr>
<th>Length group</th>
<th>Treatment</th>
<th>Stem (S) Cuttings (%)</th>
<th>Root (R) Cuttings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBA Rooting Hormone in %</td>
<td>Top (T)</td>
<td>Bottom (B)</td>
</tr>
<tr>
<td>Group 1 (≤12 cm)</td>
<td>0.25</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>6</td>
<td>8.78</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>7.14</td>
</tr>
<tr>
<td>Group 2 (≥12 cm)</td>
<td>0.25</td>
<td>8</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>8</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ p = 0.926 \]
4.2 Cutting Diameter and Lengths effect on the rooting of *Melia volkensii*

4.2.1 Influence of cutting diameters on rooting percentage of stem and root sectional cutting

Small cutting diameters of 0.5cm and below significantly \((p=0.031)\) increased the rooting percentage of both stem and root cuttings with the highest rooting percentage recorded for root cuttings at 37.5\% (Table 4.9). Wider cutting diameters \((\geq 0.5 \text{ cm})\) on the other hand resulted in lower rooting percentages of both stem and root cuttings, with the lowest rate recorded at 10.04 \% under stem cuttings within that particular diameter group \((\geq 0.5 \text{ cm})\).

**Table 4.9:** Effect of diameter on rooting of stem and root sectional cuttings

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem Cuttings</th>
<th>Root Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df (%)</td>
<td>df (%)</td>
</tr>
<tr>
<td>Group 1 ((\leq 0.5 \text{cm}))</td>
<td>13 10.14, 2 37.5</td>
<td>66 10.04, 33 23.82</td>
</tr>
<tr>
<td>Group 2 ((\geq 0.5 \text{cm}))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(p) (section. diameter group)</td>
<td><em>0.031</em></td>
<td><em>0.032</em></td>
</tr>
<tr>
<td>LSD</td>
<td>7.98</td>
<td>7.98</td>
</tr>
</tbody>
</table>

\(*\)Denotes significance at \(p=0.05\)

4.2.2 The effect of the cutting diameters on the rooting percentage of (top, bottom, full) portions in stem and root sectional *M. volkensii* cuttings

In the three portions (top, bottom and full) cuttings from the stem and root section, the diameter of cuttings did not have a significant impact on the rooting as evidenced in \((p=0.886)\). However, wider diameters group of \(\geq 0.5 \text{ cm}\) led to higher rooting in the bottom portions of both stem (10.26 \%) and root sectional cuttings (22.89 \%) compared to smaller diameters of \(\leq 0.5 \text{ cm}\) where root bottom portions did not root and stem bottom portions had 10.24 \% rooting (Figure 4.2).
On the other hand, the small diameter cuttings (Group 1) increased the rooting in full portions of both the stem (11.67 %) and root sections (50%) and also increased the rooting percentage on the top root section (31.25%). Both small (≤ 0.5 cm) and wider (≥ 0.5 cm) diameters moreover led to the lowest rooting in the top portions of stem cuttings (9.21% and 7.14% respectively).

### 4.2.3 Effect of cutting length on the rooting of Melia stem and root sectional cuttings

The study revealed that the length of cuttings under both stem and root sections did not have a significant influence on their rooting ($p=0.06$). The lowest rooting percentage occurred under stem sections (10.03%) which were more elongated (lengths greater than 12cm) as shown in Table 4.10. Root cuttings of less than 12 cm in length had the highest rooting percentage (29.4%) followed by root cuttings with long lengths of more than 12 cm (22.21%). Both short (≤ 12 cm) and long (≥ 12 cm) cuttings seemed to have increased rooting capacities in the root sections as opposed to the stem sections which had the lowest rooting percentages in both lengths (Table 4.10). The root sectional cuttings thus gave the best rooting regardless of the cutting lengths as compared to the stem sectional cuttings, although the differences were not significant ($p=0.06$).
Table 4.10: Cutting lengths effects on rooting of stem and root sectional cuttings

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean rooting percentage</th>
<th>Stem Cuttings</th>
<th>Root Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>(%)</td>
<td>df</td>
</tr>
<tr>
<td>Group 1(≤12cm)</td>
<td>30</td>
<td>10.23</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>10.03</td>
<td>22</td>
</tr>
<tr>
<td>p (section. Length group)</td>
<td>0.06</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>LSD</td>
<td>5.19</td>
<td></td>
<td>5.19</td>
</tr>
</tbody>
</table>

4.2.4 The influence of cutting lengths on the rooting of top, bottom and full portions of M.volkensii stem and root section

Short cuttings (≤ 12 cm) improved rooting in all the root portions except full portion where no rooting was realized (Table 4.11). The highest rooting percentage (31.19%) was in the root bottom (RB) portion of short cuttings followed by long (≥12 cm) root full (RT) portion (30.33 %) and then root top (RT) portion (27.62%) in the short length group. Moreover, in the stem cuttings, more elongated cuttings (≥ 12 cm) improved the rooting ratios in the three portions (top, bottom and full) as compared to the counterpart short cuttings (≤ 12 cm in length). Both long and short length cuttings showed a better performance in the rooting of portions (top, full, bottom) of root sections than stem sections. Even though the rooting varied, these variations were found not to be statistically different from each other (p=0.18) as illustrated in the Table 4.11. The length of cuttings in this case therefore cannot be said to be of importance in influencing the rooting abilities of the top, bottom and full cutting portions as obtained from both the roots and the stems.
Table 4.11: Influence of Cutting Lengths on the Top, Bottom and Full Portions of Melia stem and root sections

<table>
<thead>
<tr>
<th>Length group</th>
<th>Mean rooting percentages</th>
<th>Stem (S) Cuttings</th>
<th>Root (R) Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Top (T) df</td>
<td>Bottom (B) df</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td>10 8.7 14 11.43 4 10</td>
<td></td>
</tr>
<tr>
<td>(≤ 12 cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td>17 9.29 18 9.32 12 12.1</td>
<td>7 23.5 9 17.08 4 30.33</td>
</tr>
<tr>
<td>(≥ 12 cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>P</em></td>
<td></td>
<td>0.18</td>
<td>0.18</td>
</tr>
</tbody>
</table>

4.3 Determination of the ideal cutting section from Melia plus tree that can produce high rooting potential

Root section recorded great rooting percentages throughout its interaction with other parameters when compared to the stem section. Data revealed significant differences in the rooting abilities of the root cuttings to the stem cuttings at *p* value = 0.003. There were variations observed in the stem section where the rooting percentage decreased to 9.6% from a high mean shooting percentage of 24.3% under IBA rooting hormone 0.25% treatment. This could imply that 0.25% IBA hormone favoured shooting percentages as 0.5% enhanced the rooting percentages in the stem section. On the other hand root sections performance was consistent with an increase in IBA rooting hormone leading to decreased shooting and rooting potentials as evidenced in Table 4.12. Additionally, the highest mean shooting and rooting percentage (27.3% and 21.3% respectively) was observed in the root section and the differences in their means were found to be statistically significant.

Table 4.12: The ideal cutting section for Melia propagation

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stem cuttings</th>
<th>Rooting cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBA Top Bottom Full Mean</td>
<td>IBA Top Bottom Full Mean</td>
</tr>
<tr>
<td><strong>Shooting %</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>35 40 45 24.3</td>
<td>0.25 48 37 45 27.3</td>
</tr>
<tr>
<td>0.5</td>
<td>30 20 24 23</td>
<td>0.5 31 21 29 20</td>
</tr>
<tr>
<td>0</td>
<td>8 9 0 23</td>
<td>0 3 2 2 25</td>
</tr>
<tr>
<td><strong>Rooting %</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>11 19 34 9.6</td>
<td>0.25 26 31 15 21.3</td>
</tr>
<tr>
<td>0.5</td>
<td>16 10 29 11.3</td>
<td>0.5 36 19 32 17.3</td>
</tr>
<tr>
<td>0</td>
<td>2 5 0 21</td>
<td>0 2 2 3 16.6</td>
</tr>
<tr>
<td><em>P</em></td>
<td></td>
<td>*0.003</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>*0.003</td>
</tr>
</tbody>
</table>

*Denotes significance at *p* = 0.05
4.4 Effect of merchantable height on the rooting of Melia cuttings

The data revealed no significant differences in the rooting \((p=0.495)\) of Melia as a result of the different merchantable heights. However, short plus trees of merchantable heights between 2-5 metres recorded the highest rooting percentages in the Melia cuttings at \((17.5 \%)\), followed by medium plus trees \((6-9 \text{ m})\) at \((17.05 \%)\) and then the tall plus trees \((10-13 \text{ m})\) which recorded the least rooting percentages \((10\%)\) as illustrated in the Table 4.13.

Table 4.13: Effect of merchantable lengths on the rooting percentages of Melia

<table>
<thead>
<tr>
<th>Merchantable Height</th>
<th>df</th>
<th>Mean Rooting %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short plus (2-5 m)</td>
<td>1</td>
<td>17.5</td>
</tr>
<tr>
<td>Medium plus (6-9 m)</td>
<td>2</td>
<td>17.05</td>
</tr>
<tr>
<td>Tall plus (10-13 m)</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>(p)</td>
<td></td>
<td>0.495</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>17.44</td>
</tr>
</tbody>
</table>

4.5 Relationships between key variables (IBA, cutting Length and Diameter)

Correlation results indicated that there occurred a negative correlation between the rooting percentage and the cutting lengths \((r = -0.17)\), which is to say that the shorter the length of the cuttings, the more the rooting percentage. This has been proven in the study and has been afore discussed in the previous section 4.2 of this thesis. There was a negative weak relationship between the number of roots recorded and the length of the cuttings \((r = -0.023)\), which meant more roots under short cuttings would ultimately culminate to a higher rooting percentages as was revealed from the study using short length cuttings, a phenomenon of which again has corroborated the findings of other researchers.
Table 4.1: Relationships between studied variables

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average root length</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>2 0.1063</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooting %</td>
<td>3 0.0913</td>
<td>0.0147</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of roots</td>
<td>4 0.5133</td>
<td>0.2300</td>
<td>0.1500</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoot length</td>
<td>5 0.1575</td>
<td>0.1833</td>
<td>-0.1542</td>
<td>0.0821</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cutting length</td>
<td>6 0.0213</td>
<td>0.1273</td>
<td>-0.1716</td>
<td>-0.0229</td>
<td>0.9683</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBA</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rooting %</td>
<td>2 -0.0306</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoot length</td>
<td>3 0.0919</td>
<td>-0.1542</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It was also evident that the concentrations of IBA hormone as a growth regulator negatively influenced the rooting percentage of Melia cuttings as exhibited by the negative correlation coefficient of – 0.0306. Therefore, this proves that high concentrations of IBA inhibited root development and as such less roots appeared and the rooting percentage were dismal under high concentrations of 0.5 % as earlier discussed in the previous sections of this thesis. IBA rooting hormone is directly related with the shoot length where an increase in application of IBA hormone at optimal concentrations the greater the increase in the length of the shoot/shooting efficiency.
Figure 4.3: Correlation plot of relationships among studied variates

These relationships and more are presented in the correlation plot in Figure 4.3. Each colour scheme describes the proportion of variation and the existing relationship (positive or negative from the scale indicated in the diagram) of the dependent and independent variables as per the study. IBA (2) a dependent variable for instance has a negative relationship with the rooting percentage ($r= 0.13$) (independent variable) and the lengths ($r=0.17$) (dependent variable) but positively correlated to the root numbers ($r=0.40$) and the diameter ($r=0.15$) of the cutting (Independent variable). The interpretation is as afore discussed in previous paragraph.
DISCUSSION

4.1 Effect of IBA rooting hormone on the rooting and shooting of Melia cuttings

4.1.1 Effect of IBA hormone concentrations on the shooting percentages of root and stem cuttings

The IBA hormone concentrations positively influenced the shooting percentages of the root and stem sectional cuttings at (p< 0.001). The significant difference recorded (Table 4.1) implies that the use of growth hormones is an important factor in not only influencing the elongation of adventitious buds/shoot system and ultimately shooting percentages but also in fastening the onset of the shooting procedure accentuating the number and quality of shoots (Hartmann et al., 1997; Erdag et al., 2010). This is in line with the increased shooting percentages in the study where cuttings treated with IBA at 0.25 % and 0.5 % seemed to record higher shooting percentages than those of the control treatments without IBA rooting hormone as shown in Table 4.1. Moreover a study by Aggarwal and Barna (2004) revealed that the high shoot multiplication occurs at low concentrations with IBA concentrations of 0.2% recording the highest sprouting percentages. IBA concentrations at 0.25 % for this study gave the best shooting inference in both sectional cuttings (root and stem) and can therefore be said to be the most preferred IBA concentration level to propagate Melia cuttings.

4.1.2 Effect of IBA concentrations on the shooting of different portions (top, bottom, full) of stem and root sectional cuttings

The IBA hormone concentrations significantly influenced the shooting percentages of stem and root portions (Top, Bottom and Full) at p value = 0.044 (Table 4.2). The full portions emerged with the highest shooting percentages under exposure to IBA concentrations to mean that the different portions need a combined effort to cause a colossal change in the elongation of the shoot system. This may be attributed to the physiological status of the cutting tissues and their degree of response to IBA hormone. Root full portions under IBA of 0.25 % (RF 0.25) produced highest shooting rates at (66.78 %). This implies that adventitious shoot inducing hormones are dominant in the root section that gave the best performance
in response to growth as observed and recorded in this study. The great shooting experienced at root top control (RT 0) portions further coincide with the adequate amounts of endogenous compounds dominance aforementioned that promote shooting in the root section. Callus that formed at the base of M. volkensii cuttings (agreed with by Indieka et al., 2007) favoured the shoot formation compounded by the induction of IBA hormone that enhances shooting.

This study further depicts a decreasing trend in the shooting where an increase in concentration of IBA results to a decreased shooting percentage. This implies that low concentrations of IBA for Melia cuttings favour shoot growth and elongation. Studies by Mfahaya (2008) that recorded an increase in the number of leaf of Melia cuttings at week 27 under IBA 0.33% concentration corroborate this study where high shooting performance was recorded at 0.25%.

4.1.3 Effect of IBA Concentrations on the rooting percentage of Root and Stem cuttings

The IBA hormone concentrations significantly influenced the rooting of both Stem and root sectional cuttings as revealed in Table 4.3. IBA rooting hormone concentration influenced the rooting of both stem and root sectional cuttings as shown by ANOVA ($p<0.001$) and t-test ($t (37.66) = 5.64, P<0.001$). This implies that the greater the application of IBA hormone at optimal concentrations the higher the rooting percentages and growth experienced as compared to no application at all. IBA hormone concentrations at 0.25 % enhanced the rooting of the cuttings both from stem and root sections. This is in agreement with other researchers, such as Kesari et al. (2009) for instance who noted that high concentrations of auxins led to rooting inhibition in the cuttings of Pongamia pinnata (L). However, cases of high rooting percentages with high IBA concentrations have also been recorded. At a study on Pinus pinaster, Majada et al. (2011) for instance noted that the application of growth regulator affected root development, with the highest morphological development being associated with the highest IBA levels of 40,000 ppm or 1,000 mg L$^{-1}$ at environmental temperatures (25°C). In yet another study Wendling et al. (2000) found similar effects on rooting to be high under high IBA levels. Therefore the present study is corroborated where high rooting potential cases were realized for stem cuttings under IBA rooting concentration of 0.5 %.
Other than promoting only rooting, auxins have also been known to play a critical role in a number of root developmental processes (Pasternak et al., 2002), the case in which they act as an indicator for the division, elongation, and differentiation of cells as was noted by Erdağ et al. (2010). The low rooting recorded under stem cuttings and also in controls can therefore be attributed to the limited endogenous promoting hormones or no existence of such enhancements (as in the case of 0% IBA) which would otherwise have occurred in the presence of IBA hormone where more rooting would have been realized.

The evaluation of the effect of IBA rooting hormone on root architecture ideal for seedling growth and survival using the root number and length

0.25 % IBA concentration led to increased number of roots on average (Figure 4.1) and this could have culminated to the higher rooting percentages that were realized for this concentration of IBA. Even though the high IBA concentrations at 0.5 % had a negative effect on the rooting percentage of the cuttings, the roots were longer than in 0.25% and control treatments. Additionally IBA 0.5 % significantly increased the shooting percentage of stem cuttings at (30.16%, p<0.001). This phenomenon has also been observed by Amri et al. (2010) who in their study on Dalbergia melanoxylon (Guill. & Perr) noted that IBA at 300 ppm had significantly high rooting percentages, root numbers and root length of cuttings than 0 ppm. Similar results have also been previously reported by Ofori et al. (1996) who found out that the mean number of roots per cutting was higher when the cuttings of Milicia excelsa were treated with IBA rooting hormone than cuttings which were under control treatment.

4.1.4 Effects of IBA concentrations on the rooting percentage of different portions (top, bottom, full) of Stem and Root sectional cuttings

IBA hormone positively influenced the rooting percentage of different portions (top, full and bottom) of stem and root sectional cuttings. As shown in Table 4.4 the differences in means of the rooting percentages were found to be statistically significant (P<0.001), even as root portions gave the best rooting percentages compared to stem portions. The inference is the greater the application and use of PGRs the greater the rooting percentages achieved rather than no application.
Hartmann et al. (2002) highlighted that the use of auxins and plant growth regulators in treatment of cuttings before propagation increased the percentage of the cuttings that formed roots and that they hastened root initiation and production efficiency. This therefore explains the general low rooting experienced under the full control treatments with 0 % IBA in this study. In contradiction, the high rooting percentages realized at the root top control portions (RT 0%) highlights the presence of endogenous root promoting hormones and can further be attributed to the young physiological status of the root tissue cells hence great response to rooting when placed under favourable environmental conditions. These root inducing substances concentration in the top and bottom portions of roots further give the inference that Melia cuttings from the top portions could result to high rooting where access to IBA rooting hormone is limited.

Other researchers have found out that IBA significantly influences the rooting in cuttings. Al-Bahrany (2002) for instance in his study on lime Citrus noted that the most rooting per node occurred in IBA media with medium concentrations of 2 mg/l and this also applied for the shooting of the cuttings as associated with the rooting phase. Tchoundjeu and Leakey (1996) moreover found that the best concentration of the auxin IBA which hastened rooting, increased the percentage of cuttings rooted and increased the number of roots per cutting was 200 μg per cutting, which is closer to that used in this study (0.25 %). This study where IBA concentrations of 0.25% gave the best results overall in terms of shooting and rooting percentages of the Melia cuttings compared to 0.5% concentrations which were among the least corroborate the above studies.

According to Ruchala (2002), there should be ample care taken to ensure that the right quantities in terms of auxin concentrations are used for propagation since too much concentrations of rooting hormones can be a hindrance to root growth. This scenario substantiates the fact that 0.5% concentrations of IBA as used in this study yielded less rooting percentages in the root cuttings vis-à-vis the counterpart 0.25 % concentrations. The section from which the cutting is obtained is also a critical factor that affects the amount of success in rooting of cuttings (Hartmann et al., 2002).
4.1.5 Effect of IBA hormone concentration on the diameter of stem and root cutting in influencing rooting percentage

IBA hormone negatively influenced the rooting percentages of melia stem and root cuttings at different diameters. As shown in Table 4.5 the induction of IBA hormone on the different cutting diameters did not have any significant rooting effect on the stem and root sectional cuttings \((p=0.86)\). This implies that wider diameter cuttings \(\geq 0.5\) cm do not favour rooting in comparison to Group 1 small diameter cuttings \(\leq 0.5\) cm. Thus, it’s lucid that the greater the diameter of the cutting the lower the rooting capacity hence percentage and vice versa. In agreement to this finding is a study on ‘Pixy’ plum \((Prunus insititia)\) (L.), where the rooting percentage decreased with increasing cutting diameter when the medium was rapidly draining sand rather than granulated bark (Howard and Ridout, 1991).

4.1.6 Effect of IBA hormone concentration on the rooting percentage of cutting diameters of (top, bottom, full) portions obtained from Melia stems and root cuttings

IBA hormone influence on the rooting percentage of cutting diameters of melia stems and root (sectional) cuttings obtained from (top, bottom, full) portions was insignificant as shown in Table 4.6. The low to nil rooting of portions under 0% IBA concentration in both diameter groups was the testament giving an indication that IBA hormone increases rooting of cuttings. The differences in mean rooting percentages of the portions for the small and wider diameter categories were however not significant \((p=0.92)\). This implies that wider the diameter of the cutting is the lower the rooting potentials. The high rooting as noted in the present study for smaller diameter stem cuttings are in agreement with other researchers. Sarrou et al. (2014) for instance found that the rooting percentage increased with a decrease in cutting diameters. Conflicting results have also been documented by other researchers such as Saroj et al. (2008) who in their study realized that the rooting increased with increase in cutting diameters. This can therefore explain the higher rooting exhibited in control and 0.25% IBA treatments of root cuttings for diameters greater than 0.5 cm than in those less than 0.5 cm.
High rooting percentages in top portions of both stem and root sectional cuttings under small diameters ($\leq 0.5$ cm) was also noted for IBA treatments of 0.25%. This could be explained by the fact that endogenous auxins have been known to be synthesized close to the terminal bud (Hartmann et al., 1990), and that the thinness of the diameters was an added advantage. The negative correlation between the bottom portions of the cuttings and the rooting percentage may also be alluded to variations in the physiological status of the tissues, different levels of lignifications and deficiency in endogenous auxin promoters, and an excess of inhibitors of adventitious root induction which tends to occur in the cuttings with the greatest base-diameters (Sarrou et al., 2014).

Darus (1989) moreover noted that the cylinder of sclerenchymatous cells of older shoots may constitute an obstacle to root formation and thus a decrease in the rooting percentage since the greatest base-diameter cuttings from the bottom portions tend to be more differentiated and ontogenetically older, a phenomenon which lags rooting. This thus explains the nil to low rooting of the bottom portions in small diameters ($\leq 0.5$ cm) as the results of this study indicated.

4.1.7 Effect of IBA hormone concentration on the cutting lengths of stem and root section in influencing rooting percentage

Application of IBA hormone on the cutting lengths of stem and root sections negatively influenced the rooting percentage of *Melia volkensii* cuttings. IBA hormone did not have any significant effect on the rooting percentage of both long and short length diameter sectional cuttings ($p=0.496$) as shown in Table 4.7. The implication of this is that long cuttings (Group 2 $\geq 12$ cm in length) do not favour a high rooting potential when compared to the short cuttings (Group 1 $\leq 12$ cm in length). Accordingly, rooting percentages increases with a decrease in the length of the cutting and vice versa. This is confirmed by Howard and Ridout (1991) who documented that higher rooting potentials are obtained from cuttings of shorter lengths. A research on the rooting success of *Feijoa sellowiana* cuttings from 4year old stock plants recorded better rooting capacity in short in length cuttings (8-12cm range) (Zhang et al. (2010). The stem cuttings variable results in both groups could be attributed to mature nature of the tissue cells hence reduced sensitivity to limited endogenous substances that favour growth and development. The highest rooting
that was achieved for short root cuttings and the lowest rooting that was realized under long stem cuttings further endorses root cuttings for domestication of Melia trees.

4.1.8 The effect of IBA on the rooting percentage of the cutting lengths of (top, bottom, full) portions obtained from Melia stem and root sections

The effect of IBA hormone on the rooting percentage of the cutting lengths of (top, bottom, full) portions obtained from Melia stem and root sections was not significant at \( p = 0.962 \) shown in Table 4.8. This implies that rooting percentage increases with a decrease in the cutting lengths of the portions obtained from either the stem or root section. The great rooting potentials realized at root top control (RT 0%) in group 2 corroborate a study on Tectona grandis by Husen and Pal (2003), that noted that the rooting percentage of cuttings generally increased from the portions taken from the middle positions followed by apical points, with the least occurring at basal points. Moreover, the general trend has always been set that the more morphological development has always occurred at the basal points compared to the apical points of cuttings, and this has been attributed to the fact that there are carbohydrates in plants which always accumulate at the base of the shoots (Hartmann et al., 2002). This translates as more food and ultimately more development and growth therein. Cases of bottom cutting portions rooting more than the full and top portions in this study can therefore be well substantiated and can be attributed to more carbohydrate accumulation at the basal parts of the stem. It is however worth noting that the effect of portions on rooting will never be the same and as such will vary from species to species, due to the physiological status of the cutting tissues and on the levels of growth regulators used (Hartmann et al., 2002; Husen, 2004).

4.2 Cutting diameter and lengths on the rooting of Melia volkensii

4.2.1 Influence of cutting diameters on rooting percentage of stem and root sectional cutting

The cutting diameters positively influenced the rooting percentage of Melia volkensii stem and root cuttings at \( p = 0.031 \). The high rooting percentage in larger diameters group of root cuttings in this study as compared to stem cuttings...
corroborates other researchers Tchoundjeu and Leakey (1996) for instance who found that even in the cuttings of the same length; those with larger diameters had the highest rooting percentage. This in conjunction with (Leakey et al., 1993) they argued could be an indication that cutting stem volume may be a more critical factor in rooting determination than the cutting length, since the large area tends to act as the storage sink for current assimilates prior to the formation of the new roots. Conflicting results in rooting as influenced by diameters is also documented by Sarrou et al. (2014) who discovered the best rooting at diameters of 3-4 mm in very thin cuttings. This is also therefore in agreement with the case in this study where the smaller diameter group registered highest rooting percentages with root cuttings posting a high of 37.5%.

4.2.2 Effect of the cutting diameters on the rooting percentage of (top, bottom, full) portions obtained from Melia stem and root sections

The diameter of cuttings did not have a significant effect on the rooting of the three portions (top, bottom and full) as denoted by \( p=0.886 \). The great performance of the root portions in both groups implies of the juvenile nature of the root cuttings hence high regeneration capacities. The small diameter group posting the highest rooting of 50% gives the indication that the smaller the diameter of the cutting the higher/greater the rooting potential confirming research by (Zhang et al. (2010). The root section positioning was an added advantage to the small group portions. Root bottom portions in group \( \leq 0.5 \text{cm} \) did not root implying that the tissue cells may have been undifferentiated inhibiting root initiation and development. Moreover the bottom portions in roots performed better in terms of increased rooting percentage than those from the stem sections in both groups.

4.2.3 Effect of cutting length on the rooting of Melia stem and root sectional cuttings

The rooting potentials of Melia stem and root sectional cuttings were not significantly influenced by the lengths. The high rooting percentages realized in the short cuttings under root section give the implication that long cuttings do not favour rooting potentials. However, the long cuttings under root section gave the second best in rooting percentages confirming Amina et al. (2015) who noted that
the cuttings of 22.5 cm in length gave the best rooting percentages compared to those with 7.5 cm and 15 cm. Therefore rooting percentages increase with a decrease in lengths of cutting in *Melia volkensii* substantiating the study by Howard and Ridout (1991) who observed that higher rooting potentials are obtained from cuttings of shorter lengths. Similarly this study supports studies on *Feijoa sellowiana* where shorter cuttings gave better rooting capacities within a proposed range of 8-12cm Zhang et al. (2010).

4.2.4 Effect of cutting length’s on the rooting of top, bottom and full portions from stem and root sections

There was no significant impact of Melia cutting lengths in rooting the three portions (top, bottom and full) as depicted by \( p = 0.18 \). Based on the studies of other researchers, the lengths of cuttings have different varied effects on the rooting percentages. Long cuttings have been found to have higher rooting percentages than short cuttings (Leakey, 1983) irrespective of the position of origin whether stem or root (Leakey and Mohammed, 1985). The present study however found variations though insignificant in the stem and root sectional cuttings of different length groups of \( \leq 12 \) cm and \( \geq 12 \) cm therefore disapproving their findings (of Leakey) since the short cuttings recorded higher rooting percentages than long cuttings. On the flip side, Okunlola (2013) results that approved hard wood cuttings of 20 cm in length to give the best rooting percentages compared to those of 10 cm lengths are validated by this study where great rooting was posted in long cuttings (group 2) under the root section as compared to stem portions in same group. Bottom portions performing best in rooting could be attributed to high concentration of endogenous root inducing substances/auxins and subsequently an increase in the movement of these auxins from the apex moving downwards of the stem parts (Salamini, 2003). Their findings therefore imply that variations have always occurred in rooting percentages as influenced by cutting lengths.

4.3 Determination of the ideal section for *M. volkensii* propagation

Root cuttings recorded incredibly and significantly more rooting than the stem cuttings in the study at \( p = 0.003 \). The effects of rooting of different sections have been observed by other researchers. Husen and Pal (2006) for instance in their study
highlighted that the inhibitions in stem cutting rooting could be as a result of several hindering factors as the position from the shoot where the cutting is taken, the age of the mother plant and the growth regulator used. Stem cuttings have been known to vary in rooting. The variation in rooting has been attributed to differences in: the ages of donor plants; the decrease in the content on endogenous auxins in the stems; the reduction in the sensitivity of aging tissues to rooting promoters and accumulation of inhibitory substances which inhibit rooting or both (Husen and Pal, 2007; Stenvall et al., 2004). It is therefore not a guarantee that the root cuttings will always surpass the stem cuttings in development of roots based on these variations and factors.

4.4 Effect of Merchantable Heights on the rooting of Melia cuttings

The merchantable heights did not have any significant impact on the rooting of Melia cuttings established by p value =0.495. Short plus trees produced the cuttings which had the highest influence on rooting. The merchantable or usable portion of the stem for commercial logging is a function /expression of the total tree height. Melia trees achieve a 1m height in just a year however it’s possible to find trees growing much faster in suitable environmental conditions (Kimondo et al., 2008). The study utilized trees of between 4 years to mature ones of 28 years where plus trees that were 9 years and younger formed the short plus trees of merchantable lengths 2-5m. Older trees (10 years plus) had great usable heights due to silvicultural management done in their number of years but their rooting ability was poor. Thus the juvenile nature of short plus trees further confirms the testament that the younger the tree, the better the influence on the development of roots and shoots. Majada et al. (2011) noted that the youngest mini-cuttings of Pinus pinaster had roots with high surface area, volume, diameter and length, thereby high rooting percentages of greater than 90%. Upon plants growing older, their rooting ability decreases and rooted plant cuttings taken from them display plagiotropic growth and asymmetric branching (Dietrichson and Kierulf 1982). The stage of maturation of the plus plant is therefore one of the most important factors that influence rooting capacity and as such maintaining the plant/ tree in a juvenile condition or rejuvenating is paramount to any propagation program (Anderson et al., 1999).
The employment of juvenile/young material in propagation has been known to increase the capacity of rooting besides decreasing the time required to produce viable plants from the cuttings. A study by Amri et al. (2010) revealed that cutting from juvenile donor plants gave the highest rooting (71.11%) compared to those from mature donor plants which had the lowest rooting (24.42%). Stem cuttings taken from juvenile donor plants have also been considered easy to propagate by cuttings as a result of their young physiological, chronological and ontogenetic age and also due to the low production of secondary metabolites as Amri et al. (2010) and Husen and Pal (2006) observed.

Stenvall et al. (2004) also share in this agreement by reporting that indeed the formation of adventitious roots on cuttings decreases with increasing age of plus plants. Donor age is a great factor in influencing rootability among species with an increase in age leading to a decreased rooting percentage (Kantarli, 1993). This study therefore corroborates the observations of other researchers as afore discussed, where the small plus trees proved to be the best to obtain planting materials for propagation from, followed by medium plus donor trees and least being the old plus trees with heights of more than 10 metres.
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

Analysis of the first Objective has shown significant influence in the rooting and shooting percentages of cutting of Melia as induced by IBA hormone (p<0.001). IBA concentrations of 0.25 % gave the best rooting and shooting percentages compared to 0.5% and control treatments in the stem and root sections and (top, bottom and full) portions used. IBA concentrations of 0.5 % increased the length of roots for both stem and root sectional cuttings compared to the untreated cuttings at 0% IBA. This very high concentration reduced the overall rooting percentage of Melia root cuttings but was seen to favour rooting and shooting in the stem cuttings at 23% and 11.3 % respectively. The postulated alternative hypothesis for this study-that IBA rooting hormone varies at different levels of concentrations in influencing the rooting and shooting of Melia cuttings is therefore accepted at p=0.05.

Furthermore, the lengths of cuttings do not significantly influence rooting. Short cuttings of ≤12 cm recorded more rooting at the sectional and portions level than the counterpart long cuttings of ≥12 cm. However, the lengths of cuttings do not have any significant effect on the rooting percentage of Melia cuttings as obtained from different portions. Diameter of cuttings also significantly affected rooting at p=0.031 with smaller diameter cuttings of ≤0.5 cm yielding the best rooting percentages than the wider cuttings ≥0.5cm in both stem and root sections. Cuttings from the bottom portions provided higher rooting potentials than the corresponding top and full portions. It can therefore be confirmed that indeed, there were discrepancies in the rooting of long cuttings with large diameters to the short cuttings with a smaller diameter. The second alternative hypothesis as postulated for the study is therefore accepted.

Root cuttings performed better with induction of IBA at all concentrations compared to the stem cuttings which gave the lowest shooting and rooting percentages. The difference in their means was found to be statistically significant. Once again the third alternative hypothesis that there are variations in the rooting
percentage of cuttings obtained from stem to those obtained from the roots of *M. volkensii* plus trees is therefore accepted.

The fourth and last objective analysis depict short plus donor trees with merchantable heights of 2-5 m to be the best and the most ideal in producing cuttings that can procure viable plants upon propagation, followed by medium plus trees in the range of 6-9 m, although this was not statistically significant. It is also worth noting that even though the acceptable merchantable length which could develop roots in the experimental design was those greater than 7 m, lengths below this (2-5 m) have proven to be the best in providing the cuttings with the highest rooting percentage in the final seven trees that rooted. The hypothesis that cuttings from longer bole lengthened mother plus trees have a higher rooting percentage than those from shorter bole lengthened mother plus trees is therefore rejected at $p = 0.05$.

### 5.2 Conclusions

IBA rooting hormone plays a crucial role in the enhancement of rooting and shooting of *Melia volkensii* cuttings. Optimal IBA concentrations of 0.25% should be used in propagating Melia cuttings for great rooting and shooting performance. For the best morphological development and hence great resilience under the harsh ASAL conditions then bottom portions should be utilized. Root sectional cuttings are the ideal cuttings to produce viable plants for plantation establishment.

Short small cuttings perform best in promoting rooting of stem and root sections but not of portions. Diameter of cuttings thus only influences rooting of sections of Melia (root and stem) but has no influence on the rooting of portions (bottom, full and top) as the study revealed. The negative correlation that occurred between the rooting percentage and the cutting lengths ($r = -0.17$) implies that the shorter the length of the cutting, the more the rooting percentage.

Higher merchantable heights do not serve the best purpose in providing planting materials for propagation of *Melia volkensii*, and as such other crucial factors that determine great rooting and development of Melia should be considered when initiating the propagation programme.
Consequently root bottom juvenile cuttings that are less than 0.5cm in diameter and at lengths of ≤12 cm from small plus (2-5m) Melia trees, highly and significantly promote the development of roots and shoot emergence in the cuttings of Melia and should be utilized locally as substantiated by this study.

5.3 Recommendations

The study recommends the following:

- IBA concentrations of 0.25% should be used when inducing growth of Melia cuttings. However, to produce the longest roots, IBA concentrations of 0.5% are recommended.

- Melia short (less than 12 cm) small (less than 0.5 cm) cuttings from the basal points should be used to give the best root and shoot development.

- Small plus trees (between 2-5 m in height) should provide juvenile planting material for the most viable plant production.

- Root (sectional) cuttings should be used to propagate *Melia volkensii*.

Policy Makers

- Agroforestry initiatives in the Arid and Semi-arid lands should be undertaken by the County Environmental and Natural resources department as an example to the local investors.

5.3.1 Recommendations for Further Research

Aggressive research should be done on

- Vegetative propagation by use of stem cuttings should be embarked on by learning institutions, individual’s farmers so as to re-evaluate and provide solutions to mitigate their poor rooting capacities/performance which is species specific for our case to produce adequate and reliable supply of Melia superior planting stock.

- Circumventing high post germination mortality of Melia cuttings, grading/culling- that separates the high quality seedlings to the poor quality
seedlings- should be done. The culling should be based on physical characteristics where easy rapid assessment is made by observation e.g. poor leafing (colour, form of leaves), shoot characteristics

- The selection for Melia tree improvement to be largely in the natural range (those untouched inaccessible areas) where tree growth is influenced by purely genetic composition in order to harness and conserve their genes in-situ thus obtaining a larger gene pool/bank.

- More genetic tests on *M.volkensii* for Kiambeere provenance for the establishment of a stable sustainable seed orchard in Kiambeere sub-county. The research study should engage in appropriate modern technologies that focus on capturing and maintaining a wide range of genetic potential for high quality germplasm production that ensures survival of the propagules before, during and after germination in the field where the soil moisture and nutrients is limiting. This will ultimately conserve the value of tree domestication in the dry-lands.
REFERENCES


The selection of multiple traits for potential cultivars from Cameroon and Nigeria. *Agrofor. Syst.*, 55(3), 221-229.


## APPENDICES

### Appendix I: Tree data collection sheet: Evaluation Melia volkensii plus trees

<table>
<thead>
<tr>
<th>Tree number</th>
<th>Remarks</th>
</tr>
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<tbody>
<tr>
<td>Date</td>
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<tr>
<td>Location</td>
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<tr>
<td>owner</td>
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<td>owner</td>
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<td>Remarks</td>
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### Tree characteristics

<table>
<thead>
<tr>
<th>Estimated age</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>Total height</td>
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</tr>
<tr>
<td>Diameter at 1.5m (cm)</td>
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<tr>
<td>Tree form (class 4-7)</td>
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<tr>
<td>Merchantable length (m)</td>
<td></td>
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<tr>
<td>Branch diameter (cm) (Small, medium, large)</td>
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<tr>
<td>Bark colour</td>
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<tr>
<td>Wood (straight, spiral grain)</td>
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<tr>
<td>Leaves (presence, colour)</td>
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</tr>
<tr>
<td>Flowers (presence)</td>
<td></td>
</tr>
<tr>
<td>Fruits (presence, colour)</td>
<td></td>
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<tr>
<td>Canopy max diameter (m)</td>
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<tr>
<td>Canopy min. diameter (m)</td>
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<tr>
<td>Tree shape (ball, umbrella, column)</td>
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</tbody>
</table>

### Climate

| Mean annual rainfall |         |
| Length of dry season |         |
| Mean annual temperature |         |

### Soil characteristics

| Surface texture |         |
| Subsurface texture |         |
| Colour |         |
| Salinity |         |
| pH |         |

### Site description

| Field/fallow/secondary bush | Tree form |
| Crop history | Class 4: straight and lightly branched |
| Slope/orientation | Class 5: straight and moderately branched |
| Class 6: slightly bent and lightly branched |
| Class 7: slightly bent and heavily branched |