PROPAGATION OF *OCOTEA USAMBARENSIS* ENGL. USING VARIOUS METHODS IN MT. KENYA FOREST, NITHI COUNTY, KENYA

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Declaration

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

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Dedication

To the entire Mbaabu family

Acknowledgement

During the conduct of this research and throughout my Masters studies, I have benefited greatly from assistance and good will of several people and various institutions whose identities are difficult to mention name by name in this thesis.

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List of Acronyms and Abbreviations

ANOVA: Analysis of Variance

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.

EA: East Africa

GOK: Government of Kenya

FAO: Food and Agriculture Organization

IG: Identified gaps

PAR: Photosynthetic Anti Radiation

TTSA: Tanzania Tree Seedling Agency

TU: Technical University

USD: United States Dollar

Abstract

Information on seed germination of trees is important as it forms a vital baseline for among other information on the germination of indigenous seedlings which take many years to germinate. The study was carried out to find out the effect of different light intensities and growth hormone on the propagation of *Ocotea usambarensis Engl.*The study was carried out for a period of three months (August to October 2010). The objective of the study was to determine the best propagation method using sexual and asexual parts of *Ocotea usambarensis* .Seed germinaton and sprouting of buds from various planted cuttings which had been collected from mature *Ocotea* trees in Chogoria forest was monitored. Some cuttings were first treated with azatone rooting hormone before planting. The collected planting materials were planted in a nursery and the parameters which were measured were the germination percentage, the number of sprouting buds at every ten days interval for 90 days under different light intensities, light intensity measurements using Photosynthetic Active Radiation meter, root collar diameter and height of wildlings from the tree over the same period and the shoot : root biomass taken after 90 days. Other materials for collecting data were measurement equipment like Vanier Calipers, rulers and weighing balances. Data analysis was done using GENSTAT computer soft ware. Analysis of variance (comparison of the means of the sprouting buds), percentages and shoot: root ratios were used to establish the best Camphor propagation materials and the best rooting and growth conditions. The results revealed that sprouting of buds was highest in treated sucker stem cuttings with a rooting hormone (mean number of sprouting buds=16.44, light intensity of 8220 Lux) while at 575 Lux site, mean number of buds sprouting was only 7.89. Untreated stem cuttings produced a mean of 7.0 buds at the same level of 8220 Lux lightt intensity. Mean number of sprouting buds from treated root sucker cuttings under light intensity of 8220 lux was observed to be 8.67, while buds from the treated branch cuttings exhibited a mean of only 1.33.Mean number of buds recorded from the treated *Ocotea* cuttings were relatively higher (62.99%), than those from the untreated cuttings (37.10%) after 90 days of the experiment. Shoot: root biomass ratio was highest for the branch cuttings (0.5) compared to the stem and root cuttings (0.43 and 0.45 respectively). However the branch cuttings had the fewest number of sprouting buds. Germination percentage recorded in *Ocotea* seeds in the experiment was only 3 %. Investigation of growth performance of *Ocotea* wildlings under different light intensities indicated that the wildlings placed in partial light intensity site of 3960 lux exhibited a higher growth performance compared to the wildlings in the other sites. Conclusion is that treated stem and root cuttings in the open produced more buds than the other cuttings and the recommendation is that stem and root cuttings should be treated with a rooting hormone before planting and that they should not be covered in the nursery to achieve better performance.

CHAPTER 1: INTRODUCTION

1.1 Background

Mass destruction of forests first occurred in the temperate zones according to Griffiths (2007), however in the last 50 years, fastest rates of deforestation (50% and 90%) occurred from 1980 in the tropics. According to FAO (2006) between 1990 – 2005, Brazil had the highest deforestation rate of 2822 ha/year in South America followed by Indonesia with a deforestation rate of 1872 ha/year.

In Kenya the gazzeted forest cover is reported to be less than 2 % of total forest cover due to deforestation. This is far below the world recommended forest cover of a minimum of 10 % Kenya Forestry Working Group (2008). The degradation and deforestation caused by illegal activities has not spared the camphor especially on Mt Kenya since the late 1970s.

The Mount Kenya ecosystem is of critical importance for Kenya as a major water tower Akotsi and Gachanja (2004) and of global relevance because of its biodiversity and scenic beauty. In a research on indigenous tree species, Oballa and Musya (2010) reported that, extensive areas of Kenya's indigenous forests have been exploited over the last 50 years for sawn-timber and other forest products such as charcoal. In some areas, they have been so extensively logged that some species, both endemic and non endemic, are threatened with extincton and included is *Ocotea usambarensis,* FAO (2001) and CITES (2003). According to the Tanzania Tree Seedling Agency (2002), with the current deforestation trend, the aspect of conserving existing gene resources for future use becomes ever more important and must form a natural part of any long-term commitment to conservation.

Governments in Africa have concentrated on planting exotic tree species. However, exotic species have failed to replace indigenous timber in places where high quality timber is needed for furniture and interior furnishings Oballa and Musya (2007). If Kenya is to earn more foreign exchange from forest products, these indigenous species must not only be conserved but be improved and grown side by side with the exotics. Oballa and Musya (2007) categorize promising indigenous tree species for planting into three categories namely; those planted for their valuable timber, multipurpose species for agroforestry and those planted as ornamentals.

Ocotea was once dominant in the wet forests of the Eastern Aberdares and Mt. Kenya up to altitude of 2,600 metres above sea level, but it is now rare due to over-exploitation, low seed viability, browsing, game damage and poor regeneration Gachathi (2007). Germination of seeds is sporadic often taking 2-3 months. The trees mature in 60-75 years. Due to difficulties in seed supply, the species can be raised through use of natural suckers which are produced by stumps of felled trees. According to Bussmann (2001), large scale logging of Camphor trees predominantly destroys its regeneration leading to secondary forest types.

The East African (EA) Camphor wood (*Ocotea usambarensis*) is targeted for its valuable timber for furniture and joinery Gathaara (1999). The situation is compounded by the slow growth rate, low seeds viability, browsing by wild animals, game damage and difficult in seedlings propagation Albrecht (1993). Its medicinal value and high quality timber has led to its overexploitation endangering this unique tree species. The tree species has been traded internationally in limited amounts, but there are no statistics

on production and trade of the timber. Okeyo *et al*., (2008) note that, in 2000–2001 the timber was the most highly priced in Kenya and that, exploitation of the bark for medicinal purposes was considerable, but there is no information on amounts. Camphor seems to have good prospects as a plantation timber tree, providing wood of excellent quality. Marura and Lemmens, (2008) observe that although the species provides valuable timber and has been over exploited, very little research has been done on its wood properties, growth rates and propagation methods. *Ocotea usambarensis* regenerates mainly by suckers because regeneration from seeds is uncommon due to high damages of seeds, Louppe, *et al.,* (2008). There is need for research to be able to develop sound methods of propagation of the tree species.

1.2 Problem Statement/Justification

Though *Ocotea usambarensis* is a threatened species, a visit to the tree seedlings nurseries in Mt. Kenya area reveals that there is a shortage of these indigenous hardwood seedlings. Propagation of the tree using seed is difficult due to low viability and vigor of the seed and the wildlings are easily damaged by wild animals in the forest. While studying growth rates of important East African montane forest trees using seeds, in Mt Kenya, Bussmann (2000), deduced that, of all the species examined, *Ocotea usambarensis* showed the lowest growth rate. According to Bussman (2001), investigation of the germination rates and rooting of various cuttings of *Ocotea usambarensis* is significant in formulation of faster methods of *Ocotea* seedlings propagation in nurseries for enhanced seedlings production for enrichment planting and rehabilitation of degraded areas to halt and reverse the disappearance of this valuable endangered species.

The purpose of this study therefore was to establish better methods of *Ocotea* seedling propagation using seeds and cuttings. The results obtained shall be used to recommend better ways of propagating the *Ocotea* seedlings in the nursery since the tree has become endangered due to its medicinal and high timber value, Gachathi (2007).

1.3 Research Questions

To achieve its objectives, the study was guided by the following questions;

1. How does shading affect the growth rate of different *Ocotea* propagation materials?

2. Which cutting has the best rooting system for propagating *Ocotea usambarensis* among the stems, roots and branches?

3. Does azatone rooting hormone affect the rooting and growth performance of the different Ocotea cuttings?

1.4 Broad Objective

The main objective of the study was to determine the best propagation method using sexual and asexual parts of *Ocotea usambarensis*.

The specific objectives of the study were to:

1. Find out the effect of different light intensities on germination and growth performance of *Ocotea usambarensis* seeds, cuttings and wildlings.

2. Determine the impact of the position of cuttings of *Ocotea usambarensis* on rooting intensity.

3. Determine the effect of azatone rooting hormone on the growth performance of the various cuttings in the study.

4. Find out the best quality cutting for planting using the shoot: root ratio biomass test.

1.5 Research Hypotheses

1. The growth rate of *Ocotea usambarensis* cuttings is not significantly improved by shading.

2. Cuttings from root suckers of *Ocotea usambarensis* have a significantly higher rooting

intensity.

3. Azatone rooting hormone significantly improves the growth rate of *Ocotea usambarensis* cuttings.

1.6 Significance of the Study

Extensive illegal logging of indigenous trees on Mt. Kenya forest has led to serious destruction of the trees below the bamboo-*Podocarpus* belt. Over 75 % of clear – felled plantations have not been replanted with tree seedlings although all these areas were formally under the Shamba-system, Gathaara *et al.*, (1999). The *Ocotea* seeds are easily damaged by fungi, wild animals and insects in the forest. Collection of the seeds is also difficult and all these aspects make it difficult to propagate the tree using seeds in the nursery according to Gachathi (2007). The seeds are also low in vigor and viability. Thus a better and faster method of raising *Ocotea* seedling in the nurseries will increase the supply of the seedlings for replanting in the deforested and degraded areas of the Mt. Kenya forest improving the conservation one of the most important water

catchment areas in the country and biodiversity according to Bussman (2001). Conserving the threatened tree species requires a holistic research approach to factors involved in the propagation of these trees.

1.7 CONCEPTUAL FRAMEWORK ON PROPAGATION OF *OCOTEA u.*

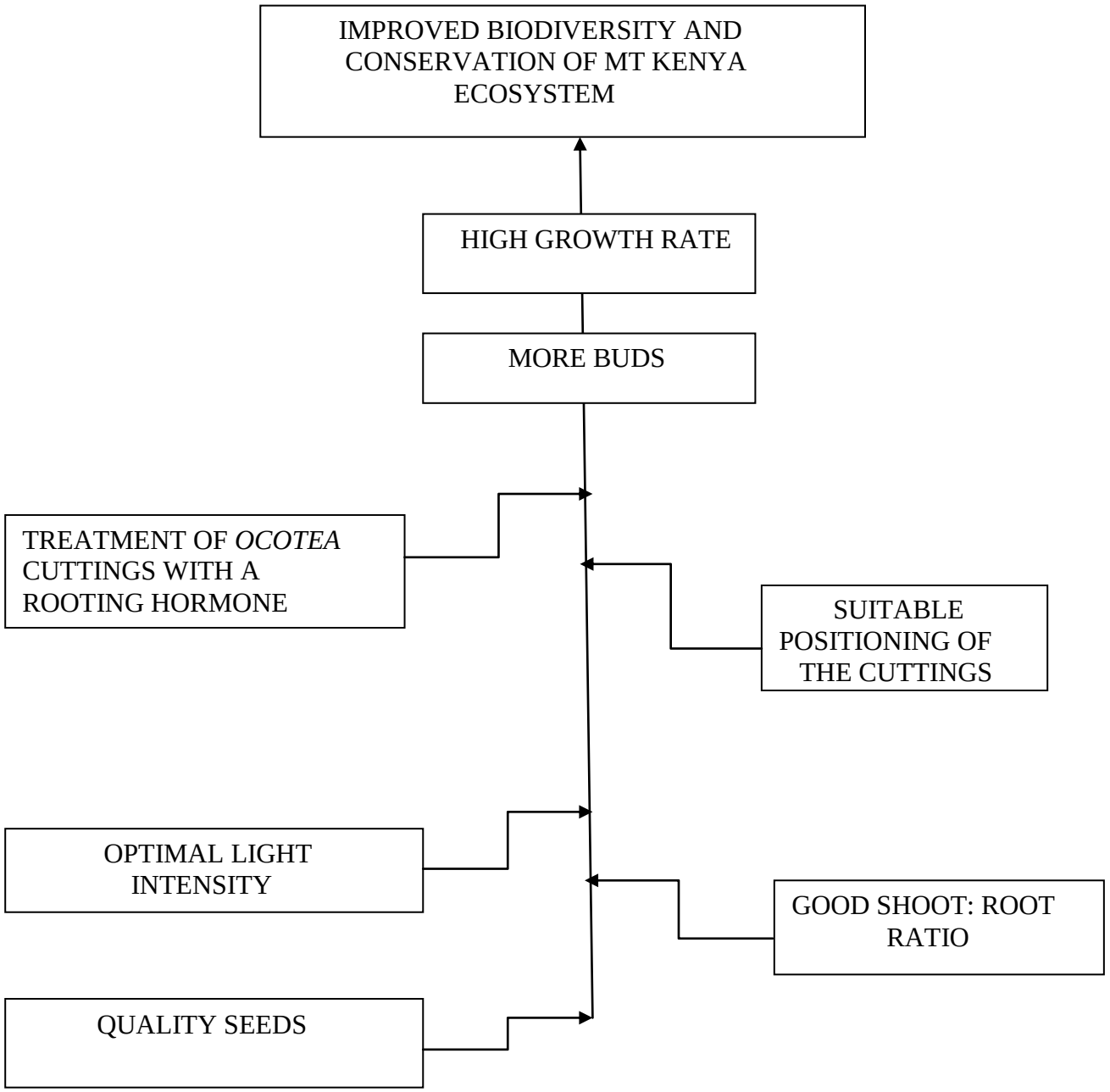

Figure 1.0: Conceptual Framework on propagation of *Ocotea usambarensis*.

Efficient and effective supply of quality and quantity indigenous tree seedlings is crucial for the continued conservation of our vital ecosystems especially the water catchment areas. This will lead to conservation and increase of the gene pool in forests ecosystems improving the environment in our water towers in the country. Most of the

valuable indigenous tree species in the country like *Ocotea* are already endangered with extinction due to the increasing population pressure. Many of the tree nurseries in the country cannot meet the increasing demand of indigenous tree seedlings. Alternative methods of raising such tree seedlings ought to be put in place to address the increasing demand of the same.

Provision of the right conditions for *Ocotea* propagation, quality cuttings of the tree and seeds, optimal light intensity, application of a rooting hormone to the cuttings before planting and acquisition of propagation material from the correct position will result in sprouting of more buds, higher growth performance of the propagation materials increasing supply of *Ocotea* seedlings for replanting in degraded areas. This will increase biodiversity and improve conservation of Mt. Kenya forest and other ecosystems.

1.8 Operationalization of Terms

1.8.1 Optimal Light Intensity

Optimal light intensity is the best amount of energy given off by light leading to best growth performance in plant. In the study, growth performance of various propagation materials were tested at three light intensity sites (575 lux – low, 3960 lux – medium and 8220 lux – high). Suitable light intensity will enhance photosynthetic processes and optimize physiological activities in the cells of the sprouting buds. This will lead to increased growth activities in the cells increasing the sprouting of more buds, increased rooting activity and as a consequence more seedlings will be produced in the nurseries. Photosynthesis is light dependent. At low light intensities, this may become the limiting

factor, one reason why plants grow better outdoors, rather than in the house. There is also a level of light intensity above which photosynthesis cannot take place any faster as other factors become limiting slowing growth, for example level of carbon dioxide in the atmosphere or temperature.

1.8.2 Application of a Rooting Hormone to the *Ocotea* Cuttings.

A rooting hormone as used in the study, is any chemical that promotes elongation, stimulation of differentiation and branching in a plant. The rooting hormone also stimulates opening of buds causing rapid growth.

Treating the various *Ocotea* cuttings with a rooting hormone improves the rooting of the cuttings and hence growth performance of the cuttings. Rooting intensity increases leading to better growth performance and consequently production of a higher number of quality *Ocotea* seedlings in the nursery

1.8.3 Position of the Cuttings and Good Nursery Practice.

In vegetative propagation, position of the cuttings on the tree whether low section, middle or top section of the stem or whether underground is crucial in determination of growth performance in cuttings. Rooting intensity various at different positions or with different sections of a cutting from a plant.

The correct position of the cuttings will lead to improved sprouting of the buds, increased rooting intensity, better performance of the cuttings leading to a production and supply of the seedlings in the nurseries.

1.9 Definition of Terms

1.9.1 Biodiversity

Due to overexploitation, *Ocotea usambarensis* has become an endangered tree species, threatening its existence and/or total loss of the germplasm. This will lead to loss of biodiversity if the trend is not reversed by identifying better and faster methods of propagating the tree to improve biodiversity using parts of the tree itself. A section of a plant shoot, root or leaf can grow to form a whole new plant that contains the exact genetic information of its own source plant. In this study, stems, root and branch cuttings were used in propagation of the tree.

"Biological diversity" or "biodiversity" can have many interpretations. It is most commonly used to replace the more clearly defined and long established terms, species diversity and richness. This study notes that, species diversity of *Ocotea* tree is threatened due to overexploitation coupled with the difficulty in propagating the tree using seeds. Biologists most often define biodiversity as the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most circumstances and presents a unified view of the traditional three levels at which biological variety has been identified: species, ecosystem and genetic diversity.

1.9.2 Wildlings

Young seedlings which develop naturally in the wild. They are sometimes transplanted. When viable seeds from trees drop on the ground and conditions for their germination are right, young seedlings develop naturally. These seedlings can be planted elsewhere in the forest or further developed in a tree nursery.

1.9.3 Propagation

Propagation refers to reproduction, and other forms of multiplication of an organism. Plant is the production of more plants by seeds, cuttings, grafting or other methods. It can also be described as the process of creating new plants from a variety of sources: seeds, cuttings, bulbs and other plant parts. Placing cuttings in a suitable rooting substrate under appropriate humidity greatly enhances sprouting of leaves. The method is simple, affordable and can be used to grow many trees with desired traits.

1.9.4 Scope, Limitation and Assumption

Collection of the samples was done inside the forest and movement was difficult due to the thick bushes and forests. The other constraint was the unpredictable weather during collection of samples and recording of the data. It was also difficult to ascertain the physiological maturity of the seeds collected for planting in the nursery. Low accuracy of the measuring equipment was also a major challenge and determination of maturity of the *Ocotea usambarensis* trees in the forest. Transportation of the samples was also not easy due to the poor infrastructure as a result of the wet conditions in the forest.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Ocotea usambarensis belongs to the family Lauraceae and is native to Eastern and Southern African countries of Kenya, Tanzania, Malawi, Zambia and Uganda. It requires deep fertile soils with good drainage Maundu and Tengnas (2005). Common names include East African Camphorwood, Mkulo (Tanzania), Maida (Uganda), Muwong, (Masai) and Muthaiti (Meru). It is a large evergreen tree growing to 35 m (exceptionally upto 45 m) tall (Plate 4.5), with fast growth (up to 2 m per year) when young. The leaves are opposite (sometimes alternate on fast-growing stems), elliptic to oval, 4-16 cm long and 2.5-9 cm wide, dark green above, pale below, with an entire margin and an acuminate apex. The foliage has a distinct scent of camphor. The flowers are inconspicuous, greenish-yellow; the fruit is a small drupe 1 cm long Okeyo (2008).

2.2 Species Diversity

The estimated number of species in *Ocotea* ranges from two hundred (200) to three hundred and fifty (350) species, most of them in tropical America while mainland Africa has about seven species and Madagascar about 35, Okeyo (2008). In Kenya, the tree was once dominant in the wet forests of the Eastern Aberdares and Mt.Kenya up to an altitude of 2,600 metres above sea level, but it is now found in very few areas due to its very high demand and difficulties in propagating the tree, Gachathi (2007).

Figure 2.0: Map of Africa showing distribution of *Ocotea* in the continent.

Source: ICRAF (2008)

The following table shows the percentage contribution of various causes of deforestation in the tropics;

Table 2.0 Estimates showing the various causes of tropical deforestation, 2000 - 2005

Serial No	**Cause of Deforestation**	**Percentage Contribution**
1.	Small – holder agriculture	35 – 45 %
2.	Cattle Pasture	20 – 25 %
3.	Large – scale agriculture	15 – 20 %
4.	Logging	10 – 15 %
5.	Others: urbanization, infrastructure development, forest fires (not for agriculture.) hydroelectric projects, fuelwood collection.	5 %

Globally the above report FAO (2006), reported that between 1990 – 2005, Brazil had the highest deforestation rate of 2822 ha/year in South America. Indonesia was second with a deforestation rate of 1872 ha/year, (Table 2.1).

Table 2.1 Various countries annual deforestation rate (ha/yr)

Country	**Deforested area (1000 ha/year, average 1990 - 2005**	**Trend 1990 - 2005**
Brazil	2,822	up
Indonesia	1,872	up
Sudan	589	-
Myanmar	467	-
DR Congo	461	DOWN
Zambia	445	-
Tanzania	412	-
Nigeria	410	-
Zimbabwe	313	-
Venezuela	288	-
Kenya	186	-
Other 68 countries	3,257	UNKNOWN

Source: FAO (2006)

The degradation and deforestation caused by illegal activities has not spared the camphor especially on Mt. Kenya since the late 1970s. In a research on indigenous tree species, Oballa and Musya (2010) reported that, extensive areas of Kenya's indigenous forests have been exploited over the last 50 years for sawn-timber and other forest products such as charcoal endangering *Ocotea usambarensis* among other indigenous tree species. Species diversity has also gone down due to such activities Benton (2001), in those areas.

2.3 Ecology and Distributions

2.3.1 Natural Habitat

Ocotea usambarensis is found in diverse mountain forest associations, the so-called *Ocotea* forests. The tree is distributed throughout East Africa and is common in water forests, Gachathi (2007). Where it occurs naturally, there is a distinct dry season of 2-3 months, but with mist or clouds present throughout the year. It is found mainly in Kenya, Tanzania, DR Congo, Rwanda, Northen Malawi, Northern Zambia and sparsely in Uganda. In Kenya, it occurs on the moist slopes of the Aberdares, Mt Kenya, Taita Hills and Nyambene hills and it was once a dominant tree in the wet forests of these areas but is now limited in numbers Gachathi (2007). In Uganda, it occurs in upland and mountain forests, commonly in the impenetrable (Bwindi), Kalinzu and Kasyoha-Kitomi Forests.In Tanzania, it occurs on Mt Kilimanjaro, the Usambara, Pare and Uluguru Mountains, and in Tukuyu and Iringa, Okeyo (2008).

2.4 Botanic Description

Ocotea usambarensis is a large tree, 3.5m-36m (max. 45m) high with a spreading crown and stem diameter of upto 3.75 – 9.5m, Okeyo (2008). Bole is straight, slightly fluted, buttressed at the base and unbranched for 9-15m. Bark is grey or reddish brown, much fissured, granular, scaly and flaking off in small round patches or thick squares; slash white or faintly pink with a characteristic sweet scent. Leaves opposite (alternate on sucker shoots), simple, elliptic to elongate – ovate or almost round, 4-16.5 cm long, 2.5 – 9 cm wide, dark green above, Okeyo (2008). Whitish below and camphor, scented; margin rolled under in mature leaves, glabrous to shortly tomentose or pubescent with spreading ferruginous hairs, rounded to sharply acuminate at the apex,

cuneate, rounded or truncate at the base, venation closely reticulate above, lateral nerves impressed above; veins wavy and brown; petiole 0.5 – 2.2 cm long.

Cymose panicles tomentellous, axillary and terminal, 1.2 – 2.5 cm long, grayish or ferruginous, pubescent; peduncles 2 – 5 cm long; pedicles less than 2 mm long, obtuse, densely pubescent, soon deciduous. Perianth green, whitish or yellow, pubescent, about 1.5 mm long; inner lobes ovate, outer elliptic – oblong, 3 mm long, spreading. Separate male and female flowers, 8 – 10, each 5 mm long, yellow – white – green, hairy, stalked, held in a calyx cup. Stamens of hermaphrodite flowers with linear filaments as long as anthers; stamens of 3rd whorl with yellow, subglobose sessile or shortly stalked glands inserted on either side at the base; staminodes filiform, 1 mm long with dark tip. Female flowers with stamens and staminodes much reduced. Ovary ovoid, glabrous; style slender, 1 mm long; stigma discoid. Fruit a glabrous drupe, ellipsoid or globose, 8 – 11 x 1 - 6.5 mm, borne in a cup 4 – 6 mm wide and 2 – 3 mm long, smooth and green when mature; pedicel thickened below cup. Seeds very small and surrounded by pulp, Bussman (2001).

2.5 Propagation

Ocotea usambarensis produces seeds every ten years. Fresh seeds are recommended to be used for sowing, Travis (2009). The germination rate is often low, up to 45 % because seeds are often heavily attacked by insects. The seeds usually start germinating in 30 – 45 days, but germination may take up to 90 days, Bussman (2001). In their study on propagation of *Ocotea*, Kowalski and Van (2000) reported that, propagation of *Ocotea* by seed is difficult as the flowers and fruits are attacked by fungal diseases and

insects and the fruits quickly loose viability in storage. Louppe, *et.*, (2008) reported that *Ocotea* regenerates mainly by suckers because undamaged seed is uncommon.

In Kenya, flowering of *Ocotea* can be observed in the month of February in Chogoria forest and in May and June in Ragati forest, Okeyo (2008). Seeds are sensitive to desiccation and should be sown fresh. Pre treatment of seeds is not necessary and under ideal conditions, seeds germinate in 30 – 45 days and the expected germination rate of mature, healthy and properly handled seeds is 45 %, Bussman (2001).

Regeneration by root suckers is also possible since they produce roots easily. Travis (2009) reported that *Ocotea* seeds should be kept intact when planted for best results. Cyril and Pedro (2001) found that after keeping various *Ocotea* cuttings for 12 weeks in the nursery for rooting, 95 % success rate was realized. However there were difficulties in obtaining planting from seeds since *Ocotea* exhibits mast fruiting with 1 to 10 years between seeding years and also success rates of different cuttings like stem, root and branch were not given, Hartman, *et.*, (1999).

According to Jaenickle and Beniest (2002), a piece of plant material can grow to form a new plant that contains the exact genetic information of its own source plant through vegetative propagation. *Ocotea* seeds in the wild are parasitized and the regeneration potential is reduced. The seed must be picked, cleaned and sown immediately.

Tonin (2006) observed that storage of *Ocotea* seeds decreased their viability and vigour. In a study on propagation Bussman (2001), it was observed that the rooting of hardwood cuttings proved to be a very difficult task in most species. According to the same author, propagation of indigenous trees requires coordinated and considerable amount of research because propagation of most of the trees using seed is difficult.

Palzer (2002) observed that, 95 % rooting success of cuttings was attained by treating cuttings in a medium containing two auxins and various inorganic and organic nutrients. Luciana (2008) while studying propagation of *Ocotea usambarensis*, found that natural propagation of the tree with seed is difficult because they are recalcitrant and present tegumental dormancy, irregularity and low germination percentage. Before sowing, seeds shooud be cleaned to remove the pulp by rubbing in water. Seeds are sensitive to desiccation but can be stored for a short period in moist saw dust, Gerald (2010).

2.6 Growth and Development

Records of growth rates of *Ocotea usambarensis* are contradictory. Growth rates of up to 2 m/year have been recorded for young trees, but this seems to be exceptional. In a 75 year – old plantation at 2450 altitude in Kenya, trees were 15 – 29 m tall, with a bole diameter of 19 – 51 cm. The mean annual diameter increment was 6.2 mm until 18 years after planting, but thereafter decreased gradually to 4.4 mm at 75 years old. It was suggested that the initial spacing (1.5 m x 1.5 m) was too close to enable good growth, Lannoti (2007). In Tanzania, 49 – year – old trees were 15 – 24.5 m tall, with a mean bole length of 10 m and mean bole diameter of 40 – 49 cm. It was recorded that 90 % of the trees showed Heart rot, ranging from 4 – 24 % of the log volume, but in another

study 60 % of the trees was recorded to be free of heart rot, Okeyo (2008) and Duncan (2009). Trees may produce fruits in large amounts, but usually only once in 10 years, so – called mast years Bussman (2001). They often develop root suckers, but these are often eaten by large animals such as elephants. Regeneration by suckering and coppicing is high after clear felling, Louppe et *al.,* (2008).

2.7 Management

Ocotea usambarensis is mainly harvested from natural stands, and the extent of plantations is very limited and confined to Kenya and Tanzania. Large – scale logging leads to secondary forest types in which *Ocotea usambarensis* does not play a significant role because of lack of regeneration, Bussman and Langes (2000). In plantations a heavy first thinning is recommended 15 – 20 years after planting, reducing the stock to about 700 trees/ha, with subsequent thinning at intervals of 7 – 10 years. Rotation cycles of 60 – 70 years have been practiced in Tanzania, but these may be reduced to 50 years with proper thinning regimes to finally 220 trees/ha. Trees can be managed by coppicing, to which they respond well at any age Palmer (2000) and Okeyo (2008).

2.8 Regeneration.

Under natural conditions, *Ocotea usambarensis* regenerates mainly by suckers because undamaged seed is uncommon. After natural mortality of an old tree, the gap is first filled

by fast – growing pioneer species, in the shade of which the *Ocotea usambarensis* suckers can establish, and after death of the pioneer species, they can develop into new

trees, Bussman (2001). In Kenya, the flowering of *Ocotea usambarensis* can be observed in February in Chogoria Forest, and in May and June in Ragati Forest, Okeyo (2008).

2.9 Diseases and Pests

Fruits are often heavily attacked by gall insects. Standing older trees often show heart rot caused by fungi such as *Ganoderma applanatum* and *Fomes* spp. The bark of young trees is stripped by squirrels and tree hyraxes and the leaves are browsed by elephants and the wood is susceptible to termites, Gachathi (2007).

2.9.1 Importance of *Ocotea*

The wood, often traded as 'camphor', is valued for joinery, panelling, poles for building, doors, window frames, shutters, furniture, cabinet work, vehicle bodies, sliced veneer and plywood. It is used for flooring of local houses and for implements. The wood is suitable for construction, ship building, boxes, crates, vats, matches and pulpwood. It is less suitable for draining boards and kitchen utensils because of the camphor – like smell. It is also used as firewood and for charcoal production, ICRAF (2008). Bark and roots are used in traditional medicine. The pounded bark of roots, bole and branches is applied to swellings, boils and wounds. A bark decoction is given to treat whooping cough and measles. Bark powder is taken against stomach – ache. Roots steamed in water are taken to treat malaria and back pain. *Ocotea usambarensis* is occasionally planted as an ornamental shade tree, but its crown is too dense to be useful for agroforestry purposes, ICRAF (2008).

2.9.2 Functional Uses

2.9.2.1 Products

Ocotea usambarensis is a good source of firewood and charcoal. The heartwood is light yellowish – brown, darkening to a deep brown on exposure; sapwood slightly paler and not clearly demarcated. The texture is medium to fine and even; grain interlocked producing a stripe figure; sometimes lustrous; timber has a distinct camphor scent, Okeyo *et al.,* (2008), the wood seasons well and is resistant to acids and fungi but not to termites. It can be used for furniture, railway – coach frames, joinery, panelling, building poles and the production of veneer Gathaara (1999). Medicine: Bark or roots are pounded, water added and the resulting paste applied on swellings such as those on the throat and other tumours. Inner bark may be pounded, mixed with *Brucea* spp and *Myrica salicifolia* and taken in meat soup as a remedy for abscess, whooping cough and measles.

In Kenya, the Taita people boil the bark in water and use it to treat a fatal childhood disease called ‘nyago’ (Kitaita) characterized by strong muscular contractions, stomach pains and disturbed breathing, or it may be scraped and the resulting powder used to dress wounds. Malaria and backache are treated using a solution obtained from roots that have been pounded and soaked in water, Okeyo *et al.,* (2008).

2.9.3 Prospects

Ocotea usambarensis seems to have good prospects as a valuable indigenous timber tree, providing wood of excellent quality, Kimondo (2007). Although it is considered valuable

and has been over – exploited, very little research has been done on its growth rates and propagation methods. The common use of the bark in local medicine warrants more research on the pharmacological activities and on sustainable collection of the bark ICRAF (2008).

2.9.4 International Trade

Ocotea usambarensis is traded internationally in limited amounts, but there are no statistics on production and trade of the timber. Exploitation of the bark for medicinal purposes is considerable, but there is no information on amounts, Benton (2001).

2.9.5 Shoot: Root Biomass Ratio

The shoot: root biomass ratio is an important measure for seedling survival. It relates the transpiring area (shoot) to the water absorbing area (roots). A good ratio, one which indicates a healthy plant is 1:1 to 1:2 shoot: root dry mass, Hannah (1999). This technique thus is vital in establishing the quality of different propagation materials. Itimplies that the best quality planting material would be one with a higher root biomass compared to the shoot biomass.

2.9.6 Literature Gaps

Ambasht and Navin (2002), in their study on *Ocotea* propagation argue that, since regeneration of *Ocotea* by seedlings is very rare, suckers are the best alternative mode of propagation. There is need to determine among the stem, root, sucker cuttings and branch cuttings the fastest growing propagation material. The research study specifically examined the growth performance of stem, root suckers and branch cuttings hence it identified the best cutting of the three.

Crutz (2005**)** argued that one of the fastest ways of developing a plant species is through root cuttings and development of microcutting programs involving shoot propagation. Performance of stem and branch cuttings was omitted in his study. My study research included stem and branch cuttings to compare their performance with those of the root cuttings. Rokotovao *et al.,* (2007) while carrying out a study on vegetative propagation of native species by cuttings in Madagascar, found that, the *Ocotea* cuttings sprouted in 2-3 months in the nursery then withered. The study however did not specify the type of cutttings investigated and the growth performances under different conditions and why they withered.

This study will examine the performance of the stem, root and branch cuttings individually to identify the one with the best growth performance to improve propagation of *Ocotea* in the nurseries.The research study on propagation of *Ocotea* thus attempted to bridge the gaps identified above and also equip the farmers and nursery managers with more information on *Ocotea* propagation and eventually increase seedlings supply of the threatened tree species.

CHAPTER 3: STUDY AREA, METHODS AND MATERIALS

3.1 Location of the study Area

The study was carried out in Chogoria Forest Station, Meru South Forest Zone, Eastern side of Mt Kenya. Chogoria forest is part of Mt Kenya forest and it extends from 1613 metres to 5300 metres above sea level. It lies between latitude 37^{o}, 36^{o} East and 14^{o} South. Total forest cover is 21,000 hectares distributed as follows; 14,800 hectares (high indigenous forest), bamboo (3100 hectares) and bushland (2300 hectares) and no forest plantations, GOK (2008). Chogoria forest site was chosen for the trials because *Ocotea usambarensis* is native to the area and does very well on this side of Mt. Kenya. The soils, temperatures, rainfall are very ideal for the proper growth of the tree in the area.

The soil types in Mount Kenya roughly correspond with different altitudinal zones. They are developed on older volcanoes and they include, haplic phaeozems lithosols, eutric regosols FAO (2006). Soils on Mount Kenya are generally very fertile due to their volcanic origin. Some of them have been created by eroding glaciers while others are due to millions of years of fluvial erosion. volcanic ash which increases fertility sometimes forms part of the mixture of these soils . Ash and pyroclastic rocks turn into soil faster than volcanic rocks. The soils on the mountain are easily eroded but vegetation including the forest protects it well. Once exposed the soil quickly erodes down to bedrock, often by landslides, Speck (2007). The temperature in the study area ranges from 15^{o}C to 30^{o}C and seasonal variations are distinguished by duration of rainfall rather than by changes of temperature. The study area has two rainy seasons, the long rains falling between April and June and the short rains between October and

December with a mean annual rainfall of 1600 – 2450 mm, map of study area is illustrated below.

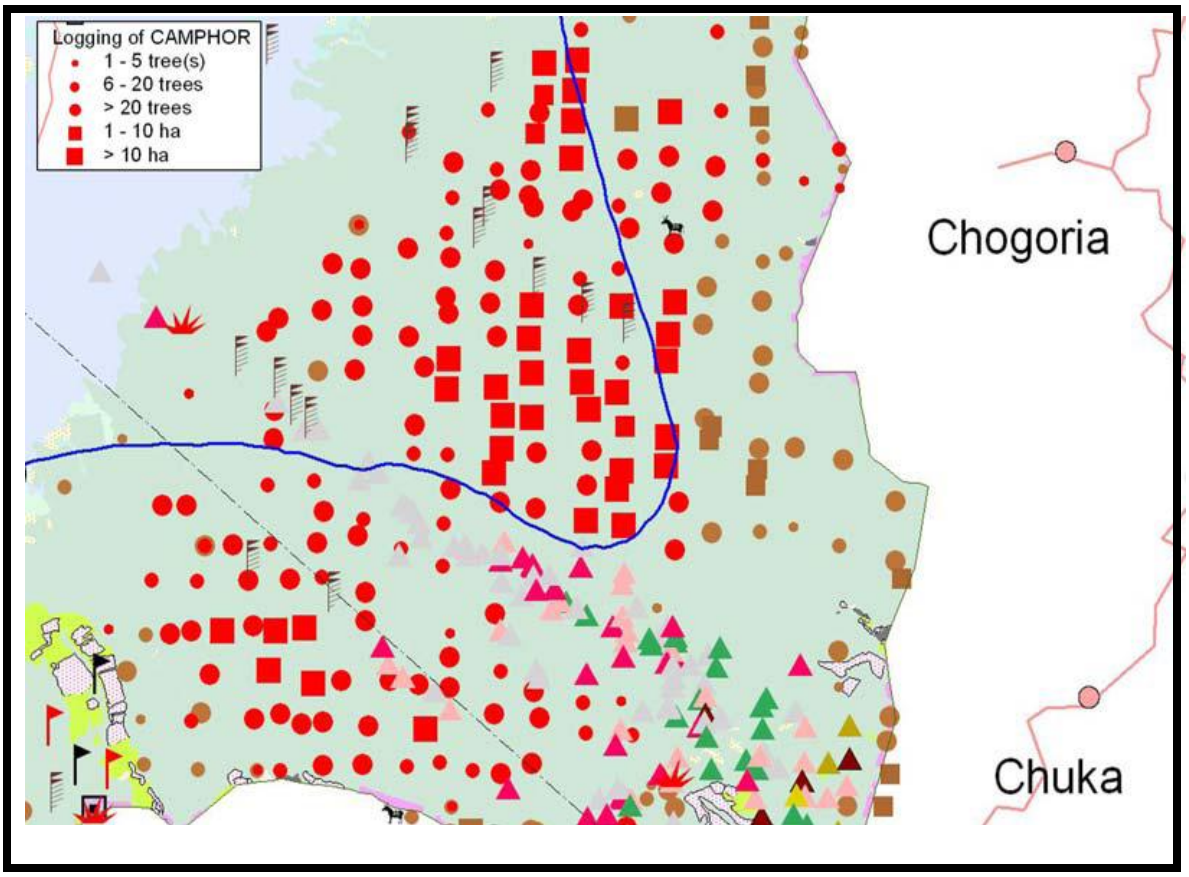

Figure 3.0: Map of the study area: Chogoria forest; Source, Larry (2009)

3.1.1 Sampling Method and Data Collection

3.1.2 Propagation Materials

The Propagation materials collected were stem, root suckers and branch cuttings. The materials were randomly collected from Chogoria forest from different mature *Ocotea* trees growing between 1600 – 2600 metres above sea level. For each category (roots,

stem, branches), 75 samples were collected. The total number of samples collected were 216.

3.1.3 Preparation

Before collection of the propagation samples, 216 medium sized polythene tubes of size 10 cm X 15 cm were filled with fine forest soil collected from the same forest. The tubes were for planting the cuttings. Using block random design, a 5m x 1.3m nursery bed was prepared and divided into three equal blocks where different light intensities (low, medium, high) was provided. Each of the blocks was further subdivided into two equal blocks (one for control experiment and the other for propagation materials treated with a rooting hormone). Finally each of these six blocks was subdivided into 9 units each to contain 4 cuttings of each type for purposes of replication. To achieve complete random block design, 9 pieces of paper were numbered 1 to 9, folded and placed in a container and drawn randomly to assign each of the 9 units in a block a number, Mugenda and Mugenda (1999). This was repeated for the six blocks in the nursery.

3.1.4 Replication

Every cutting was replicated three times and each unit contained 4 cuttings, (number of cuttings in each treatment was thus 12). The cuttings from root (Plate 4.6), stem and branch (4 in each unit numbered) were thus planted in the tubes and placed in the units already numbered randomly. In each untreated block the three sets of stems each containing four cuttings were assigned numbers 1U, 1U and 1U, root cuttings 2U, 2U and 2U, branches 3U, 3U and 3U. For the treated cuttings, the three sets of stems were

assigned 1T, 1T and 1T, roots 2T, 2T and 2T, branches 3T, 3T and 3T. This was repeated in all the blocks as shown in Figure 3.0 below;

Low light intensity Medium High

U	U	U		T	T	T		U	U	U		T	T	T		U	U	U		T	T	T
U	U	U		T	T	T		U	U	U		T	T	T		U	U	U		T	T	T
U	U	U		T	T	T		U	U	U		T	T	T		U	U	U		T	T	T

Figure 3.1: Showing replication in the various blocks.

3.1.5 Treatments

Thirty six cuttings (12 from stem, 12 from root ,12 from branches) were first dipped in a rooting hormone (3 gms azatone hormone in 10 litres of water) before planting in the tubes and placing in the low light intensity block next to the untreated control block 1U above containing also 36 cuttings of stem, root and branch. The former treated block was labeled block 1T. The method of application of the hormone to the cuttings was that reported by Palzer (2002), where the bases of the cuttings were dipped in a highly concentrated azatone (500 -10111 ppm) solution for 3 – 5 seconds before planting.The same procedure was repeated for block 2U and 2T (medium light intensity) and block 3U and 3T for high light intensity.

3.1.6 Data Collection Procedures

The number of buds sprouting and the time in days taken for the buds to sprout for the various cuttings after every 10 days interval were recorded. After 90 days a destructive sampling was carried out and dry biomass of the roots and shoots measured in grams.

The shoot and root biomass were carefully collected for drying. The collected biomass was placed between old newspaper cuttings and placed in an open, well ventilated place and left to dry naturally for three weeks. The shoot: root biomass ratio for the different propagation materials was thus established. Light intensity (Lux) was taken daily at 10 am and 4 pm during the study period using Photosynthetic Active Radiation ((PAR) meter.

3.1.7 *Ocotea* Seeds

One hundred (100) *Ocotea* fresh seeds were randomly collected from twenty randomly selected mature *Ocotea* trees from Chogoria forest and randomly planted fresh in the nursery in three different light intensities. The number of seeds adopted, (100) seeds was that used by Justice (1972) in is germination tests of various seeds. The number of days and number of *Ocotea* seeds germinating under different light intensities were recorded after every ten days for 90 days during the study.

3.1.8 Wildlings

In each of the three sites with different light intensities, a set of twelve *Ocotea* wildlings were placed. Total wildlings were thus thirty six (36). Their growth performance was monitored and girth readings and height measured at ten (10) days intervals.

3.2 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) after which any significant differences in the means of the sprouting buds between and within the untreated and treated propagation materials under different conditions were determined

using Turkeys method. The formula for calculating shoot: root biomass ratio, adopted was that used by Hannah (1999) which gave a clear indication of the quality of the various *Ocotea* propagation materials. Germination percentages, various statistical tests for example correlation coefficients were determined to examine the relationship between time and germination or number of sprouting buds of the various cuttings under different conditions and treatments. The analyzed data was presented using tables, bar charts, graphs and pie charts.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This study was conducted to determine the best propagation method using sexual and asexual parts of *Ocotea usambarensis*. The chapter presents findings on the effect of light intensity on germination of seeds and growth performance of *Ocotea usambarensis* stem, root and branch cuttings. Light intensity units adopted in the study were (Lux), described by Nwinkler (2004) and Ledtronics (2009) as lumens per square foot (one lux is equals 0.0929 footcandles .The effect of azatone hormone on growth performance, and growth of wildlings under different light condition is also presented. Finally, conclusions drawn from the study and recommendations on the way forward are given at the end of this chapter.

4.2 Effect of different Light Intensity on Germination of Seeds and Growth Performance of *Ocotea usambarensis* Cuttings.

Ocotea usambarensis cuttings showed different growth performance under different light intensities, (open site 8220 lux, parial shade 3960 lux and full shade 575 lux). In the open site (under 8220 lux), light intensity the untreated stem cuttings showed a peak (18 buds) on the 60^{th} day while the untreated peaked on the 70^{th} day (12 buds) at the end of the study period – (Fig. 4.0). The untreated set of cuttings planted in open site; 2 buds were first recorded from root cuttings after 20 days, 6 buds were recorded from the stem cuttings on the 40^{th} day and no buds were noted from branch cuttings after the 90 days of the experiment, as shown in Figure 4.0 and Table 4.1a.

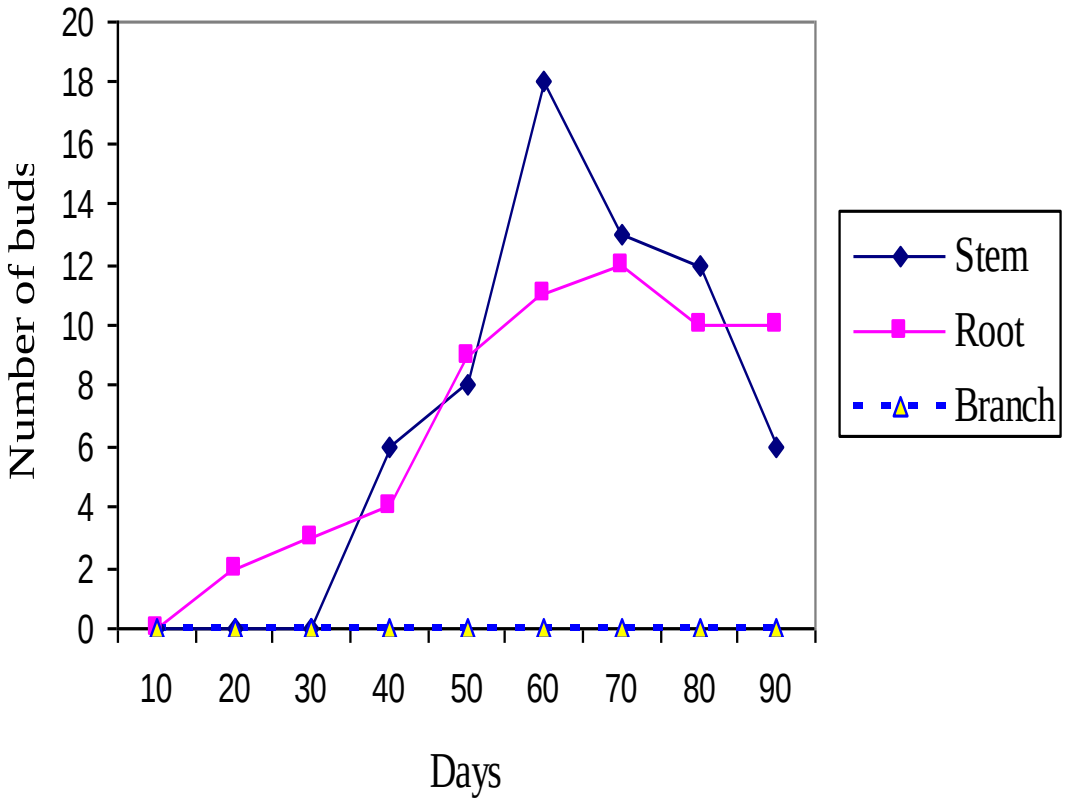

Figure 4.0, The number of sprouting buds recorded from the untreated *Ocotea* cuttings in open site (8220 Lux).

The highest number of buds (18) was recorded on day 60 from the untreated stem cuttings and from the untreated root cuttings, 12 after 70 days. However for the first 30 days as illustrated in the graph, the stem cuttings had not yet yielded any buds. The untreated branch cuttings yielded no buds during the study period.

After subjecting the above data to ANOVA (Appendix 7.5), it was deduced that there was a significant difference between the means of sprouting buds in the three groups (stem, root and the branches. Under 8220 Lux light intensity, numbers of sprouting buds recorded were significantly higher in stem (mean 7.00) and root (mean 6.78) than in the

branch which had no sprouting bud (F = 1.6, df = 2). A plot of the number of sprouting buds against the time in days, Figure 4.0 showed that, the number of sprouting buds from stem and root cuttings continued to increase with the number of sprouting buds from the stem being highest after 60 days. After 60 days the number of sprouting buds started declining. This implies that, both the stem and root cuttings are good propagation materials for propagating *Ocotea* tree.

These findings are consistence with the findings of Brink *et al.,* (2008) who when working on propagation of *Ocotea* using root sucker cuttings reported that root cuttings exhibited good performance compared to other propagation materials. Due to the good performance of the cuttings, they recommended the suckers as one of the propagation methods since *Ocotea* seeds are scarce and difficult to germinate. Since most farmers cover propagation materials in the nurseries, leaving the *Ocotea* cuttings uncovered in the nursery leads to better sprouting of buds in stem and root cuttings compared to branch.

Table 4.1a: Number of sprouting buds recorded from the untreated cuttings in open site (8220 Lux)

	Number of sprouting buds recorded		
Time (Days)	Stem	Root	Branch
10	0	0	0
20	0	2	0
30	0	3	0
40	6	4	0
50	8	9	0
60	18	11	0
70	13	12	0
80	12	10	0
90	6	10	0
Total	63	61	0
Mean	7.00a ± 2.15	6.78a ± 1.50	0b ± 0.00

NB: Mean values denoted by similar letters are not significantly different at 95% critical interval.

Mean number of sprouting buds was highest in stem with a mean of 7.0 ± 2.15 while roots had a mean of 6.78 ± 1.50. Branch cuttings did not yield any buds. The mean number of buds after analysis was found to be higher for stem though there was no significant difference between the two means after they were separated, Table 4.1a.

Optimal light intensity thus improves growth performance of the cuttings and hence the sprouting of more buds from the stem and root cuttings in the open site. The findings agree with those of Rokotovao et al., (2007) who reported a positive correlation between light intensity and number of sprouting buds while working on propagation of *Ocotea* using cuttings.

After subjecting the data to Pearson Correlation Coefficient for light intensity and the number of sprouting buds, the coefficient was found to be 1.0 implying that there is a

strong perfect positive correlation between the light intensity and number of sprouting buds. Thus as the light intensitty increases, number of sprouting buds also increases.

4.2.1 Partially Open Site (3960 Lux) Light Intensity

In partially open site, the number of sprouting buds recorded from the untreated stems and root cuttings were first noted after 40 days. However, branch cuttings did not record any sprouting bud after 90 days in partially open (3960 lux) site, Figure 4.1.

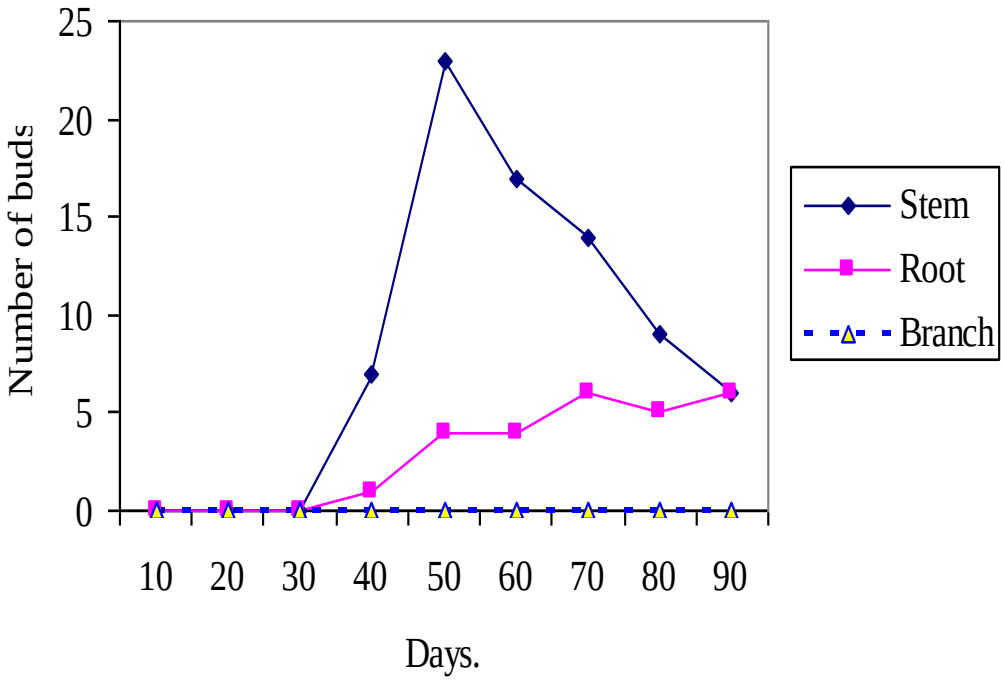

Figure 4.1: A plotting of the number of sprouting buds recorded from the untreated cuttings in partially open site (3960 Lux) in the 90 days. Throughout the ninety days period of the experiment, it was evident that the number of buds sprouting from stem cuttings were consistently higher than for the roots, Figure 4.1.

On subjecting the above data to Analysis of Variance, it was clear that there was a significant difference in the means of the sprouting buds from the three groups of cuttings stem, root and branch.

Table 4.1b: Number of sprouting buds recorded from the untreated cuttings in partially open site (3960 Lux)

	Number of sprouting buds recorded		
Time (Days)	Stem	Root	Branch
10	0	0	0
20	0	0	0
30	0	0	0
40	7	1	0
50	23	4	0
60	17	4	0
70	14	6	0
80	9	5	0
90	6	6	0
Total	76	26	0
Mean	8.44a ± 2.73	2.89ab ± 0.873	0b ± 0.00

NB: Mean values denoted by similar letters are not significantly different at 95% critical interval.

Rooting in the partially open site (lux 3960) showed that numbers of sprouting buds were significantly higher in stem (mean 8.44 ± 2.73) and root (mean 2.89 ± 0.873). The branch cuttings produced no buds at this site after the 90 days of the experiment, ($F = 2.0$, $df = 2$). However, it was deduced that the number of buds from stem and root were not significantly different at 95 % critical interval, Table 4.1B. In both cases buds started appearing after 40 days with stem cuttings showing 7 buds and root cuttings with 1 bud having sprouted during the same period. Again, there is more sprouting of buds from stem compared to the other cuttings. Possibly this could be attributed to the high vigor and better physiological state of the stem cuttings to produce more buds than the other cuttings followed by the root cuttings and the branch cuttings had the lowest

physiological state and vigor to produce buds hence low growth performance compared to the other cuttings. Light availability also played a major role in the sprouting of buds in stem cuttings and root than in branch cuttings.

These findings are in agreement with findings of Louppe *et al.*, (2008) who while working on propagation of *Ocotea* using cuttings reported that cuttings of stem and root performed better than those of branch by producing more buds than the branch cuttings. Physiological condition of the stem and branch cuttings could be better than that of the branch cuttings and hence the production of more buds from the former. Lighting induces sprouting of buds faster in the stem and root cuttings than in the branch cuttings other factors being constant in the nursery.

When the data was subjected to correlation analysis, it was found that there was correlation coefficient of 0.85 indicating that there was a positive relationship between the light intensity and sprouting of the buds. However, since the coefficient is less than one, the deduction is that the relationship at 3960 Lux is not as strong as the relationship at 8220 Lux.

4.2.2 Under Full Shade Site (575 Lux) Light Intensity

Under 575 Lux site, untreated rooting cuttings were the first to produce buds where two buds were recorded after day 40 while the untreated stem cuttings at the same site produced the first one bud after day 50. However, no buds were recorded from the branch cuttings over the 90 days period.

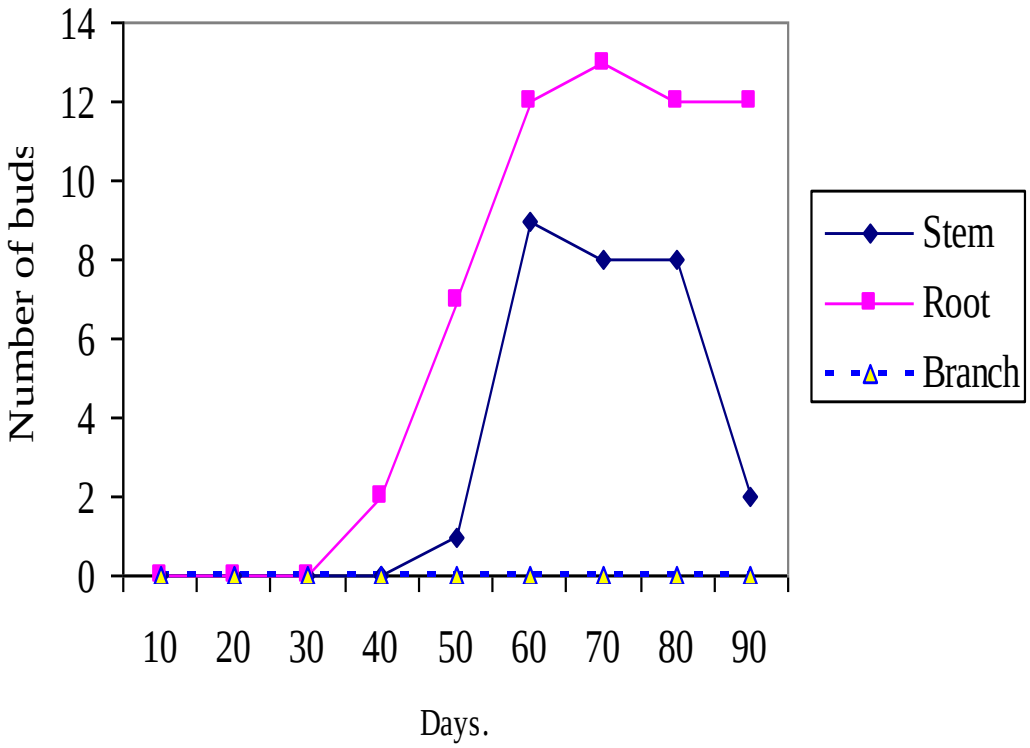

Figure 4.2: Number of sprouting buds recorded from the untreated cuttings in full shade (575 Lux) in 90 days

After carrying out ANOVA of sprouting buds in stem, root and branch, it was again observed that there was a significant difference in the number of sprouting buds from the three groups of cuttings ((F = 5.51, df = 2. However, the number of sprouting buds from stem and root were again noted not to be significantly different. At this site, number of sprouting buds from the root cuttings was higher (mean 6.44) than in the stem cuttings (mean 3.11). The findings agree with those of Brink *et al.*, (2008). Numbers of buds from the root cuttings were consistently higher throughout the 90 days of the experiment.

Rooting under full shade site (575 lux) showed that the numbers of sprouting buds from roots (mean 6.44) was significantly higher than sprouting buds from branch and stem cuttings. Highest number of sprouting buds (13) from roots was recorded on day 70 and from stems, 8 buds were recorded at the same time. Studies by Brink *et al.,* (2008) and Rokotovao *et al.,* (2007) on root sucker cuttings propagation of *Ocotea* trials in Tanzania closely agree with the findings in the experiment. Findings of root sucker *Ocotea* cuttings propagation trials in Tanzania by Brink *et al*., (2008) and Rokotovao *et al*., (2007) agree with findings in the study where they concluded that the root sucker cuttings performed better than other cuttings in their study.

Table 4.2: Number of sprouting buds recorded from the untreated cuttings in full shade (575 Lux)

	Number of sprouting buds recorded		
Time (Days)	Stem	Root	Branch
10	0	0	0
20	0	0	0
30	0	0	0
40	0	2	0
50	1	7	0
60	9	12	0
70	8	13	0
80	8	12	0
90	2	12	0
Total	28	58	0
Mean	3.11ab ± 1.33	6.44a ±1.97	0b ± 0.00

NB: Mean values denoted by similar letters are not significantly different at 95% critical interval.

At a lower light intensity of 575 Lux, more buds were recorded from the root cuttings, mean of 6.44 ±1.97, total 58 buds compared to a mean of 3.11 ± 1.33 from stem cuttings with a total of only 28 buds, Table 4.2. Thus lower light intensity favoured the

sprouting of more buds in the root cuttings than in stem cuttings possibly due to increase in cell division in the roots and hence more growth of buds. Shading effect thus induced more sprouting of buds in root cuttings than in the stem cuttings which performed better at a higher light intensity than the root cuttings

4.2.3 Treated Cuttings

4.2.3.1 Open Site (8220 Lux) Light Intensity

Among the treated set of cuttings planted in open site (8220 lux), 2 buds were first recorded from stems after 10 days as opposed to the untreated set of cuttings where first buds appeared after 20 days, 3 buds were recorded on the 30^{th} day from root cuttings and 1 bud was recorded from branch cuttings after the 30 days of the experiment, Figure 4.3.

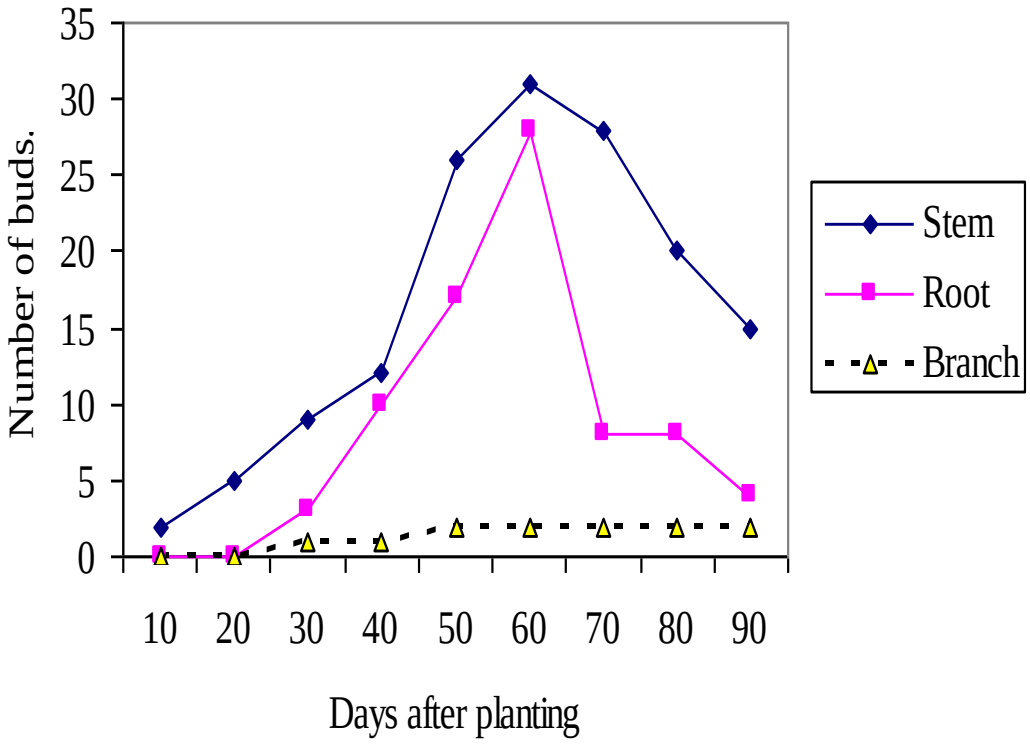

Figure 4.3: Number of sprouting buds among treated cuttings over 90 day period in 8220 Lux site.

It was evident that the treated cuttings started producing buds earlier than the untreated cuttings which started producing buds from day 20. The above graph also clearly indicates the trend of the number of sprouting buds from the various cuttings throughout the study period where number of sprouting buds from the stem cuttings were consistently higher than in root and branch. Highest number of buds from the treated stem cuttings were recorded on day 60 (31 buds) and from the treated root cuttings, 28 buds. However, after 60 days the number of buds which sprouted started declining. When the number of sprouting buds from treated cuttings were compared with those from the untreated cuttings, it was found that the treated cuttings produced more buds

than the untreated cuttings in all the cases. These findings further agree with those of Kowalski and Van (2000) who reported that treated cuttings with a rooting hormone produced more buds than the untreated cuttings.

The peak at day 60 for both the stem and root cutting buds could be attributed to optimal physiological state and vigor of the stem and root cuttings leading to high sprouting of buds at day 60 and hence highest growth performance at this level. At this best growth performance the cuttings were very healthy and ready for transplanting. After day 60, possibly the physiological state of the cuttings, vigor and reserve nutrients started declining leading to reduced growth and a decline of the buds. Between day70 and 80 for the graph of the number of buds sprouting from the root, there was a leveling out of the graph possibly due to a stagnation of growth due that specified period. According to Ingram (2004) and Palzer (2002), treating plant cuttings with a rooting hormone induces Sprouting buds from the treated branch cuttings were the least during the period under study at this site possibly due to low physiological state and vigor of the branch cuttings leading to low growth performance compared to the stem and root cuttings.

Table 4.3: Number of sprouting buds recorded from the treated cuttings in open site (8220 Lux)

	Number of sprouting buds recorded		
Time (Days)	Stem	Root	Branch
10	2	0	0
20	5	0	0
30	9	3	1
40	12	10	1
50	26	17	2
60	31	28	2
70	28	8	2
80	20	8	2
90	15	4	2
Total	148	78	12
Mean	16.44a ± 3.47	8.67ab ± 3.00	1.33b ± 0.289

NB: Mean values denoted by similar letters are not significantly different at 95% critical interval.

On subjecting the data in (Table 4.3) to ANOVA and means were separated, it was evident that the means of the sprouting buds was highest for the treated stem cuttings (16.44 ± 3.47) followed by that of the treated root cuttings (8.67 ± 3.00) and treated branch cuttings had the lowest (1.33 ± 0.289). Mary (2006) reported that, treatment of the cuttings greatly enhanced sprouting hence more rooting of *Ocotea*. The findings also agree with those of Ze' ev and Tchoundjeu (2002) who while working on vegetative propagation of various indigenous trees reported that treatment of cuttings of the trees with a rooting hormone before planting stimulated more sprouting of buds from treated cuttings than in untreated ones.

4.2.3.2 Partially Open Site (3960 Lux) Light Intensity

In partially open site (3960 lux), 6 buds were recorded from the stem cuttings after 20 days and 2 buds from root after 30 days. There were no buds observed from the branch cuttings throughout the experiment. The results recorded from this site are tabulated in Table 4.4 below;

Table 4.4: Number of sprouting buds from the treated cuttings in partially open site (3960 Lux).

	Number of sprouting buds recorded		
Time (Days)	**Stem**	**Root**	**Branch**
10	0	0	0
20	6	0	0
30	7	2	0
40	9	13	0
50	27	16	0
60	21	16	0
70	22	14	0
80	21	15	0
90	12	11	0
Total	125	87	0
Mean	13.89a ± 3.05	9.67a ± 2.32	0b ± 0.00

NB: Mean values denoted by similar letters are not significantly different at 95% critical interval.

Highest number of buds was recorded after 50 days (27) from stem cuttings and 16 from root cuttings. On subjecting data observed in Table 4.4 to ANOVA, it was noted that, there was a significant difference in the means of the sprouting buds especially between treated stem means (13.89 ± 3.05) and branch means (0). Further it was observed that there was insignificant difference between the mean number of sprouting buds from treated stem (13.89 ± 3.05) and those of treated root cuttings (9.67 ± 2.32) as

denoted by the results in the table at 95 % critical interval, (F=4.5, df=2 with a probability of 0.02).

A plotting of the results (Figure 4.4) illustrates how the number of buds from stems and roots were increasing steadily (stem cutting buds being higher) up to a peak and then a decline.

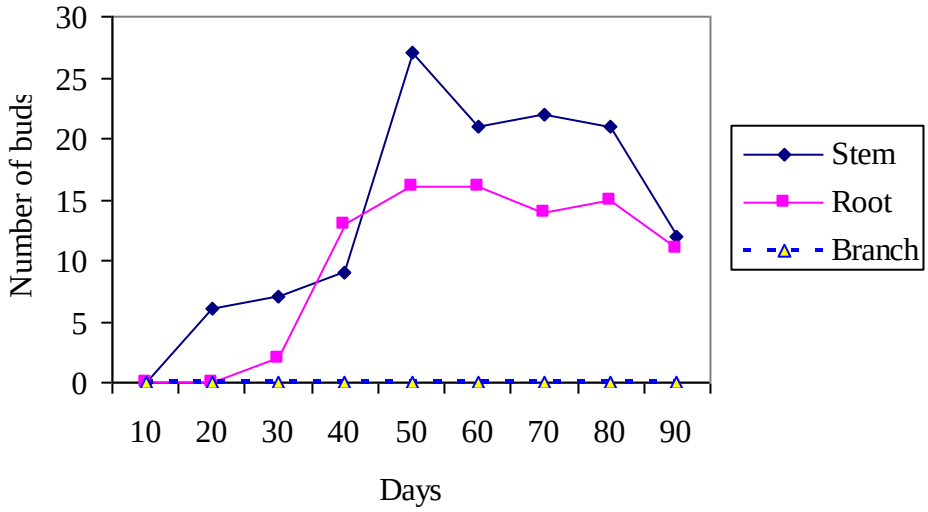

Figure 4.4: A graph of the number of sprouting buds recorded from the treated cuttings in partially open site (3960 Lux) in 90 days

While working on effect of rooting hormone on *Ocotea* cuttings, Farnsworth and Wilma (2009) observed that, a rooting hormone was a viable rooting medium with the cuttings rooting within 60 days. Their results agree very closely with the findings in this study. Generally it is evident that the number of sprouting buds from the treated cuttings are higher in all the sites than for the untreated *Ocotea* cuttings under the same conditions in the experiment. Jaenicke and Beniest (2002) reported similar findings in their work on plant hormones where they deduced that, the rooting hormones induced development of roots and hence rooting intensity.

4.2.3.3 Full Shade Site (575 Lux), Light Intensity

The results at this site are presented in the Table 4.5 below;

Table 4.5: Number of sprouting buds recorded from the treated cuttings in 575 Lux site

	Number of sprouting buds recorded		
Time (Days)	Stem	Root	Branch
10	0	0	0
20	0	0	0
30	0	0	0
40	8	0	0
50	19	0	0
60	15	1	0
70	15	3	0
80	7	5	0
90	7	1	0
Total	71	10	0
Mean	7.89a ± 2.39	1.11ab ± 0.588	0b± 0.00

NB: Mean values denoted by similar letters are not significantly different at 95% CI.

In full shade site (575 Lux); 8 sprouting buds were first recorded after 40 days from treated stem and 1 bud from treated root after 60 days. In the shade, no sprouting bud was recorded in treated branches, (Table 4.5). The highest number of sprouting buds (19) was recorded from treated stem cuttings after day 50 and mean number of buds recorded from the same treated cuttings after the 90 days of experiment were 7.89 ± 2.39 compared to that of roots with a mean of only 1.11 ± 0.588.

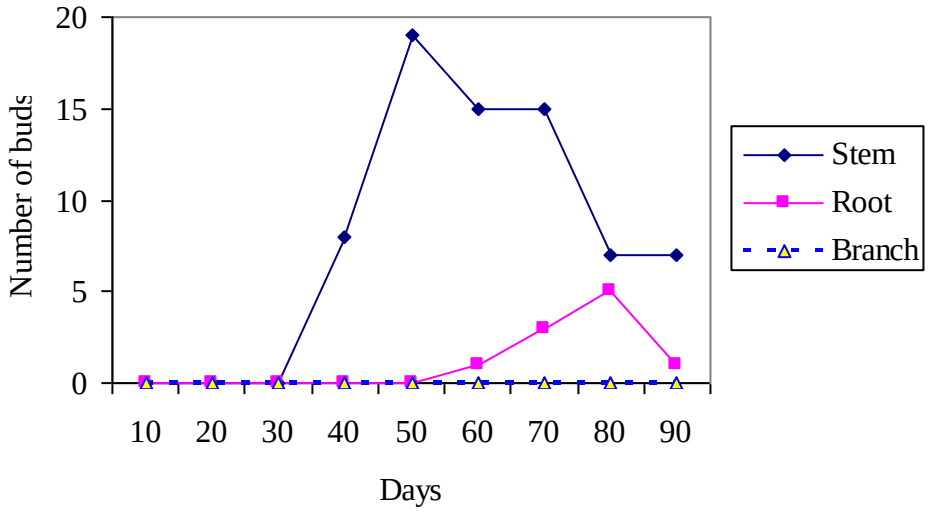

Figure 4.5. A graph of the number of sprouting buds recorded from the treated cuttings in full shade site (575 Lux) in 90 days

Buds sprouting from the treated stem cuttings were consistently higher throughout the experiment than those from root reaching a peak on day 50 then a decline, Figure 4.5. Untreated stem cuttings had only 8 buds after 60 days and total number of buds were 28 only during the period of the experiment. Number of sprouting buds started appearing earlier than in the untreated cuttings when the first buds appeared after day 50. Sengusch (2003) reported similar findings in the study on effect of various rooting hormone concentrations on enhancement of growth in various plant cuttings.

Analysis of variance showed that there was a significant difference in the means of the sprouting buds from the treated stem, root and branch cuttings at 575 Lux light intensity. The means of buds from root and branch cuttings were however noted to be insignificant as illustrated in Table 4.5 at 95 % critical interval.

A plot of the same data revealed the pronounced differences of the number of sprouting buds in the various cuttings in the experiment, Figure 4.5. Lannoti (2007) working on

rooting hormone reported similar findings for *Ocotea* cuttings where the hormones induced sprouting of buds in stems and rootings cuttings more than in the branch cuttings.

4.3 The Effect of Azatone Rooting Hormone on the Growth Performance of *Ocotea usambarensis* Cuttings.

Rooting hormone effect on formation of buds from the plant cuttings was tested. Concentration of the azatone rooting hormone adopted was that of Palzer (2002), where the cuttings were dipped for 3 – 5 seconds in azatone (500 – 10111 ppm solution) before planting.

Findings showed that the number of buds formed, 531 increased when the rooting hormone was used in the cuttings. From untreated cuttings, only 312 buds were recorded. Rooting hormones used therefore had a significant effect on the buds formation from the plant cuttings ($t = 4.098$, $df = 80$, $P < 0.001$). These findings are in agreement with those stimulated and improved opening of buds. Treating the various *Ocotea* cuttings with a rooting hormone improves the rooting of the cuttings and hence growth performance of the cuttings. Rooting intensity increases leading to better growth performance and consequently production of a higher number of quality *Ocotea* seedlings in the nursery.

Using paired t-test to compare the number of buds formed from treated and untreated cuttings, revealed that rooting hormones was significantly effective on sprouting of buds from plant stem and branch as shown by the t-values but not significant in promotion of sprouting of buds from root cuttings. However, when the root cuttings

were treated with the rooting hormone, there was a slight increase in the number of sprouting buds. Untreated branch cuttings with a rooting hormone did not produce any buds because the rooting hormone was acting as a stimulant in stimulating production of more buds leading to higher growth performance.

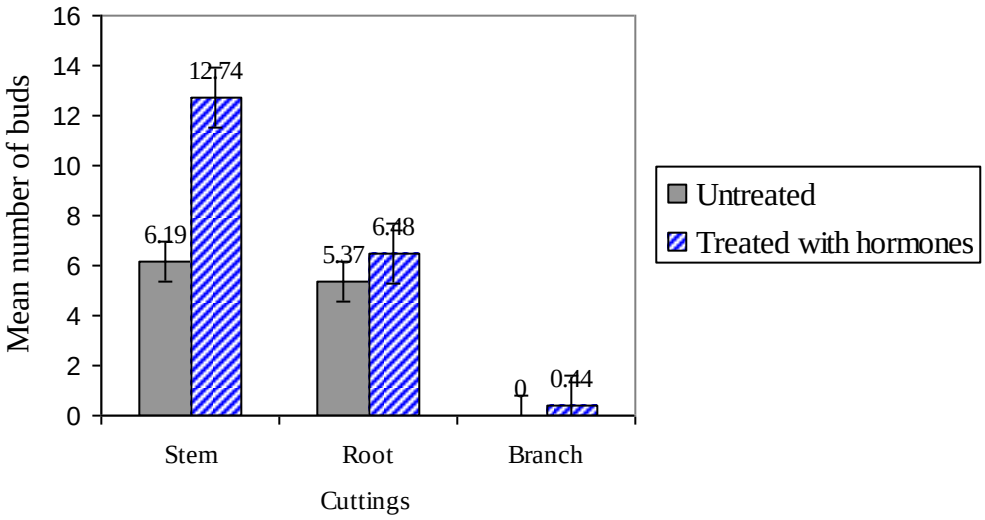

Figure 4.6: Mean number of buds formed by untreated and treated cuttings

A comparison of the means of the number of sprouting buds from the treated cuttings and those from the untreated cuttings produced the pattern shown in Figure 4.6. The mean number of buds from treated stem cuttings was higher (12.74) than for the untreated stems (6.19). Treated root cuttings exhibited a similar trend producing a mean of (6.48 buds) compared to untreated roots (5.37 buds).Treated branch cuttings produced a mean of (0.440 buds) while untreated had none as deduced earlier during the 90 days.

High number of sprouting buds from the cuttings after treatment with a rooting hormone could be attributed to stimulation of the physiological state and vigor leading

to more accelerated growth as opposed to the untreated cuttings. According to Lannoti (2007) and Hortus (2009), treatment of *Ocotea* cuttings with a rooting hormone increased rooting within 60 days.

4.3.1 Overall Effect of Shading on the Plant Cuttings

Ocotea usambarensis cuttings performed better under light condition (8220 lux) than when placed under partial (3960 lux) or full shade (575 lux). Under open condition, mean number of buds sprouting was 6.70 which was significantly higher than in full shade, mean 3.09 buds and in partially open site, mean of 5.8. Light availability thus had an effect on the sprouting of buds from some of the cuttings. Branch cuttings only produced buds particularly after treatment with rooting hormone under light of 8220 lux and not in partial (3960 Lux) nor in full shade (8220 Lux.

Overall sprouting of the buds was therefore found to be more in treated cuttings grown in the open followed by those treated, in the partially open sites. The least number of buds were recorded in plants propagated under the full shade (Figure 4.7).

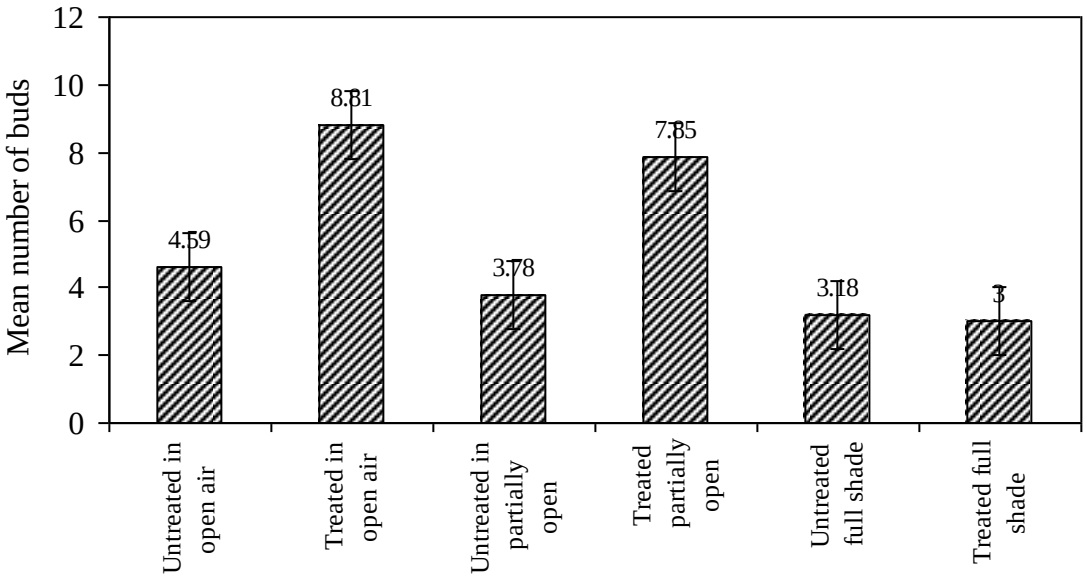

Figure: 4.7: Mean number of buds formed in the experiment (treated versus untreated)

The effect of the respective lighting regimes on the sprouting of buds were as shown in the figure 4.5 in open air, partial and full shade. Farnsworth and Wilma (2009), Lannoti (2007) and Hortus (2009) report that treatment of *Ocotea* cuttings with a rooting hormone increased rooting within 60 days. Their findings are consistent with the findings of this study that, treatment of cuttings with a rooting hormone in the open greatly enhanced sprouting of buds.

4.3.2 Untreated Verses Treated Stem, Root and Branch Cuttings

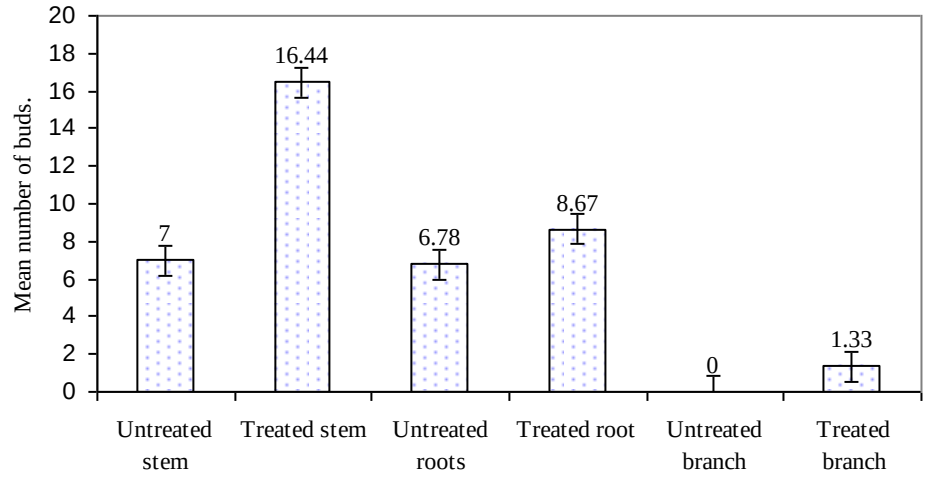

Figure 4.8: Mean number of sprouting buds in open air (8220 Lux) (treated verses untreated)

When the cuttings were not treated with the rooting hormones for experiment in the open site (8220 Lux), the number of buds formed in untreated stem (mean 7.000 ± 2.15) was higher than the number formed in the roots (mean 6.78 ± 1.50).

Table 4.6: Mean number of buds sprouting after treatment with rooting hormones

	Cuttings		
	Stem	Root	Branch
Untreated	6.19 ± 1.27	5.37 ± 0.91	0.00 ± 0.00
Treated with hormones	12.74 ± 1.81	6.48 ± 1.44	0.44 ± 0.154
t- value	6.506	0.764	2.884
p- value	0.000	0.452	0.008

A comparison of the means and standard error of the treated and untreated cuttings also revealed that the means of the treated cuttings were higher than the untreated.

As shown in Table 4.6 comparison of means and standard error of the treated and untreated cuttings revealed that the treated cuttings were performing far much better than the untreated cuttings, especially at the open site with higher light intensity hence the higher means of treated cuttings compared to the untreated cuttings with a rooting hormone.

4.3.3 Partially Open Site Treated Verses Untreated Cuttings

In the partial shade (3960 lux), the number of buds formed by untreated stem (mean 8.44 ± 2.73) was significantly higher (t = 2.457, df = 8, P = 0.040) than those formed by root cuttings (mean 2.89± 0.87). Similarly in this site, there was no bud formed from the branch cuttings, as shown in Figure 4.9

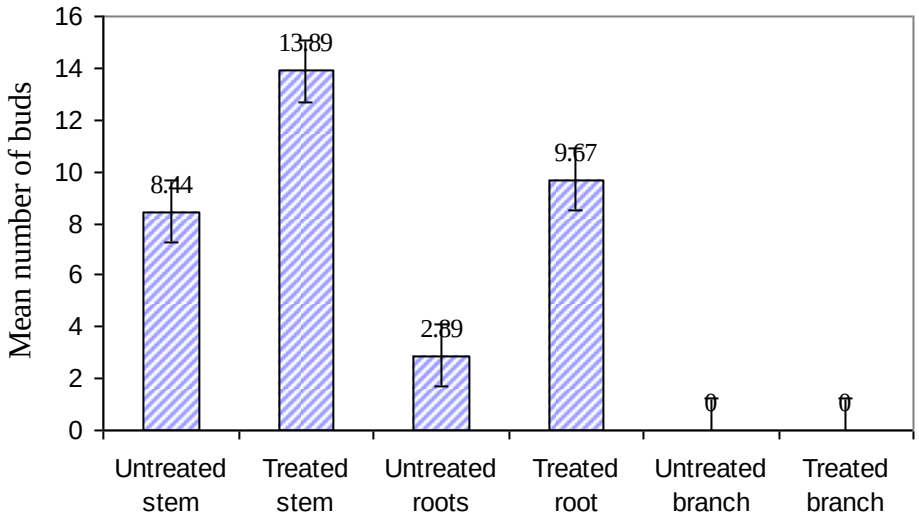

Figure 4.9: Sprouting buds in partially open site (3960 lux) (treated verses untreated)

It was observed that, the treated cuttings were performing better than the untreated cuttings among the stem and root cuttings.

Again, it was evident that treating the cuttings with a rooting hormone leads to inducement of the physiological activities and multiplication of the growth cells in the sprouting buds leading to more sprouting of buds in the treated cuttings.

4.3.4 Full Shade (575 lux) Light Intensity Treated verses Untreated Cuttings

Table 4.7: Mean number of buds formed by cuttings from untreated stem, root and branch at 575 Lux site.

Cutting	Full Shade (575 lux)
Stem	3.11
Roots	6.44
Branch	0.00

Under full shade (575 lux), the number of buds formed by root cuttings (mean 6.44 ± 1.97) were significantly higher ($t = 2.981$, $df = 8$, $P = 0.018$) than the stem cuttings (mean 3.11 ± 1.33). Branch cuttings recorded no bud, (Table 4.7). This implies that shading effect induced more growth performance in the root cuttings than in the stem cuttings. This is very vital information to nursery managers and farmers since not all propagation materials require complete covering in the nursery while others like root cuttings will require complete cover in the nursery. Possibly the shading effect was favouring more physiological activity in the root cutting cells increasing vigor and multiplication of the cells hence more bud sprouting from the covered root cuttings. The findings in the study are consistent with those of Crutz (2005) who reported that, root cuttings performed better under full shade conditions.

In the whole experiment mean number of buds was highest for stem cuttings followed by root and finally branch. This shows that the best section of the plant to use for the propagation of *Ocotea usambarensis* is the stem (mean number of buds formed 9.46 ±1.83). The stem cuttings produced significantly higher number of buds than from root cuttings (mean 5.93 ± 0.85) and branch cuttings (mean 0.22 ± 0.08.

In some instances, mean number of sprouting buds from stem and root cuttings showed no significant differences implying that either of the two could be used for propagation of *Ocotea* seedlings for example the stem or branch cuttings.

Plate 4.0: Extracted stem sucker cutting showing small sprouting roots and the base after extraction from the main *Ocotea* trunk.

Plate 4.1: *Ocotea* cuttings in the nursery showing the height of the sprouting buds as indicated by the arrow on the label – STO – Stem treated open site.

4.4 Shoot /Root Biomass Ratio for the Different Propagation Materials.

To determine the quality of the cuttings, the roots were assessed by getting the shoot to root biomass ratio of the various cuttings. The ratio was higher in branch cuttings (mean ratio 1:2.0 ± 0.00) implying low quality compared to stem and root cuttings which had a shoot/root ratio of 1:2.3 ± 0.05 and 1:2.2 ± 0.07 respectively. There was however, no significant differences in mean shoot/ root ratios of the stem and root cuttings (F = 0.068, df = 2, P = 0.934), Table 4.8 below.

Table 4.8: Shoot to root ratio of the cuttings

Cuttings	Total dry wt of roots in gms	Total dry wt of shoots in gms	shoot/root ratio
Stem	41	17.47	1:2.3
Root	27	12.07	1:2.2
Branch	2	1.00	1:2.0

4.4.1 Shoot /Root Biomass Ratio for the Different Lighting Sites

Plant cuttings under full shade (575 Lux) had a significantly higher shoot/root ratio than (0.58± 0.08) those in the open (1:2.27 ± 0.06) and those in partial shade (3960 Lux) (1:3.12 ± 0.06) (F = 3.347, df = 2, P = 0.041, Table 4.9. While studying shoot: root biomass ratio of various plants, Gerald (2011), reported that increased fine root biomass increases performance of the plants since absorption area of the plant is increased as opposed to high shoot biomass. Shoot area or section loses water vapour to the atmosphere decreasing the quality of a propagation material Hanna (1999).

Table 4.9: Shoot/ root ratio of the cuttings under different light intensity

Cuttings	Total dry wt of roots in gms	Total dry wt of shoots in gms	shoot/root ratio
Open air (lux 8220)	29	12.84	1:2.27ab
Partial (3960 Lux)	23	7.3	1:3.12b
Full shade (575Lux)	18	10.4	1:1.72a

NB; Mean values in same column denoted by same letters are not significantly different

Cuttings from full shade thus recorded low root biomass compared to shoot biomass resulting in the higher ratio of (1:1.72) in full shade implying shoots had a higher biomas at the site. Suarez and Litzberyer (2008) obtained similar results while working on recruitment patterns and composition shifts in Patagonian forests.

4.4.2 Shoot /Root Biomass Ratio for the Plant Cuttings Treated With the Rooting Hormones and Untreated Cuttings

When the plant cuttings were treated with rooting hormones, ratio of shoot/root biomass recorded a mean of 0.46 ± 0.06 which was noted to be higher than in the untreated cuttings which recorded a mean ration of 0.40 ± 0.05 ($F = 0.060$, $df = 1$, $P = 0.461$).

This implies that the shoot biomass, and hence the transpiring area for the treated cuttings was higher than for the untreated translating to the higher shoot/root biomass ratio for the treated cuttings. Hannah (1999) noted that for a good quality planting material, a low shoot/root is desired. The difference in the ratios of the treated and untreated cuttings was however not significant at 95 % critical interval.

Table 4.9.1: Shoot/ root ratio of the rooting hormone treated and untreated cuttings

Cuttings	**Total dry wt of roots in gms**	**Total dry wt of shoots gms**	**shoot/root ratio**
Treated cuttings	39	8.04	1:2.17
Untreated cuttings	31	12.50	1:2.50

Biomass of the treated root (39) was found to be higher than for the untreated roots (31) (Table 4.9.1). Consequently shoot/root ratio for treated cuttings was found to be higher 1:2.17 compared to 1:2.50 for the untreated cuttings. Possibly the rooting hormone was stimulating more physiological and multiplication of the cells activity in the shoot cells compared to the root cutting cells resulting in more shoot biomass than the root biomass.The difference was however, not significant. In both cases, shoot biomass was found to be less than the root biomass. The higher the root biomass, the higher the quality of cuttings for propagation purposes Hanna (1999). Higher root biomass implies higher absorption of nutrients and water. Higher dry shoot biomass implies more water loss from the sprouting cuttings because transpiring area increases with more shoot biomass. In the study, the results agree with those of Hanna (1999) since cuttings reported to have a higher shoot biomass implied a higher transpiration area hence more water loss during propagation making such cutting to be of an inferior quality.

4.5 Germination of *Ocotea* Seeds.

The findings showed that out of 100 seeds sown in the three different sites with different light intensities, only 3 seeds germinated after the 90 days experiment in the open site of 8220 Lux with the highest light intensity. This translated to a low germination rate of only 3%. The low germination rate could be due to the poor seed viability and low vigor of the planted seeds in the nursery. The findings are consistent

with those of Tonin (2006) and Brick (1995) who observed that, storage of *Ocotea* seeds decreased their viability and vigour. Louppe *et al.,* (2008) reported that *Ocotea* regenerates mainly by suckers because undamaged seed is uncommon and that it produces seeds only during good seed years ('mast' years) which occur every 3 to 4 years.

There was no pretreatment of the *Ocotea* seeds carried out because according to Okeyo (2008), the seeds are sensitive to desiccation and should be sown flesh, hence pretreatment is not necessary under ideal conditions. Turnbull (1975a) and Wightman (1999) in their work on tree seed collection and handling reported that *Ocotea* seeds were difficult to collect and handle compared to seeds of other indigenous trees.

Plate 4.2: Planted *Ocotea* cuttings in the nursery showing healthy sprouting buds at a height of about 9 cm.

Plate 4.3: A *Ocotea usambarensis* wildling growing naturally in Chogoria Forest.

Plate 4.4: A mature *Ocotea usambarensis* tree with suckers. Note the straight clear trunk/bole.

Plate 4.5: Nursery at Chogoria Forest with beds made of cheap quality locally available materials. Note the vigorously growing wildlings of *Ocotea usambarensis*.

4.6 Wildings

Ocotea wildlings that were growing in the wild (Plate 4.4) were collected and planted in the nursery under different light intensities during the study. Their girth diameters were regularly taken in centimeters (cm) immediately after planting and during the 90 days of the experiment. The findings indicated that, there was a significant difference in girth sizes of the wildings in the various sites. Girth of wildings in open site (mean 0.2 cm) and those under full shade site (mean 0.15 cm) were significantly ($F = 31.6$, $df = 2$, $P < 0.001$) lower than girths of the plants in partial shades mean 0.31 cm, (Figure 4.9.1). Thus light availability enhances performance of wildlings since the wildlings under full shade performed poorly compared to the wildlings in the other sites. Roland *et al.,* (2007) while

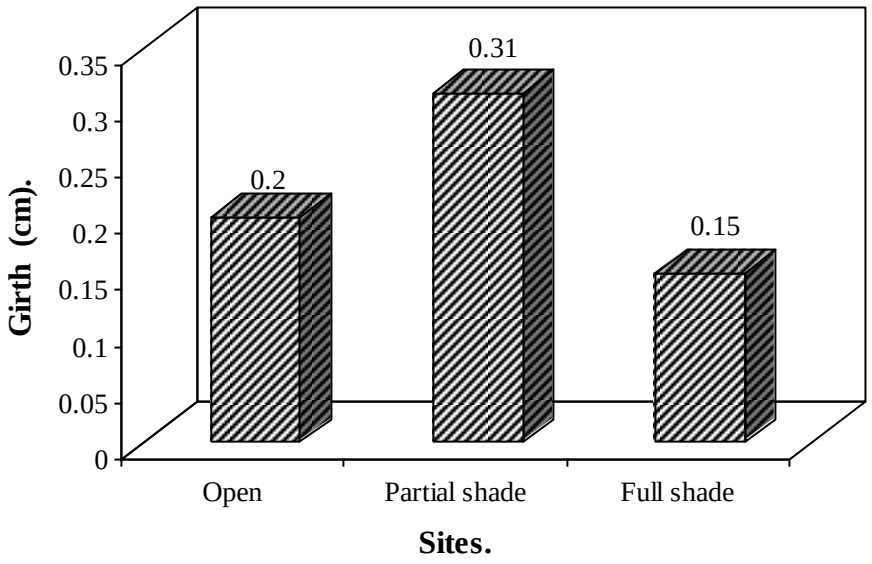

Figure 4.9.1: Girth of the wildings in Open, partial and full shade.

working on growth rates of five rain forest indigenous species in Madagascar, reported that wildlings of the trees performed better under medium light intensity. The findings

also agree with those of Freiberg (2000) and Christine (2009) who found that wildlings in the partial shaded site were doing better than the wildlings in the other sites in their study. It was therefore deduced that, too much shade inhibited performance of the Ocotea wildlings. Too much light was also found not to favour good performance of the wildlings. They required increasing but moderate light intensity.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents conclusions drawn from the analysis and the recommendations by the researcher. The main objective of the study was to determine the best propagation method using sexual and asexual parts of *Ocotea usambarensis*. The specific objectives were to examine the effect of light intensity on germination/sprouting and growth performance of *Ocotea usambarensis* seeds, cuttings and wildlings, find out the best quality cutting for planting using the shoot: root biomass ratio test and finally determine the effect of azatone rooting hormone on the sprouting of buds from various *Ocotea* cuttings.

5.1.1 Conclusions

The general conclusion from the study was that, asexual parts of *Ocotea* in the open were found to perform better than the sexual parts in terms of growth. Specifically, stem cuttings of the tree were found to perform better than the other cuttings followed by the root cuttings.

Using seeds to propagate some hard wood trees like *Ocotea* is difficult due to their low viability and vigor coupled with the difficult of collecting the same from the forest. Therefore use of asexual parts to propagate *Ocotea* was found to be better than sexual propagation. Increasing but moderate light intensity improved performance of the cuttings especially stem cuttings. The stem cuttings were also the best in quality and rooting intensity. Branch cuttings exhibited the lowest growth rate compared to the other cuttings.

Treating the cuttings with a rooting hormone tremendously improved sprouting of buds in all the sites even in the branch cuttings which had the lowest growth rate. Supply of *Ocotea* seedlings can therefore be increased by treating the cuttings of the tree with a rooting hormone before planting because the hormone improves sprouting of buds.

Ocotea wildlings performed better under partial cover. To improve quality of the wildlings of the tree, it is therefore important to cover the wildlings partially in the nursery.

Ocotea seeds did not perform very well in the study since their germination percentage was very low compared to the other planted materials.

That stem, root and branch cuttings of *Ocotea* should be planted in the open to enhance sprouting of buds rather than cover them in the nursery. Root cuttings however, can be covered for better growth performance since shading induces sprouting of more buds in the root cuttings of *Ocotea.*

Both above and below ground sections of *Ocotea* cuttings are suitable for vegetative propagation of the tree species excluding branch cuttings.

All the cuttings with sprouting buds had started developing small roots but since the cuttings had been placed in a small polythene tube, vital nutrients could have been exhausted by day 60 leading to withering of some of the buds. Before this point is reached, a stimulant nutrient mixture possibly needs to be applied to the planted cuttings to sustain the development of more buds or transplanting the cuttings before withering of the buds sets in.

5.2 Recommendations on Effect of Light Intensity on Growth Performance of the *Ocotea* Propagation Materials in the Study.

The following recommendations can be made based on the research study;

1. The best propagation materials for propagating *Ocotea* are the stem cuttings.
2. It is also recommended that both stem and root cuttings can be used in combination for propagating *Ocotea* for better results.
3. All cuttings of *Ocotea* should be treated with a suitable rooting hormone before planting in the nursery to enhance growth performance of the cuttings.
4. Wildlings are also recommended as good propagation materials for propagating *Ocotea.*

5.3 Recommendation for Further Research on *Ocotea* Propagation

1. To maintain continued and healthy growth of buds from *Ocotea* cuttings, investigations should be carried out to determine the nutrients or conditions required to sustain growth of the seedlings in the nursery before transplanting.
2. Grafting trials should also be carried out to determine other better methods of propagating the tree.
3. Trial plots of different spacings of the *Ocotea* cuttings should be tried to determine the best spacing for optimal growth performance of the cuttings.
4. Seedling growth depends on the soil properties and compositions Nafasi (2006), more trials should be done with different types of potting substrates or different type of potting materials so as to determine their effect on growth of the *Ocotea* seedlings.

5. Further investigation should also be carried out on growth performance of different tissues from different parts of the *Ocotea* tree.
6. More research is also needed on the handling and best germination medium and conditions for the *Ocotea* seeds.
7. More parameters like the influence of humidity on the performance of the *Ocotea* planting materials should also be carried.
8. The influence of temperature and water or moisture availability on the development and growth performance of the various *Ocotea* planting materials should also be studied.

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Appendix 7.0: ANOVA table for untreated cuttings in 8220 (lux) light intensity

Source	DF	SS	MS	F	Prob.
sites	2	136.96	68.481	1.6	0.213
Resid	24	997.11	41.546		
Total	26	1134.1			

Overall Mean = 6.185 s (Residual) = 6.446

Appendix 7.1: ANOVA table for untreated cuttings in 3960 (lux) light intensity

Source	DF	SS	MS	F	Prob.
sites	2	83.63	41.815	2.0	0.155
Residual	24	496.67	20.694		
Total	26	580.3			

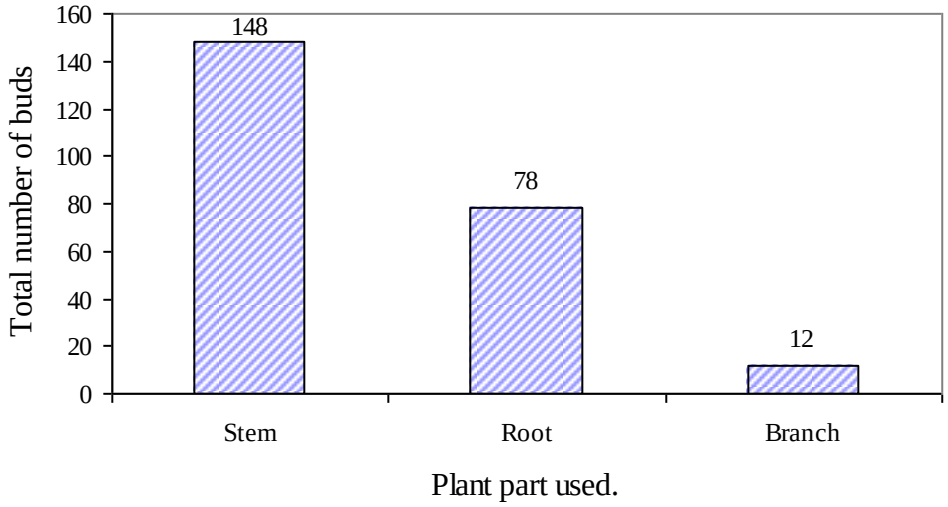
Overall Mean = 5.37 s (Residual) = 4.549

Appendix 7.2: ANOVA table for treated cuttings in 8220 (lux) light intensity

Source	DF	SS	MS	F	Prob.
sites	2	347.19	173.59	2.1	0.140
Residu.	24	1948	81.167		
Total	26	2295.2			

Overall Mean = 12.74 s (Residual) = 9.009

Appendix 7.3: Number of sprouting buds from hormone treated stem, root and branch cuttings.



Appendix 7.4: ANOVA table for treated cuttings in 3960 (lux) light intensity

Source	DF	SS	MS	F	Prob.
sites	2	393.85	196.93	4.5	0.023
Residual	24	1060.9	44.204		
Total	26	1454.7			

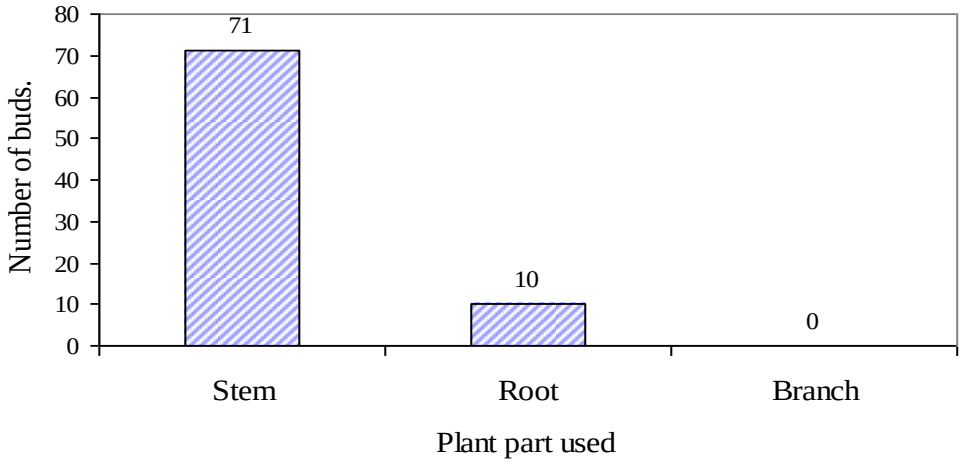
Overall Mean = 6.481 s (Residual) = 6.649

Appendix 7.5: ANOVA table for treated cuttings in 575 (lux) light intensity.

Source	DF	SS	MS	F	Prob.
sites	2	10.667	5.3333	21.3	0.000
Residual	24	6	0.25		
Total	26	16.667			

Overall Mean = 0.4444 s (Residual) = 0.5

Appendix 7.6: Number of sprouting buds from treated stem, root and branch in full shade (575 lux) light intensity.



Appendix 7.7: ANOVA table for girth size and length of wildlings at different light intensities

Source	DF	SS	MS	F	Prob.
treatment	2	0.48106	0.24053	31.6	0.000
Residual	106	0.80757	0.00762		
Total	108	1.2886			

Overall Mean = 0.244 s (Residual) = 0.0873