KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF AGROFORESTRY

PROPAGATION STUDIES OF *Voacanga africana* STEM CUTTINGS FOR THE PROTECTION OF WATER BODIES IN THE TRANSITIONAL ZONE OF GHANA.

A THESIS SUBMITTED TO THE DEPARTMENT OF AGROFORESTRY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

BY

IBRAHIM HAKEEM KONTOH (B.A Hons)

FEBRUARY, 2008

DECLARATION

I declare that except for references to other people's research which have been duly cited, this thesis submitted to school of graduate studies, Kwame Nkrumah University of Science and Technology, Kumasi for the degree of Master of Science in Agroforestry is my own investigation.

IBRAHIM HAKEEM KONJOH	[signature]	2-7-09
Student	Signature	Date
Dr. Richard Akromah	[signature]	2-7-09
Supervisor	Signature	Date
Dr. K. Twum-Ampofo	[signature]	02-07-09
Head of Dept.	Signature	Date

DEDICATION

To everyone who contributed in the writing of this thesis.

God Bless you all.

ABSTRACT

In Ghana, riverine forests (riparian buffers) have been seriously degraded resulting in the drying up of several rivers, which supply water to certain communities, especially in the rural areas. The restoration of these degraded lands is mostly done using exotic tree species which have the tendency to colonise and dominate indigenous tree species and eventually lead to loss of biodiversity. This research therefore examines the propagation of *Voacanga africana* tree species which could be used to protect water bodies, restore biodiversity loss and also provide economic benefits to the local people by harvesting its fruits for sale. Two experiments were conducted at the Faculty of Agriculture and Renewable Natural Resources lath house in K.N.U.S.T on 6th July, 2006 and completed on 9th December, 2006. The first experiment consisted of three wood types of *Voacanga africana* (hardwood, semi-hardwood and softwood), raised in three soil types (topsoil, sand and mixture of topsoil and sand) and treated with three growth hormone (IBA, IBA+NAA and Control) which gave a 3x3x3 factorial in a Completely Randomised Design. The main plot factor was the growing media (soil types), the sub-plot factor was the growth hormone whiles the sub-sub plot factor was the wood types. These gave twenty –seven treatment combinations with ten cuttings each which were replicated three times. Cuttings were evaluated for shoot sprouts, rooting, number of roots, root length and disease infection. The results showed that, hardwood and semi-hardwood cuttings of *Voacanga africana* performed better in terms of sprouting and rooting. Dip'N'grow (an IBA/NAA premix) was the best among the growth hormone, Seradix '3' powder (NAA) was also consistent. Among the growing media, materials raised in a mixture of topsoil and sand performed better than any of the soil types alone. The general performance of *Voacanga africana* cuttings which had no cover and those that were covered with polythene were not remarkably different. The conclusion drawn from the research findings were that, a micro-climate should be created to aid in the successful sprouting of *Voacanga africana* stem cuttings; semi-hardwood and hardwood cuttings without hormone treatment (control) or treated with dip 'n'grow in a mixture of topsoil and sand should be considered for future propagation of Voacanga *africana* stem cuttings. GIS and Remote Sensing technology was also identified as a very effective tool in gathering reliable and accurate information about natural resources degradation.

Table of Contents

LIST OF TABLES

TABLES **PAGES**

EXPERIMENT ONE

EXPERIMENT TWO

LIST OF PLATES

ACKNOWLEDGEMENT

I am grateful to the almighty God for seeing me through this research work.

I would like to express my sincere appreciation to all lecturers and staff of Agroforestry Department and the Faculty of Agriculture especially my supervisors Dr. Richard Akromah, Senior Lecturer, Crop Science Department, Professor P.Y.Boateng, Department of Horticulture, and Professor S.J Quarshie-Sam, Head of Department of Agroforestry, for their constructive criticisms and guidance which made my research a reality.

A special acknowledgment is extended to Mrs. Agnes Danso of Crop Research Institute, Fumesua, for her immense help during the statistical analysis of data.

A special acknowledgment is also extended to Dr. Francis Ofori, Director, Institute of Agricultural Research, University of Ghana, for his material and moral support towards my research.

I am also grateful to Mr. Owusu, Chief Technician of Faculty of Renewable Natural Resources, my course mates, Gabriel, Sarah, Lawrence and Evelyn for their assistance, contribution, guidance and encouragement.

Lastly, special thanks go to my parents, Mr. and Mrs. Hakeem Kontoh for their immense financial, moral and spiritual support, my uncle, Alhaj Dr. M.B.Ibrahim, my siblings Arafat, Haleema and Mariam and my friends Fareeda, Sakina and

Ramla for their spiritual support and encouragement which has made my research a reality. God bless you all.

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Biodiversity or the diversity of life in all forms and at all levels of organization has come under serious threat in many places in recent times. Ironically, most of the global hotspots of biodiversity are at the same time areas where human population density has increased tremendously which has extinction levels paralleling previous mass extinction events (Myers ''et al''., 2001)

As a result, the conservation of biodiversity has now become a widely shared goal among nations, leading to attempt to save natural areas from degradation or destruction. The degradation of catchment areas and watersheds has been cited as one of the major environmental hazards that has received little attention (Abeney, 1998).

Scherr, (1991) in an assessment of 148 watersheds globally, emphasized that expanding human demands for resources have intensified watershed degradation with the result that some watersheds with the greatest biological production are becoming the most seriously degraded.

Globally, of the 8.7 billion hectares of agricultural land, forest, woodland and rangelands, over 22% have been degraded since the 1920's with 3.5% being severely degraded (Scherr, 1991).

(Lal, 1997), has indicated that by the year 2025, 45 countries in the tropics will have less than 0.1 hectares of arable land per capita. According to the Ghana National Biodiversity Strategy Report, 2002, biological resources in the country have been negatively impacted by increasing pressure from agricultural expansion, mining and timber extraction.

In addition to this, it is estimated that Ghana has incurred an economic loss of about US $54 billion through biodiversity loss due to environmental degradation; that is deforestation and forest degradation. This amount is equivalent to 4% of the national G.D.P, and is comparable to the country's annual economic growth, (Tutu "et al"., 1993).

In Ghana, riverine forests have been degraded by anthropogenic activities such as logging, farming, urbanization and mining. This has resulted in the drying up of several rivers which supply water to certain communities, especially in the rural areas. Attempts have been made to restore degraded lands surrounding most rivers by several organizations, NGO's and certain communities (Hawthorne, 1995).

Generally, the tree species commonly used for the restoration of the degraded vegetations are *Tectona grandis* (teak) and *Acacia* spp., both of which are exotic. The continuous use of these exotic species may endanger the development of biodiversity in the country in the near future if not reviewed. This is because, certain exotic species have the tendency to colonise a reasonable proportion of land within a very short period of time. This inhibits the development of indigenous tree species and results in the loss of biodiversity (Hawthorne, 1995). Besides, the trees do not provide long-term protection to the rivers because they are harvested as timber or fuel wood at maturity.

There is therefore the need to pursue measures to forestall the destruction of biodiversity during restoration of degraded vegetation. This requires formal study and documentation of indigenous trees species that naturally grow along water bodies.

Many indigenous trees and shrubs are being used in different Agroforestry systems in the developing world (Nair, 1988). Most of these woody perennials have multiple uses, and wherever grown, they are highly valued by the local farmers. However, very little scientific knowledge is available on the growth and management needs of these species. With the prevailing high demand for Agroforestry species, there is a growing need for developing simple and easy methods of growing such indigenous woody species.

It is in the light of the above reasons that reforestation projects currently seek to promote the cultivation of indigenous trees as alternative to exotic trees in an attempt to enhance and sustain biodiversity (Prebble, 1997). Apparently, the failure of indigenous tree species in plantations can be attributed to the lack of knowledge of their ecology, silviculture, pest management and general growth requirements (Pokua Bonsu, 1998).

This study was therefore an attempt to provide sprouting and rooting characteristics of an indigenous tree species that could be used for plantation establishment to serve as buffers in degraded areas along water bodies in the transitional zone of Ghana.

1.2 Justification

As part of its social responsibility to the community, the British American Tobacco Company (BAT), a tobacco producing company operating in the study area, established a 1 acre teak plantation along the mid-section of River Baamire at Nwoase near Wenchi . Although the trees are providing some amount of protection to the river, their long term sustenance cannot be guaranteed. This is because, in the near future, most of the trees shall be cut down for sale because of their high commercial value. This will expose the river to a lot of pollution and hazards and its eventual dry up.

Ideally, local tree species of the natives own choice should have been used for the experiment, some of which include "Nwo" (Cleistopholis patens), "Kane" (P*teleopsis hylodendron*), "Subaha" (H*allea ledermanni*) and Mahogany (K*haya senegalensis*). However, these species cannot serve as buffers because most of them cannot survive near water bodies and do not have dense canopies. As a result, an indigenous Ghanaian tree species, *Voacanga africana* was selected in consultation with the farmers in the area.

This species would not only protect the river by providing shade and erosion control, but would also help to restore the biodiversity of the area. Besides, the people would harvest the seeds annually as a source of income, thus providing incentive to the local people to ensure the species sustainability and offer long-term protection to the river bodies. The general objectives of the research was to examines the propagation of *Voacanga africana* tree species which could be used to protect water bodies.

The specific objectives were therefore to :

(i) Study the main and interaction effects of growth media, growth regulators and wood types on *Voacanga africana* cuttings

(ii) Determine the performance of *Voacanga africana* cuttings under polythene cover and those without polythene cover

(iii) to ascertain the extent of vegetation change in the study area using GIS and remote sensing technology application.

CHAPTER TWO

LITERATURE REVIEW

2.1 Botanic description and ecology of *Voacanga africana*

Voacanga is a well-known plant widely distributed over the secondary forest in the transitional zones in the country. It is mostly found in the wild and as a shade plant around communities but occasionally cultivated on commercial basis in certain parts of central region. It is sometimes planted in newly established cocoa plantations to provide shade in the first three years of establishment and finds ready use as stakes for yams. Field observation revealed that a fully-grown plant yields between 2000 and 3000 pods. About 110-120 pods yield a kilogram of the dry seeds which gives an estimated yield of 10 – 23kg of seeds per plant. The plant flowers in May and fruits mature in July.

2.1.1 Pharmacological constituents of *Voacanga africana* tree

As a relative of Tabermanthe iboga and many other psychoactive members of the Apocynaceae, Voacanga species are generally ingested to increase endurance and stamina and also for magic and religious purposes. The seeds contain up to 15% indolealkaloids, including voacamine, voacangine and many related compounds. The same alkaloids are found in the bark, but in much lower levels (2%) (Leewenberg "et al"., 1985). This group of indole alkaloids when ingested causes a mild to strong stimulation lasting several hours. Higher doses have a strong hallucinogenic effect (Leewenberg "et al"., 1985).

2.1.2 Uses of *Voacanga africana*

Voacanga is a medicinal tree and shrub, which contains 10 alkaloids as well as edible oil. Local medicinal uses of *Voacanga* include the use of the root, leaves and the bark and sap in making decoctions. These are then used to treat ailments such as fungal infections, eczema, heart – troubles and others. The seeds are used as poison, stimulant and aphrodisiac purposes (www.voacanga-africana.com.gh, 2007).

Moreover, a lot of foreign exchange is generated from the export of the seeds as a non-traditional export commodity. Currently, 13kg of dry Voacanga seeds is sold for $20 on the international market. It also generates substantial income for the rural poor who are engaged in the Voacanga business. The *Voacanga africana* tree's architecture also has great potential to protect river bodies. Its broad leaves, dense canopy and well spread out crown as well as its ability to survive in a wide range of soil types makes it very ideal for plantation along river bodies.

2.2 Vegetative propagation of tree species

Vegetative propagation of tree species is a means of producing plants of those species whose seeds do not germinate easily or readily. It is also a means of producing a number of generally identical individuals, which can be used in experiments. Various scientist have found cuttings from young seedlings or shoots of trees to root easily, (Pryor "et al". 1981). It also refers to the vegetative portions of a plant (leaf, stem or root) separated from the mother plant to be grown on its own which will result in the production of the same plant from which the material was taken. They are considered to be very important because they are easy to obtain in sufficient quantities (Hartman and Kester, 1965).

Many indigenous trees and shrubs are being used in different agroforestry systems in the developing world. Most of these woody perennials have multiple uses and wherever grown, they are highly valued by the local farmers. Vegetative propagation is one of the potentially promising and useful methods, which needs to be tried for these species, since most of the multi- purpose trees outcross easily and have not been fully domesticated. Moreover, due to the unpredictability of the flowering patterns and uncertain viability patterns of seeds of different species, sexual methods of propagation may pose problems for at least some of these species (Hartman and Kester, 1965).

Voacanga seeds are recalcitrant, hence do not tolerate drying and cold storage. Moreover, if the seeds are used for seedlings, market stocks will be depleted. Recalcitrant seeds are those that undergo little or no drying and remain desiccation sensitive both during development and after they are shed. Many forestry and tropical fruit species have recalcitrant seeds. These seeds cannot be dried without loss of viability. Its storage in carbon dioxide may delay senescence, but usually not beyond one year (Harrington, 1970).

According to (Evans, 1951), several major industrial plantation projects in the tropics now use vegetative propagation with cuttings to develop clonal plantations. This is because, rooted cuttings for vegetative propagation take a relatively shorter time to flower and fruit, and they also preserve the genetic integrity of the parent ensuring true-to-type reproduction (Evans, 1953). It is also important for clonal testing, fertility studies, testing for diseases and drought resistance and study of incompatibility problems between stock and scion where identical genotypes are desired (Hartman and Kester, 1958).

2.3 Factors affecting the growth and rooting of stem cuttings

Environmental conditions can influence the ability of stem cuttings to grow and root. The most common external factors are light, seasons, temperature, humidity, moisture level of cutting and rooting medium (Leopold, 1960; Hartman "et al"., 1997). However, according to Archibald, (1953) genetically, there can be differences in the rooting ability of cuttings, but in practice, the external factors can be controlled to a considerable extent to give a reasonably high rooting percentage and high production of healthy hardened plants.

2.3.1 Effect of rooting Media

The composition of the rooting medium has a considerable influence upon the type of root system produced and the cuttings response to later media treatment (Archibald, 1953). An ideal rooting medium provides sufficient porosity to allow good aeration; has a high water- retaining capacity but well drained and free from fungi and bacteria. In coarse sand, the roots produced are thick and brittle with few laterals. Such roots are readily broken when the plants are potted.

When cuttings are rooted in sand and peat moss or perilite and peat moss, the roots developed are well branched, slender and flexible, a type much more suited for digging and repotting (Archibald, 1953; Hartman "et al"., 1997). Among some of the rooting media used in Ghana is a mixture of equal parts of coarse river sand and composted oil palm fiber. The fiber holds moisture while the sand keeps the mixture open and well aerated (Brian, 1962).

Archibald, (1953), showed that sand/ fiber mixture gave a higher percentage of rooting success and produced stronger and more fibrous roots than sand, fiber or peat moss alone. Bowman, (1950) stated that with optimum moisture supply, successful rooting could be achieved in a wide range of media. Cheesman and Spencer, (1936) stated that rooting media with temperature of about 27° C to 30°C in the afternoon and a minimum of 24°C to 26°C in the morning are suitable for rooting. Hess and Snyder, (1957) and Hartman "et al". (1997) stated that a basal temperature of 25°C could also enhance root formation. The use of bottom heating according to Hartman "et al". (1997) is essential in maintaining the temperature of the rooting medium to about 24°C in the morning and facilitates rooting.

2.3.2 Effect of seasons:

Seasonal timing or period of the year in which cuttings are taken can play an important role in rooting, (Bassuk "et al". 1981). In propagating deciduous species, hardwood and semi-hardwood cuttings can be taken during the dormant season when buds are not active and before buds start to force out in the rainy season. There is an optimal period for rooting many species, which is necessary to maximize the rooting process (Leopold, 1960; Arnand and Herbalein 1975; Hartman "et al". 1997).

Davis Jr., (1984) observed a vivid seasonal change in shoot production and rooting. Heavy flushing was also observed during the rainy periods, a time of intense vegetative growth, which may tend to increase rooting percentage. Cuttings do not root normally in the dry season, however, rejuvenated shoots may still have superior root development probably because of higher food reserves and other rooting co- factors. Evans, (1992), contended that probably the best time to take cuttings from the field is at the beginning of the rainy season.

2.3.3 Effect of relative humidity

The relative humidity in a propagation system is related to the light intensity upon the cuttings and the associated temperature. Much emphasis has been laid on the need to have a near saturation around the leaves of rooting cuttings. The ability of the propagation system to provide the near saturation atmosphere around cuttings is a good indicator of the effectiveness of that propagation system (Loach, 1977). Evans, (1953) also found that cuttings rooted well in an atmosphere that was virtually saturated.

The water supply is closely linked to the aeration of the medium especially the texture. Adjustment of the water content thus, augments the moisture content to prevent the drying out of the cuttings. Watering in the morning and afternoon are given in practice (Chessman and Spencer, 1936).

2.3.4 Effect of light

Light has a strong effect on rooting. If the entire plant is exposed to light, root initiation and root growth are inhibited (Went, (1934). Rooting occurs when light is applied only to the parts of the cuttings above the ground (Stoutemeyer and Close, 1947). Evans, (1953) found that the minimum light intensity at which rooting occurred was dependent on the temperature. This factor involved the availability of carbohydrates over and above the threshold point where there is a balance between photosynthetic and respirational requirements.

Low temperatures seem to promote the formation of callus tissue. The development of root primordia on undifferentiated callus tissues is much easier than the formation of root from well-differentiated tissue (Leopold, 1960). Low light intensity does not favour rooting since carbohydrates resources are depleted due to inadequate photosynthesis. Also there is rapid defoliation of cuttings at very low light intensity (Bowman, 1950). Similarly, Evans, (1953) also observed that under high light intensities, carbohydrates are accumulated in excess over nitrogenous fractions, so that the leaf becomes pale yellow in colour and subject to breakdown. Also when cuttings are provided with sucrose and amino acids, there is a possibility for them to root in darkness.

2.4 Effect of growth regulators on the growth and rooting of stem cuttings

According to Leopold and Kridemann (1975), the plant physiologist knows of five main types of chemical growth regulators namely, auxins, gibberellins, cytokinins, abscisic acid and ethylene. They further added that the five growth substances have been grouped into three: Promoters (auxins, cytokinins and gibberellins), Inhibitors (abscisic acid), and Ethylene.

2.4.1 Effect of auxins

In the 1930's studies of the physiology of the auxins showed its involvement in varied plant activities such as stem growth, adventitious root formation, lateral root formation, lateral bud inhibition, abscission of leaves and fruits, and activation of cambial cells

(Haissig, 1972). It has been known for many years that the presence of leaves and buds on cuttings favour the development of roots when the basal portion is severed and introduced in a suitable medium. These observations suggest that root initiation in cuttings is favoured by growth regulators, which are synthesized in the buds and young leaves and translocated to the basal portion. It was observed that a naturally occurring auxin found in these parts was indoleacetic acid (IAA) which was active in inducing root formation (Kogl, 1933; Thimann and Koepfli, 1935).

There is considerable evidence that auxins act primarily in a regulatory capacity in some phases of the carbohydrate metabolism of plants. A suggestive finding in this connection is that, the introduction of auxins into leaves of cuttings induces a marked hydrolysis of starch (Mitchell and Whitehead, 1940). Auxins also appear to participate in some aspects of the respiratory process (Commoner and Thimann, 1941; Berger et al. 1946). Cooper and Went (1934) stated that if one treatment of auxin is not quite sufficient, retreatment of the cuttings can be used successfully.

Mixtures of root-promoting substances are sometimes more effective than either component alone. For example, equal parts of indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) when used on a widely diverse species, were found to induce a higher percentage of cuttings to root and more roots per cutting than either auxin alone (Ellyard, 1981). Adding a small percentage of certain phenoxy compounds to either IBA or NAA increased rooting and produced root systems better than those obtained when phenoxy compounds are used alone, (Davis and Haissig, 1990).

Application of synthetic auxin to stem cuttings at high concentrations can inhibit bud development and sometimes to the point at which no shoot growth will take place even though root formation has been adequate (Sun and Bassuk, 1993). It is clear that auxins stimulate the formation of roots by an interaction involving organic materials in plants, particularly carbohydrates and nitrogenous materials. This interaction apparently controls the basic step of morphological differentiation at the cellular level (Leopold, 1960).

2.4.2 Effect of co-factors

Cofactors are naturally occurring substances capable of acting synergistically with auxins to promote rooting (Kozlowski and Kramer, 1979; Jules "et al". 1981). High rooting capacity is associated with high levels of cofactors than those that are difficult-to –root (Kozlowski and Kramer, 1979). Girouard, (1969) extracted four rooting cofactors from juvenile and matured English ivy cuttings. The experiment suggested the regulation of rooting by the interactions of hormones and possible cofactors. As the temperature increased towards an optimum for root initiation, the balances of endogenous growth regulators and cofactors may be changed to bring out the stimulating effects of auxins over the inhibitory effects of gibberellins and cytokinins.

Hess (1968), presented an attractive model for internal control of the formation of adventitious roots, which postulated that, cuttings that are easy to root have all the four rooting cofactors namely chlorogenic acid, isochlorogenic acid, oxygenated terpenoids and promoter (P-257) and enough IAA for cell division. Adventitious roots will be triggered in such cuttings in the presence of adequate carbohydrate and nitrogenous substances. Phenolic compounds as well as other substances like carbohydrate, growth promoters, auxins and enzyme systems help in the synthesis of protein and nucleic acid, which enhance adventitious root formation (Haissig 1974 : Davis 1984).

2.5. Physiological and biochemical factors affecting the growth and rooting of stem cuttings

There are physiological and biochemical factors inherent in cuttings that are known to be involved in the rooting of cuttings. Some of these are polarity, buds, inorganic materials, age of cuttings and carbohydrates/nitrogen levels.

2.5.1. Polarity effect on rooting

According to Leopold (1960), root formation takes place mainly at the base of the cutting where the auxins accumulate because the movement of auxins and other substances in the stems are from the apex to the base. The basipetal movement takes place in the shoot even if it is turned upside down. It moves through the parenchyma and similar tissues at a rate which is greater than can be explained by diffusion alone.

As it moves down the shoot, its concentration becomes less, partly due to the action of an enzyme IAA oxidase or by combining with other compounds. The resulting auxin gradient within the shoot has several important effects on development. Berrie "et al"., (1993) also reported that the cutting length should range between 15cm and 16cm to allow easy translocation of most plant substances to the base of cuttings.

2.5.2 Effect of buds on rooting

Buds on a cutting have a strong promoting effect on rooting (Leopold, 1960; Kozlowski and Kramer, 1979). Lek,, (1934) discovered that root formation was almost absent if all the buds were removed from woody cuttings or if all the buds were essentially dormant especially in species without preformed root initials. For root formation, the presence of an actively growing shoot tip (or a lateral bud) is necessary during the first three or four days after the cuttings are made (Haissig et al. 1982). A bud-less cutting would not form roots even when treated with an auxin-rich preparation. This indicates that a factor other than auxin presumably produced by the bud was needed for the root formation (Went, 1934).

2.5.3 Effect of inorganic substances on rooting

The most active material that influences rooting is soluble nitrogen fraction in a plant. While a level of nitrogen is beneficial to rooting, large quantities are inhibitory. The lower the carbohydrate level of a plant, the greater is the inhibitory effect of high nitrogen levels (Pearse, 1946). Boron also has a strong influence on rooting; lack of it in the rooting medium can eliminate the capacity of the cutting to form roots, (Jackson, 1986). Although, deficiencies of other inorganic nutrients such as phosphorus, potassium, calcium and magnesium can lower the rooting response, their effects are not pronounced as it is for nitrogen and boron.

2.5.4 Effect of juvenility on rooting

The effect of the physiological age of the wood cuttings is of greater importance in evergreen propagation. This is a fact that better rooting results are obtained from cuttings taken from young trees two to ten years of age, as compared to cuttings from trees over forty years of age (Gardiner, 1951). Cuttings from older stock plants appear to be progressively more difficult-to-root with or without auxin treatment whiles cuttings taken from young seedling plants in juvenile growth phase root more readily, (Gardiner, 1951).

Mature and difficult-to-root plants may be made easy-to-root by a reversion to the juvenile stage through coppicing (Hartmann "et al". 1997). Generally, adventitious shoot from the base of the mature plants can assume juvenile characteristics (Jules et al. 1981). Juvenility in relation to rooting may possibly be explained by low levels of rooting inhibitors as well as high levels of photosynthates, but as the plant grows older, the inhibitor levels increases (Paton "et al". 1970). Reduction of rooting as plants age may possibly be as a result of lower phenolic levels. Good rooting was observed for rejuvenated shoots as well as growth enhancement (Chevalier, 1948).

2.5.5 Effect of carbohydrate and nitrogen levels on growth and rooting of stem cuttings.

The most important sugar in plants is sucrose (disaccharide), which makes up to 95%of the dry weight of translocated material in the sieve tubes of the phloem. Its high concentration in cells results in its wide distribution and metabolic importance (Kozlowski and Kramer, 1979). Polysaccharides are found in trees as cellulose and play an important role as cell wall constituent, which forms the framework of woody plants. Starch is the most abundant carbohydrate reserve in woody plants (Albersheim, 1965).

The evidence of the essentiality of carbohydrate for rooting comes from several sources. Hess and Snyder (1957) found that rooting capacity is positively correlated with carbohydrate availability. Wounding the bases of cuttings by splitting and prolonged soaking in sucrose often improves responses (Hambrick "et al"., 1991). Wiegel "et al". (1984) hypothesized the importance of carbohydrate-to-nitrogen (C/N) ratio in plant growth and development.

High C/N ratio in cutting tissue promotes rooting but do not accurately predict the degree of rooting responses (Struve, 1981). The ability of a stem to root has been shown to be due to an interaction of inherent factors present in the stem cells as well as transportable substances produced in leaves and buds, the major one being carbohydrate with others as nitrogenous compounds and vitamins (Jules et al., 1981). Modification of carbohydrate accumulation and partitioning as well as nitrogenous compounds for synthesis of proteins and nucleic acids accentuate the development of roots on cuttings (Haissig, 1974). Nanda "et al". (1968) found that Hibiscus cuttings rooted best in June; when starch reserves in cuttings were lower than in other months. Carbohydrates in actual sense do not initiate rooting, instead, it augments the survival in the cutting prior to rooting as well as growth development (Hartmann "et al".,1997).

2.5.6 Storage of cutting materials

Cuttings from stock plants should be in the day when cuttings are still turgid. If the cuttings cannot be set immediately, they are misted to reduce transpiration and held overnight in refrigerator facilities at 4^0C to 8^oC. In general successful storage of unrooted cuttings depends on storage conditions, state of the cuttings and species. It is important that dry matter losses and pathogens be minimized. Within the storage unit, it is best to maintain nearly 100% humidity. Temperature should be as low as the hardiness of the given species can tolerate. Soaking cutting bases in two to five percent sucrose for twenty hours prior to storage improves rooting, (Paton and Schwabe, 1987).

2.5.7 Leaching of nutrients from cuttings

The development of intermittent mist revolutionalised propagation, but mist can severely leach cuttings of nutrients especially difficult-to-root species, which take a longer time under it. Nutrients like N, P, K, Ca and Mg are leached from cuttings under mist system (Good and Turkey,1964); Blazich et al., 1983). Nitrogen and Manganese are easily leached without difficulty (Turkey and Whittner, 1958). Both leaching and mineral nutrient mobilization contribute to foliar deficiencies of cuttings (Blazich and Wright, 1979).

The amount of leaching depends on the growth stage of the cutting material. Apparently, young growing tissues quickly tie up nutrients by using them in the synthesis of cell walls and other cell components, (Good and Turkey, 1964). In the early 1950s, endogenous chemical inhibitors were reported to retard rooting in selected plant species especially with grapes. Leaching cuttings with water at times enhances the quantity and quality of roots produces (Spiegel, 1954).

2.5.8 Effect of fungi and disease pathogens on cuttings

Disease pathogens affect growth of woody plants by altering the rates and balance of physiological processes. Disease symptoms vary widely and may be expressed as colour changes, necrosis, vein clearing, wilting, leaf spot on leaves, rooting of tissues and dieback or abscission of plant parts. An initial fungal attack accelerates a sequential and very complicated series of metabolic disturbances, rather than a simple change in only one process, such as photosynthesis as is sometimes supposed. For example, defoliation results in depression of photosynthesis and a decrease in transport of carbohydrates and hormonal growth regulators to the lower stem. These affect adversely cambial growth (point of root initials in stem) and sequentially root formation (Kozlowski, 1969).

The invasion by fungi may involve aggressiveness of the parasites, availability of nutrients at the infection site and the presence of inhibitors of toxic substances produced by the host or parasite (Hare, 1966). The specific nature of the diseases resistance may involve morphological exclusion of the parasite and the restriction of growth after or destruction after entry. Many trees produce as variety of antifungal and anti bacterial compounds, which endowed them with various degrees of diseases resistance. For example a toxic extractable substance deposit during the formation of hardwood makes some trees or parts of some trees, quite resistant to certain fungi.

The phenols appear to be the most important. But specific inhibitory compounds vary greatly among species. For example tannins, pinosylvins and chlorogenic acids occur in temperate zone trees, while in tropical trees various alkaloids, rotenoids and saponins may contribute to disease resistance, Some compounds which do not affect much resistance to disease individually, may act synergistically and together provide resistance (Kozlowski, 1969).

2.6 An overview of Remote Sensing and Geographical Information Systems and their application to natural resources protection.

Geographical Information Systems (GIS) can be defined as a system of computer hardware, software and procedures, designed to support the capture, management, manipulation, analysis, modeling and display of spatially referenced data for solving complex planning and management problems . A GIS handles both spatial data and non-spatial attributes of that data (Howard, 1991). Remote sensing is the science and art of obtaining information about an object, area of phenomena through the analysis of data acquired by a device that is not in contact with the area or phenomena under investigation as defined by (Lillesand and Kiefer, 1979).

Remote sensing usually refers to the use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to yield useful information (Curran, 1986). When electromagnetic energy is incident upon an object on the earth's surface, it can be reflected, transmitted, or absorbed, or can interact with the object in all the three ways (Young and Giese, 1996). Factors such as the wavelength and the incidence angle of the electromagnetic energy as well as the composition of the surface waterfalls determine whether the energy is reflected, transmitted or absorbed. These differences make ~~it possible~~ to distinguish between the many earth features, (Young and Giese, 1996).

For example, healthy vegetation normally appears green because the blue and red components of the incident light are absorbed by chlorophyll present in the leaves. Again, the dependency on wavelength implies that even within a given feature type, the proportion of reflected, transmitted, and absorbed energy will vary at different wavelengths. Therefore, two features may be different in one spectral range and may be indistinguishable in another wavelengths band (Lillesand and Kiefer, 1979).

The percentage of each wavelength reflected comes from spectral reflectance curves. Remote sensing has been used as a cost effective means of data acquisition over large areas. The use of remotely sensed data in natural resources management in Ghana dates back to the 1960's. In particular, aerial photos were used to produce soils, vegetation, land use and drainage maps for the Upper East region. Also landsat, multispectral scanners and ancillary data were used to produce land use map for the Upper East region (IFAD, 1990).

Remote sensing has been applied to locate forest fires, detect diseased crops and trees, study wildlife, monitor flood damage, analyse population growth and distribution, determine locations and extent of oil spills, monitor water quality and detect the presence of pollutants and accomplish numerous other tasks over large areas for the benefit of mankind. In 1992, the Environmental Protection Council (EPC) explored the use of the GIS technology for resource management and planning in the country. ~~For example~~, GIS technology was used in assessing land degradation in northern Ghana (Gyamfi – Aidoo, 1987) and pollution control in Obuasi near Kumasi (Danso, 1992).

GIS technology is used for updating and maintaining a current forest inventory and for modeling and harvesting, forest rehabilitation, forest road construction, ecology and biodiversity, watershed conservation, forest and climate change. The effective integration of remote sensing and GIS remote sensing in natural resources assessment can decrease the cost of gathering resource information and increase the detail of such information (Bulley, 1996).

For example, GIS remote sensing technologies can be used to assess the extent of degradation within the study area. A simple landsat image or aerial photograph spanning a period of ten years would be a very important tool in determining the actual changes that have occurred in vegetation cover and its consequent effects on watershed conservation in the study area.

2.7 An Outline of Water Degradation

2.7.1 Water Pollution

Globally, 2.3 billion people suffer from diseases linked to water. Providing safe drinking water and adequate sanitation would have major health benefits. Some benefits include an estimated 2.1 million fewer deaths from diarrheal diseases, 150 million fewer cases if shistomiasis, and 75 million fewer cases of trachoma, (WHO, 1997). Water-borne diseases also known as "dirty water" diseases, result from using water contaminated by human, animal or chemical wastes.

These diseases cause an estimated 12 million deaths a year, 5 million of them from diarrheal diseases. Most of the victims are children in developing countries, (UNDP, 1998). In many places both surface and ground waters are fouled with industrial, agricultural and municipal wastes.

According to the World Commission on water for the 21st Century, more than half of the world's major rivers are so depleted and polluted that they endanger human health and poison surrounding ecosystems, (Inter-Press Service, 1999).

Demand for freshwater is rising rapidly as population grows and becomes more urban, and as water use per capita increases. Some areas already face shortages, and more will face them in the future unless steps are taken to manage water resources better. The supply of freshwater of earth is finite. Thus, as population grows, there is less water per capita; in 1989 there were about 9000 cubic meters of freshwater per person available for human use, (Clarke, 1991).

By 2000, because of population growth, that amount dropped to about 7800 cubic meters per person, (Gleick, 1993). If the world's population grows to over 8 billion in 2025 as expected, the amount of water per capita will be just 5,100 cubic meters. Even this amount of freshwater per capita would be enough to meet human needs if available and if it were evenly distributed, but available freshwater supplies are not distributed evenly around the globe, throughout the seasons or from year to year. Two- thirds of the world' population – around 4 billion people live in areas receiving only one – quarter of the world's annual rainfall, (Gleick, 1993). Throughout much of the world, the renewable supply of freshwater, ~~the~~ amount available year after year on a sustainable basis comes in the form of seasonal rains that runs off too quickly for efficient use (Postel et al., 1996).

2.7.2 Water shortages

Population growth and rising use per capita are creating water shortages in many countries. A country is said to experience water stress when annual water supplies drop below 1,700 cubic meters per person per year, the country faces water scarcity for all or part of the year. Swedish hydrologist Malin Falkenmark developed these concepts of stress and scarcity to gauge current and future water needs against available supplies (Falkenmark, 1990; 1994; Gardener, 1997).

In 1995, Population and Action International (PAI) adapted Falkenmark's concepts to calculate water stress and scarcity in countries around the world. PAI updated this estimated in 1997, based on population projections for 2025 and 2050. The results were startling: in 1995, 31 countries, home to nearly a billion people - regularly faced either water stress or water scarcity. In 2025, 18 countries, with about 3 billion people, are projected to face water shortages (Engelman and Leroy, 1995; Gardener, 1995)).

The 20 countries of the Near East and North Africa face the worst prospects. Africa also faces serious water problems. Already, over 200 million Africans live in water – stressed or water scarce countries. By 2025, the number will rise to about 700 million, of whom over half will live in countries that face severe shortages for most of the year (Falkenmark, 1994; PRB, 2000).

Ghana is fairly well-endowed with water resources, but there is a high variability in the amount of available water within the year and over several years. The south-western part is better watered than the coastal and northern parts. The present water availability of $300m^3$ per annum is decreasing due to rapid population growth. The cost of exploiting new water supplies is also rising sharply, particularly costs associated with abstraction and with transferring water from rivers and lakes to distant places.

2.7.3 Watershed Restoration

The demand for water, along with increasing pressures on water from pollution, urbanization and over exploitation of aquatic resources, is also creating biodiversity crises in freshwaters (Abramovitz, 1996). It has been estimated that humanity now uses 54 percent of accessible runoff, a figure that could rise to 70 percent by 2005, (Anon, 2005). Because of population growth, the average annual per capita availability of renewable water resources is projected to fall from 6600 cubic meters today to 4800 cubic meters in 2025 (ICARDA, 1996). In 1998, 28 countries experienced water stress of scarcity (defined as when available water is lower than 1000 cubic meters per person per year). By 2025, this number is predicted to rise to 56.

As the number of people in urban areas grows so does the demand for water, food and for irrigation in agricultural areas close to the city adding further pressures on water resources. Most of the world's surface is covered in water mostly from rainfall with great regularity all over the world. However, the increasing per capita demand for water and increase human population growth means that provision of adequate water supply is now a major problem for most countries in the world. A safe supply of water is now a major source of concern, expense and even international tension. At the World Summit on sustainable development in Johannesburg in 2002. Over 80 percent of the participating decision makers identified water as a key issue to be addressed by Heads of State from countries throughout the world (World Bank, 2002).

One issue of high priority for tight protection within the watersheds are the forested strips of land along the streams in question. These riparian zones are probably the most critical of all needing protection in a water supply catchments (Hamilton, 2003). Intact forests along streams at least 20 – 30 meters in width can filter and immobilize sediment and other compounds, reducing water pollution.

They can also trap sheet and rill erosion as in hillsides, which can break through most normal-width buffers. Riparian forests also reduce stream bank erosion and also keep streams cooler. When these water-related values are added to their great value in providing terrestrial and avian fauna habitat and safe access to water, rich riparian plant habitat, and healthier stream habitat for fishes and other aquatic life, the critical nature of these zones become apparent. Since they form the vital link between watershed lands and stream systems, they merit protected status as areas of great significance. (Bury, 1991; Franklin, 1992).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The studies were carried out in the Faculty of Agriculture lath house located at the Faculty's nursery site at the Kwame Nkrumah University of Science and Technology in Kumasi. The experiments began in the wet season from July, 2006.

3.2 Source and type of cuttings

All the *Voacanga* propagation plant materials for the experiment were collected from the wild at Anwomaso, a suburb of Kumasi and Kokofu in the Amansie East District of the Ashanti region. Some of the propagation materials were obtained from mature (5 - 15 years) and juvenile (4 - 10 years) trees. The types of cuttings used were softwood, semi-hardwood and hardwood stem cuttings of *Voacanga africana.*

Softwood cuttings were made from the soft and succulent parts of *Voacanga* trees which were produced at the tip of the branches during the rainy season. The leaves of softwood cuttings were pale green and not fully matured.

The semi – hardwood are partially matured green – brown and slightly woody. It was taken from the previous growth and is thicker and harder than the softwood. The leaves were green and more matured than the leaves of the softwood.

Hardwood cuttings are the fully matured brownish and woody parts of the trees. It is thicker, denser and harder than the semi – hardwood. The leaves are dark green and more matured than the semi – hardwood.

3.3 Propagation structure

Propagation structures used in the experiments were the black polythene nursery bags (plate 3.1) for (Exp.1 and 2) and the polythene propagator (Exp. 2). They were both placed under the lath house at the Faculty of Agriculture . The polythene propagator was a rectangular wooden frame which measures 4.1m x1.6m (lower heights and 0.86m (upper heights) and covered with a white polythene sheet, 0.00029m thick. A wooden lid was fixed at the upper end and opens at the lower end. (Plate 3.2)

Three types of media (top soil, sand and topsoil mixture and sand) were used for the various experiments. Topsoil , eutric leptsol (FAO,1990) collected from the adjoining lands of the Faculty of Agriculture was from the soil surface to a depth of a depth 20cm. Sand was collected from River Wiwi on KNUST campus.The topsoil and sand were mixed at a ratio of 1:1 that is 1 part of topsoil to 1 part sand. They were thoroughly mixed before it was set. The various media were put in black polythene nursery bags, and watered a day before setting the cuttings.

3.4 Preparation of stem cuttings

Stem cuttings of the various wood types (Softwood, semi – hardwood and hardwood) of *Voacanga africana* was normally 15cm long and a diameter of between 0.5cm and 1.5cm with an average of about three nodes on each cutting.

The freshly prepared cuttings were put in transparent polythene sacks to prevent desiccation. The base of two- third of the cuttings up to 2cm was dipped in rooting medium concentrations for 20 seconds and allowed to dry for 10 seconds before inserting them in the nursery bags. Watering of the hormone treated cuttings was done after setting them in the medium. The other quarter of the propagation cutting materials were used as control and as such had no treatments applied.

3.5 Types of rooting growth regulators.

Rooting growth regulators used were Dip N Grow (already manufactured) and Seradix '2' powder. The Dip N Grow is composed of 5000ppm naphthalene acetic acid (NAA), 10,000ppm Indobutyric acid (IBA) and boron. The Seradix '2' powder used is composed of IBA (active ingredient). The parameters studied include:

-number of sprouts

-leaf width

-number of roots

-root length

3.6 Experiments

Two experiments were conducted in the latter part of the rainy season. The first experiment was set up on 3rd July, 2006 and the second was on 9th July, 2006.

3.6.1 Experiment One: Effect of growth regulators and soil media on wood types.

3.6.2 Experimental procedure and design:

The experimental set up was a 3x3x3 factorial arranged in a Completely Randomised Design. The main plot factor was the soil media (top soil, mixture of topsoil and sand, sand), the sub – plot factor was the growth regulators (no hormone – control, Seradix '2' and Dip 'N' grow), and the sub – sub- plot factor was the wood types (softwood, semi – hard wood, hardwood). These gave twenty seven treatment combinations. Ten cuttings were used per each treatment combination and these were replicated three times. Plate 3.1 shows the setup without polythene cover.

3.6.3 Nursery practices

The soil media was set on 5th July, 2006. Topsoil and sand were thoroughly mixed in a ratio of 1:1 to get a third soil medium. The soil media was then carefully filled in polythene nursery bags. The wood types were divided into three, one third of each wood type was used as control, that is without any hormone application. The other third was dipped in Seradix'2' growth regulator powder (IBA), and another third dipped in Dip 'N' grow growth regulator solution. The Dip 'N' grow hormone solution was prepared using 5ml of the hormone to one part of water. It was then thoroughly stirred to get the final solution.

Plate 3.1 Softwood, semi-hardwood and hardwood cuttings in nursery bags.

Plate 3.2 Voacanga cuttings covered with white polythene sheet

3.6.4 Nursery management practices

Watering was done once every two days in the morning with 36 litres of water. Fallen, infected and dead cuttings were removed daily to avoid spreading of diseases. Daily picking out of weeds was done to avoid competition with the cuttings for nutrients. The nursery bags were encircled with wood ash to prevent snails from destroying the cuttings.

3.7 Experiment Two: effect of growth regulator application, soil media and humidity on the performance of *Voacanga africana* cuttings.

3.7.1 Experimental procedure and design.

A 3x3x3 factorial in a completely randomised design was used. High humidity (cover) is the main plot factor, with the sub – plot factor as soil types and the sub – sub – plot factors being the wood types (softwood, semi – hardwood, hardwood) and growth regulator of Seradix '2' powder, Dip 'N' grow solution. These gave twenty seven treatment combinations. Ten cuttings were used per each treatment combination and these were replicated three times. Plate 3.2 shows the setup with polythene cover.

3.7.2 Nursery practices

The experiment which started on 9th and 19th July, 2006 respectively were carried out in shallow germination pits under a lath house. Each wood type was divided into two (defoliated and non-defoliated). One- third of each wood type was used as control whiles the other third was dipped in Seradix '2' powder. A third of each wood type was dipped in Dip 'N' Grow solution. The black polythene nursery bags were filled with topsoil, sand and a mixture of top soil and sand. Half of the cuttings were covered with polythene sheet for high humidity whiles the other half has been opened.

3.7.3 Nursery management practices

The polythene propagator was opened and watered once every two days. Diseased cuttings and detached leaves were regularly removed.

3.8 GIS and Remote Sensing

The images used for the GIS and remote sensing application comparison were the Landsat Multi Spectrum Scanner (MSS -1973) and Landsat Thematic Mapper (TM2000)

The software used was Erdas Imagine 8.7 and the classification method used was unsupervised. Classification. Change detection method used was post classification method.

3.9 Data analysis

Microsoft Excel program was use to enter and manage the data as well as plot graphs. The data was then analysed using and MSTATC statistical software version. Data on number of sprouted cuttings, leaf width, number of roots and root length measurement of Voacanga cuttings were subjected to Split-split factorial Analysis of variance (ANOVA) and the differences between the means were compared using Least Squared Difference (LSD).

CHAPTER FOUR

RESULTS

4.1 Experiment One: Effects of growth regulators, soil media and wood types on the performance of *Voacanga africana* cuttings.

Observations

At the end of the experiment, most of the cuttings were infected by fungus and as a result, about 70% of the cuttings died (plate 4.1). The pathogens that infected the cuttings were identified as fusarium spp. The infection started at the bark of the cuttings, turning the bark from green to dark brown with black spots in them. The cuttings then dried up. The leaves also became yellowish and finally turned black and dropped. As a result, rooting was very poor and most of the cuttings rooted after 65 days for all the treatments on the average.

Plate 4.1 Voacanga cuttings infected with fungi

4.1.2 Main effects of soil types, growth regulator (GR) application and wood types on the performance of cuttings.

Table 1 shows that cuttings that were set in sand and mixture of topsoil and sand were not significantly different from each other in terms of the number of sprouts produced, however, cuttings set in soil and a mixture of topsoil and sand produced significantly more sprouts than cuttings set in topsoil alone. The leaf width value obtained from all the three soil types was not significant (P>0.05) but topsoil and sand mixture gave the largest leaf width.

Table 1: Main effects of growing media, growth regulator application and wood types on the performance of *Voacanga africana* cuttings.

Treatments	Number of sprouts	Leaf width (cm)	Number of roots / cutting	Average root length (cm)
Soil types				
Top soil	1.5	1.1	4.9	1.6
Sand	3.0	1.1	8.4	1.4
Top+Sand	3.3	1.9	10.3	1.1
LSD $_{0.05}$	0.6	ns	0.8	ns
G.R. Application				
Control	2.4	1.3	7.6	1.4
Seradix '2' powder	2.6	1.2	7.8	1.0
Dip 'N' grow	2.8	1.6	8.1	1.8
LSD $_{0.05}$	ns	ns	1.5	ns
Wood types				
Hardwood	3.2	1.9	9.1	2.5
Semi-hard wood	3.2	1.3	8.1	1.3
Softwood	1.3	0.8	0.2	0.5
LSD $_{(0.05)}$	ns	ns	0.9	ns

ns - not significant

There was no significant (P>0.05) effect of the soil types on the average root length but topsoil produced the highest value (1.6cm) on the average for root length whiles topsoil and sand mixture produced the least root length (1.1cm) on the average. Growth regulator (G.R) application did not significantly (P>0.05) affect the number of sprouts developed but Dip'N'grow produced more sprouts than Seradix'2' powder and control with control having the least number of sprouts (Table 4.2).

Cuttings which had no hormone application (control) had the highest number of leaves on the average whiles Dip'N'grow produced the least number of leaves on the average. There was significant (P<0.05) effect of G.R. application on the leaf width. Cuttings which had no hormone treatment (control) and Seradix '2' powder were significantly (P<0.05) different from each other, however, they were lower than Dip'N'grow which had the highest value for leaf width.

The effect of G.R. Application on the number of roots per cutting was highly significant (P>0.05). Dip'N'grow produced the highest number of roots per cutting whiles Seradix '2' powder and cuttings which had no hormone treatment (control) had the least value. Cuttings which were treated with Dip'N'grow produced the longest root length on the average whiles Seradix '2' powder had the least value for root length on the average.

There were no significant (P<0.05) differences in wood types on the average number of sprouts produced. The number of sprouts produced from hardwood and semi-hardwood were not significantly ($P<0.05$) different from each other but was higher than the number obtained from softwood. The wood types also had no significant ($P<0.05$) effect on the leaf width. Hardwood cuttings produced the highest value for leaf width whiles the least value was obtained from softwood cuttings. There was significant ($P>0.05$) differences in with regards to the wood types on the number of roots per cutting developed. The hardwood cuttings produced the highest number of roots whiles the softwood cuttings produced the lowest number. Average root length obtained from semi-hardwood cuttings was higher than that of softwood.

Table 2 shows the interactive effects among the treatments. Interaction between wood types and growth regulator application significantly ($P>0.05$) affected the number of sprouts. Softwood cuttings which had no hormone treatment (control) had the highest number of sprouts whiles hardwood cuttings treated with Dip'N'grow produced the least number of sprouts.

There was no significant ($P<0.05$) effect of treatment interaction on the number of roots per cutting developed and the average root length. Hardwood and semi-hardwood cuttings treated with both Seradix '2'powder and Dip'N'grow produced the highest number of roots per cutting whiles softwood cuttings treated with Seradix '2' powder, Dip'N'grow and control (no hormone).

Plate 4.2: Sprouted *Voacanga africana* cuttings (treated with Dip 'N' Grow solution)

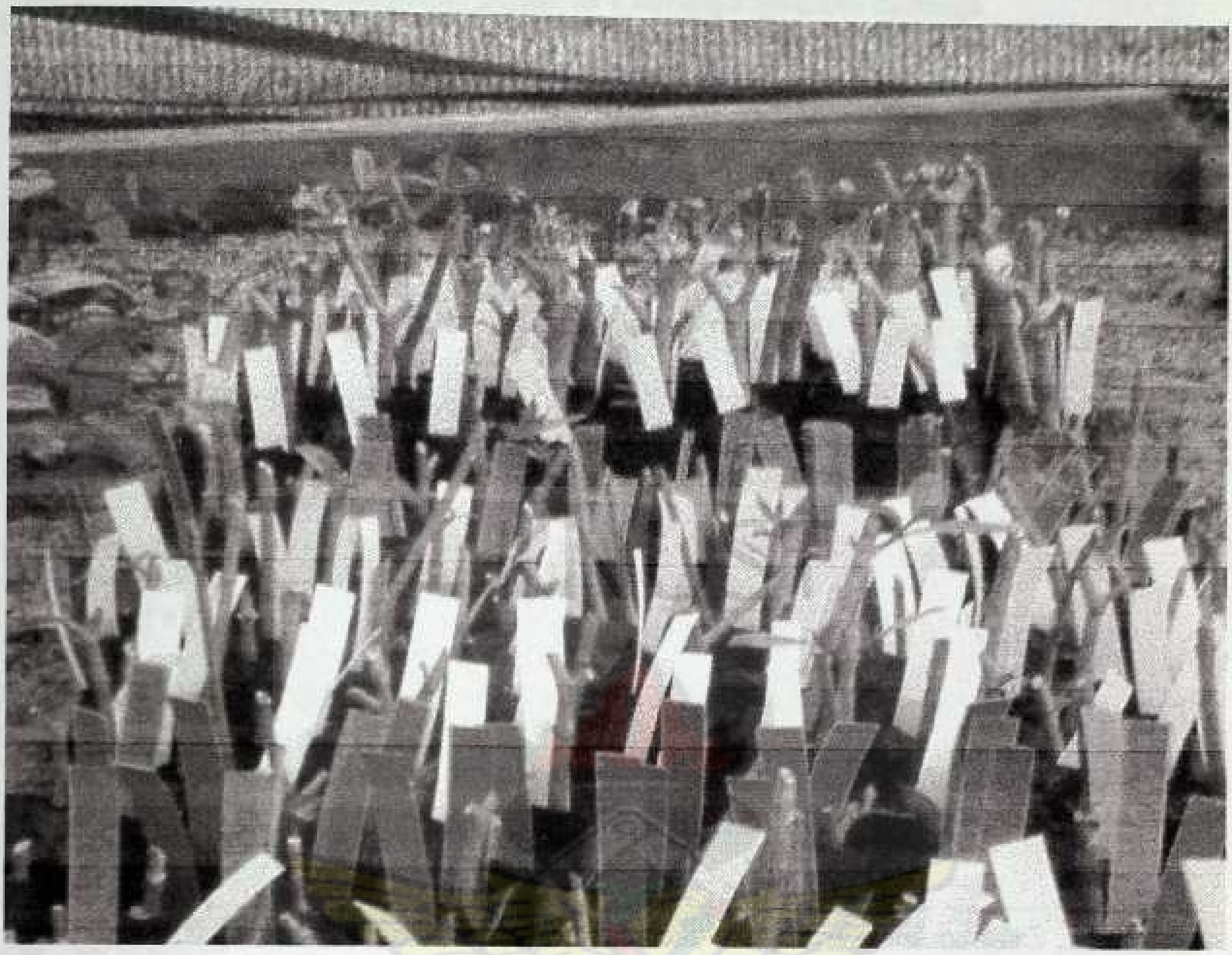


Plate 4.3: Sprouted *Voacanga africana* cuttings without treatment (control)

Table 2: Treatment interaction effects between wood types and growth regulator applications on the performance of *Voacanga africana* cuttings

Wood types/G.R. Application	Number of sprouts	Leaf width (cm)	Number of roots / cutting	Average root length (cm)
Hardwood * Control	3.0	1.5	0.0	0.3
Hardwood * Seradix'2' powder	3.0	1.5	1.0	1.3
Hardwood * Dip'N'grow	1.0	0.8	2.0	2.6
Semi-hardwood * Control	3.0	2.1	0.3	0.3
Semi-hardwood* Seradix'2'powder	3.0	0.9	1.0	1.0
Semi-hardwood * Dip'N'grow	1.0	0.7	2.0	1.7
Softwood * Control	4.0	2.2	1.0	0.8
Softwood * Seradix'2' powder	3.0	1.5	2.0	1.4
Softwood * Dip'N'grow	2.0	1.0	2.0	3.2
Interaction LSD $_{(0.05)}$	0.7	ns	ns	ns

* Interaction between treatments
ns - not significant

recorded the least values. Semi-hardwood cuttings treated with Seradix '2'powder recorded the highest value for average root length whiles softwood cuttings with all the three treatments recorded no value. Treatment interactions between wood types and soil types did not (P<0.05) have any significant effect on the number of sprouts, average number of leaves, leaf width and average root length except number of roots per cutting developed (Table 3).

Semi-hardwood and softwood cuttings set in topsoil alone and sand alone produced the highest number of sprouts whiles hardwood cuttings set in a mixture of topsoil and sand recorded the least number of sprouts. Softwood cuttings set in topsoil recorded the highest value for leaf width whiles hardwood cuttings set in a mixture of topsoil and sand gave the lowest value for leaf width. Hardwood cuttings set in sand produced the highest number of roots per cutting (plate 4.3b), whiles softwood cuttings set in sand produced the least number of roots per cutting.

Average root length of hardwood cuttings set in a mixture of topsoil and sand produced the highest value whiles softwood cuttings set in sand alone gave the least value. Table 4 shows that there was no significant (P<0.05) interaction effect of soil types and growth regulator application on the parameters except the number of sprouts and the number of roots developed. Cuttings set in sand and treated with Dip'N'grow as well as cuttings set in a mixture of topsoil and sand without hormone treatment (control) produced the highest number of sprouts. The least number of sprouts was recorded by cuttings set in a mixture of topsoil and sand which had no hormone treatment (control).

Table 3: Interaction effects of wood types and growing media on the performance of *Voacanga africana* cuttings.

Wood types/Soil types	Number of sprouts	Leaf width (cm)	Number of roots per cutting	Average root length (cm)
Hardwood * Topsoil	2	1.6	6.0	0.6
Hardwood * Sand	2	1.2	4.0	1.0
Hardwood * Top+Sand	1	0.5	5.0	3.0
Semi-hardwood * Topsoil	4	1.8	11.0	0.3
Semi-hardwood * Sand	4	0.7	8.0	1.1
Semi-hardwood * Top+Sand	2	0.8	6.0	2.1
Softwood * Topsoil	4	2.4	11.0	0.6
Softwood * Sand	4	2.0	12.0	1.7
Softwood * Top+Sand	2	1.3	8.0	2.3
Interaction LSD $_{(0.05)}$	ns	ns	1.5	ns

* interaction between treatments
ns - not significant

Table 4: Treatment interaction effects between growing media and growth regulators on the performance of *Voacanga africana* cuttings.

Soil / Hormones	Number of sprouts	Leaf width (cm)	Number of roots per cutting	Average root length (cm)
Topsoil * Control	1.3	0.8	4.0	1.2
Topsoil * Seradix'2' powder	1.6	1.3	4.9	1.4
Topsoil * Dip'N'grow	1.6	1.3	6.0	1.9
Sand *Control	2.4	0.9	9.1	1.4
Sand * Seradix'2'powder	3.2	1.3	8.7	0.8
Sand * Dip'N'grow	3.5	1.1	7.4	1.3
Top +Sand * Control	3.5	2.1	9.9	1.6
Top +Sand * Seradix'2'powder	3.3	1.2	10.0	0.8
Top+Sand *Dip'N'grow	3.3	2.4	11.0	2.2
Interaction LSD $_{(0.05)}$	0.7	ns	1.5	ns

* interaction between treatments
ns - not significant

Plate 4.4a: Rooted *Voacanga africana* semi-hardwood cuttings without treatment (control)

Plate 4.4b: Rooted *Voacanga africana* semi-hardwood cuttings with Dip N Grow

A mixture of topsoil and sand with Dip'N'grow gave the highest value for leaf width, number of roots and the average root length. Cuttings set in topsoil without hormone treatment (control) recorded the lowest value for leaf width and number of roots. Cuttings treated with Seradix '2' powder and set in a mixture of topsoil and sand and sand alone gave the least value for average root length.

Table 5 shows the three-factor interaction between soil types, hormone application and wood types. The leaf width and the number of roots per cutting developed were significantly (P>0.05) different among the treatment interactions. However, no consistent pattern was observed between the interactions and the parameters studied.

Table 5: Treatment interaction effects between growing media, growth regulators and wood types on the performance of *Voacanga africana* cuttings.

Soil / G.R/Wood types	Number of sprouts	Leaf width (cm)	Number of roots/ cutting	Average root length
Topsoil * Control * Hardwood	2.0	0.9	5.0	0.3
Topsoil * Control * Semi-hardwood	1.4	0.9	4.0	1.0
Topsoil * Control * Softwood	0.6	0.6	3.0	2.3
Topsoil * Seradix'2' powder * Hardwood	1.3	2.1	7.0	0.3
Topsoil * Seradix'2' powder * Semi-hardwood	2.3	1.2	2.0	1.0
Topsoil * Seradix'2' powder * Softwood	1.2	0.5	6.0	3.0
Topsoil * Dip'N'grow * Hardwood	2.2	1.8	5.0	1.0
Topsoil * Dip'N'grow * Semi-hardwood	1.9	1.6	6.0	1.0
Topsoil * Dip'N'grow * Softwood	0.8	0.5	6.0	3.6
Sand * Control * Hardwood	2.7	1.1	12.0	0.3
Sand * Control* Semi-hardwood	3.3	0.8	9.0	1.0
Sand * Control * Softwood	1.2	0.8	6.0	3.0
Sand * Seradix'3' powder * Hardwood	4.1	2.3	11.0	0.3
Sand * Seradix'3' powder * Semi-hardwood	3.8	0.8	9.0	1.3
Sand * Seradix'3' powder * Softwood	1.6	0.7	6.0	0.7
Sand * Dip'N'grow * Hardwood	4.7	2.0	10.0	0.3
Sand * Dip'N'grow * Semi-hardwood	4.1	0.5	5.0	1.0
Sand * Dip'N'grow * Softwood	1.6	0.8	7.0	2.7
Mixture * Control *Hardwood	3.9	2.5	12.0	0.3
Mixture * Control * Semi-hardwood	4.5	2.9	12.0	2.0

Continuation of Table 5

Mixture * Control * Softwood	1.9	1.1	6.0	2.3
Mixture * Seradix'2' powder * Hardwood	4.6	1.8	10.0	0.3
Mixture * Seradix'2' powder * Semi-hardwood	4.1	0.9	13.0	0.7
Mixture *Seradix'2' powder * Softwood	1.1	1.0	7.0	1.3
Mixture * Dip'N'grow * Hardwood	3.5	2.9	11.0	1.0
Mixture * Dip'N'grow * Semi-hardwood	4.3	2.4	12.0	2.3
Mixture * Dip'N'grow * Softwood	2.1	1.8	9.7	3.3
LSD (0.05)	ns	0.7	2.6	ns

* Interaction between treatments
ns - not significant

4.2 Experiment Two: Effect of humidity, growth regulators, soil media and wood types on the performance of *Voacanga africana* cuttings.

4.2.1 Observations

In this experiment, the fungal infection started at a later stage when the polythene cover was removed from the cuttings after 5 days of sprouting. The rate of infection was very pronounced than was in experiment 1. Rooting occurred after 70 days after setting them in the various soil, hormone and wood types.

4.2.2 Main effects of growing media, growth regulators and wood types on the performance of voacanga africana cuttings under polythene cover.

Table 6 shows that the soil types had significant ($P<0.05$) effect on the number of sprouts, with cuttings set in a mixture of topsoil and sand producing the highest number of sprouts. Topsoil alone recorded the lowest number of sprouts. The soil types did not have any significant ($P<0.05$) effect on leaf width measurement. Cuttings set in a mixture of topsoil and sand recorded the highest value for leaf width whiles sand alone had the least value. The number of roots per cutting developed by topsoil and sand was not different from each other. However, the number of roots produced by each of the above soil type was less than the number of roots developed in the mixture of topsoil and sand. The average root length recorded by cuttings set in a mixture of topsoil and sand was very high whiles the lowest value was recorded by cuttings set in sand alone.

Growth regulator application to the cuttings significantly (P>0.05) affected the number of sprouts developed. The number of sprouts produced from cuttings without hormone treatment (control) was the highest whiles cuttings treated with Dip'N'grow recorded the least number of sprouts. There was no significant (P<0.05) effect on leaf width but cuttings treated with Dip'N'grow had the highest value whiles

Table 6: Main effects of growing media, growth regulators and wood types on the performance of *Voacanga africana* cuttings under polythene cover

Treatments	Number of sprouts	Leaf width (cm)	Number of roots/ cutting	Average root length (cm)
Soil types				
Top soil	2.6	1.1	1.3	1.1
Sand	3.3	1.0	1.3	0.7
Mixture	4.2	1.7	1.5	1.2
LSD $_{0.05}$	1.6	0.3	ns	ns
G.R. Application				
Control	3.7	1.2	1.4	0.9
Seradix '2' powder	3.3	1.2	0.9	0.9
Dip 'N' grow	3.1	1.5	1.8	1.3
LSD $_{0.05}$	0.6	ns	0.5	ns
Wood types				
Hardwood	3.2	1.8	1.4	1.0
Semi-hard wood	3.5	1.1	2.3	2.0
Softwood	3.4	0.9	0.5	0.1
LSD $_{(0.05)}$	0.6	ns	0.5	0.6

ns - not significant

the least value for leaf width was recorded by cuttings set in topsoil alone and sand alone. The growth regulator application significantly (P>0.05) affected the number of roots per cutting developed. Cuttings treated with Dip'N'grow had the highest number of roots per cutting developed whiles the least number was obtained from cuttings treated with Seradix '3' powder. The growth regulators did not (P<0.05) significantly affect the average root length produced by cuttings which were treated with Dip 'N'grow but the values produced were higher than those which had no hormone treatment (control) and cuttings which were treated with Seradix '3' powder.

The effect of wood types on the number of sprouts was significant (P>0.05). The number of sprouts produced by semi-hardwood cuttings was the highest among the three wood types whiles hardwood cuttings recorded the least number of sprouts. Hardwood cuttings recorded the highest value for leaf width measurement whiles softwood cuttings had the least value. The wood types also affected the number of roots per cutting developed significantly.

The hardwood cuttings recorded the highest number of roots whiles the least was recorded by softwood cuttings. The average root length was also significantly (P>0.05) affected by the wood types. The highest value for root length was recorded by hardwood whiles softwood cuttings recorded the least value. The interaction effect of wood types and growth regulator application significantly (P>0.05) affected the number of sprouts developed (Table 7). Hardwood cuttings which had no hormone treatment (control) had the highest number of sprouts whiles the lowest value was recorded by hardwood cuttings treated with Dip'N'grow. Hardwood cuttings treated with Dip'N'grow and Seradix '3'powder had the highest

Table 7: Treatment interaction effect between wood types and growth regulator application on the performance of *Voacanga africana* cuttings under polythene cover.

Wood types/G.R. Application	Number of sprouts	Leaf width (cm)	Number of roots/ cutting	Average root length (cm)
Hardwood * Control	4.0	1.5	0.4	0.0
Hardwood * Seradix'3' powder	3.9	1.3	1.4	1.0
Hardwood * Dip'N'grow	3.0	0.8	2.4	2.0
Semi-hardwood * Control	3.0	2.0	0.3	0.1
Semi-hardwood *Seradix'3'powder	3.5	0.8	1.0	1.0
Semi-hardwood * Dip'N'grow	3.6	0.9	1.4	1.5
Softwood * Control	2.5	2.0	0.7	0.1
Softwood * Seradix'3' powder	3.1	1.4	1.7	1.2
Softwood * Dip'N'grow	3.6	1.1	3.0	2.1
Interaction LSD $_{(0.05)}$	1.1	ns	ns	ns

* Interaction between treatments
ns – not significant

value for leaf width measurement. The least value for leaf width was obtained from softwood cuttings without hormone treatment (control) and semi-hardwood cuttings treated with Seradix '3' powder. Hardwood cuttings without hormone treatment (control) produced the highest number of roots per cutting whiles the lowest number was produced by softwood cuttings without hormone application (hormone). The highest value for average root length was recorded by semi-hardwood cuttings treated with Dip'N'grow whiles the lowest value was obtained from softwood cuttings treated with Seradix'3 powder.

Interaction effects of wood types and growing media significantly (P>0.05) affected the number of sprouts produced with hardwood cuttings set in topsoil producing the highest number (Table 8). The lowest number was recorded by softwood cutting set in a mixture of topsoil and sand. Softwood cuttings set in topsoil gave the longest value for leaf width measurement whiles the lowest values were recorded by hardwood cuttings set in sand and semi-hardwood cuttings set in sand. Hardwood cuttings set in a mixture of topsoil and sand as well as semi-hardwood cuttings set in sand alone produced the highest number of roots per cutting. The least number of roots per cutting developed was recorded by softwood cuttings set in all the three soil types. The highest value for average root length was produced by hardwood cuttings set in a mixture of topsoil and sand whiles softwood cuttings set in all the three soil types produced the least value for average root length.

Table 8: Interaction effects of wood types and growing media on the performance of *Voacanga africana* cuttings under polythene cover

Wood types/Soil types	Number of sprouts	Leaf width (cm)	Number of roots per cutting	Average root length (cm)
Hardwood * Topsoil	4.4	1.5	0.4	0.1
Hardwood * Sand	4.1	1.1	1.1	1.3
Hardwood * Mixture	4.0	0.7	2.4	1.9
Semi-hardwood * Topsoil	3.6	1.6	0.4	0.0
Semi-hardwood * Sand	3.3	0.7	1.4	0.6
Semi-hardwood * Mixture	3.1	0.8	2.0	1.8
Softwood * Topsoil	2.7	2.3	0.6	0.3
Softwood * Sand	2.7	1.7	1.6	1.2
Softwood * Mixture	2.4	1.2	2.4	2.1
Interaction $_{LSD\ (0.05)}$	1.1	ns	ns	ns

* Interaction between treatments
ns - not significant

Interaction effects of growing media and growth regulators on the number of sprouts was significant (P>0.05) (Table 9). Cuttings set in topsoil without hormone treatment (control) produced the highest number of sprouts whiles cuttings set in a mixture of topsoil and sand treated with Dip 'N 'grow gave the least number of sprouts. Cuttings set in a mixture of topsoil and sand treated with Dip'N'grow recorded the highest value for leaf width whiles cuttings set in topsoil without hormone treatment (control) had the least value.

There was no significant (P>0.05) interaction effects of growing media and growth regulators on the number of roots per cutting developed. Cuttings that were dipped in a mixture of topsoil and sand treated with Dip 'N'grow produced the highest number of roots per cutting whiles cuttings set in sand alone treated with Seradix '3'powder as well as cuttings set in a mixture of topsoil and sand and treated with Seradix '3' powder produced the least number of roots per cutting.

Cuttings that were dipped in a mixture of topsoil and sand and treated with Dip 'N'grow recorded the highest value for average root length whiles cuttings dipped in topsoil and treated with Seradix '3'powder as well as cuttings dipped in mixture of topsoil and sand without any hormone treatment (control) recorded the least average root length. From Table 10, the three-factor interaction between soil types, hormone application and wood types under plastic cover significantly affected the number of sprouts. Leaf width measurement and the number of roots per cutting developed were not significantly (P>0.05) different among the treatment interactions. However, no definite pattern was observed between the interactions and the parameters studied.

Table 9: Treatment interaction effects between growing media and growth regulators on the performance of *Voacanga africana* cuttings under polythene cover.

Soil / Hormones	Number of sprouts	Leaf width (cm)	Number of roots per cutting	Average root length (cm)
Topsoil * Control	4.5	0.8	1.4	1.0
Topsoil * Seradix'2' powder	4.1	1.3	1.2	0.7
Topsoil * Dip'N'grow	4.0	1.2	1.3	1.1
Sand * Control	3.6	0.9	1.6	1.2
Sand * Seradix'2'powder	3.3	1.0	0.8	0.9
Sand * Dip'N'grow	3.1	1.2	1.6	0.9
Mixture * Control	2.9	1.8	1.3	0.7
Mixture * Seradix'2'powder	2.6	1.2	0.8	1.0
Mixture * Dip'N'grow	2.3	2.2	2.4	1.4
LSD $_{(0.05)}$	1.1	ns	ns	ns

* interaction between treatments
ns – not significant

Table 10: Interaction effects of growing media, growth regulator applications and wood types on the performance of *Voacanga africana* cuttings under polythene cover.

Soil / G.H/Wood types	Number of sprouts	Leaf width (cm)	Number of roots per cutting	Average root length (cm)
Topsoil * Control * Hardwood	5.2	1.1	0.3	0.0
Topsoil * Control * Semi-hardwood	4.9	0.7	2.7	0.8
Topsoil * Control * Softwood	4.7	0.6	1.3	2.2
Topsoil * Seradix'3' powder * Hardwood	4.3	1.8	0.3	0.0
Topsoil * Seradix'3' powder * Semi-hardwood	4.2	1.4	2.3	1.5
Topsoil * Seradix'3' powder * Softwood	4.1	0.8	1.0	0.7
Topsoil * Dip'N'grow * Hardwood	3.9	1.7	0.7	1.4
Topsoil * Dip'N'grow * Semi-hardwood	3.7	1.2	2.3	1.3
Topsoil * Dip'N'grow * Softwood	3.7	0.6	1.0	0.4
Sand * Control * Hardwood	3.5	1.2	2.7	0.1
Sand * Control * Semi-hardwood	3.4	0.7	1.3	1.4
Sand * Control * Softwood	3.4	0.8	0.7	2.1
Sand * Seradix'3' powder * Hardwood	3.4	2.1	0.3	0.0
Sand * Seradix'3' powder * Semi-hardwood	3.3	0.3	1.3	0.8
Sand * Seradix'3' powder * Softwood	3.3	0.7	0.7	1.7
Sand * Dip'N'grow * Hardwood	3.3	1.6	0.3	0.0
Sand * Dip'N'grow * Semi-hardwood	3.2	1.0	2.7	1.9
Sand * Dip'N'grow * Softwood	3.1	0.9	1.7	0.9
Mixture * Control * Hardwood	3.1	2.3	2.0	0.0

Continuation of Table 10

Mixture * Control * Semi-hardwood	3.0	2.3	1.7	0.5
Mixture * Control * Softwood	2.9	0.9	0.3	1.6
Mixture * Seradix'3' powder * Hardwood	2.8	2.0	0.3	0.4
Mixture * Seradix'3' powder x Semi-hardwood	2.7	0.7	0.7	1.2
Mixture * Seradix'3' powder x Softwood	2.4	1.0	1.3	1.4
Mixture * Dip'N'grow x Hardwood	1.9	2.6	2.8	2.9
Mixture * Dip'N'grow x Semi-hardwood	1.7	2.1	2.3	1.4
Mixture * Dip'N'grow x Softwood	1.4	1.8	1.0	0.0
LSD $_{(0.05)}$	1.9	ns	ns	ns

* Interaction between treatments
ns – not significant

4.5 COMPARISON OF EXPERIMENT ONE AND EXPERIMENT TWO

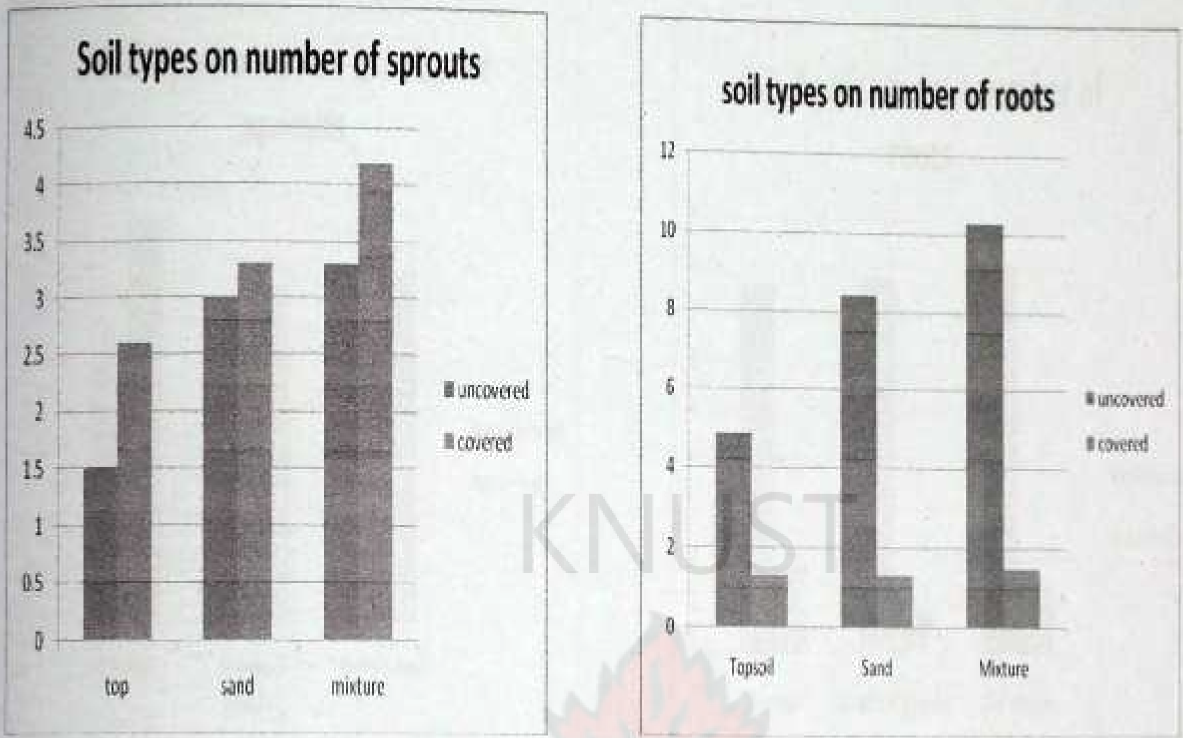
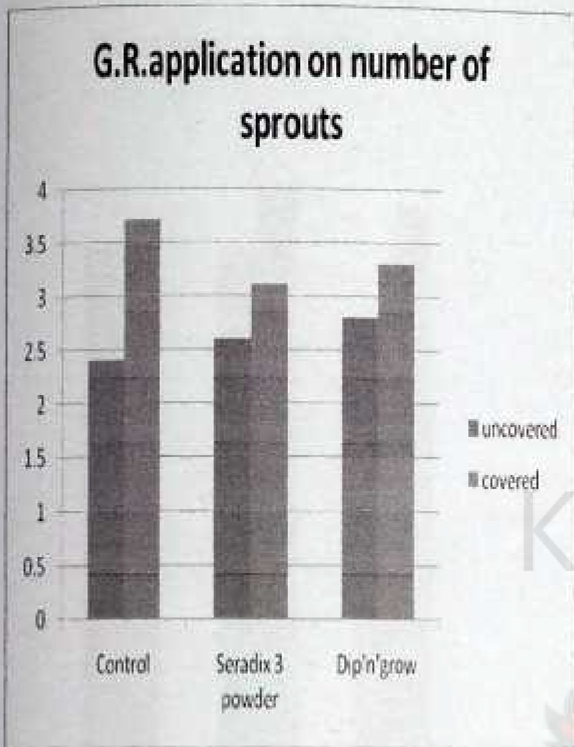


Fig.4.1

From the graph above, the three soil types which were covered produced more sprouts than those which were not covered. However, with regards to the number of roots, the soil types which were not covered performed better than those which were covered.

COMPARISON OF EXPERIMENT ONE AND EXPERIMENT TWO



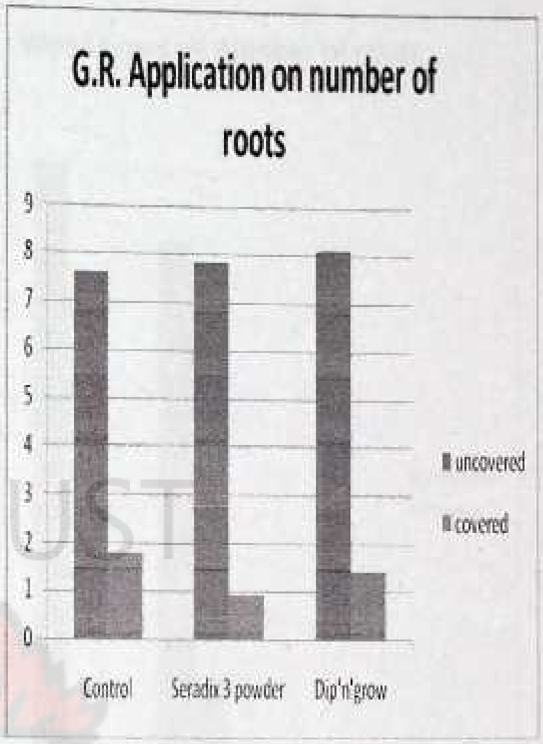
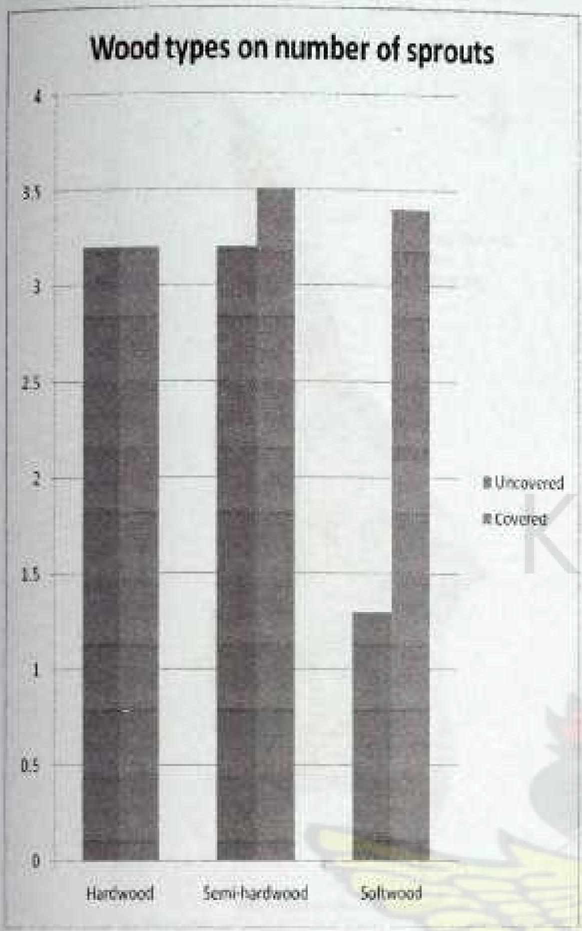


Fig.4.2

The application of growth regulators on the cuttings which were covered in the experiment produced more sprouts than those which were not covered. The comparison of both experiments also show that cuttings which were not covered produced more roots than those which were covered.

COMPARISON OF EXPERIMENT ONE AND EXPERIMENT TWO



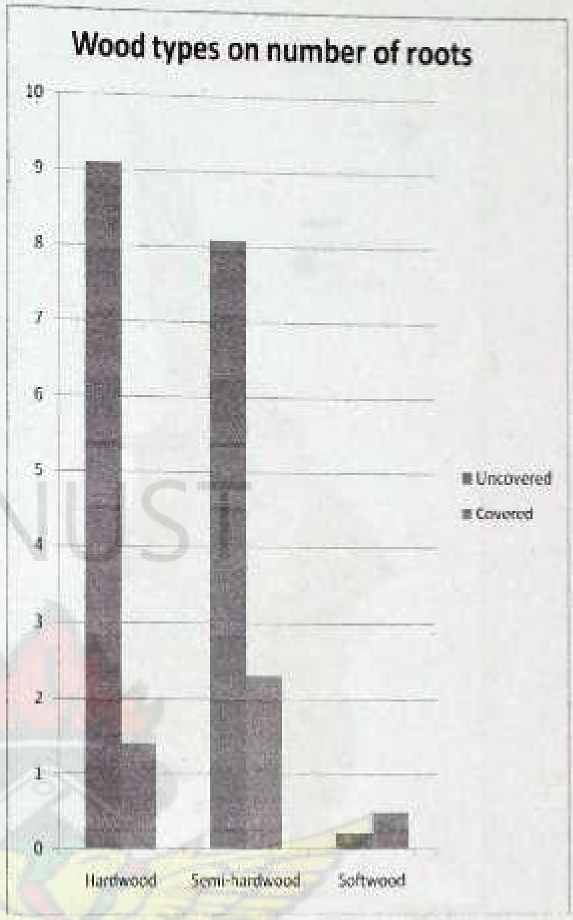


Fig.4.3

There was no significant difference between hardwood and semi-hardwood types which were covered and those which were not covered. The softwood cuttings which covered however, produced more sprouts than those which were not covered. All the wood types which were not covered produced more roots than those which were covered with the exception of softwood cuttings in which the covered cuttings produced the most number roots.

Land Cover Map of Wenchi District

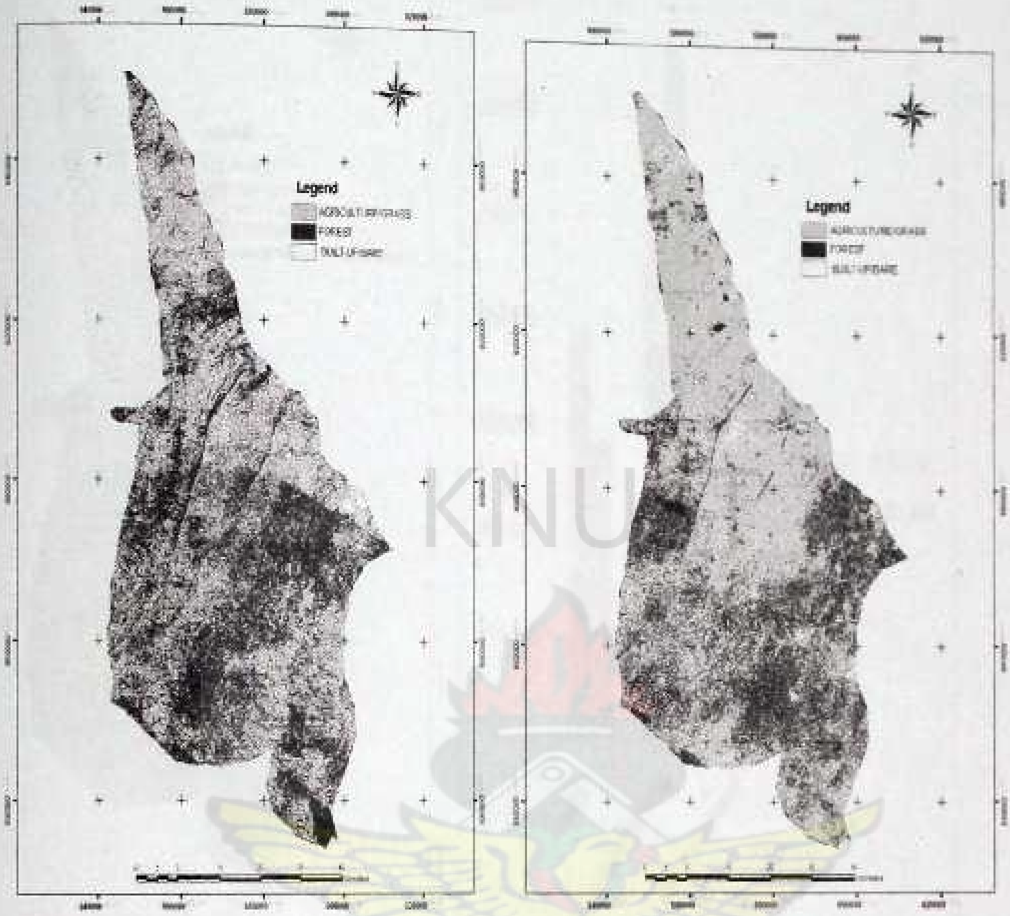


Fig. 4.4 **MSS - 1973** **TM - 2000**

The two maps above – the Multi-spectrum scanner for 1973 and the Thematic Mapper for the year 2000 show the forest cover and the general land use of the Wenchi district. A comparison of the two maps will determine the changes that have taken place in the area.

CHANGE MAP OF THE STUDY AREA

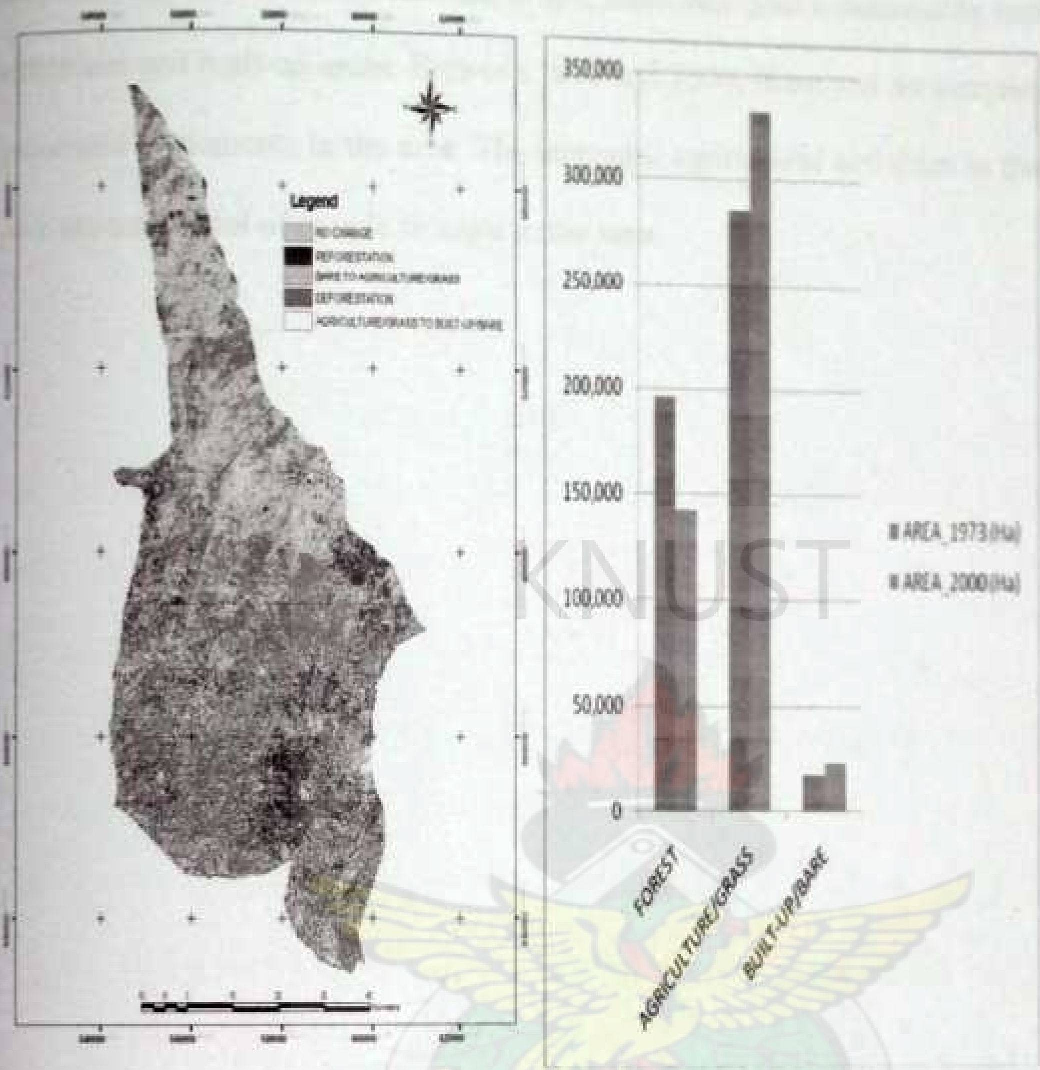


Fig. 4.5

The change map above was obtained by comparing the two landsat images for 1973 and 2000. the actual changes in figures have been provided in the graph above. Between 1973 and 2000, the forest cover in the area reduced by 128,537 hectares. This might be due to the fact that the transition zone is prone to bushfires during the harmattan season and the area is also well noted for charcoal production. There was however an increase in agricultural activities from 1973 to 2000. The land area put under agricultural production increased by 47,251 hectares which might also be due to increase in population and the fact that agriculture happens to be the major pre-occupation of the people living in that area. From the graph, there was also a reasonable increase in the settlement and built-up areas. Between 1973 and 2000, there was an increase of 5,904 in household settlements in the area. The increased agricultural activities in the area might have attracted a lot of people to settle in the area.

CHAPTER FIVE

DISCUSSION

The analysis of the experiments conducted on *Voacanga africana* cuttings using three growth media , growth regulator and wood types, show that in all the experiments, semi-hardwood cuttings recorded the highest (P>0.05) number of sprouts and rooting per cutting than softwood and hardwood types.

The high number of sprouts and roots developed could be attributed to their physiological age or juvenility. This is due to the fact that, better rooting results are obtained from cuttings taken from young trees two to ten years of age as compared to cuttings taken from trees which are over forty years of age, (Hartman "*et al*"., 1984).

Furthermore, the presence of carbohydrates in the cuttings help in the growth and development of roots as well as sustain the cutting while it is in the medium. Wiegel *et al,* (1984) also reported that carbohydrates enhance metabolic activities that occur at the base of the cuttings to aid cell division which brings about root initiation.

Mixture of topsoil and sand in all the experiments produced more (P>0.05) sprouts and roots than the other soil media used. IFCC,(1972) report indicated that, the effect of various media on the performance of cuttings is closely associated with temperature and water relation. A medium temperature of 25^0C to 26^0C in the morning and 27^0C to 30^0C in the afternoon could enhance germination and rooting (Cheeseman and Spencer, 1936).

Hardy (1960), also revealed that, the suitability of a medium depended on the amount and frequency of aeration. These findings were observed with sand and topsoil mixture medium. The high aeration in the sand medium might have created a good environment for increased respiration at the base of the cuttings and encourages rooting as reported by Evans (1953).

The results from the experiment show that with the exception of the experiment one where cuttings which had no hormone treatment (control) produced more sprouts, the others which were treated with Dip'N'grow produced more sprouts and roots than the seradix'2' and control. It has been suggested by Middleton *et al.* (1980) that, carbohydrate concentrations may be influenced by auxin treatment which can also enhance mobilisation of carbohydrates in leaves, upper stem and increase transport to the rooting zone.

Hitchcock and Zimmerman (1940) also observed that, auxin treatment results in high percentage rooting and the development of more roots per cutting. Apparently, the movements of boron (B), nitrogen (N), zinc (Zn) and potassium (K) to the rooting zone as observed by Blazeich *et al.* (1983) is enhanced by auxin treatment.

Mixtures of root promoting substances are sometimes more effective than each compound. For example, equal parts of indolebutyric acid (IBA) and naphtaleneacetic acid (NAA) when used on a widely diverse species were found to induce a higher percentage of cuttings to give more roots per cutting than either auxin alone as stated by Ellyard, (1981). It has also been observed by Davis and Haissig (1990) that, adding a smack percentage of certain phenoxy compounds to either IBA or NAA increased rooting and produced root systems better than obtained with phenoxy compounds alone.

According to Archibald (1953), and Hartman *et al.* (1997), an ideal rooting medium provides sufficient porosity to allow good aeration; has a high water retaining capacity but well drained and free from fungi and bacteria. In coarse sand, the roots produced are thick and brittle with few laterals. Such roots are readily broken when the plants are potted. However, a mixture of topsoil and sand produced more sprouts and roots in all the experiments. Among some of the rooting media used in Ghana is a mixture of equal part of coarse river sand and composted oil palm fibre. The fibre holds moisture while the sand keeps the mixture open and well aerated as stated by Brian (1962). On the contrary, equal parts of topsoil and sand are also good for rooting as evidenced in all the experiments.

The greater sprouting percentage and the number of roots developed may probably be due to juvenility. All the cutting materials were obtained from young seedling plants in juvenile growth phase which according to Gardiner (1951) root more readily. Paton *et al*,(1970) also observed that juvenility in relation to rooting may possibly be explained by low levels of rooting inhibitors as well as high levels of photosynthates, but as the plant grows older, the inhibitor levels increases. The high number of sprouts and roots recorded from the wood types could also be attributed to the effect of buds on the cuttings. Buds on a cutting have a strong promoting effect on rooting as observed by Leopold, 1960; Kozlowski and Kramer, (1997). For root formation to occur the presence of an actively growing shoot tip (or lateral bud) is necessary during the first three or four days after the cuttings are made as stated by Haissig *et al*. (1992).

Hess and Snyder (1957), indicates that rooting capacity is positively correlated with carbohydrate availability. The importance of carbohydrate-to-nitrogen (C/N) ratio in plant growth and development has been hypothesised by Wiegel *et al,* (1984). High C/N ratio in cutting tissue promotes rooting but do not accurately predict the degree of rooting responses as observed by Struve (1981). The ability of a stem to root has been shown to be due to an interaction of inherent factors present in the stem cells as well as transportable substances produced in leaves and buds, the major one being carbohydrate with others such as nitrogenous compounds and vitamins as reported by Jules *et al*. (1981).

5.1 Experiment One

5.1.1 Treatment interactions

Wood types and growth regulators interacted to give the number of roots per cutting for both hardwood and semi-hardwood cuttings treated with Seradix '3' powder and Dip'N'grow. Semi-hardwood cuttings dipped in Dip'N'grow produced more sprouts and the longest root length. The better performance of Dip'N'grow than the other hormones could be attributed to the fact that the mixtures of root promoting substances are sometimes more effective than either component alone. Hardwood and semi-hardwood types might have had high levels of carbohydrate and nitrogen concentration in them.

Interaction effects of wood types and growing media was not significant for the parameters studied except for the number of roots per cutting where hardwood cuttings set in a mixture of topsoil and sand produced the highest number of roots. The high number of roots per cutting developed by hardwood cuttings in a mixture of topsoil and sand may be due to the fact that the topsoil holds moisture while the sand keeps the medium open and well aerated.

Interaction effects between hormone application and growing media did not give any significant difference on leaf width and average root length except for the number of sprouts and roots per cutting developed, where cuttings dipped in a mixture of topsoil and sand, treated with Dip'N'grow gave the highest number of sprouts and roots per cutting developed. The reason for the high numbers might have been due to the excellent moisture supply and the effectiveness of the mixture of the two root promoting substances.

Significant difference existed on the number of sprouts, leaf width and the number of roots in the three-factor interaction involving growing medium, growth regulator application and wood types. Hardwood cuttings dipped in sand and treated with Dip'N'grow produced the highest number of sprouts which might have been due to effectiveness of the growth regulators and the excellent condition provided by the growing media. The high number of roots obtained from hardwood cuttings inserted in a mixture of topsoil and sand without hormone treatment (control) might be due to the optimum moisture supply provided by the growing medium and the possible high carbohydrate to nitrogen ratio concentration in the cuttings.

5.2 Experiment Two

5.2.1 Treatment interactions

Wood types and growth regulator application interaction did not give any significant difference on the parameters studied except for number of sprouts where softwood cuttings treated with Dip'N'grow produced high number of sprouts. The possible reason may be due to juvenility, which may be explained by low levels of rooting inhibitors as well as high levels of photosynthates and higher phenolic levels as reported by Chevalier (1948). The application of Dip'N'grow solution might have also increased the level of endogenous auxin, which is important in cell division and differentiation.

Wood types and growing media did not interact significantly on the parameters studied except for the number of sprouts where hardwood cuttings set in topsoil produced the highest number of sprouts. The hardwood cuttings, generally, might have assumed juvenile characteristics through the formation of adventitious shoots from the base of the mature plants (Jules *et al.*,1981). The topsoil medium might have also encouraged biochemical processes through the provision of optimum moisture supply for successful sprouting and rooting (Bowman 1950).

Growing media and growth regulator application interacted significantly on the number of sprouts and the number of roots per cutting with cuttings set in topsoil and treated with Seradix'3' powder giving the highest number of sprouts. The topsoil might have encouraged biochemical processes through temperature regulation as well as respiration at the base of the cutting. The initiation in cutting is favoured by growth regulators which are synthesized in the buds and young leaves and translocated to the basal portion, (Kogl, 1933). Cuttings which were dipped in a mixture of topsoil and sand and treated with Dip'N'grow gave a high number of roots per cutting. The topsoil holds moisture whiles the sand keeps the mixture open and aerated. Dip'N'grow consists of indolebutyric acid (IBA) and naphtaleneacetic acid (NAA) which have been found to induce a higher percentage of cuttings and more roots per cutting than either auxin alone (Ellyard 1981). These reasons might have been responsible for the high number of sprouts and roots for the interaction.

The three –factor interaction involving growing media, growth regulator application and wood types showed a consistent pattern in the number of sprouts with hardwood cuttings without hormones (control) and set in topsoil producing the highest number of sprouts. The topsoil might have regulated the basal temperature to enhance sprouting whiles the hardwood cuttings with its high level of carbohydrates and total free phenols might have promoted growth and development of the sprouts.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Several factors affect the growth and rooting of Voacanga africana cuttings. However, the most prominent among them was fungal infection and snail attacks. A fungicide was used to prevent the fungal infection whiles snail bait was used to poison the snails.

Also at the end of the experiment, among the wood types, hardwood and semi-hardwood recorded the highest number of sprouts and roots on the average in experiment one, whiles semi-hardwood cuttings produced the best results in experiment two. Among the soil types, a mixture of topsoil and sand produced the best results in both experiment one and two.

Furthermore, among the growth regulators, cuttings which were treated with Dip N Grow produced the highest number of sprouts and roots in experiment one whiles cuttings which had no treatment (control) produced the best results in experiment two.

Lastly, GIS and Remote sensing application was identified as a very effective and efficient tool in gathering accurate and timely information about changes in the environment.

RECOMMENDATIONS

Based on the results obtained from the experiments, it is therefore recommended that

1. biological means of fungal and pest control should be investigated to prevent future attacks by fungus and snails on Voacanga africana stem cuttings.
2. semi-hardwood cuttings treated with Dip N Grow or without any treatment (control) in a mixture of topsoil and sand medium should be considered for future propagation of Voacanga africana cuttings.
3. further work needs to be done in trying other propagation methods such as bottom heating, mist propagator, green house propagation among others.
4. Landsat images of the study area spanning a period of about 30 years should be obtained to determine the actual changes that have occurred in the environment and its consequent effects on water bodies in the area.

Also, further studies should be conducted to find out the performance of the *Voacanga* seedlings on the field, especially within the catchment area of the river in the study area. This will enable us to know whether the tree will be able to colonise the vegetation along the watershed and subsequently provide the needed shade and also check erosion among others.

In the course of the experiment, there was fungal infection on the cuttings as well as snail attacks. A fungicide was used to prevent the fungal infection whiles snail bait was used to poison the snails. It is therefore recommended that biological means of fungal and pest control should be investigated.

This research was conducted on only one multi-purpose tree species (MPTS) and as such recommend that more MPTS should be identified and research conducted on them to determine their growth characteristics. Moreover, micro-propagation using small parts of a tree such as the embryo- tissues among others should be studied. It is also recommend that a longer duration should be used for a more detailed and comprehensive research to be conducted on *Voacanga africana* tree species.

REFERENCES

Abeney, E.A., (1998). Forestry education – meeting challenges in sustainable forestry development in the 21st century. *Proc.* 20th International Forestry Students Symposium in Ghana. P.1-8.

Abramovitz, J. (1996). Imperiled waters, impoverished future: The decline of fresh water ecosystems. Washington, D.C., World watch Institute. (World watch paper No. 128) 80 pp.

Archibald, J.F., (1953). Factors concerned in the rooting response of cuttings. Proc. West Africa International cacao Res. Conf. , pp 40 – 42.

Albersheim, P. (1965). The structure and function of the cell wall. In "Plant Biochemistry (Bonner, J. and Varner, J.E. eds), pp 151 – 186.

Arnand, V.K. and Herbelein, G.T. (1975). Seasonal changes and effect of auxin on rooting in stem cuttings of Ficus infectoria. Plant physiology, 34: 330 – 334

Annon, E. (1970): Annual Report 1970/71, Forrest Products Research Institute (CSIR), Kumasi. Pp 11-16.

Anon, (2005).at a glance: the world's water crisis: Our Planet, UNEP, Nairobi, Kenya.

Bassuk, N.L., and Howard, B.H. (1981). Seasonal rooting changes in the apple hardwood cuttings and their implications to nurserymen. Comb. Proc. Intl. Plant Prop. Soc., 30: 289 – 293.

Berger, J., Smith, P. and Avery, G.S. Jnr. (1946). The influence of auxin on the respiration of the avena coleoptile. Amer. Jour. Bot., 33: 601 – 604

Berrie, G.K., Berrie, A. and Eze, J.M.O. (1993). Tropical Plant Science Longman Singapore Publishers Pte. Ltd., pp 67-78.

Blazich, F.A and Wright, R.D. (1979). Non mobilization of nutrients during rooting of *Ilex crenata* Thumb. c.v. Convexa stem cuttings. *Hort. Science*. 14:242

Blazich, F.A., Wright, R.D. and Schanffer, H.E. (1983) Mineral nutrition status of "convexa" holly cuttings during intermittent mist propagation as influenced by exogenous auxin application. *J. Amer. Soc. Hort. Sci.*, 109:350 – 355.

Bowman, D. (1950). Propagation of cacao by softwood cuttings. Cacao, 12: 1- 6

Brandon, D. (1939). Seasonal variations of starch content in the genus Rosa and their relation to propagation by stem cutting. *Jour. Proc. Hort. Sci.*, 47: 147 – 148

Brian,W.J. (1962). Agriculture and land use in Ghana. "Oxford Univ. Press, London".

Bulley, H.N.N. (1996) Assessment of Land Cover Changes and Hydrologic Response of Tamne River Basin. *MSc. Thesis*, Faculty of Forestry, Lakehead Univ., Ontario, Canada. 137 pp.

Bury, R.B., P.S. Corrn and K.B. Aubry (1991). Regional patterns of terrestrial amphibian communities in Oregon and Washington, In: Wildlife and Vegetation of unmanaged Douglas-Fir Forests, U.S.D.A Forest Service General Technical Report, PNW – GTR, 285: 341 – 352

Carlson, M.C. (1929). Microchemical studies of rooting and non- rooting rose cuttings. Bot. Gaz., 87:64-80.

Cheesman, E. E. and Spencer, G.E.L. (1936). The propagation of cuttings in tropical climate. *Trop Agriculture, Trin.*, 13,201 – 206

Chevalier, A. (1948). Nouvelles recherchers sur L'arbre 'a beure du soudan. Revue Internationale de Botanique Appliquee et'a AgricultureTropicale, 28:241 – 256.

Clarke, R. (1991). Water: The International Crisis. Cambridge, Massachusetts, MIT Press, (xii). 193 p.

Cline, M.N. and Neely, D. (1983). The histology and histochemistry of the wound heeling process in geranium cuttings. *J. Amer. Soc. Hort. Sci.*,108:452 – 496.

Commoner, B. and Thimann, K.V. (1941). On the relation between growth and respiration in the Avena coleoptile. Jour. Gen, Physiol., 24:279 – 296.

Cooper, W.C. (1935). Hormones in relation to root formation on stem cuttings. *Plant Physiol.*, 10:789 – 794.

Cooper, W.C. and Went, F.W. (1938). Effect of root formation on retreating cuttings with growth substances. *Science*. 87:390.

Curtis, O.F. (1918). Stimulation of root growth in cuttings by treatment with chemical compounds. *Cornell Univ. Agric. Expt. Sta. Mem.*, 14:75 – 138.

Curran, P.J. (1986) Principles of Remote Sensing. Longman Group. (UK). 282 pp

Danso, J.K. (1992) Application of GIS In Pollution Control, pp 24 in EPC, 1992. GIS environment for resource management. Proc. Workshop on GIS, April 9-10, 1992. EPC, Accra, Ghana, 34 pp.

Davies, F.T. Jr. (1984). Shoot RNA, cambial activity and IBA effectively in seasonal rooting of juvenile and mature *Ficus pumila* cuttings. *Physiol. Plant*. 62:571-575.

Davies, F.T. Jr., Lazarte, J.E. and Joiner, J.N. (1982). Initiation and development of roots in juvenile and mature leaf bud cuttings of *Ficus pumila* L. *Amer. J. Bot*., 69:804 – 811.

Davies, T.D. and Haissig, B.E. (1990). Chemical control of adventitious root formation in cuttings. *Plant Growth Reg. Soc. Amer. Quart*., 18(1): 1- 12

Engelman, R. and Leroy, P. (1995). Sustaining water: An update. *Population Action International*, Washington, D.C.

Ellyard, R.K. (1981). Effect of auxin combinations on the rooting of *Personia chamaepitys* and *P. pinfolia* cuttings. *Comb. Proc. Intl. Plant Prop. Soc*., 31: 251-255.

Environmental Protection Council (EPC). (1992) GIS for environmental Resource Management. Proc., workshop on GIS, April 9-10, 1992. Env. Evans, H. (1953). Recent investigations on the propagation of cacao. Report on Cacao research. (1945 – 51), pp 182-210.

Evans, H. (1951). Investigations on the propagation of cacao. *Trop. Agriculture, Trin*. 28; 14: 7 – 23

Evans, H. (1953). Recent investigations on the propagation of cacao. Report on Cacao research. (1945 – 51), pp 182 – 210.

Evans, J., (1992). Plantation Forestry in the Tropics. 2nd Ed. Pergamon Press, Oxford – London, N.Y., Paris 236 pp.

Falkenmark, M. (1990). Population growth and water supplies: An emerging crisis. *People* 17 (3): 18 – 20

Falkenmark, M. (1994) Landscape as the support provider: Water – related limitations. In: Graham – Smith, F., ed. *Population: The complex reality*. Golden Colorado. North American Press. Pp 103 – 116.

Food and Agriculture Organisation (FAO) (1990) – second level. Soil map of Ghana, CSIR, Soil Research Institute, .Accra.

Gardener – Outlaw, T. and Engelman, R. (1997). Sustaining water, easing scarcity: A second update. *Population Action International*, Washington D.C. 20 p.

Gardiner, F.E (1951). Growth substances in relation to the production of tree fruits. Plant growth substances.(Skoog). Union- Wisconsin Press p 207 -223

Geneve, R.L. (1991). Patterns of adventitious root formation in English Ivy. *J. Plant Growth Regul.*, 10:215 -220.

Gleick, P. (1993). An introduction to global fresh water issues. In: Gleick, P., ed. *Water in crisis*. New York, Oxford, Oxford University Press. Pp 3 -12

Ginzburg, C. (1967). Organisation of the adventitious root apex in *Tanarix aphylla*. *Amer. J. Bot.*, 5: 54 – 88.

Girouard, R.M. (1969). Physiological and biochemical studies of adventitious root formation. Extractable rooting co-factors from *Hedera helix*. Can. J. Bot. 47 (5) : 487 – 499.

Good, G.L. and Turkey, H.B. Jr. (1964). Leaching of nutrient from cuttings under mist. *Contrub Proc. Int. Plant Prop. Sci.*, 14:138 -142.

Gyamfi – Aidoo, J. (1987). Application of GIS to the Assessment of Land Degradation and Associated Hazards In the Upper East Region of Ghana. *Proc. 2nd Int. Conf. And workshop on GIS*, San Francisco, pp. 487 -497.

Hall, J.B. and Swaine, M.D. (1981). Distribution and Ecology of vascular plants in a Tropical Rain Forest: Forest vegetation in Ghana. W. Junk Publi. The Hague 383 pp.

Haissig, B.E. (1972). Meristematic activity during adventitious root primordium development. *Plant Physiology*. 49 :889-892.

Haissig, B.E (1974). Influence of auxin and auxin synergist on adventitious root primodium initiation and development. *N.Z.J. For. Sci.*, 4, 301-322.

Haissig, B.E. (1982). Carbohydrate and amino acid concentration during adventitious roots primodium development in *Pinus banksiana* Lamb cuttings. *For Sci.*, 28:815 821.

Hambrick, C.E., Davis, F.T. Jr. and Pemberton, H.B. (1991). Seasonal changes in bohydrate/nitrogen levels during field rooting of *Rosa multiflora* "Brook 56" hardwood. *Cuttings Scientia Hort.*, 46:137 -146

Harbage, J. F., Stimart, D.P. and Evert, R.F. (1914). Anatomy of adventitious root formation in micro cuttings of Malus domestica Borkh. " Gala". J. Amer. Soc. Hort. Sci., 118:680 – 688.

Hardy, F. (1960). Cacao manual. *Int. Amer. Inst. Agric. Sci.*, Turrialba, Costa Rica pp.134-158

Hare, R.C. (1966). Physiology of resistance to fungal diseases in plants. *Bot. Rev.*, 32,95 – 137

Hamilton, L.S. (2003): op cit

Harrington, J.F. (1970). Seed conservation of plant gene resources. In *Genetic Resources in Plants- Their Exploration and Conservation*, ed. O.H. Frankel and E. Bennett, IBP Handbook No. 11, pp. 501-21. Blackwell Scientific Publications, Oxford.

Hartmann, H.T., and C. J. Hansen (1958). Effect of season of collecting, indolebutyric acid, and pre-planting storage treatments on rooting of Marianna plum, peach, and quince hardwood cuttings, *proc. Amer. Soc. Hort. Sci.*, 71:57-66

Hartmann, H.T., and F. Loreti (1965). Seasonal variation in the rooting of olive cuttings, proc. Amer. Soc. Hort. Sci., 87:194 - 198

Hartmann, H.T., Kester, D.E., Davies, F.T. and Geneve, R.L. (1997). Plant propagation principles and practices. Prentice hall ENG. Cliffs, New Jersey 07632 pp 276 -391.

Hawthorne, W.D. (1995). Ecological profiles of Ghanaian Forest Trees. Tropical Forestry papers 29, Oxford Forestry Institute, Department of Forest Sciences, University of Oxford Press. Pp. 202-204.

Hess, C.E. and Snyder, W.E. (1957). A physiological comparison of the use of mist with other propagation procedures used in rooting cuttings. *Report on 14th International Horticulture Conference*, Scheningen 2:1133

Hess, C.E. (1968). Internal and external factors regulating root initiation. In Root Growth: *Proc. 15th Easter School in Agric Science*. University of Nottingham. Pp 42 – 64. Butterworths, London.

Henry, P.H., Blazich, F. A. and Hinesley, L.E. (1992). Nitrogen nutrition of containerized eastern red cedar. II. Influence of stock plant fertility on adventitious rooting of stem cutting. *J. Amer. Soc. Hort. Sci.*, 117:568 -570

Hitchcock, A.E. and Zimmerman, P.W. (1940). Effects obtained with mixture of root-inducing hormones and other substances. *Contrib. Boyce Thomp. Inst.*, 11:143 – 60

Howard, B.H., (1985). The contribution to rooting in leafless cultivar plum cuttings of applied to the epidermis. *J. Hort. Sci.* 60: 153 – 159.

Howard, J.A. (1991). Remote Sensing of Forest Resources: theory and applications. First Edition. Published by Chapman and Hall.

International Center for Agricultural Research in the Dry Areas (ICARDA). (1996). Biodiversity: A key to food security. Aleppo, Syria.

IFAD. (1990). Ghana: Upper East Region Land Conservation and small holder Rehabilitation Project. International Fund for Agricultural Development (IFAD). Rome, Rept. Number 0244. GH, Vol. 1 and 2.

Institute Francais de Cacao, Café (IFCC) (1972) (Antenne de Tamatave). Rapports mensuels. Nov. 1969 a Avril, 1972. Tome' 179 pp.

Inter- Press Service (IPS) (1999). Most rivers in the world are polluted. Washington D.C. Inter- Press wire service.

Jackson, M.B. (1986). Development in plant and soil sciences. New root formation in plants and cuttings. Martinus, Nijhoff publishers, Dordrecht. Pp. 149 -158: 162-179.

Jules, J., Schery, R.W., Woods, F.W and Ruttan, V.W. (1981) Plant science, an introduction to world crops. 3rd ED. W.H. Freeman and Company, San Francisco, U.S.A. 868 pp.

Kogl, F. (1933). One plant hormone (auxin A and auxin B). Rep. British Association. pp 600 -609.

Kozlowski, T.T. (1969). Tree physiology and forest pest. J. For., 69, 118 – 122.

Kozlowski, T.T. and Kramer, P.J. (1979). Physiology of woody plants. 2nd ed. Academic Press. New York. Pp 534 – 536.

Lal, R. (1997). Residue management, conservation tillage, and soil restoration for mitigating greenhouse effect by CO_2 – enrichment, soil and tillage research 43, 81.

Laoch, F. (1977). Leaf water potential and the rooting of cuttings under mist and polythene. *Physiol. Plant*, 40 (3), 191 – 197.

Lean, G. and Hinrichsen, D. (1994). Atlas of the environment, *Harper Perennial*, New York. Pp 192.

Lek, H.A., A. Vander (1934). Over den involed der knoopen op de wotelvorming der stekken (with summary: on the influence of the buds on roots development in cuttings). Mededel. Land bouuhoogesh Wageningen, 38, 1- 95.

Leewenberg, V., A. Ernst (1985). Reaction of Indole- alkaloids. John Wiley and Sons. 87p.

Leopold, A.C. (1960). *Auxins and plant growth.* 2nd ED. University of California Press. Berkeley and Los Angeles. 354 pp.

Leopold, A.C. and Kriedermann, P.E. (1975). Plant growth and development. McGraw-Hill, New York.

Lillesand, T.M. and Keifer, R.W. (1979). Remote Sensing and Image Interpretation. 2nd Edition.

Lundgreen, B. (1978): soil conditions and nutrient cycling under natural and plantation forests in Tanzanian highlands. Longman Scientific Publications pp. 71-123

Myers, N., Mittermeier, R. A., Mittermeier, C.G., (2001). Biodiversity hotspots for conservation priorities. Nature, 403: 853 -858.

Mayer and Poljakoff – Mayber A., (1963). Factors Affecting Germination in the Germination of seed. 2nd Ed. Pergamon Press, Oxford, London. 236 pp.

Middleton, W., Jarvis, B.C. and Booth, A. (1980). The role of leaves in auxin and boron pendent on rooting of stem cuttings of *Phaseous aureus* Roxb. *The new Phytologist.* 84: 287 – 297.

Mitchell, J.W. and Whitehead, M.R. (1940). Starch hydrolyses in bean leaves as affected by application of growth regulating substances. *Bot. Gaz.*, 102: 393 - 399

Nanda, K.K., Purohit, A.N., Bala, A. and Arnand, V.K. (1968). Seasonal rooting response of stem cutting of some forest tree species to auxins. *Indian Forest*, 94:154 -162.

Nair, P.K.R. (ed) (1988). Agroforestry Systems in the Tropics. Martins Nijhoff, The Hague.

(In Press).

Noggle, G.R. and Fritz, J.F. (1983). Introductory plant physiology 2nd ed. Prentice- Hall Inc, Engle wood Cliffs. New Jersey. Pp. 440 – 442.

Paton, D.M., Willing, R.R., Nichols, W. and Pryor, L.D. (1970). Rooting of stem cuttings of eucalyptus. Rooting inhibitor in adult tissue. Austral. J. Bot, 18:175 – 183.

Paton, F. and Schwabe, W.W. (1987) Storage of cuttings of *Pelargonum* and *hortorum Bailey, J. Hort. Sci.* 62: 79 – 87

Pearse, H.L. (1943). The effect of nutrition of phyto-hormones on rooting of vine cuttings. *Ann. Botany* (N.S), 7: 123 – 132.

Pearse, H.L. (1946). Rooting of vine and plum as affected by nutrition of the parent plant and by treatment with phyto-hormones. *Union S. Africa, Dept. Agr. Sci. Bull*., pp 249.

Pokua – Bonsu, E. (1998). BSc. Thesis Assessment of the growth performance of some indigenous trees. UST. Kumasi.

Postel, S., Daily, G. and Ehrlich, P. (1996). Human appropriation of renewable fresh water, *Science* . 271(5250): 785 -788.

Population Reference Bureau (PRB) (2000). World population data sheet. Washington, D.C.

Prebble, C. (1997). A plantation perspective. *ITTO* Vo. 7 No. 2, pp 1

Pryor, L.D. and Willing, R.R. (1963). The vegetative propagation of Eucalyptus: an account of progress. *Australian Forester* 27: 52 - 62

Sachs, J. (1980). und form der pfamzenorgane. I and II. *Arb. Bot. Inst*. W'urzburg. 2:452 - 488.

Sachs, J. (1982). und form der pfamzenorgane. I and II. *Arb. Bot. Inst*. W'urzburg. 4: 689 - 718.

Scherr, S.J. (1991). Methods of Participatory on –farm agroforestry research. ICRAF, Nairobi, 72.

Skoog, F. and Tsui, C. (1948). Chemical control of growth and bud formation in Tobacco stem and callus. *Amer. Jour. Bot*., 35: 782-787.

Spiegel, P. (1954). Auxins and inhibitors in cuttings of vitis. *Bull. Res. Coun*., Israel, 4: 176 - 183

Stoutemeyer, V.T. (1938). Talc as a carrier substance inducing rooting in cuttings. *Proc. Amer. Soc. Hort. Sci*., 36: 817- 822.

Stoutemeyer, V.T and Close, A.W. (1947). Changes of rooting response in cuttings following exposure of stock plants to light of different qualities. *Proc. Amer. Soc. Hort. Sci*., 9: 392 – 394.

Struve, D.K. (1981). The relationship between carbohydrate and nitrogen in rooting of stem cutting. *Plant Propagation*, 27: 6-7.

Sun, W.Q. and Bassuk, N.L. (1993). Auxin induced ethylene synthesis during rooting and inhibition of bud break of "Royalty" rose cuttings. *J. Amer. Soc. Hort. Sci.*, 118: 438-463.

Swaine, M.D., Agyemang, V.K., Kyereh, B., Orgle, T.K., Thompson, J., Veenendaal, E.M., (1997). Ecology of Forest Trees in Ghana – ODA Forestry Series No. 7, O.D.A.

Thimann, K.V., and Koepfli, J.B. (1935). Identity of the growth – promotion and root-forming substances of plants. *Nature,* pp 135 – 201.

Thimann, K.V. and Poutasse, E.F. (1941). Factors affecting root formation of *Phaseolus vulgaris*. *Plant Physiol*. 16,585 -598.

Thimann, K.V. and Went, F.W. (1934) On the chemical nature of the root forming hormone. K. Akad. Wetenschap. Amsterdam. *Proc. Sect.,* 37,456 -459.

Turkey, H.B. Jr. and Whittner, S.H. (1958). Loss of nutrients by foliar leaching as determined by radioisotope. *Proc. Amer. Hort. Sci*., 71, 496 -506

Tutu, K., Ntiamoah – Baidu, Y. and Asuming – Brempong, S. (1993). The economics of living with wildlife in Ghana – In Bojo J. (ed).11- 38.

United Nations Department For Policy Coordination and Sustainable Development. (1997). Critical trends: Global change and sustainable development. New York, UN.

United Nations Development Programme (UNDP). (1998). Human Development Report 1998. New York, UN.

Van Overbeek, J., Gordon, S.A. and Gregory, L.E. (1946). An analysis of the function of the leaf in the process of root formation in cuttings. *Amer. Jour. Bot.,* 33, 100 – 107.

Went, F.W. (1934). On the pea test method for auxin, the plant growth regulator. K. Akad. Wetenschap. *Amsterdam. Proc. Sect. Sci*., 37,547 – 555.

Wiegel, K., Horn, H. and Hock, B. (1984). Endogenous auxin levels in terminal stem cuttings of *Chrysanthemum morifolium* during adventitious rooting. *Physiologia Plantarum*, 61, 422 - 428.

World Bank (2000). Expanding the measure of wealth. Indicators of environmentally sustainable development. Washington, D.C. In: Environmentally sustainable development studies and monograph series No.17, 110 p.

World Health Organisation (WHO) (1997). Health and Environment in Sustainable development. *Five years after the Earth Summit*. Geneva, W.H.O, 242. p

Young, R.A. and Giese, R.J. (1996). Introduction to forest science. 2nd Ed. John Wiley and sons. 586pp

Zimmerman, P.W., Crocker, W. and Hitchcock, A.E. (1933). Initiation and stimulation of roots from exposure of plant to carbon monoxide gas. *Contr. Boyce Thompson Inst.*, 5,1 – 17.

Reps	M-Plot	Sub-plot	Sub-Subplot	Sprout Count	Number of leaves	Leaf Width(cm)	Number of roots	Root length (cm)
1	Top	Ho	A	2	3	1.4	0	0
1	top	Ho	B	1.3	4	0.2	3	2.4
1	top	Ho	C	0.6	3	0.5	2	2
1	top	H1	A	1.6	6	2.3	0	0
1	top	H1	B	2	2	1.9	2	0
1	top	H1	C	1.3	5	0.9	2	1.4
1	top	H2	A	2.6	5	2.1	0	0
1	top	H2	B	2	7	1.7	2	4.1
1	top	H2	C	1.6	6	0.6	4	4.1
1	mix	Ho	A	3	12	1.2	0	0
1	mix	Ho	B	3.6	10	0.6	1	0.5
1	mix	Ho	C	1.3	5	0.8	2	2.2
1	mix	H1	A	5.3	10	2.3	0	0
1	mix	H1	B	4	8	0.3	3	1
1	mix	H1	C	2	6	0.9	0	1.5
1	mix	H2	A	3.6	10	2	0	0
1	mix	H2	B	4	6	1.2	2	2.5
1	mix	H2	C	1.6	6	0.9	3	2
1	sand	Ho	A	3	10	2.1	1	0
1	sand	Ho	B	4	12	2.1	2	0.5
1	sand	Ho	C	2	4	0.8	2	1
1	sand	H1	A	4.6	10	2.1	0	0
1	sand	H1	B	4	15	0.7	2	3.5
1	sand	H1	C	1.6	5	1	2	4.1
1	sand	H2	A	3.3	12	2.6	1	0
1	sand	H2	B	4.3	13	2.4	2	2.2
1	sand	H2	C	1.6	7	1.9	4	3.2
2	Top	Ho	A	2	5	1.1	0	0
2	top	Ho	B	0.6	4	0.8	1	0
2	top	Ho	C	0.3	4	0.3	3	2.4
2	top	H1	A	1	6	1.2	0	0
2	top	H1	B	2	3	1.1	1	2.1
2	top	H1	C	0.6	5	0.9	4	1
2	top	H2	A	2.3	5	1.5	1	0
2	top	H2	B	1.3	6	0.2	0	0
2	top	H2	C	0.3	6	0.4	2	2
2	mix	Ho	A	2.6	12	1.1	0	0
2	mix	Ho	B	3.6	10	0.7	0	0
2	mix	Ho	C	0.3	8	0.9	4	2
2	mix	H1	A	3	13	1.9	0	0
2	mix	H1	B	4	10	0.4	1	1.1
2	mix	H1	C	0.6	6	0.5	2	2.6
2	mix	H2	A	6	8	1.5	0	0
2	mix	H2	B	3.3	4	0.9	1	0
2	mix	H2	C	1.6	6	0.7	2	2.5
2	sand	Ho	A	4.6	11	2.2	0	0
2	sand	Ho	B	4.3	13	2.7	1	1.5
2	sand	Ho	C	1.6	7	1	2	2.6
2	sand	H1	A	4.3	14	2.2	0	1.5
2	sand	H1	B	4.6	12	0.5	0	0
2	sand	H1	C	1	9	1.2	2	0
2	sand	H2	A	4.3	12	2.4	1	0
2	sand	H2	B	3.6	14	1.8	3	0
2	sand	H2	C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Reps	M-Plot	Sub-plot	Sub-Subplot	Sprout Count	Number of leaves	Leaf W
1	Top	Ho	A	2	3	
1	top	Ho	B	1.3	4	
1	top	Ho	C	0.6	7	
1	top	H1	A	1.6	5	
1	top	H1	B	2	3	
1	top	H1	C	1.3	6	
1	top	H2	A	2.6	5	
1	top	H2	B	2	6	
1	top	H2	C	1.6	4	
1	mix	Ho	A	3	12	
1	mix	Ho	B	3.6	13	
1	mix	Ho	C	1.3	6	
1	mix	H1	A	5.3	4	
1	mix	H1	B	4	9	
1	mix	H1	C	2	10	
1	mix	H2	A	3.6	7	
1	mix	H2	B	4	8	
1	mix	H2	C	1.6	5	
1	sand	Ho	A	3	13	
1	sand	Ho	B	4	16	
1	sand	Ho	C	2	5	
1	sand	H1	A	4.6	10	
1	sand	H1	B	4	18	
1	sand	H1	C	1.6	8	
1	sand	H2	A	3.3	12	
1	sand	H2	B	4.3	14	
1	sand	H2	C	1.6	6	
2	Top	Ho	A	2	7	
2	top	Ho	B	0.6	8	
2	top	Ho	C	0.3	5	
2	top	H1	A	1	5	
2	top	H1	B	2	3	
2	top	H1	C	0.6	6	
2	top	H2	A	2.3	5	
2	top	H2	B	1.3	6	
2	top	H2	C	0.3	4	
2	mix	Ho	A	2.6	13	
2	mix	Ho	B	3.6	16	
2	mix	Ho	C	0.3	9	
2	mix	H1	A	3	6	
2	mix	H1	B	4	13	
2	mix	H1	C	0.6	14	
2	mix	H2	A	6	5	
2	mix	H2	B	3.3	11	
2	mix	H2	C	1.6	6	
2	sand	Ho	A	4.6	12	
2	sand	Ho	B	4.3	14	
2	sand	Ho	C	1.6	8	
2	sand	H1	A	4.3	14	
2	sand	H1	B	4.6	11	
2	sand	H1	C	1	12	
2	sand	H2	A	4.3	8	
2	sand	H2	B	3.6	15	
2	sand	H2	C	3.6	12	
3	Top	Ho	A	1.6	7	
3	top	Ho	B	2.3	8	