KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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EFFECT OF FIVE SOILLESS MEDIA AND METHOD OF PROPAGATION ON ROOTING AND GROWTH OF THREE DIFFICULT-TO-ROOT ORNAMENTAL PLANTS

BY

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JANUARY, 2010

EFFECT OF FIVE SOILLESS MEDIA AND METHOD OF PROPAGATION ON ROOTING AND GROWTH OF THREE DIFFICULT-TO-ROOT ORNAMENTAL PLANTS

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE AND RESEARCH STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (MSc. FLORICULTURE) DEGREE

BY

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DECLARATION

I hereby declare that, except for references to other peoples' work which have been duly acknowledged, this write-up, submitted to the School of Graduate and Research Studies, KNUST, Kumasi is the result of my own original research and that this thesis has not been presented for any degree elsewhere.

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DEDICATION

To my parents who are also my best friends,

Edward Soga and Prudence Selby

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ABSTRACT

Studies were carried out at the Department of Horticulture, KNUST from 17th June, 2009 to 26th August, 2009 to determine the most appropriate soilless rooting and growth medium and also to determine the best propagule type that would facilitate root development of *Ixora coccinea, Ficus benjamina* cv. Starlight and *Thuja occidentalis* using stem cuttings and air-layers. All data collected were square-root transformed before analysis using Analysis of Variance (Statistix Statistical Software) and means separated using the least significant difference (LSD) test at 5% probability level. For the stem cutting experiment, a 6 x 2 factorial in randomised complete block design replicated three times was used. The different media used served as the first factor with 6 levels (100% topsoil, 100% palmix, 50% teak sawdust+50% coconut coir, 50% palmix+50% coconut coir, 50% palmix+50% teak sawdust and 50% palmix+25% teak sawdust+25% coconut coir) and the stem cuttings as the second factor with 2 levels (straight stem and heel stem). The study revealed that 50% teak sawdust+50% coconut coir was the best soilless medium, in terms of physical and chemical properties, and produced the highest number of leaves (2.59) in *Ixora coccinea* and the highest number of rooted cuttings (1.39) in *Thuja occidentalis*, 50% palmix+25% teak sawdust+25% coconut coir medium had more survived cuttings (1.13) and produced the longest roots (1.05cm) per cutting in *Ficus benjamina* cv. Starlight while 50% palmix+50% coconut coir produced the longest root length (2.38cm) in *Thuja occidentalis.* The heel stem cutting produced the highest number of leaves (2.32) at eight weeks after setting in *Ixora coccinea* while straight stem cuttings produced more leaves (2.49) for *Ficus benjamina* cv. Starlight four weeks after start of experiment. In the air-layering experiment on the three stock

plants (using a complete randomised design with 6 different media replicated three times), the best soilless medium found to promote rooting in *Thuja occidentalis* was 50% palmix+50% teak sawdust. The study concluded that 50% teak sawdust+50% coconut coir and heel stem cuttings could be used for stem cutting propagation. For air-layering, 50% palmix+50% teak sawdust could be used for root regeneration in *Ixora coccinea* and *Thuja occidentalis* while 50% palmix+50% coconut coir could be used for root regeneration in *Ficus benjamina* cv. Starlight.

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1.0 INTRODUCTION

The success of any ornamental industry begins with proper nursery activities in terms of relevant methods, effective and efficient use of materials (Kessler, 2002).

Most of the ornamental dealers and nursery operators still use, mainly, topsoil for their operations even though it is bulky and heavy, very inconsistent in quality and environmentally unfriendly as the practice results in a continuous depletion of the topsoil. Developing alternatives to soil media therefore is critical if the nursery business is to grow in Ghana and compete on the international market.

The timber, coconut and oil palm industries are gradually becoming potential sources of environmental hazard in Ghana because they contribute a lot of waste into the environment. According to Ellis *et al.* (2006) sawdust is an industrial by-product which is piled up in significant quantities in our towns and cities. Also the most significant waste products generated during palm oil extraction are the empty fruit bunch, oil palm fibre, sludge or mill mud and boiler ash. Coconut also produces waste, husk, from the coconut-oil processing and fresh fruit industry. Collectively, these waste products are dumped as refuse in most towns and cities to rot. However, according to Handreck and Black (1999), these waste products are renewable resources that can be used in the formulation of soilless media when properly treated for the floriculture industry. Soils as they occur in nature consist of mineral elements. They are dense and bulky. Plants are not always grown outdoors in fields. Some are grown indoors and require containers to hold the soil. Because of the bulky nature of natural soil, scientists have developed methods for synthesizing growing media for a variety of purposes. The ingredients in such mixes may be natural or artificial. The goal of such creations is to use proportions of these ingredients in mixes such that the results mimic the environment that a natural soil would provide for a seed or plant. In fact, since humans are in control, they are able to manipulate the proportions of ingredients to create a wide variety of growing conditions not available to nature. These mixes are sometimes called soilless mixes because they consist of materials that are not true soil ingredients (Acquaah, 2005).

Herren (1997), stated that the substances that plants are grown in are termed media. Rice and Rice (2006), defined the medium as any material used for rooting or potting of plants. It is soil-like in that it performs the same functions a soil does for plants outdoors: supporting the roots and acting as a reservoir for moisture, nutrients and air.

The advantages of the soilless media include being free of contamination from diseases, pests and weeds after composting and also the reduced transport costs due to their light weight. In effect, using soilless media can be inexpensive as well as being environmentally friendly (Spiers, 1997).

Some of the ornamental plants in high demand for landscape works, bouquetsmaking, cut flowers and wreaths in Ghana are *Ixora coccinea, Ficus benjamina* cv. Starlight and *Thuja occidentalis*. Yet, these economically important ornamental plants have a low genetic and physiological capacity for adventitious root formation and therefore limit their commercial production. Such ornamental plants have been popularly termed as “difficult-to-root”. Economically, the demand for these ornamentals necessitates that the difficult-to-root phenomenon should be solved. To this end, different soilless media and stem cutting types need to be explored to optimise the rooting of these ornamentals.

The objectives of the study were therefore;

- To determine the most appropriate soilless rooting and growth medium for promoting rooting of *Ixora coccinea, Ficus benjamina* cv. Starlight and *Thuja occidentalis*.
- To determine the best propagule type that would facilitate root development of *Ixora coccinea, Ficus benjamina* cv. Starlight and *Thuja occidentalis*.

2.0 LITERATURE REVIEW

2.1 CURRENT STATE OF THE ORNAMENTAL INDUSTRY

In a very real sense, the foundation of all agriculture is the growing of plants. One large and expanding aspect of agriculture is the growing of ornamental plants. Americans spend millions of dollars each year buying plants to beautify their homes whiles in Ghana a number of people spend thousands of cedis to purchase ornamental plants and flowers to improve on the aesthetics of their surroundings, for weddings, funerals and other festive occasions (Herren, 1997). Herren (1997), further reported that each year many people make their living raising plants in greenhouses for people to buy. Most potted plants grown are started from cuttings in a medium that takes several weeks to a few months to produce a healthy blooming potted plant.

The most common method to propagate plants asexually is from stem cuttings (Ingram and Yeager, 2003). Rooting cuttings can be challenging and creative (Rothenberger, 2000). Propagation by straight stem cuttings is the most commonly used method to propagate many woody ornamental plants (Hartmann *et al*., 2002).

The trend away from loam-based mixes is due to a lack of suitable uniform soils, high bulk density, low levels of readily available water if it is to contain much clay, added cost of sterilization to kill pathogens and the costs of handling or transportation of the heavier soils compared to the lighter materials (Hartmann *et al*., 1997; Handreck and Black, 1999). The industry has been shifting away from soilbased media in favour of soilless based mixes for three primary reasons;

- In many areas it is becoming increasingly difficult to obtain good quality soil to use in the growing media.
- In some cases it may be more economical to purchase mixed soilless media than invest in the equipment needed to prepare and pasteurize the topsoil.
- Most soilless mixes are light in weight and that is an advantage when moving pots around the greenhouse as well as when transporting pots over long distances (Holcomb, 2000).

2.2 VEGETATIVE PROPAGATION

Plants can be propagated, or multiplied, in several different ways. Most people are familiar with growing new plants from seeds, but new plants can also be created by cutting off a portion of an established plant by using budding, grafting or by layering. The common method to propagate plants asexually is from cuttings (Welch-Keesey and Lerner, 2002). Cuttings can be made from stems, roots, leaves, or combinations of plant parts such as stems with leaves (Ingram and Yeager, 2003). Cuttings are probably the most important method for starting new plants. A cutting is any detached plant part from a parent plant or stock plant which under favourable conditions for regeneration, will produce a new plant identical to the parent plant (Hamilton and Midcap, 2003).

The cutting is placed in an environment that encourages it to produce new roots and/or stems, thus forming a new, independent plant. The advantages associated with propagating plants using cuttings are that the plant will look identical to the parent plant and keep the special characteristics of that plant. Planting by cuttings also avoids the difficulties of propagating by seed, and cuttings usually mature faster and flower sooner than a plant grown from a seed (Welch-Keesey and Lerner, 2002).

Other advantages of propagation through cuttings are that they are inexpensive, rapid, and simple and do not require the special techniques necessary in grafting, budding or micro-propagation (Hartmann *et al*., 1990).

Layering is another easy way to start new plants from old ones. The principle of layering is to encourage development of new roots on a stem while it is still attached to the parent plant. The rooted stem is then detached to become a new plant growing on its own root system (Lerner and Dana, 2001). The new plant receives nutrients and water from the parent plant until roots develop. This method of asexual propagation yields a large plant in a relatively short time. It is an excellent way to produce a small number of plants in the home landscape or to propagate plants that are difficult to increase by other methods (Ingram and Yeager, 2003).

2.3 STOCK PLANT

Stock plant describes the plant(s) from which stem cuttings are taken for the purpose of inducing adventitious rooting for plant production. The significance of proper stock plant management has long been recognized by horticulturists. The selection of individual plants as stock plants depends on two types of criteria. Plant specific criteria include true-to-name and type, freedom from insects and diseases and a proper physiological condition that promotes ready adventitious rooting (Hartmann *et al*., 1990; Scianna, 2004).

Several sources may serve as stock plant sites including parks, home landscapes, field production crops, container production crops, from the wild just to mention a few (Hartmann *et al*., 1997). Scianna (2004) stated that, the physiological condition of the stock plant has a strong influence on adventitious rooting and reflects the interaction between stock plant genotype and environmental factors. Additionally, the ability of cuttings to form roots depends on the plant material itself and also on conditions under which the cuttings are kept during the rooting process. Furthermore, the ability of the cuttings to form adventitious roots decreases with the increase in the age of the plant. The decreased rooting potentiality of a cutting with the age of the stock plant may possibly be due to an increase in rooting inhibitors (Paton *et al*., 1970).

2.3.1 *Ixora coccinea* L.

Ixora coccinea L., known as the Flame of the Woods is a common flowering shrub native to Asia. It is a dense, multi-branched evergreen shrub belonging to the family Rubiaceae. It is propagated by cuttings and can grow to reach a height of 6 m with a rounded architecture. The glossy, leathery, oblong leaves are about 10 cm long and are carried in opposite pairs or whorled on the stems. The leaves are bronzy when young later turning to a glistering dark green. Small tubular, scarlet flowers in dense rounded clusters 5-15 cm across are produced almost all year long. It bears dark red stone fruits crowned by four sepals. It thrives well in full sun in moist but welldrained acid soil and can tolerate some shade. There are numerous named cultivars differing in flower colour (yellow, pink, orange, white) and plant size (Gilman, 1999).

The profuse branching of *Ixora coccinea* makes it ideal for hedges, borders, screens, massed in flowering bed or grown as a specimen shrub or small trees and may be pruned at anytime. It can also be grown in containers looking very distinguished as a patio or poolside plant (Gilman, 1999).

2.3.2 ***Ficus benjamina*** **L. cv. Starlight**

In the ornamental fig family Moraceae, are found houseplants which vary from stately trees to lowly creepers. The all-green rubber plants are much easier to grow than the variegated ones. The weeping fig is increasing in popularity because it is a splendid specimen plant for the modern home. Its leaves are not very large but it is so much more tree-like and graceful than the rubber plant. The Starlight weeping fig is a new variegated form of durable green weeping fig. It is a large evergreen shrub with slender-pointed green leaves broadly margined with creamy-white. It requires moist but well-drained loamy soil and will grow in most soil types. It tolerates a wide range of pH and attains a height of 2.5 m (Hessayon, 1998; Anon, 2007).

2.3.3 ***Thuja occidentalis*** **L.**

Thuja occidentalis is a slow-growing tree that reaches a height of 6 m to 12 m and width of 4 m preferring a wet or moist rich soil. Its common name is Arborvitae which means 'tree of life' due to its unchanging evergreen nature in cold dry climates. It belongs to the family Cupressaceae. It is native to North America. It has a symmetrical canopy with a smooth dense outline and it is pyramidal in shape. The evergreen leaves are simple, fragrant and arranged in alternate forms on its stem. It does well in well-drained loam or sand soils, acidic soil and requires full sun or partial sun/shade to grow.

In Ghana, some use *Thuja occidentalis* as a Christmas tree during the Christmas, decorated with lights, ribbons, glow balls, among others. It is best used as a screen or hedge, for buffer strips around parking lots and as a reclamation plant. It can also be placed at the corner of a building or other area to soften a view. It has given rise to many cultivars many of which are shrubs. It is susceptible to pest and diseases such as scales, mites and leaf blight respectively. It is mostly propagated by seeds but can be propagated from cuttings (Gilman and Watson, 2006).

2.4. TYPES OF STEM CUTTINGS

Stem cuttings can be taken from herbaceous plants, shrubs and woody trees. The four main types of stem cuttings are herbaceous, softwood, semi-hardwood and hardwood. These terms reflect the growth stage or age of wood of the stock plant which is one of the most important factors influencing the rooting of a cutting (Welch-Keesey and Lerner, 2002; Evans and Blazich, 1999). In propagation by stem cutting, segments of shoots containing lateral or terminal buds are obtained with the expectation that, under proper conditions, adventitious roots will develop and thus produce independent plants (Hartmann *et al*., 2002).

According to Sadhu (1989), stem cuttings taken from the lateral shoots root better than those taken from the terminal shoots. Further, the lateral shoots have more rooting tendency due to the increased level of stored food or carbohydrates. He noted that the vigorously growing terminal shoots usually contain comparatively less carbohydrates and therefore rooted poorly. In woody plants rooting varies depending on whether the cutting is made from upper or lower half of the shoot. In most hardwood cuttings, rooting is higher from the basal portion due to the accumulation of carbohydrates at the base of the shoot. Also root promoting substances from buds and leaves move polarly from the tip to the base and some root initials may already be formed in the basal portion under the influence of high C:N ratio and root promoting substances (Sadhu, 1989).

Generally, research on improvement of cutting propagation methods had focused on better rooting and neglected survival and further growth of the rooted cuttings (Spethmann, 2007).

2.4.1 Hardwood Stem Cutting (Deciduous species)

Hardwood cuttings are taken from dormant, mature stems with no obvious signs of active growth. The wood is firm and does not bend easily (Evans and Blazich, 1999). Hartmann *et al*. (2002), reported that the use of hardwood cuttings is one of the least expensive and easiest methods of vegetative propagation. Some deciduous shrubs and needled evergreens will root from hardwood cuttings (Welch-Keesey and Lerner, 2002). Unlike the deciduous plants, hardwood cuttings of narrow-leaved evergreens retained their foliage when propagated. The type of wood to use in making the cutting varies considerably with the particular species being rooted.

Norman, (2004) provided a concise description of hardwood cuttings as follows; the length of the cuttings made depends upon the species and it varies from 15 cm to 23 cm. The diameter of the cuttings ranges from 1.3 cm to 2.5 cm. Each cutting must have at least 2 nodes. Roots develop around the lower node whilst the shoot arises from one of the upper buds. The cuts are made just below a node about 1.3 cm at the base and about 2.5 cm above a node at the top. It is useful to differentiate between the top and base of the cutting in order to facilitate orientation of cuttings for bundling, storing or planting. The basal cuts can be made straight across and the top at a slant away from a bud with all leaves clipped off leaving only the buds before planting (Norman, 2004).

In preparing cuttings it is often recommended that a heel be retained at the base of the cutting in order to obtain maximum rooting. For hardwood cuttings of some plants this may be true (Hartmann *et al*., 2002). In Quince, considerably better rooting was obtained with the heel type of cutting probably owing in this case to the presence of preformed root initials in the older wood (Hartmann *et al*., 1990).

The hardwood cuttings should be enclosed in a plastic bag to prevent moisture loss and placed in a 21 °C to 27 °C location and roots should form in less than six weeks while dormant buds should begin growing shortly thereafter. The cuttings can be hardened off and transplanted several weeks later (Rice and Rice, 2006). However, for narrow-leaved evergreens, they are usually best rooted in greenhouses or polyhouses with relatively high light irradiance and under conditions of high humidity or very light misting but without heavy wetting of the leaves as they are slow to root
(Hartmann *et al*., 2002).

2.4.2 Hardwood Stem Cuttings (Narrow-Leaved Evergreen Species)

Narrow-leafed evergreen cuttings must be rooted under moisture conditions that will prevent excessive drying as they usually are slow to root sometimes taking several months to a year. Some species root much more readily than others. In general, *Chamaecyparis pisifera*, *Thuja orientalis* and the low-growing *Juniperus chinensis* species root easily; the *Taxus baccata* fairly well whereas the upright *Juniperus virginiana*, *Picea abies* and *Pinus pinea* are more difficult (Hartmann *et al*., 1990).

Furthermore, there is considerable variability among the different species in these genera with regard to the ease of rooting of cuttings. Stem cuttings taken from young seedling stock plants root much more readily than those taken from older trees. The type of wood to use in making the cutting varies considerably with the particular species being rooted. Mature terminal shoots of the previous season's growth are usually used. Rapid handling of cuttings after the material is taken from the stock plants is important (Hartmann *et al*., 2002).

For narrow-leafed evergreens, the length of the cuttings is made between 10 cm and 20 cm with all the leaves removed from the lower half. Mature terminal shoots of the previous season's growth are usually used. Narrow-leaved evergreens cuttings often but not always root more readily if a heel old wood is retained at the base of the cuttings (Hartmann *et al*., 2002).

2.4.3 Specialized Hardwood Stem Cuttings

In addition to classifying hardwood stem cuttings on the basis of the type of plant from which they are collected, they are also classified based on the age of the wood. Cuttings may contain tissues that represent wood from more than one growing season. Previous year's growth on the stem cuttings it determined when the stem cutting snaps into two when it is bent than the current's year that curves upon bending. Three types of cuttings are recognised under the age-of-the-wood classification.

i. Heel Cutting: A small section of older wood of the previous season's growth is included at the base of the cutting.

ii. Mallet Cutting: An entire section of older stem wood is included. It can be further explained as the node of a mature wood of the previous season with a branch of current season's growth intact.

iii. Straight Cutting: This cutting does not include older wood and is the type of hardwood cutting that is most commonly used.

The heel and mallet cuttings are used for plants that might otherwise be more difficult-to-root and have been found to give better rooting responses. Basal wounding is beneficial in rooting cuttings of many species, especially cuttings with older wood at the base. This response is related to several physiological and mechanical factors as enumerated below;

1. Physiological factors

Physiological factors include changes in the wounded area in the natural accumulation of auxins, ethylene and carbohydrates that will stimulate cell division and result in the formation of callus and root primordia along the margins of the wound.

2. Mechanical factors

Mechanical factors include,

(i) an increase in the surface area of the cutting through which water or auxins may be absorbed and

(ii) a mechanical separation of the layer of sclerenchyma tissues (fibre cells) present in some species, which act as a physical barrier to the penetration of developing root primordia (Evans and Blazich, 1999).

2.5 LAYERING

2.5.1 Air - Layering

Air-layering can be used to propagate large, overgrown house plants such as *Ficus elastic*a (Rubber plant), *Codiaeum variegatum* (Croton), *Rosa hybrida* (Rose) or *Dieffenbachia picta* (Dumbcane) that have lost most of their lower leaves. For optimum rooting, air layering must be done only during the wet season when the atmosphere is usually humid. For woody plants, stems of pencil size diameter or bigger are best.

2.6 TREATMENT OF CUTTINGS

2.6.1 Storage of Cuttings

Only high quality cuttings should be collected for propagation. Quality control of cuttings begins with stock plant quality. Propagules from stock plants are collected early in the day when cuttings are still turgid. If cuttings are not stuck immediately, they are misted to reduce transpiration overnight and used the next day. 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 (Hartmann *et al*., 2002).

2.6.2 Wounding

Basal wounding is beneficial in rooting cuttings of certain species such as *Rhododendron macrophyllum* and *Juniperus chinensis* especially cuttings with the older wood at the base. Following wounding, callus production and root development frequently are heavier along the margins of the wound (Hartmann *et al*., 1990). According to MacKenzie *et al*. (1986), wounded tissues are stimulated into cell division and production of root primordia. This is due, perhaps, to a natural accumulation of auxins and carbohydrates in the wounded area and to an increase in the respiration rate in the creation of a new sink area (MacKenzie *et al.*, 1986).

Wounded cuttings absorb more water from the medium than unwounded and also permit greater absorption of applied growth regulators by the tissue at the base of the cutting (Hartmann *et al*., 2002). Wounding may stimulate rooting by promoting cell division and may also remove tough tissue that inhibits outward root growth from the cutting. Wounding is used most often on evergreen plants, but it may be useful on deciduous plants as well (Larsen and Guse, 1997).

2.6.3 Fungicide Application

Adventitious root initiation and survival of the rooted cuttings are two different phases. Often cuttings root but do not survive for long. During the rooting and immediate post-rooting period, cuttings are subject to attack by various microorganisms. Treatment with fungicides should give some protection and result in both better survival and improved root quality (Hartmann *et al*, 1990).

2.7 ROOTING OF CUTTINGS

Adventitious root formation has many practical implications in horticulture and agronomy and there is a lot of commercial interest because of the many plant species that are difficult to root (Davies *et al*., 1994; Kovar and Kuchenbuch, 1994).

Rooting of cuttings starts when the environmental conditions are favourable and callus develops at the basal end of the cutting (Hartmann *et al*., 1997). Propagation by stem cuttings requires only the formation of a new adventitious root system since a potential shoot system (a bud) is already present. The formation of adventitious roots and buds is dependent on the ability of plant cells to differentiate and develop into either a root or shoot system (Hartmann *et al*., 2002).

2.8 FACTORS AFFECTING ROOTING OF CUTTINGS

2.8.1 Anatomical Development of Roots in Stem Cuttings

The precise location inside the stem where adventitious roots originate has intrigued plant anatomists for centuries (Hartmann *et al*., 2002). Adventitious roots in stem cuttings of woody perennial plants usually originate from living parenchyma cells, in the young, secondary phloem but sometimes from vascular rays, cambium, phloem, callus or lenticels. Two patterns of adventitious root formation emerge; direct root formation of cell in close proximity to the vascular system (generally more easy-toroot species) and indirect root formation where non-directed cell divisions, including callus formation, occur for an interim period before cells divide in an organized pattern to initiate adventitious root primordia (generally more difficult-to-root species) (Hartmann *et al*., 2002).

The time for root initials to develop after cuttings are placed in the propagation bed or medium varies widely. Phloem ray parenchyma cells in juvenile (easy-to-root) cuttings of *Ficus pumila* undergo anticlinal cell division and root primordia formation more quickly than mature (difficult-to-root) plants which undergo optimal auxin treatments. Once primordia are formed, there is a comparable time period (seven to eight days) between root primordia elongation (emergence) and maximum rooting in both the easy and difficult-to-root plants (Davies *et al*., 1982).

Lovell and White (1986), stated that preformed or latent root initials generally lie dormant until the stems are made into cuttings and placed under environmental conditions favourable for further development and emergence of the primordia as adventitious roots.

2.8.2 Callus Formation

Callus is an irregular mass of parenchyma cells in various stages of lignifications that commonly develop at the basal end of the cutting when the cutting is placed under environmental conditions favourable for rooting. Callus growth proliferates from cells at the base of the cutting in the region of the vascular cambium, although cells of the cortex and pith may also contribute to its formation (Hartmann *et al*., 1990;
2002).

Frequently, roots appear through the callus leading to the belief that callus formation is essential for rooting. The formation of callus and the formation of roots are independent of each other even though they both involve cell division. That they occur simultaneously is due to their dependence upon similar internal and environmental conditions (Hartmann *et al.*, 1990). In some species, callus formation is a precursor of adventitious root formation while in other species excess callusing may hinder rooting. The origin of adventitious roots from callus tissue has been associated with difficult-to-root species such as Pine (*Pinus radiata*), and the mature phase of English Ivy (*Hedera helix*) (Hartmann *et al*., 2002).

2.8.3 Physiological Basis of Adventitious Root and Shoot Initiation

Studies with pea cuttings confirmed that specific factors other than auxin were manufactured in the leaves and were necessary for root formation as postulated by Went in 1938 (Eriksen and Mohammed, 1974; Mohammed, 1975). Thus for roots initiation, 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 and Davis, 1994).

It has long been known that the presence of leaves on cuttings exerts a strong stimulating influence on root initiation (Reuveni and Raviv, 1981). Cuttings of difficult-to-root cultivars under mist soon shed their leaves and die, while cuttings of cultivars that rooted retained their leaves for about nine months. In the same study, after five weeks in the rooting bed, there was five times more starch in the base of the easily rooted cuttings than there was at the beginning of the test (Reuveni and Raviv, 1981).

Janick (1986) reported that an important component of the capacity for a stem to root is the nutritional status of the plant. In general, high carbohydrates levels are associated with vigorous root growth. Carbohydrates translocated from the leaves undoubtedly contribute to root formation. However, the strong root-promoting effects of leaves and buds are probably due to other more direct factors (Hartmann *et al.,* 2002). Leaves and buds are known to be powerful auxin sources and the effects are observed directly below them showing that polar apex-to-base transport is involved (Acquaah 2005; Hartmann *et al*., 1990) and auxins translocated to the base of the cuttings are needed for cell division and cell elongation (Edmond *et al*., 1994). A budless cutting would not form roots even when treated with auxin-rich preparations and that removal of the buds from cuttings in certain plants will stop root formation almost completely especially without preformed root initials (Hartmann *et al*., 2002).

2.9 ENVIRONMENTAL CONDITIONS DURING ROOTING

2.9.1 Light

Light is a contributing factor in the adventitious root and bud formation (Anon, 1979; Eliasson, 1980). Cuttings of some woody plants species root best under relatively low irradiance (Johnson and Hamilton, 1977; Loach, 1979). However, according to Carpenter *et al*. (1973) in some species, the photoperiod under which the cuttings are rooted may affect root initiation. Thus long days or continuous illumination are generally more effective than short days while Smally *et al*. (1991) in contrast states that in other species photoperiod has no influence.

In working with cuttings of some plants that are difficult-to-root, possible enhancement of rooting may be obtained by rooting the cuttings at reduced irradiance levels by placing the container grown stock plants in a shade house (Hartmann *et al*., 1990). Further, Acquaah (2005), reported that rooting cuttings in full light under a mist makes them root more quickly. However, when light intensity is excessive, plants may be in jeopardy of moisture stress. During such periods, shading is required.

2.9.2 Temperature

Temperature of the propagating medium can be suboptimal for rooting due to the cooling effect of mist or seasonally related ambient air temperature. Air temperatures should be maintained between 18 °C and 27 °C during the day and 16 °C and 18 °C at night (Scianna, 2004). High air temperatures tend to promote bud elongation in advance of root initiation and to increase water loss from the leaves. It is important that adequate moisture status be maintained by the propagating system so that cuttings gain the potential benefit of the higher basal temperature (Hartmann *et al*., 2002).

Air temperature and especially medium temperature are important for callus and root development. A desirable medium temperature for most species during callus formation is between 23 °C and 25 °C, which usually requires bench heating. Air temperature should be maintained between 20 °C and 23 °C when bottom heat is utilized. However, if bottom heat is not available, air temperature should be increased between 25 °C and 27 °C so that medium temperature is adequate. Maintaining air temperature lower than medium temperature retards shoot growth and promotes root development. During root initiation and formation, temperatures can be slightly lowered: air temperatures between 19 °C and 21 °C and media temperatures between 22 °C and 24 °C. Adequate shading should stop the air temperature in a poly-propagator from rising above 28 °C to 33 °C, and the temperature of the rooting medium above 25 °C to 30 °C (Lopez, 2008; Longman,

2002).

Furthermore, root initiation in cuttings is temperature-driven but subsequent root growth is strongly dependent on available carbohydrates. This is particularly evident in leafless hardwood cuttings in which excessive root initiation and growth can so deplete stored reserves that there are insufficient available carbohydrates for satisfactory bud growth (Hartmann *et al*., 2002). Preece (1993), suggests that the optimum air temperature for growing a crop is probably the best for rooting cuttings.

2.9.3 Moisture and Humidity

The water status of cuttings is a balance between transpirational losses and uptake of water. Water absorption through the leaves is not the major contributor to water balance in most species. Rather, the cutting base and any foliage immersed in the propagation media are main entry points for water (Anon., 1988). Evaporative cooling of an intermittent mist system can help control the propagation house microenvironment and reduce the heat load on cuttings thereby permitting utilization of high light conditions to increase photosynthesis and encourage subsequent root development (Hartmann *et al*., 1990).

However, although the presence of leaves on cuttings is a strong stimulus to root initiation, loss of water from the leaves may reduce the water content of the cuttings to such a low level as to cause them to die before root formation can take place (Hartmann *et al.*, 2002). In cuttings, the natural water supply to the leaf from the roots has been cut off, yet the leaf is still capable of carrying on transpiration. In species which root rapidly, quick root formation soon permits water uptake to compensate for that removed by the leaves but in more slowly rooting species, transpiration of the leaves must be reduced to a very low rate to keep the cuttings alive until roots form. Acquaah (2005), stated that cuttings do not have roots and hence are unable to absorb moisture. However, the exposed plant parts are subject to evaporation. To reduce moisture loss, cuttings are generally maintained under conditions of high moisture by misting them. Initially, misting may be required almost continuously. As time goes by the misting schedule is modified being less frequent and less intense.

It has long been a standard practice in propagating frames and greenhouses to sprinkle water on the cuttings frequently as well as the walls and floor so as to maintain high humidity. Cuttings under mist conversely can be synthesizing food in excess of that used in respiration with such nutrients being very important in promoting the initiation and development of new roots (Hartmann *et al.*, 2002). According to Norman (2004), the rooting medium and the air surrounding the cuttings must have an adequate and uniform moisture supply. High relative humidity reduces the amount of moisture loss from the cuttings and would thus prevent drying. High humidity can be maintained by use of mist. In relation to humidity, Longman

(2002), stated that maintaining high humidity is important because below about 90% relative humidity cuttings will soon dry up.

2.9.4 Aeration

It is important to ensure that the moisture content of the rooting medium is not maintained at the expense of aeration. Poor drainage or too frequent watering causes a reduction of air supply in the rooting medium and thus prevents rooting. The rooting medium and the propagating container must be well-drained (Norman, 2004).

2.9.5 Rooting Media

Choosing a rooting medium for growing greenhouse crops in containers seem a monumental task when one considers all the different components and recipes available to choose from. Flower producers often spend a lot of time and energy on media formulations, mixing and management. Others simply purchase commercially available bag mixes to grow the crops. Sometimes, blaming poor crop performance on the growing substrate is an over-simplified supposition. However, no amount of cultural adjustment can overcome the limitations of a poor medium. Many growers find a great challenge in trying to develop a custom blend that outperforms all the others available (Kessler, 2002).

Generally a rooting medium must provide four basic functions to support good plant growth:

1. Media must provide anchorage or support for the plant. Individual roots grow among soil particles and provide a firm foundation for physically supporting the stem as it grows.

2. Media must serve as a reservoir for plant nutrients. With the exception of carbon and oxygen, plants obtain all essential elements from the growing medium. These elements must be in an available form, in sufficient quantities, and in proper balance for adequate growth. Nutrient elements must not only be present in the medium but also available for root uptake.
3. Media must hold and provide available water. A container medium must hold sufficient quantities of water to provide plants' need.
4. Media must provide adequate gas exchange between the roots and the atmosphere. Respiration is required by roots to provide the energy for uptake of water and nutrients and root growth. The substrate must provide sufficient oxygen and remove carbon dioxide for metabolic processes to occur.

Individual media components can provide some or all four of the functions of a medium but not at the required levels of each (Kessler, 2002). Larson (1992), indicated that the components that make up a mix are not as important as the effect of their chemical and physical properties. He further observed that it was difficult to suggest a growing medium that will be acceptable to every grower or for every condition.

2.9.6 Rooting Media Components

A good propagation medium is made up of components that provide optimum aeration, drainage and moisture holding characteristics. Since the growth medium relates to every cultural practice in the production of nursery crops in containers, the selection and preparation of the medium is extremely important and will pay great dividends in terms of plant growth and quality (Hall, 2003). There is no universal or ideal rooting mix for rooting cuttings. An appropriate propagation medium depends on the species, cutting type and propagation system. The cost and availability of the medium components are other considerations. Several combinations of media with desirable physical, chemical and biological properties can be used but the goal should be consistency from batch to batch (Longman, 2002).

A media is composed of solid, liquid, and gaseous components and understanding the attributes of each of these media components, as well as the interactions between these components, is essential for the successful operation of a nursery (Anon., 1997).

1. Solid materials usually constitute 33% - 50% of the media volume. Spaces or pores, between the solid particles are filled with air or water. As water moves through container media, it is retained by smaller pores, but drains through larger pores.
2. The second fraction of the media, the liquid portion, consists of nutrients, organic materials, dissolved gases, and water.
3. The third media phase consists of gaseous materials including oxygen and carbon dioxide. Although media oxygen levels vary from 0% - 21%, a concentration of at least 12% oxygen is necessary for root initiation to occur. Roots of most plants fail to grow in a media atmosphere containing less than 3% oxygen. The carbon dioxide content of the media may range from 0.03% to 21%; however, very high carbon dioxide contents may be detrimental to plant health.

Media are categorically divided into two components; the inorganic and organic media. The major types of organic media used are peat, spent mushroom compost, hardwood barks, coconut coir, rice hulls, compost, sawdust and wood shavings. Materials such as vermiculite, perlite and sand represent the inorganic fraction often used in media formulations.

Organic media have physical and chemical properties that make their use unique as compared to inorganic media. Organic media exhibit to some extent, both adsorptive and absorptive properties; so they act more like soil, while these characteristics are not found in inorganic substances. Moreover organic substances provide buffering capacity which can work to the advantage of the grower, serving as a storage mechanism for the essential elements and thus reduce the likelihood of elemental excesses and shortages. In addition, organic substances used contain some of the essential elements required by plants in sufficient quantity to satisfy the crop requirement (Anon., 1997).

2.9.6.1 Organic components

i. Sawdust and wood shavings

Sawdust is occasionally from one species of tree but is more usually mixtures of several species. Composted coarse sawdust initially has good physical properties (Handreck and Black, 1999).

Sawdust, wood shavings and wood chips constitute a rather broad category of wood particles generated by sawmills and other wood processing industries, often involving a wide range of particle sizes and several tree species. Wood particles are generally less desirable for potting media than bark because wood has a much greater C:N ratio of about 1:1000 for fresh wood compared to 1:300 for bark. Addition of approximately 25 to 30 pounds of nitrogen per ton of fresh sawdust or other relatively fine wood particles will supply sufficient nitrogen for microorganisms to prevent nitrogen deficiency during plant production. Sawdust of hardwood species ties up nitrogen and breaks down about three to four times faster than sawdust of softwood species (Ingram *et al*., 2003).

ii. Coconut coir

Coconut coir, a by-product of the coconut industry has been promoted as an alternative to peat moss in soilless media (Holman *et al*., 2005) with excellent properties for aeration and water retention. It is a totally organic, environmentally friendly media, derived exclusively from coconut fibre. It has been used for many years in commercial greenhouses in both developed and underdeveloped countries as a growth media and it is a totally renewable resource (Holman *et al*., 2005).

There is no bio-hazard or any disposal problems associated with coconut coir, because it is completely natural. It offers greater moisture retention capabilities than many other media types commonly used. Coconut coir also maintains greater oxygen levels than Rock wool, and is reusable (after being sanitized). It can also be composted into soil gardens. Coconut coir contains natural anti-fungal properties, offering the gardener protection from many common root diseases (Mahmood, 2004).

Coir dust is very similar to peat in appearance. It is light to dark brown in colour and consists primarily of particles in the range of 0.2 mm to 2.0 mm. Unlike sphagnum peat, there are no sticks or other extraneous matter. It also has superior structural stability, water absorption ability and drainage, and cation exchange capacity compared to sphagnum peat and sedge peat (Meerow, 1994; Cresswell, 1992). Coir dust also tends to be high in both sodium and potassium; the high potassium present in coir dust may be beneficial to plant growth (Handreck, 1993; Handreck and Black, 2002).

According to Meerow, (1994) and Mahmood, (2004) the qualities listed below makes coir dust an alternative to peat;

1. High water holding capacity; it can hold water up to eight times of its weight and releases it over a period of time.
2. Excellent drainage and air porosity for better plant growth.
3. Absence of weeds and pathogens as it has some anti-fungal properties that help plants to get rid of soil-borne diseases.
4. Greater physical resiliency
5. It is a 100% renewable resource, with no ecological drawbacks to its use as it is consistent in high quality and also environmentally friendly.
6. Coir dust has an ideal pH in the range of 6-6.7
7. It is very low in electrical conductivity and has an acceptable cation exchange capacity.
8. It is a biodegradable source that decomposes more slowly and has a life of three to four years.
9. Contains significant amounts of phosphorus (10-50 ppm) and potassium (150-450 ppm).
10. It is very easy to re-hydrate after being dehydrated and light in weight
11. It promotes better root systems in a short time.

iii. Compost

Mature compost is an excellent organic fertilizer and soil amendment. Composting is also a way to transform the waste materials left over from agricultural production and processing into a useful resource. The recycling of agricultural wastes such as palmfibre (Norman, 2004) and by-products by composting is an important part of sustainable agriculture. Composting has two main functions: to provide farmers with organic fertilizer and to recycle organic wastes (FFTC, 2002). The major advantage of this medium is that not only does it provide support to plants as a medium, but it also provides additional nutrients for plant growth. Microbes present in compost also help in converting unavailable nutrients to available nutrients (Mahmood, 2004). Increasing organic matter content in potting media is best accomplished through addition of composted organic materials. A well-managed compositing operation can produce a compost with almost all of the properties (light-weight, good water holding capacity, among others) of a good potting media without being prohibitively expensive (Miller and Jones, 1995).

2.9.6.2 Inorganic components

i. Soil

Soil is used in nurseries in the tropics as a means of increasing the water-holding capacity of media for large pots, providing nutrients and support for plant growth. Elsewhere, most media are now soilless. A major problem with soil is maintaining quality. Potting mixes with more than about 30 volume percent soil usually have poor aeration and a high bulk density. It must be assumed that any soil might contain pathogens that must be destroyed by air-steaming or with methyl bromide. If soil is to be used, it should be a sandy loam or loamy sand (Handreck and Black, 1999). According to Holcomb (2000), soil easily provides retained nutrients to plants for growth.

2.10 FORMULATION OF A ROOTING OR GROWING MEDIUM

Handreck and Black, (1999) reported that there are important properties (aside the availability and cost of materials) which must be considered when formulating a mix. These are the physical, chemical and biological properties. It was further documented that mixtures of many different proportions can give satisfactory plant growth if all these properties are met. It is possible to formulate a growth medium for a specific container size, growth environment, management intensity and the plant's requirements. It pays to purchase or formulate a container medium suited for each production system (Ingram *et al.*, 2003).

The formulation can range from straight, composted pine bark, through two component mixtures such as 3 bark:1 sand and three-component mixtures such as 2 bark:1 sawdust:1 sand. Each mix needs its own watering and fertilization schedule. A change in the quality of one component can upset the whole system and may cause serious losses of production, thus simple mixes are easiest to make and can be repeated with consistency. Correct media mixing is imperative for successful nursery crop production. Uniformity of the mix is essential to avoid potential drainage, aeration, and plant growth problems. The formation of aggregates in the media, enhanced by the addition of water, helps maintain mix homogeneity. When mixing media, uniform quantities of materials should be added to produce a consistent, final product from batch to batch (Anon., 1997).

In formulating a media, source of regular and ready supplies of raw materials is important to prevent interruptions in the production cycle of an enterprise though the materials used would be of varying cost. On the other hand, the mix prepared should meet the needs of the operation in terms of plant requirements (Acquaah, 2005).

2.11 PROPERTIES OF A ROOTING OR GROWING MEDIUM

2.11.1 Physical Properties

This is the proportion of air and water in a mix when drained and the ease with which plant roots can extract water. Other important physical properties include texture, structure, colour, air porosity and bulk density. These physical properties depend on the shape, size and density of individual particles, the relative proportions of different sizes present, whether or not the particles have internal pore space and the way they are packed together (Handreck and Black, 1999).

The setting of the physical properties of a mix is done before potting. It is therefore critically important that a mix is formulated on the basis of measured air-filled porosity and water-holding capacity on trial mixtures. Porosity is one of the most important physical properties in a growing media because it determines the space available in a container for air (aeration) water and root growth (Liegel and Venator, 1987).

Aeration is also important because the root system 'breathes' (exchange oxygen and carbon dioxide) in the large air-filled pores (macropores). The growing media must allow adequate drainage from macropores so that water does not remain in the bottom of the container where it would inhibit root respiration. The presence of macropores is a function of particle size, particle arrangement and the degree of compaction. Increasing particle size increases the aeration porosity but water holding capacity declines (Landis *et al*., 1990). Pasian (1997), also stated that increasing aeration decreases water retention and vice versa. Good growth of most plants is possible only when some of the pores in the medium around their roots contain air. Between 10% and 50% of the volume of a medium in a container should contain air immediately after drainage has stopped (Handreck and Black, 2002). Ideally, growers prefer the media with high bulk density when outdoors to minimize blowover but are desirous of a light weight medium during plant movement and transportation (Robbins and Evans, 2006a).

Although good drainage is desired of a medium, so is a high water-holding capacity. If the container is small, water must be made available to seedlings by irrigation. The presence of small pores (micropores) helps retain water. Organic matter provides a large number of micropores, so they improve the water-holding capacity of potting media (Landis *et al*., 1990). Further smaller pores present higher resistance to water flow, which in turn increases water holding capacity (Pasian, 1997).

The water holding capacity of any medium is a very important characteristic. Organic soilless mixes that hold generous amount of water are less subject to leaching losses of nutrients. For a good organic mix the desired water holding capacity is 40% - 50% (Mahmood, 2005).

2.11.2 Chemical Properties

The chemical properties which determine suitability of a growing media are primarily; pH, cation-exchange-capacity (CEC) and fertility. The desired pH of most growing media is slightly acid, ranging from 5.0-6.5 but the optimum pH of a container medium differs with plant species (Miller and Jones, 1995). Plants such as *Juniperus chinensis*, *Thuja occidentalis* prefer a pH in the 6.5-7.0 range. A low or high pH can adversely affect the plant in terms of nutrient availability which is greatly influenced by the materials used for making the mix (Mahmood, 2005).

Landis *et al*. (1990) defined cation-exchange-capacity as a measure of a soil or potting media's ability to hold nutrients. A low CEC (<10 me/100g) means that nutrients will not be retained but a high CEC (140me/100g) implies that nutrients will be held to the mix and made available to the seedlings. The greater the addition of organic matter to composts the higher the CEC of the mix (Miller and Jones, 1995). Handreck and Black, (2002) further stated that media components have a general effect on nutrition through their cation exchange and buffer capacities. A high cation exchange capacity (CEC) ensures a continuous supply of nutrient cations to plants. High buffer capacity will also reduce the possibility of large changes in pH. Losses of nutrients by leaching are reduced when CEC increases (Robbins and Evans, 2006b).

The presence of toxins such as high level of salts, chemical of natural origin, and added chemicals must be checked. Soluble nitrogen is consumed when waste such as barks, sawdust, coir are decomposed by microorganisms. Media components contain and supply nutrient elements. Compost, as a good source of all or most trace elements whereas coir dust has very high Potassium (K) content (Handreck and Black, 2002).

According to Will and Faust, (2005) media testing during the growing season is an important tool for managing crop nutrition and soluble salts levels. Based on several years of work, the University of Tennessee has provided a standardised guideline for the nutrient content of media for potted plants (Table 2.1).

Table 2.1: General guidelines for saturated media extract (SME) test results

Analysis	Low	Optimal	High
EC (mS/cm)	< 1.5	2.0-3.0	> 3.5
pH	< 5.6	5.8-6.0	> 6.4
Nitrate-N (ppm)	< 50	100-200	> 250
Phosphorus (P) (ppm)	< 3	6-9	> 12
Potassium (K) (ppm)	< 50	100-200	> 250
Calcium (Ca) (ppm)	< 100	150-250	> 300
Magnesium (Mg) (ppm)	< 30	40-80	> 100

Source: Agricultural Extension Service; University of Tennessee, PB1618

2.11.3 Biological properties

The presence or absence of pathogens and beneficial microorganisms should be considered in media formulation. In a well balanced mix, microorganisms that can feed on pathogens will normally keep the pathogens in check. But if conditions favour the proliferation of the pathogens then damage to plants in the mix can be severe. With good nursery hygiene and appropriate treatment of mixes before use, low level of pathogens in materials being considered for potting mixes need not be a main reason for not choosing them (Handreck and Black, 2002).

2.12 PROPAGATING STRUCTURES

Polythene is the most popular covering for propagation houses. Several types of plastic are available but most propagators use either single or double layered polythene. Poly materials are lightweight and relatively inexpensive compared with glass. Their lightweight also permits a less expensive supporting framework than is required for glass. Polythene permits the passage of oxygen and carbon dioxide necessary for the growth processes of plants while reducing the passage of water vapour. Even in a greenhouse, humidity is not always high enough to permit satisfactory rooting of certain kinds of leafy cuttings. Enclosed frames covered with polythene or glass may be necessary for successful rooting. Good shade control to reduce light irradiance is essential for this system (Hartmann *et al*., 2002).

In using all such structures care is necessary to avoid the build-up of pathogenic organisms. The warm, humid conditions, combined with lack of air movement and relatively low light intensity provide excellent conditions for the growth of various pathogenic fungi and bacteria (Hartmann *et al*., 2002).

2.13 CONTAINERS FOR PROPAGATING AND GROWING LINER PLANTS

Polythene bags are widely used in less developed countries in the tropics for growing rooted cuttings to a saleable size. These polythene bags of various sizes are available to suit most purpose of growing plants in the nursery (Rao, 2000). They are considerably less expensive than rigid plastic containers and facilitate easy handling of plants. They are usually black but some are black on the inside and light coloured on the outside. The light colour reflects heat and lowers the root temperature (Hartmann *et al*., 2002).

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

The study was carried out at the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi from 17th June, 2009 to 26th August, 2009.

3.2 SOURCE AND TYPE OF STOCK PLANTS

Cuttings from stock plants of *Ixora coccinea*, *Ficus benjamina* cv. Starlight and *Thuja occidentalis* were obtained from the ornamental gardens of the University Hospital, Commercial Area and the Department of Horticulture respectively all on the KNUST Campus.

Two types of hardwood cuttings; straight stem cuttings and heel stem cuttings were made from each of the three stock plants. For the heel stem cutting, a small piece of older wood was included at the base of the cutting while the straight stem cutting did not have any piece of older wood attached to its base.

3.3 PREPARATION OF CUTTINGS

The length for each cutting of *Ixora coccinea*, Ficus *benjamina* cv. Starlight and *Thuja occidentalis* was 20 cm. At this length, *Thuja occidentalis* had 15-18 nodes whereas *Ixora coccinea* and *Ficus benjamina* cv. Starlight had 2-4 nodes. All cuttings were obtained between 6 am to 10 am in the morning. Both straight and heel stem cuttings of *Ixora* spp. and *Ficus* spp. were completely stripped of their leaves. The *Thuja* spp. cuttings were stripped of its lower leaves 2 cm from the base of cuttings. All cutting types were not treated with hormone.

A B

H **S** **S** **H**

C

H **S**

Plate 3.1: Straight (S) and Heel (H) stem cutting of A- *Ixora coccinea*, B-*Ficus benjamina* cv. Starlight and C-*Thuja occidentalis*

3.4 SOURCE OF MEDIA COMPONENTS

The raw materials used for the media formulations were empty oil palm (*Elaeis guineensis*) fruit bunch, dried mill mud, oil palm fibre, boiler ash from oil palm processing, teak (*Tectona grandis*) sawdust and coconut (*Cocos nucifera*) fibre. Topsoil obtained from the Department of Horticulture served as a control for the experiment.

The oil palm wastes were obtained from the Juabeng Oil Palm Company in Kumasi. The coconut fibre and teak sawdust were obtained from coconut sellers at Anloga Junction and Angola Timber Market, respectively, all in the Kumasi Metropolis. All the soilless components for the formulation with the exception of coconut fibre, dried mill mud and boiler ash were composted over a period of eight (8) weeks.

3.5 MEDIA PREPARATIONS

3.5.1 Oil Palm Bunch Composting

The empty oil palm bunch was chopped into pieces and milled to particle sizes ranging between 1 mm and 15 mm in length. The milled bunch was thoroughly mixed with the oil palm fibre. A match box full of urea (3g) was added to every ten litre (10 L) bucket of the mixture and mixed thoroughly. A total number of seven buckets full of the mixture was put in an eighty litre (80 L) plastic bowl and the remaining gap below the brim made stirring manageable. Prior to the filling, the bowl was lined with a high density black polythene sheet to prevent spillage of water from the mixture and to cover the material under composting. The urea in the mixture served as the activating agent for the composting. The mixture was then moistened with water to make the mixture feel damp but not soggy.

The mixture was turned every day for the first two weeks, every other day for the following two weeks, every other two days for the next two weeks and then once a week in the last two weeks of composting when the level of heat in the compost reduced as recommended by Ellis *et al*. (2006). The mixture was moistened when it showed signs of drying up. The compost was allowed to cure for a week after the eight weeks of composting then passed through steam for thirty minutes to kill pathogenic organisms before it was used for the rooting experiment.

3.5.2 Teak Sawdust Composting

An eighty litre black plastic bowl with similar lining as in the oil palm bunch composting was used for the teak sawdust composting during the eight week period. A match box full of urea (3g) serving as the activating agent was added to every ten litre bucket full of the teak sawdust and mixed thoroughly then put into the lined plastic bowl. The mixture was moistened to make it damp but not soggy. The mixture was turned every day for the first two weeks, every other day for the following two weeks, every other two days for the next two weeks after which it was done once a week with the reduction in temperature from the mixture in the final two weeks (Ellis *et al*., 2006). The compost was moistened when it showed signs of drying up. After eight weeks, the compost was allowed to cure for a week and passed through steam for thirty minutes before it was used for the rooting experiment.

Plate 3.2: Composting of oil palm by-products and teak sawdust

3.5.3 Coconut Coir Preparation

The coconut fibre collected from sellers was sorted to ensure the fibre was free from shells and stones. The fresh fibre was beaten with a mallet and completely submerged in 1.50 m^3 of water in a concrete tank of 4 m x 0.82 m x 0.75 m dimension for fermentation. The end of fermentation period was indicated by the seizure of the formation of bubbles on the water surface on stirring. This lasted for ten days. The water in the concrete tank was drained at the end of the fermentation process and the fibre re-soaked with fresh water for 12 hours. The soaking tank was finally drained and the fibre sieved and de-watered by packing in punctured polystyrene sacs to allow excess water to drain. The fibre was sun dried to reduce the wetness and then the semi-dried fibre was further beaten with a mallet, milled and sieved to pass through 0.5 mm wire mesh. The resultant fine coir was collected and used as medium (Ellis *et al*., 2006).

Coconut husk Soaked in tub for 3-4 Coconut husk collected days for fermentation de-watered

Shredded coconut husk

Sieved coconut coir

Plate 3.3: Coconut coir preparation

3.5.4 Media Treatment

The topsoil collected from the Department of Horticulture was sieved to get rid of stones and other extrogenous material. The sieved soil was pasteurised for 3 hours using a steam chamber. The soilless media together with the pasteurized topsoil were further solarised for 2 weeks in order to kill pathogenic organisms and weed seeds.

Plate 3.4: Solarisation of topsoil and soilless media

3.6 MEDIA FORMULATION

The media formulation was based on a volume by volume (v/v) combination of the analysed composted materials and topsoil which served as the control medium. The following media combinations were done;

- 100% Topsoil (Control)
- 100% Palmix (mixture of oil palm waste)
- 50% Teak sawdust+50% Coconut coir
- 50% Palmix+50% Coconut coir
- 50% Palmix+50% Teak sawdust
- 50% Palmix+25% Teak sawdust+25% Coconut coir

M0:100%Topsoil M1:100%Palmix M2:50%TeakSawdust+50% Coconut Coir

M3:50%Palmix+50% Coconut Coir M4:50%Palmix+50% Teak Sawdust M5:50%Palmix+25%Teak Sawdust+25%Coconut Coir

Plate 3.5: Topsoil and formulated soilless media

3.7 STEM CUTTING EXPERIMENT

3.7.1 Experimental Design and Treatments

The experimental design used was a 6 x 2 factorial in Randomised Complete Block Design (RCBD). The different media served as the first factor with 6 levels and the stem cuttings as the second factor with 2 levels. The six levels of media were 100% topsoil, 100% palmix, 50% teak sawdust+50% coconut coir, 50% palmix+50% coconut coir, 50% palmix+50% teak sawdust and 50% palmix+25% teak sawdust+25% coconut coir and the two levels of the stem cuttings were straight stem and heel stem giving twelve (12) treatment combinations. The experiment was replicated three (3) times giving a total of thirty-six (36) treatments. Each treatment was represented by three cuttings. The treatment combinations of the media and stem cutting types were as follows;

100% topsoil+straight stem cutting

100% topsoil+heel stem cutting

100% palmix+straight stem cutting

100% palmix+heel stem cutting

50% teak sawdust+50% coconut coir+ straight stem cutting

50% teak sawdust+50% coconut coir+heel stem cutting

50% palmix+50% coconut coir+straight stem cutting

50% palmix+50% coconut coir+heel stem cutting

50% palmix+50% teak sawdust+straight stem cutting

50% palmix+50% teak sawdust+heel stem cutting

50% palmix+25% teak sawdust+25% coconut coir+straight stem cutting

50% palmix+25% teak sawdust+25% coconut coir+heel stem cutting

3.7.2 Layout of Treatments

Three experiments, one for each of the above-named ornamental stock plant, were carried out. The three experiments were set-up under fruit trees in the Fruit Section of the Department of Horticulture, KNUST. The layout for each stock plant was a poly-propagator which had twelve polythene bags representing the number of treatment combinations.

Perforated polythene bags of dimension 15 cm x 10 cm were filled with equal volumes of each medium; 100% topsoil, 100% palmix, 50% teak sawdust+50% coconut coir, 50% palmix+50% coconut coir, 50% palmix+50% teak sawdust and 50% palmix+25% teak sawdust+25% coconut coir and cuttings; straight stem and heel stem of each stock plant was put in the filled polythene bags and put under the poly-propagator box of dimension 1.5 m x 0.6 m x 0.6 m. Transparent polythene sheets were used to cover all sides of the poly-propagator to create the microclimate condition necessary for rooting of the cuttings.

Plate 3.6: Layout of stem cutting experiments

The perforations on the black polythene bag were to drain off excess water from the medium. The medium was firmed in the black polythene bags so that it was able to hold the cuttings in place. Before cuttings were inserted into the medium, the medium was moistened and allowed to settle overnight. A dibber was used to create the hole for the insertion of the cuttings. After inserting the cuttings in an upright form, the medium was firmed around the cuttings and then watered.

Plate 3.7: Perforated black polythene bags measuring 10cm x 15cm each

3.7.3 Data Collected

These included:

i. Temperature of medium and poly-propagator: The temperature for the different media and poly-propagator was recorded with a laser temperature reader (ThermoTrace Infrared Thermometer (Model 15030), DeltaTRAK, USA) throughout the experimental period. Temperature readings were taken between 9:00 am and 3:00 pm on each recorded date.

ii. Humidity of poly-propagator: The internal humidity of the poly-propagator containing the cuttings was also recorded using a temperature-humidity reader (Micronta LCD Indoor/Outdoor Thermometer Hygrometer (Model 63-867), InterTAN, UK) between 9:00 am and 3:00 pm on each recorded date.

iii. Days to sprouting: This was the number of days for the cuttings of *Ixora coccinea* and *Ficus benjamina* cv. Starlight to sprout. However, observations were made on the sprouting behaviour on the *Thuja occidentalis* which was indicated by the continued prolific sprouting on the cuttings.

iv. Number of survived cuttings: This was the number of cuttings that did not die during the experimental period but did not root after callus formation. This was recorded at the end of the experimental period.

v. Number of rooted cuttings: This was the number of cuttings that had successfully rooted. Records were taken at the end of the experimental period.

vi. Root length per cutting: The root length was measured using a pair of dividers and ruler from the point of attachment of the roots to the distal end of the stem cuttings. This was done on two randomly selected roots and the average root length recorded. The root length measurement was done at the end of the experimental period.

vii. Number of fully developed leaves per cutting: This was the number of fully developed leaves from the sprouts on the cuttings of *Ixora coccinea* and *Ficus benjamina* cv. 'Starlight'. Records were taken at 4 weeks after propagation (WAP) and subsequently on weekly basis till the experiment were terminated in the 10th week.

3.7.4 Statistical Analysis

Data collected were square-root transformed before analysis using Analysis of Variance (ANOVA) using Statistix statistical software. Differences between treatment means were separated using the least significant difference (LSD) test at

5% probability level.

3.8 AIR - LAYERING EXPERIMENT

3.8.1 Experimental Design and Treatments

A Complete Randomised Design (CRD) was used with 6 treatments (media) which were replicated three times giving a total of 18 treatments on each stock plant of all three difficult-to-root plants used.

3.8.2 Layout of Treatments

This experiment was done by removing between two nodes a strip of bark 2 cm wide completely around the stem on six stems of each of three difficult-to-root stock plants to expose their inner woody tissues. A transparent polythene sheet of size 12 cm x 10 cm was fastened securely around the stem using a raffia rope below the first ring mark for each stock plant and filled with the six different moistened media respectively as treatments (as in the stem cutting experiment) and fastened above the second ring mark. Different polythene tags represented the media as follows; White - 100% topsoil, Blue - 100% palmix, Black - 50% teak sawdust+50% coconut coir, Yellow - 50% palmix+50% coconut coir, Violet - 50% palmix+50% teak sawdust and Green - 50% palmix+25% teak sawdust+25% coconut coir.

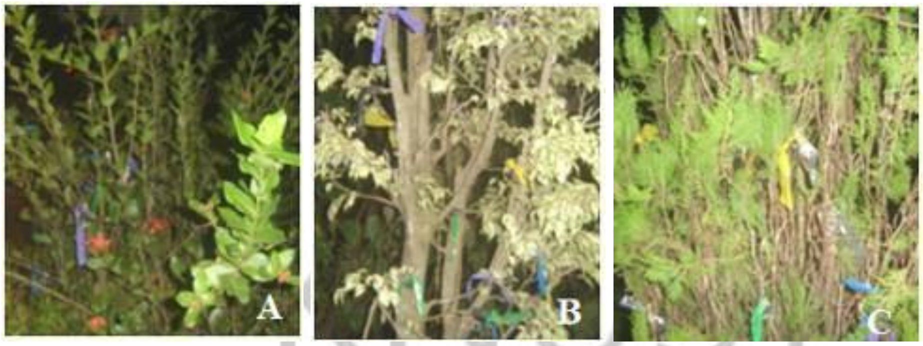


Plate 3.8: Layout of air-layering experiments

3.8.3 Data Collected:

These included;

i. Temperature of medium: The temperature for the different media was recorded with a laser temperature reader (ThermoTrace Infrared Thermometer (Model 15030), DeltaTRAK, USA) from the first day after air-layering. Temperature readings were taken between 9:00 am and 3:00 pm on each recorded date till the end of the experiment.

ii. Humidity of ambient: The humidity of the ambient was also recorded using a temperature-humidity reader (Micronta LCD Indoor/Outdoor Thermometer Hygrometer (Model 63-867), InterTAN, UK) between 9:00 am and 3:00 pm throughout the experimental period.

iii. Days to root emergence: This was the number of days it took for the air-layers to root. This was taken as and when the roots appeared from the 1st day after airlayering till the end of the experiment.

iv. Number of survived air-layers: This was the number of air-layers that did not die during the experiment period but did not root after callus formation. This was taken at the end of the experimental period.

v. Number of rooted air-layers: This was the number of air-layers that had successfully rooted. Records were taken at the end of the experimental period.

viii. Root length per air-layer: The root length was measured using a pair of dividers and ruler from the point of attachment of the roots to the distal end of the stem cuttings. This was done on two randomly selected roots and the average root length recorded. The root length measurement was done at the end of the experimental period.

3.8.4 Statistical Analysis

Data collected were square-root transformed before analysis using Analysis of Variance (ANOVA) using Statistix statistical software. Differences between treatment means were separated using the least significant difference (LSD) test at 5% probability level.

3.9 PHYSICO-CHEMICAL ANALYSIS

Analysis were carried out for the media listed below following procedures found in the FAO fertilizer and plant nutrition bulletin 19 (Motsara and Roy, 2008);

(i) 100% Topsoil

(ii) 100% Palmix

(iii) 50% Teak sawdust+50% Coconut coir,

(iv) 50% Palmix+50% Coconut coir,

(v) 50% Palmix+50%Teak sawdust,

(vi) 50% Palmix+25% Teak sawdust+25% Coconut coir for water holding capacity and air-porosity using the gravimetric method by Motsara and Roy (2008), total nitrogen using Kjeldahl method by Motsara and Roy (2008), while the organic matter content was determined using the colorimetric method by Datta *et al*. (1962). The pH value was determined using 1.1 distilled water method by Motsara and Roy (2008), exchangeable calcium and magnesium contents were determined using EDTA (Ethylenediamine tetraacetic acid) titration method by Cheng and Bray (1951). Available potassium was determined using flame photometer method by Toth and Prince (1949) and available phosphorus determined using bray's method no.1 by Bray and Kurtz (1945). The analyses were carried out at the CSIR - Soil Research Institute, Kumasi.

3.10 MANAGEMENT PRACTICES

Watering of the cuttings was done as and when necessary. Removal of foreign material such as weeds was done as and when they appeared. The polythene sheets lining the top of the poly-propagator frames were opened whenever the humidity in the poly-propagator was very high above 90%. All the cuttings were sprayed with a systemic fungicide, Topsin-M 70% WP (Thiophanate-methyl...70%); after they were set to control disease incidence on *Ixora coccinea*, *Ficus benjamina* cv. Starlight and *Thuja occidentalis* stem cuttings. A second spraying was done one month after setting cuttings.

4.0 RESULTS

4.1 PHYSICO-CHEMICAL COMPOSITION OF THE SIX DIFFERENT

MEDIA

4.1.1 Physical Properties of Media

The water holding capacity varied (Figure 4.1) among the soilless media. The 50% teak sawdust+50% coconut coir had the highest water holding capacity of 594.70%, 21.8 times greater than the control medium of 100% topsoil with water holding capacity of 27.24%. The other soilless media (100% palmix, 50% palmix+50% coconut coir, 50% palmix+50% teak sawdust and 50% palmix+25% teak sawdust+25% coconut coir) had water holding capacity ranging between 4.1 times and 9.1 times that of the 100% topsoil.

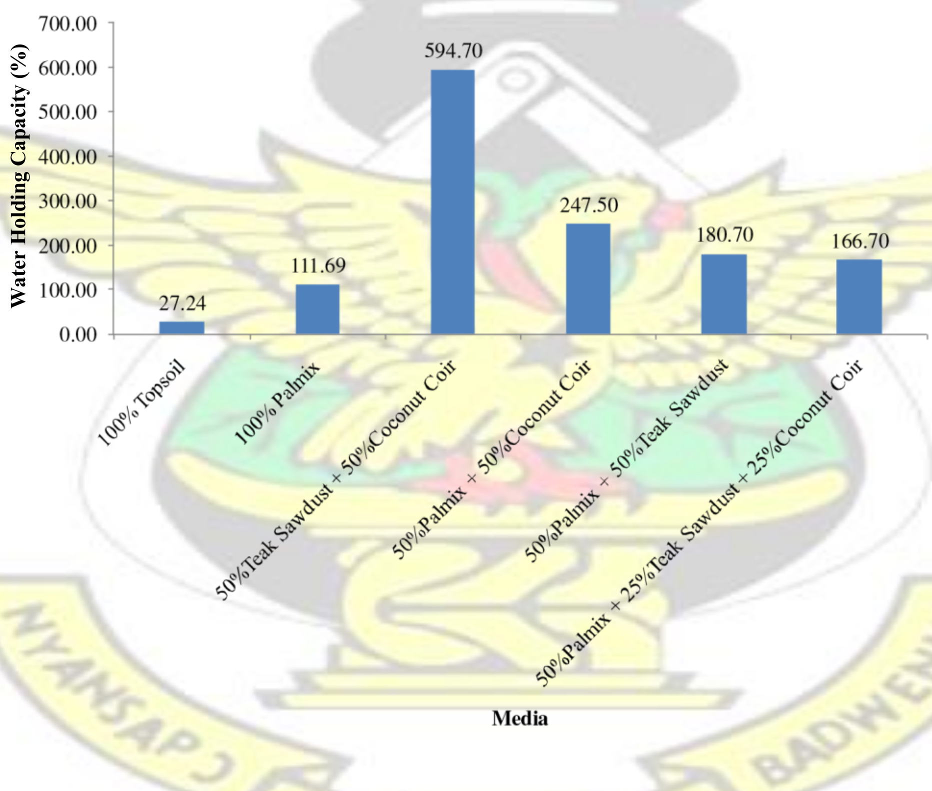


Figure 4.1: Water holding capacity of six different media

Percentage air-porosity in 100% topsoil (Figure 4.2) was lower than the soilless media. Among the soilless media the highest air-porosity was recorded in the 50% teak sawdust+50% coconut coir while the 100% palmix recorded the lowest.

Generally, there was increased porosity of the media after the stem cutting propagation except for 50% palmix+50% teak sawdust. However, a decrease (83.10% to 77.40%) in porosity was recorded in 50% palmix+50% teak sawdust.

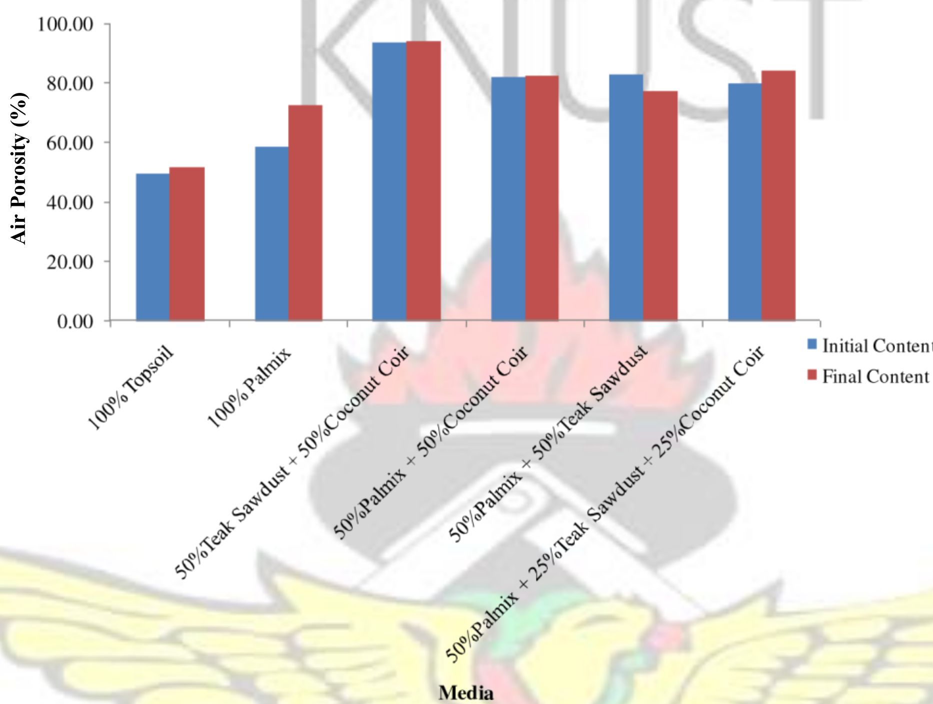


Figure 4.2: Percent air-porosity of six different media before and at the end of the experiment

4.1.2 Chemical Properties of Media

The nitrogen content in the 100% topsoil was lower than all the soilless media (Figure 4.3). Among the soilless media, nitrogen content was highest in 50% palmix+50% coconut coir and lowest in 100% palmix and 50% teak sawdust+50% coconut coir before and at the end of the experiment. There was a general decrease in nitrogen content at the end of the experiment for most of the media, except for 100% palmix and 50% teak sawdust+50% coconut coir where increases in nitrogen content were recorded.

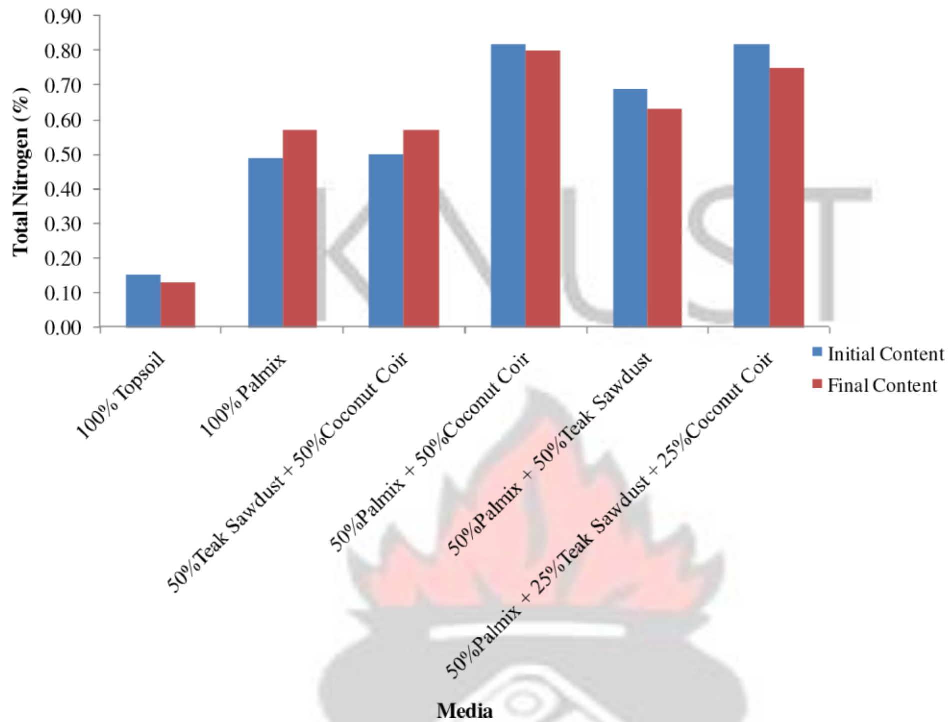


Figure 4.3: Percent total nitrogen content of the six different media before and at the end of the experiment

For organic matter, the trend was mixed (Figure 4.4). Whereas the organic matter content decreased at the end of the experiment for 100% palmix, 50% palmix+50% coconut coir and 50% palmix+50% teak sawdust, there was increase in organic matter for 50% teak sawdust+50% coconut coir and 50% palmix+25% teak sawdust+25% coconut coir. As regards the 100% topsoil the organic matter content did not change over the period of the experiment.

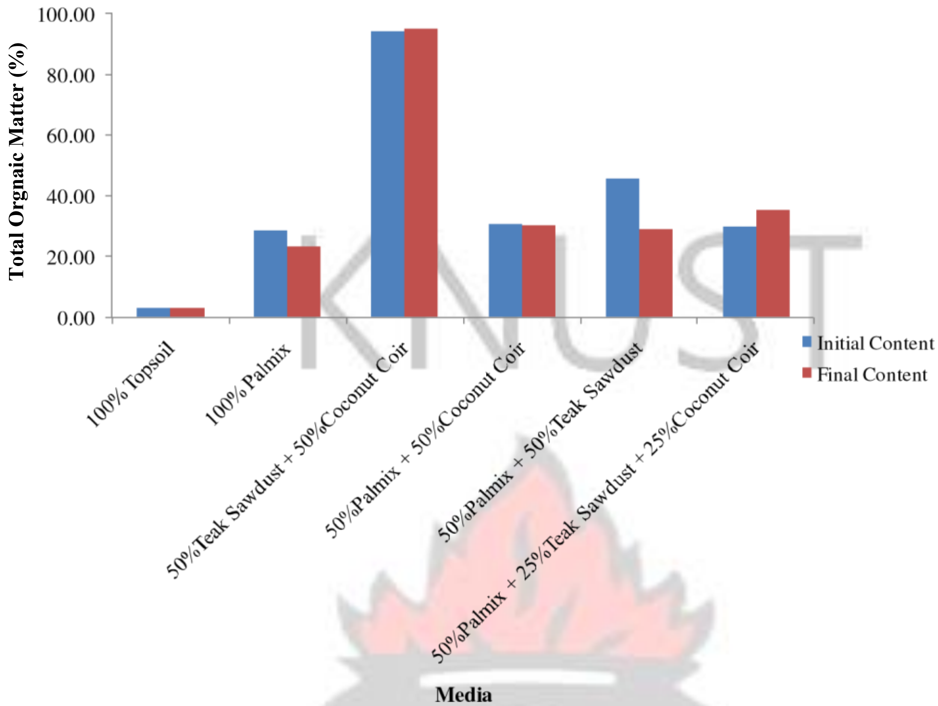


Figure 4.4: Percent organic matter content in six different media before and at the end of the experiment

The pH of the different media ranged from slightly acidic (5.76) to neutral (7.77) (Figure 4.5). Among the soilless media, 50% teak sawdust+50% coconut coir recorded the minimum pH (5.76) which was slightly acidic, with 50% palmix+50% teak sawdust having the highest pH (7.39) which was near neutral. The 100% topsoil had similar near neutral pH.

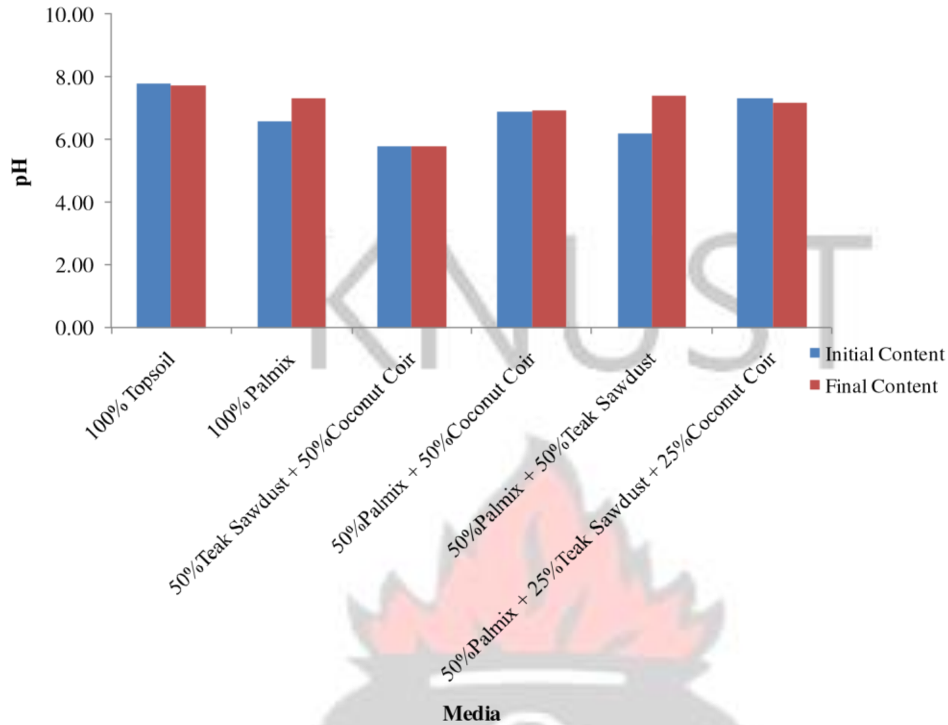


Figure 4.5: pH of six different media before and at the end of the experiment

The calcium content of 50% teak sawdust+50% coconut coir and 50% palmix+50% coconut coir were higher than the 100% topsoil (Figure 4.6). However, the calcium content of the 100% topsoil was comparable to the 50% palmix+50% teak sawdust and 50% palmix+25% teak sawdust+25% coconut coir. The medium with the least calcium content was 100% palmix.

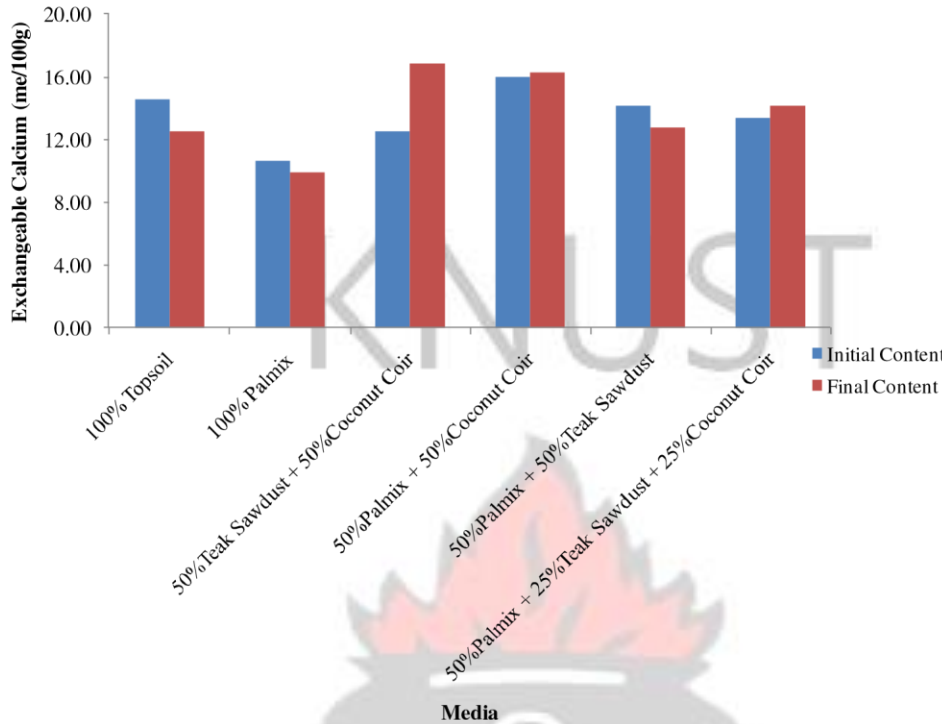


Figure 4.6: Calcium content of the six different media before and at the end of the experiment

The potassium content recorded in all the soilless media was higher than what was recorded for the 100% topsoil (Figure 4.7). Except in 100% palmix and 50% teak sawdust+50% coconut coir where potassium increased at the end of the experiment, potassium content generally decreased over the period of the experiment for the other soilless media.

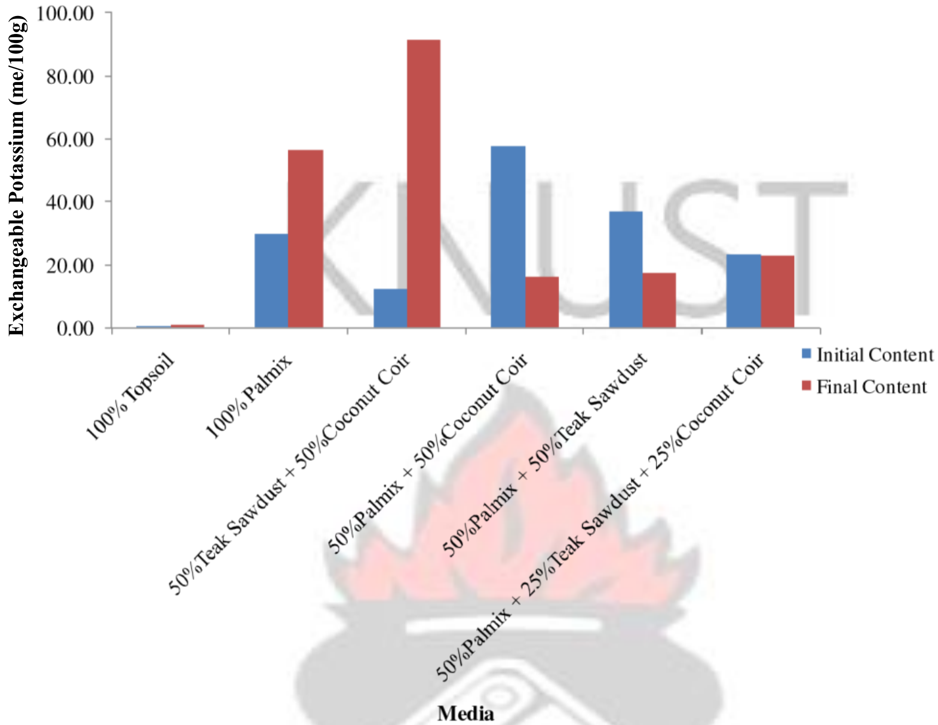


Figure 4.7: Potassium content of the six different media before and at the end of

the experiment

The soilless medium 50% teak sawdust+50% coconut coir had the lowest magnesium content among the soilless media (Figure 4.8). However, in comparison to the 100% topsoil, all the soilless media had higher contents of magnesium than the 100% topsoil. In general, there was an increase in magnesium content of all the media except the 100% palmix at the end of the experiment.

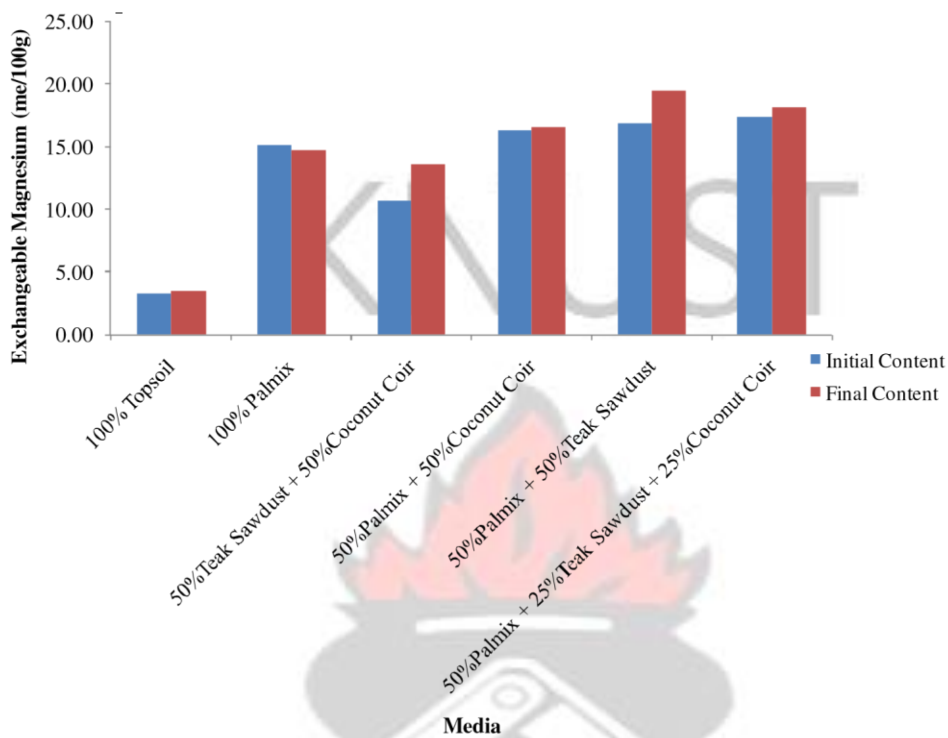


Figure 4.8: Magnesium content of the six different media before and at the end of the experiment

Similar to the trend observed for the other nutrients, available phosphorus (Figure 4.9) was greater in the soilless media compared to the 100% topsoil. Over the period of the experiment, 100% palmix contained higher contents of phosphorus than the other soilless media. The least amount of phosphorus was found in the 50% teak sawdust+50% coconut coir medium.

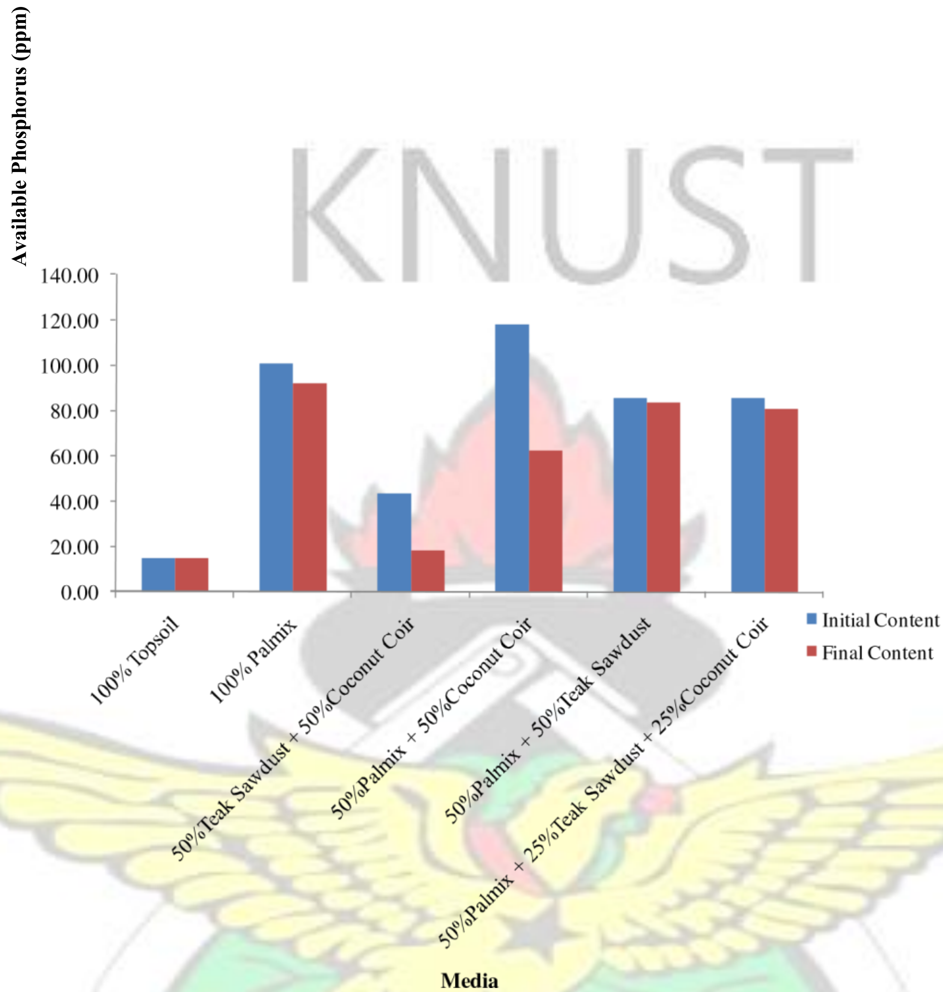


Figure 4.9: Phosphorus content of the six different media before and at the end of the experiment

4.2 PROPAGATION OF IXORA, FICUS AND THUJA PROPAGULES

4.2.1 Temperature of Media and Poly-Propagator

Temperatures in the media were similar over the 10-week period. The temperature in the poly-propagator was between 26.0 °C and 31.0 °C and that of the various media ranged from 23.0 °C to 34.0 °C (Figure 4.10). Temperature was higher than that in the poly- propagator recorded across the media in the 4th week. By the 5th week, temperature of the different media had declined to that of the 1st week and below that of the poly-propagator. Further temperature decreases were observed up to the 10th week across the media and the poly-propagator.

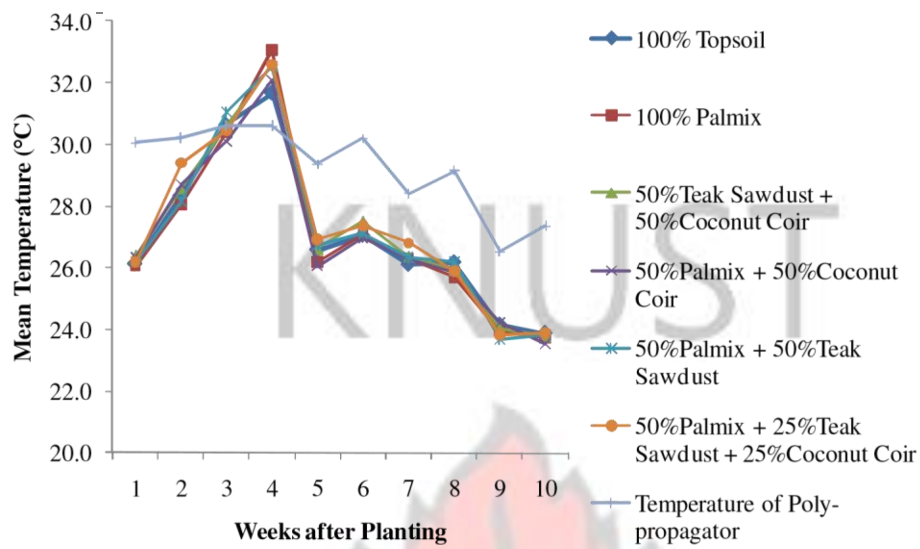
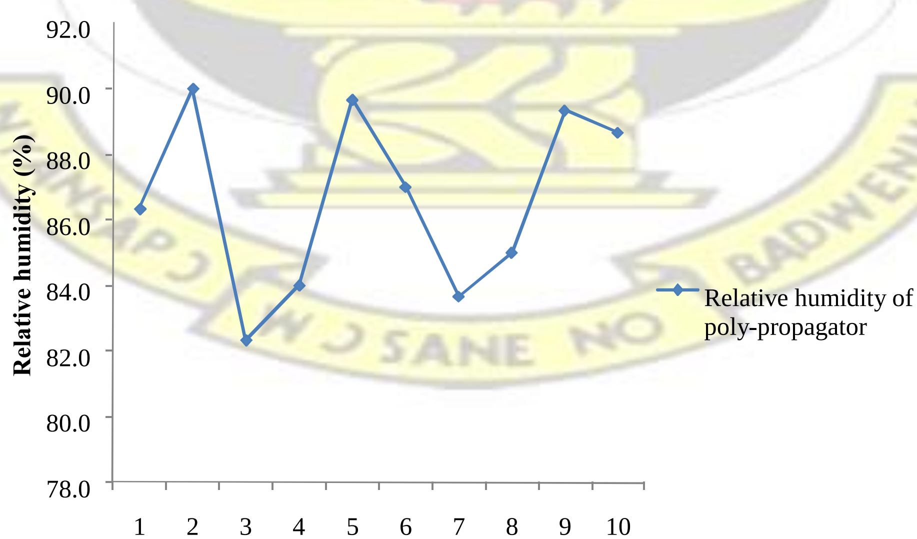


Figure 4.10: Mean media and poly-propagator temperature over time

4.2.2 Relative Humidity of Poly-Propagator

The relative humidity within the poly-propagator (Figure 4.11) ranged from 82.0% to 90.0%. There were fluctuations in the relative humidity within the poly-propagator over time. High relative humidity of 90.0% was recorded in the 2nd week while the minimum relative humidity was recorded in the 3rd week.



Weeks after Planting

Figure 4.11: Relative humidity in poly-propagator over time

4.2.3 Sprouting, Survival and Rooting of *Ixora coccinea* Propagules

The different media, stem cutting types and their interactions did not significantly affect the number of days to sprouting, survived cuttings, rooted cuttings and the root length (cm) of the propagules. However, in terms of trend, the soilless medium of 50% teak sawdust+50% coconut coir contained more survived cuttings (1.57) with more roots (0.79) and longer root length (1.11 cm) than the other media. Among the stem cuttings, the heel stem cuttings had more survived cuttings (1.43), with more roots (0.79) and longer root lengths (0.98 cm) than the straight stem cutting.

4.2.4 Leaf production of *Ixora coccinea* Propagules

There was significant stem cutting by media interaction (P = 0.0055) in leaf production (Table 4.1) only at the 4^{th} week after planting (WAP). Heel stem cutting in 100% topsoil produced the greatest number of leaves (2.63), significantly different from the other treatment combinations. The heel stem cuttings in 100% topsoil produced 3.7 and 1.5 times more number of leaves than the heel stem cutting in 50% palmix+50% teak sawdust and 50% teak sawdust+50% coconut coir, respectively. Among the soilless media, heel cuttings in 50% teak sawdust+50% coconut coir produced significantly higher number of leaves (1.72) than the other soilless media and stem cutting treatments. Straight stem cuttings in 100% topsoil and in 50% teak sawdust+50% coconut coir produced 2.2 and 2.6 times less leaves, respectively than the heel stem cutting in 100% topsoil. Heel stem cuttings in 50% teak sawdust+50% coconut coir also produced 72% and 142% times more leaves, respectively than straight stem cuttings in 50% teak sawdust+50% coconut coir and 50% palmix+50% coconut coir.

Table 4.1: Stem cuttings by media interaction effect on number of leaves of *Ixora coccinea* propagules at 4 weeks after planting (WAP)

	Stem cuttings		
Media	Straight stem	Heel stem	Means
100% Topsoil	1.17	2.63	1.90
100% Palmix	0.88	0.71	0.79
50% Teak sawdust+50% Coconut coir	1.00	1.72	1.36
50% Palmix+50% Coconut coir	0.71	1.05	0.88
50% Palmix+50% Teak sawdust	0.71	0.71	0.71
50% Palmix+25% Teak sawdust+25% Coconut coir	1.10	0.88	0.99
Means	0.93	1.28	

Lsd (0.05) Media = 0.44; Cuttings = 0.26; Medium x Cuttings = 0.23

From the 5th to the 10th week there were no significant interactions in leaf production. Significant differences were observed only in the main effects of media and stem cutting types. In the 5th week, there were significant (P = 0.0022) differences among the media in the production of leaves (Figure 4.12). The 100% topsoil and 50% teak sawdust+50% coconut coir developed 1.8 times more leaves than 50% palmix+25% teak sawdust+25% coconut coir as well as 50% palmix+50% teak sawdust. From the 6th week to the 10th week, leaf production was significantly highest in 100% topsoil as compared to the other media. Among the soilless media, leaf production in 50% teak sawdust+50% coconut coir was significantly different than the others. Over the period, the least leaf production was observed in 50% palmix+50% teak sawdust. At the 10th week, the 100% topsoil produced 1.8 times more leaves than 50% palmix+50% coconut coir whereas 50% teak sawdust+50% coconut coir produced 1.7 times more leaves than 100% palmix.

Cumulatively, at the end of the 10-week period, the highest number of leaves (3.11) was observed in 100% topsoil whereas the minimum number of leaves (1.43) was found in 50% palmix. Among the soilless media the 50% teak sawdust+50% coconut coir recorded an average number of leaves of 2.40 followed by 50% palmix+25% teak sawdust+25% coconut coir which recorded 2.36 leaves.

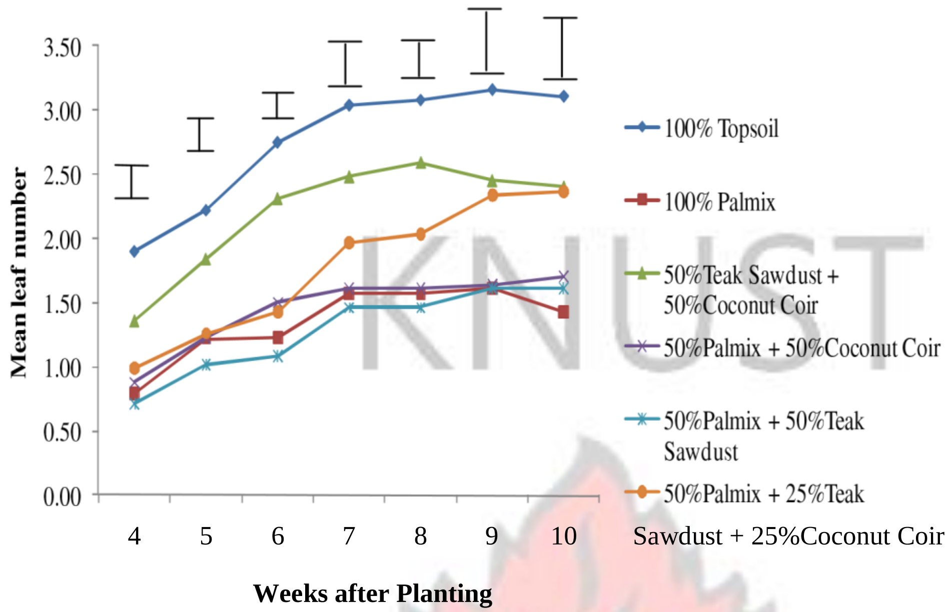


Figure 4.12: Effect of media on number of leaves of *Ixora coccinea* propagules over time. Lsd bars are at p=0.05.

Among the stem cutting types there were significant differences in leaf production between the straight and heel stem cuttings in the 6th week (P = 0.0119), 7th week (P = 0.0499) and 8th week (P = 0.0318) after planting (Table 4.2). Heel stem cuttings produced 1.3 times more leaves than the straight stem cuttings at each of these periods.

Table 4.2: Effect of stem cuttings on number of leaves of *Ixora coccinea* Propagules at 6, 7 and 8 weeks after planting (WAP)

Treatment	6WAP	7WAP	8WAP
Straight stem	1.46	1.79	1.79
Heel stem	1.98	2.25	2.32
Lsd (0.05)	0.39	0.46	0.47

Plate 4.1: Leaf developments of heel stem cuttings in 50% teak sawdust+50% coconut coir of *Ixora coccinea*

Plate 4.2: Leaf developments of straight stem cuttings in 100% topsoil of *Ixora coccinea*

4.2.5 Sprouting, Survival and Rooting of *Ficus benjamina* cv. Starlight Propagules

The different media did not significantly affect the root length of cuttings in Ficus. However the 50% palmix+25% teak sawdust+25% coconut coir medium recorded the longest root length of 1.44 cm. There were no significant differences in the stem cutting types and the stem cutting by media interaction of Ficus in the number of days to sprouting, number of stem cuttings that survived, number rooted and also the root length per cuttings. Straight stem cuttings however sprouted earlier (2.98 days) and had more survived cuttings (0.85) with more roots (0.82) of longer root lengths (1.06 cm).

There were significant differences between the media in the number of days to sprouting, number of stem cuttings that survived and number rooted (Table 4.3). Cuttings in the 50% palmix+50% coconut coir medium significantly (P = 0.0361) sprouted earlier (2.92 days) than in the other media. Sprouting of stem cuttings in 100% topsoil was 1.1 times longer than in 50% palmix+50% coconut coir. The 50% palmix+25% teak sawdust+25% coconut coir contained significantly (P = 0.0009) more survived cuttings (1.13) than the other soilless media and the 100% topsoil. There was 1.6 times greater number of survived stem cuttings in 50% palmix+25% teak sawdust+25% coconut coir than in 100% topsoil. The number of rooted cuttings was significantly (P = 0.0407) affected by the different media. More rooted stem cuttings (1.05) were observed in 50% palmix+25% teak sawdust+25% coconut coir than the 100% topsoil, the difference being 59%.

Table 4.3: Effect of media on number of days to sprouting, number of survived cuttings and number of rooted cuttings of *Ficus benjamina* cv. Starlight propagules

Media	Days to Sprouting	Survived cuttings	Rooted cuttings
100% Topsoil	3.13	0.71	0.71
100% Palmix	2.95	0.71	0.71
50% Teak sawdust+50% Coconut coir	3.02	0.79	0.79
50% Palmix+50% Coconut coir	2.92	0.79	0.79
50% Palmix+50% Teak sawdust	2.97	0.88	0.88
50% Palmix+25% Teak sawdust+25% Coconut coir	2.97	1.13	1.05
Lsd (0.05)	0.13	0.23	0.22

4.2.6 Leaf Production of *Ficus benjamina* cv. Starlight Propagules

There were significant stem cuttings by media interaction (P = 0.0336) in the number of leaves produced in the 8th and 9th weeks (Table 4.4). Straight stem cuttings in 50% palmix+50% teak sawdust produced more leaves (1.71) than the heel stem cuttings in the same medium as well as straight and heel stem cuttings in 100% topsoil (0.71). Thus, straight stem cuttings planted in 100% topsoil produced 2.4 times less number of leaves than straight stem cuttings in 50% palmix+50% teak sawdust.

Table 4.4: Stem cuttings by media interaction effect on number of leaves on *Ficus benjamina* cv. Starlight propagules at 8 week after planting (WAP)

	Stem cuttings		
Media	Straight stem	Heel stem	Means
100% Topsoil	0.71	0.71	0.71
100% Palmix	0.71	0.71	0.71
50% Teak sawdust+50% Coconut coir	0.71	0.71	0.71
50% Palmix+50% Coconut coir	0.71	1.18	0.94
50% Palmix+50% Teak sawdust	1.71	0.71	1.21

50% Palmix+25% Teak sawdust+25% Coconut coir	0.71	0.71	0.71
Means	0.88	0.79	

Lsd (0.05) Media = 0.41; Cuttings = 0.23; Media x Cuttings = 0.58

In the 9th week, straight stem cuttings in 50% palmix+50% teak sawdust significantly (P = 0.0138) produced more leaves (1.79) than the heel stem cuttings in 50% palmix+50% coconut coir (1.00). With the exception of the heel stem cuttings in 50% palmix+50% coconut coir that produced 1.8 times less number of leaves than the straight stem cuttings in 50% palmix+50% teak sawdust, all the other straight or heel stem cuttings in 100% topsoil and other soilless media produced 2.5 times less number of leaves than 50% palmix+50% teak sawdust (Table 4.5).

Table 4.5: Stem cuttings by media interaction effect on number of leaves on *Ficus benjamina* cv. Starlight propagules at 9week after planting (WAP)

	Stem cuttings		
Media	Straight stem	Heel stem	Means
100% Topsoil	0.71	0.71	0.71
100% Palmix	0.71	0.71	0.71
50% Teak sawdust+50% Coconut coir	0.71	0.71	0.71
50% Palmix+50% Coconut coir	0.71	1.00	0.85

50% Palmix+50% Teak sawdust	1.79	0.71	1.25
50% Palmix+25% Teak sawdust+25% Coconut coir	0.71	0.71	0.71
Means	0.89	0.76	

Lsd (0.05) Media = 0.36; Cuttings = 0.21; Media x Cuttings = 0.52

Plate 4.3: Rooted heel stem cuttings in 50% palmix+25% teak sawdust+25% coconut coir in *Ficus benjamina* cv. Starlight

Plate 4.4: Rooted straight stem cuttings in 50% palmix+50% coconut coir in *Ficus benjamina* cv. Starlight

For the stem cutting types, only on the 4th and 6th week after planting did significant differences in leaf production exist between the heel and straight cuttings. The straight stem cutting produced (2.49) significantly (P = 0.0404) more leaves (1.3 times) than the heel stem cutting (1.90) in the 4th week and the trend was maintained in the 6th week when the straight stem cutting produced 1.6 times significantly (P = 0.0241) more leaves than the heel stem cutting (Table 4.6).

Table 4.6: Effect of stem cuttings on number of leaves of *Ficus benjamina* cv.

Starlight propagules at 4 and 6 weeks after planting (WAP)

Stem cuttings	4WAP	6WAP
Straight stem	2.49	1.34
Heel stem	1.90	0.84
Lsd (0.05)	0.56	0.43

4.2.7 Sprouting, Survival and Rooting of *Thuja occidentalis* Propagules There was prolific sprouting on the Thuja propagules after the 4th week after planting. The different media, stem cutting types and their interactions did not significantly affect the number of survived cuttings. As a trend, the 50% teak sawdust+50% coconut coir and 50% palmix+25% teak sawdust+25% coconut coir both had more (1.77) survived cuttings. The heel stem cuttings also had more survived cuttings (1.71).

The different media significantly ($P = 0.0086$) affected the number of rooted cuttings of the Thuja propagules (Table 4.7). The maximum number of rooted cuttings (1.39) was recorded in the 50% teak sawdust+50% coconut coir whilst the minimum rooted cuttings (0.71) were observed in 100% palmix. Thus 50% teak sawdust+50% coconut coir had 1.5 and 1.9 times more rooted cuttings than 50% palmix+50% teak sawdust and 100% palmix, respectively. Stem cuttings planted in 50% palmix+25% teak sawdust+25% coconut coir had 1.6 times more rooted cuttings than 100% palmix.

The length of roots of stem cuttings in 50% palmix+50% coconut coir was the longest (2.38 cm) whilst the shortest root length (0.71 cm) was recorded by stem cuttings in 100% palmix. There were highly significant (P = 0.0005) differences in the root length among the media where stem cuttings in 50% palmix+50% coconut coir (2.38 cm) had 1.6 and 3.3 times longer root lengths than stem cuttings in 100% topsoil and 100% palmix, respectively. Rooted cuttings in 50% teak sawdust+50% coconut coir (2.19 cm) also developed 2.4 and 3.1 times longer root lengths than propagules in 50% palmix+50% teak sawdust and 100% palmix, respectively.

Further stem cuttings in 50% palmix+50% teak sawdust had root lengths 1.2 times longer than 100% palmix (Table 4.7).

Table 4.7: Effect of media on number of rooted cuttings and root length (cm) of cuttings of *Thuja occidentalis*

Media	Rooted Cuttings	Root Length (cm)
100% Topsoil	1.05	1.50
100% Palmix	0.71	0.71
50% Teak sawdust+50% Coconut coir	1.39	2.19
50% Palmix+50% Coconut coir	1.36	2.38
50% Palmix+50% Teak sawdust	0.94	0.89
50% Palmix+25% Teak sawdust+25% Coconut coir	1.16	1.56
Lsd (0.05)	0.37	0.74

Plate 4.5a: Rooted straight stem cuttings in 50% teak sawdust+50% coconut coir of *Thuja occidentalis*

Plate 4.5b: Rooted heel stem cuttings in 50% teak sawdust+50% coconut coir of *Thuja occidentalis*

Plate 4.6a: Rooted heel stem cuttings in 50% palmix+50% coconut coir of *Thuja occidentalis*

Plate 4.6b: Rooted straight stem cuttings in 50% palmix+50% coconut coir of *Thuja occidentalis*

Plate 4.7: Rooted heel stem cuttings in

100% topsoil of Thuja

4.3 AIR-LAYERING OF IXORA, FICUS AND THUJA

4.3.1 Temperature of Media and Ambience

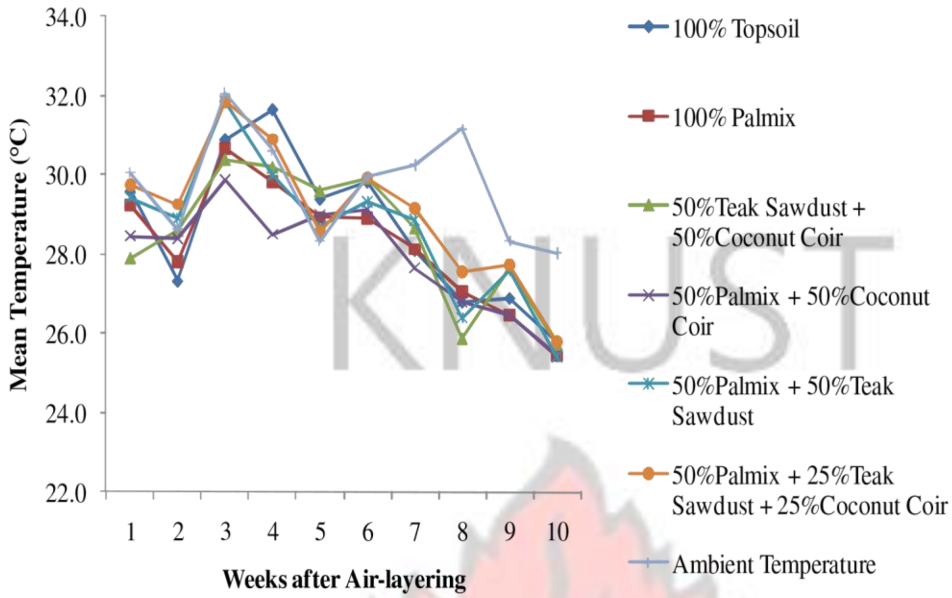


Figure 4.13: Mean media and ambient temperature over time

The ambient and media temperatures around the air-layers were fairly the same over time. The ambient temperature was between 28.0 °C and 33.0 °C while that of the media was between 25.0 °C and 32.0 °C (Figure 4.13). High media and ambient temperatures were recorded in the 3rd week with 50% palmix+50% teak sawdust recording the highest temperature of 31.9 °C and a corresponding high ambient temperature of 32.1 °C. Ambient temperatures remained higher than media temperatures from the 7th to the 10th week. While media temperatures showed a decline in temperature in the 8th week, ambient temperature increased. In the 9th week however, there was a rise in media temperatures and a decline in ambient temperature; but both media and ambient temperatures declined in the 10th week.

4.3.2 Relative Humidity of the Ambience

The relative humidity in the ambience was between 67.0% and 86.0% (Figure 4.14). The relative humidity of the ambience around the air-layers was comparatively the same from the 1st week to the 6th week. The highest relative humidity of 86.0% was recorded in the 5th week. There was a sharp decline in the relative humidity from the 7th week to the 8th week recording the lowest relative humidity of 67.3% then increased in the 9th week to 82.0% and remained constant at the 10th week. There was a sharp decrease in the relative humidity from the 7th to the 8th week and rise thereafter to 82.0% in the 10th week.

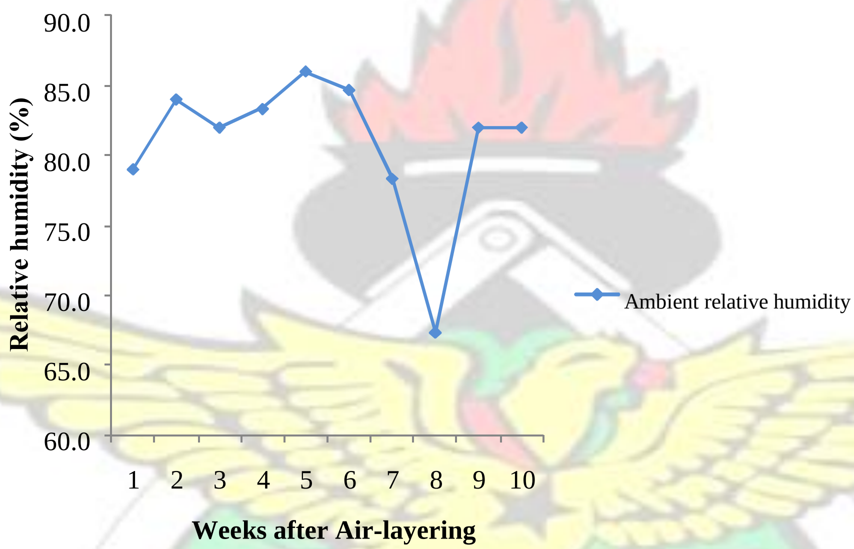


Figure 4.14: Ambient relative humidity over time

4.3.3 Survival and Rooting of *Ixora coccinea* Air-Layers

There was no significant difference among the different media used on the number of days to root emergence, survived air-layers, rooted air-layers and root length (cm) of the air-layers of Ixora. However, air-layers in 50% palmix+50% coconut coir had their roots emerging earlier (2.59 days). The 100% palmix and 50% palmix+50% teak sawdust both recorded the highest (1.05) rooted air-layers. The air-layers in 50% palmix+50% teak sawdust had the longest root length (1.96 cm).

4.3.4 Survival and Rooting of *Ficus benjamina* cv. Starlight Air-Layers There were also no significant differences between the different media used on the number of days to root emergence, survived air-layers, rooted air-layers and root length (cm) of the air-layers of Ficus. Air-layers in 100% palmix showed early appearance (3.18 days) of roots, 100% topsoil, 50% teak sawdust+50% coconut coir and 50% palmix+50% coconut coir had more survived (1.22) and rooted air-layers (1.22) among the media. The 50% palmix+50% coconut coir developed longer (2.79 cm) root lengths.

4.3.5 Survival and Rooting of *Thuja occidentalis* Air-Layers

The different media used for the air-layering in Thuja had significant (Table 4.8) effects on number of days to root emergence and length (cm) of roots per air-layer. There were significant (P = 0.0011) differences among the media, such that air-layers in 50% palmix+50% teak sawdust (7.49 days) took 2.5 times more days for its roots to emerge than air-layers in 50% teak sawdust+50% coconut coir (2.96 days). There were highly significant (P = 0.0000) differences for the root length per air-layer among the different media. Air-layers in 50% palmix+50% teak sawdust recorded the longest root length (2.56 cm) followed by 50% teak sawdust+50% coconut coir (0.88 cm) among the soilless media. Thus air-layers in 50% palmix+50% teak sawdust (Plate 4.8a and 4.8b) had root lengths 2.9 times longer than air-layers in

50% teak sawdust+50% coconut coir (Plate 4.9a and 4.9b).

Table 4.8: Effect of media on number of days to root emergence and root length (cm) of *Thuja occidentalis* air-layers

Media	Days to Root Emergence	Root Length (cm)	Lsd (0.05) 2.84
100% Topsoil	0.71	0.71	
100% Palmix	0.71	0.71	
50% Teak sawdust+50% Coconut coir	2.96	0.88	
50% Palmix+50% Coconut coir	0.71	0.71	
50% Palmix+50% Teak sawdust	7.49	2.56	
50% Palmix+25% Teak sawdust+25% Coconut coir	0.71	0.71	

0.52

Plate 4.8a: Rooted air-layer in 50% palmix+50% teak sawdust of *Thuja occidentalis*

Plate 4.8b: Closer view of rooted air-layer in 50% palmix+50% teak sawdust of *Thuja occidentalis*

Plate 4.9a: Rooted air-layer in 50% teak sawdust+50% coconut coir of *Thuja occidentalis*

Plate 4.9b: Closer view of rooted air-layer in 50% teak sawdust+50% coconut coir of *Thuja occidentalis*

5.0 DISCUSSION

5.1 PHYSICO-CHEMICAL COMPOSITION OF THE SIX DIFFERENT MEDIA

5.1.1 Physical Properties

The texture of the soilless media could have small pore spaces due to their relatively small particle sizes. This is in agreement with Landis *et al*. (1990) and Pasian (1997), who stated that smaller pores present higher resistance to water flow, which in turn increases water holding capacity. Handreck and Black (1999), also stated that no matter how perfect a growing medium may be in all other ways, unless it contains and continues to contain, enough water for plant growth, it is useless. In this study, all the soilless media had high water holding capacities ranging from 110% to 595% which implied that when used in propagation, the media could reduce the frequency of watering. Hartmann *et al*. (2002) and Kessler (2002), also drew similar implications. The water holding capacity of the 100% topsoil was low due to its sandy-loam nature with larger pore spaces and enhanced infiltration rate as compared to the soilless media.

Although the water holding capacities of the soilless media were high, the air porosities were also high in contradiction of Pasian (1997), and Landis *et al*. (1990), who stated that increasing aeration decreases water retention and vice versa. Handreck and Black (1999), stated that between 10% and 50% of the volume of a medium in a container should contain air immediately after drainage has stopped. The media used in this study had percentage air-porosities between 40% and 95%, and were therefore sufficiently porous to allow for excess water to drain out of the medium and provided adequate penetration of oxygen (Hartmann *et al*., 2002), which provides adequate gas exchange between the roots and the atmosphere in order to provide energy for uptake of water and nutrients for root growth (Kessler, 2002). Mahmood (2005), also stated that for a good organic mix the desired water holding capacity should be 40%-50%.

5.1.2 Chemical Properties

The media, according to Kessler (2002), should serve as a reservoir for plant nutrients as plants obtain all essential elements from the growing medium. These elements must also be in available forms; in sufficient quantities; and in proper balance for adequate growth. The soilless media in this study had a high organic matter; nitrogen; potassium; phosphorus; magnesium and calcium contents.

Organic matter content of the soilless media was higher than the topsoil because these were composted. Composting increases the organic matter content of a medium (Handreck and Black, 2002). Handayanto *et al*. (1997), also indicated that the organic matter, a store of nutrients, makes available to plants its nutrients through decomposition and nutrient release of the composted material. The high organic matter of all the soilless media compared to the topsoil is indicative of a high content of nutrients that will be made available to the plants on decomposition by microbial activities.

The availability of nutrients to plants in the growing media changes as pH changes. The pH of the topsoil was higher than all the soilless media because it had low organic matter content than the soilless media. Handreck and Black (1999), reported that as far as maximum nutrients supply is concerned for natural soils, a pH somewhere in the range of 5.5 to 7.5 is desirable. But the effect of pH on nutrient availability in highly organic media-the formulated media used in this experiment-is different from that in natural soils in that the optimum pH range for such media is 0.5 to 1 pH unit lower than for soils. Generally, the pH range for the soilless media used in this experiment was 0.4-1.9 pH units lower than the topsoil. This accounted for the reduction in some nutrients levels for the soilless media at the end of the experiment indicating their usage by the plants for growth. Further, the great majority of the many thousands of species and cultivars of plants produced by nurseries can be grown in organic potting media with pH values in the range of 5.5 to 6.3. The acidic nature of the these soilless media in turn supplies more cations such as Ca^{2+} and Mg^{2+}; improves the availability of other nutrients and enables the media to hold larger supplies of nutrients for plants (Handreck and Black, 1999).

5.2 PROPAGATION OF IXORA, FICUS AND THUJA PROPAGULES

5.2.1 Leaf Production of *Ixora coccinea* Propagules

Heel stem cuttings in 100% topsoil produced significantly the greatest number of leaves in the 4th week than the other treatments probably because the heel stem cuttings had their wounded site healing quickly, stimulating early cell division for the formation of callus and root primordia. It also had a maximum exposed surface area to absorb water and nutrients from the medium. This promoted early root growth and subsequent vegetative growth on the heel stem cuttings. The high temperatures in the poly-propagator compared to those in the media for the first 3 weeks also promoted shoot growth of the heel stem cuttings in the 100% topsoil with the relative humidity being sufficient to keep the stems from drying out.

Among the soilless media, heel stem cuttings in 50% teak sawdust+50% coconut coir also produced more leaves than the other soilless media and stem cutting treatments probably because the heel stem cuttings had greater exposed surface area that resulted in the natural accumulation of auxins. This stimulated cell division which resulted in the formation of callus and root primordia to absorb water and nutrients from the medium for early root growth and subsequent vegetative growth. The high water holding capacity of the medium was efficiently utilized by the stem cuttings in combination with available nutrients from the decomposition of the organic matter for shoot growth. The pH of the 50% teak sawdust+50% coconut coir also promoted the early root growth and that further promoted the development of the leaves as

Ixora coccinea thrives best in acidic soils.

The production of more leaves on the heel stem cuttings in 100% topsoil than the 50% teak sawdust+50% coconut coir can be attributed to the fact that it was welldrained and porous which improved aeration thus enhanced all the chemical and biological process needed for growth and development. High poly-propagator temperatures over media during the first three weeks initiated sprouting ahead of rooting. However, high media temperatures also accounted for early root growth and utilization of media nutrient for growth. These findings are similar to what Shah *et al*. (2006) found when they studied effect of different growing media on rooting Ficus (Amstel Queen) cuttings and realised that high internal temperatures of sawdust caused quick sprouting. The straight stem cuttings in 50% palmix+50% teak sawdust produced the least number of leaves because the cut end of the straight stem was minimally exposed for greater absorption of nutrients and natural accumulations of auxins that would heal the wounded sites quickly for cell division stimulation for root development.

Among the soilless media and as an alternative to the 100% topsoil, the 50% teak sawdust+50% coconut coir produced the second highest number of leaves because it also had a high nutrient and water levels thus making it available for uptake by the plants. The low pH of 5.7 made available nutrients that favoured the root growth in *Ixora coccinea* since it is an acid-loving plant. The 100% palmix produced the least number of leaves because it had low organic matter and consequently less available nutrients for the cuttings to use for leaf formation. Shah *et al*. (2006) also observed similar results when they studied the effect of different growing media on rooting Ficus (Amstel Queen) cuttings and saw that leaf mold gave the best performance in terms of number of leaves. This is as a result of the high organic matter content which increases the water and nutrient holding capacity of the medium. Secondly, the high nitrogen content which play vital role in the vegetative growth of the plant. Further, the high potassium content improved the water utilization capacity of the plant.

Favourable poly-propagator and medium temperature over time in the 100% topsoil and 50% teak sawdust+50% coconut coir sustained the leaf development week after week with the high relative humidity in the poly-propagator kept the stem cuttings from drying out.

Heel stem cuttings produced the greatest number of leaves than the straight stem cuttings over time because it had a bigger surface area which enabled the absorption of nutrients and the natural accumulation of auxins that stimulated cell division resulting in the formation of callus and root primordia for the absorption of water and nutrients from the medium for early root growth. Awan *et al*. (2003), also found similar results found when they worked on response of olive hardwood cuttings to different growth media and basal injuries for propagation. They observed that the 2 basal injury cut treatment gave maximum number of leaves due to maximum exposure area which initiated early root development.

5.2.2 Survival and Growth of *Ficus benjamina* cv. Starlight Propagules The early sprouting observed in the 50% palmix+50% coconut coir compared to the late sprouting in 100% topsoil was probably due to the high medium temperatures from the 1st to 4th week coupled with the higher poly-propagator temperatures and relative humidity which promotes quick sprouting. Although 50% palmix+50% coconut sprouted earlier due to its high medium temperatures compared to the 50% palmix+25% teak sawdust+25% coconut coir, the latter was richer in nutrients thus giving more nourishment to the plants which in turn maintained better survival and growth after they sprouted. Lopez (2008), observed that maintaining air temperature lower than medium temperature retards shoot growth and promotes root development. Furthermore, root initiation in cuttings is temperature-driven but subsequent root growth is strongly dependent on stored food in the stem cuttings (Hartmann *et al*., 2002).

5.2.3 Leaf Production of *Ficus benjamina* cv. Starlight Propagules

The higher leaf production recorded for straight stem cuttings in 50% palmix+50% teak sawdust compared to the heel stem cuttings in 100% topsoil in the 8th and 9th weeks after planting could be attributed to the fact that medium had high temperatures favouring early shoot growth, it was well-drained and porous thus promoting early root growth which in turn effectively used up the available nutrient stored in the medium for further growth. In comparison with the heel stem cuttings in 50% palmix+50% coconut coir the same trend was observed although sprouting was a little late in 50% palmix+50% teak sawdust than the former. This study is in contrast with what Awan *et al*., (2003) found that no basal injury gave late sprouting because the cambium was not exposed fully to develop root primordial when they studied the response of olive hardwood cuttings to different growth media and basal injuries.

Leaf production in the different media showed that 50% palmix+50% teak sawdust developed more leaves because it had more sprouted and rooted cuttings that utilized the high organic matter content which through decomposition also provided the other nutrients for absorption by the stem cuttings. The higher number of leaves was probably facilitated by the higher 50% palmix+50% teak sawdust temperatures than 50% palmix+50% coconut coir over time. The results were similar to what Shah *et al*. (2006) found with leaf mold medium which had maximum number of leaves as a result of the high organic matter content which increases the water and nutrient holding capacity of the medium. In addition, the high nitrogen content play a vital role in vegetative growth of the plant.

Straight stem cuttings had more leaves than the heel stem cuttings probably due to early sprouting and thereafter early root growth thus using more of the available nutrients that was provided in the media to further develop more leaves. Although most of the stem cuttings died during the experimental period, heel stem cuttings were the worst affected. This resulted in the straight stem cuttings having a higher number of survived and rooted cuttings. The number of leaves was however low in the 6th week because most of the leaves dropped on both stem cuttings due to disease incidence.

5.2.4 Survival and Growth of *Thuja occidentalis* Propagules

The number of rooted cuttings was high in 50% teak sawdust + 50% coconut coir probably because it had a high organic matter content which enabled the medium to have high water holding capacity thus encouraging enough uptake of water and nutrients to the stem cuttings for root development. The lower pH also made more available nutrients for absorption by the cuttings. Handreck and Black (1999), reported that the coniferous shrubs and trees prefer lower pH levels about 5.0-5.5. High poly-propagator and medium temperature supported by high relative humidity promoted more root development and prolific sprouting, respectively, of the *Thuja occidentalis* propagules over time. The longer root lengths in 50% palmix+50% coconut coir was probably due to its high air-porosity which made the roots travel longer distances in the medium to absorb the nutrients and water. Studies conducted by Shah *et al*. (2006) on the effect of different growing media on Ficus (Amstel Queen) cuttings revealed that leaf mold medium gave the maximum number of roots because of the availability of essential nutrients at the surface of the medium for effective absorption so as to produce more roots.

5.3 AIR-LAYERING OF IXORA, FICUS AND THUJA

5.3.1 Survival and Growth of *Thuja occidentalis* Air-Layers

The air-layers in 50% teak sawdust+50% coconut coir developed visible roots earlier than air-layers in 50% palmix+50% teak sawdust due to higher medium temperatures. However, the roots of air-layers in 50% palmix+50% teak sawdust could have utilized the available water and nutrients much more for further root growth. Another reason why generally there were fewer roots in the air-layers was that the stock plant was over-matured. Hartmann *et al*. (2002) reported that in airlayering, stem older than one year can be used in some cases but rooting is less satisfactory.

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Although the demand for *Ixora coccinea*, *Ficus benjamina* cv. Starlight and *Thuja occidentalis* are high in Ghana for landscape works, wreaths, bouquets, and cutflowers, they are very difficult-to-root. To solve this problem, five soilless media were formulated and evaluated to find the best medium that would promote rooting in these difficult-to-root plants by propagation through two stem cutting types and air-layering.

All the soilless media formulated were able to promote rooting and growth of the three stock plants and was facilitated through the provision of plant nutrients; the high water holding capacities and the high air-porosity which ensured gaseous exchange and better drainage. For stem cutting propagation, 50% teak sawdust+50% coconut coir was the best medium in terms of physical and chemical properties. It also produced the highest number of rooted cuttings with long roots followed by 50% palmix+25% teak sawdust+25% coconut coir. Heel stem cuttings produced more leaves than the straight stem cuttings in *Ixora coccinea* but for *Ficus benjamina* cv. Starlight, straight stem cuttings produced more leaves. The best soilless medium for air-layering of *Thuja occidentalis* was found to be the 50% palmix+50% teak sawdust medium.

It is therefore recommended that the 50% teak sawdust+50% coconut coir and variations of it, should be evaluated for other difficult-to-root ornamental plants to confirm its use as the best soilless medium. Further, the 50% teak sawdust+50% coconut coir soilless medium should be evaluated for use on other ornamental propagules to ascertain its wide application in the ornamental industry. It is also recommended that heel stem cuttings should be used for stem cutting propagation.

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APPENDICES

Appendix 1.0: ANOVA tables for stem cutting propagation of Ixora, Ficus and Thuja

1. ANOVA Table for Days to Sprouting of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	2.7590	1.37952		
MEDIUM	5	2.5941	0.51883	0.32	0.8944
CUTS	1	1.7733	1.77334	1.10	0.3056
MEDIUM*CUTS	5	6.8044	1.36088	0.84	0.5330
Error	22	35.4604	1.61183		
Total	35	49.3913			

Grand Mean 3.1003 CV 40.95

2. ANOVA Table for Survived Cuttings of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	1.29037	0.64519		
MEDIUM	5	0.85052	0.17010	1.36	0.2782
CUTS	1	0.12250	0.12250	0.98	0.3336
MEDIUM*CUTS	5	0.55263	0.11053	0.88	0.5095
Error	22	2.75709	0.12532		
Total	35	5.57312			

Grand Mean 1.3772 CV 25.70

3. ANOVA Table for Rooted Cuttings in Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	0.04335	0.02168		
MEDIUM	5	0.06503	0.01301	0.60	0.7004
CUTS	1	0.06502	0.06502	3.00	0.0973
MEDIUM*CUTS	5	0.06503	0.01301	0.60	0.7004
Error	22	0.47685	0.02168		
Total	35	0.71528			

Grand Mean 0.7525   CV 19.56

4. ANOVA Table for Root Length per Cutting of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	0.81641	0.40820		
MEDIUM	5	0.90435	0.18087	0.72	0.6131
CUTS	1	0.67514	0.67514	2.70	0.1146
MEDIUM*CUTS	5	0.90435	0.18087	0.72	0.6131
Error	22	5.50153	0.25007		
Total	35	8.80176			

Grand Mean 0.8469   CV 59.04

5. ANOVA Table for Leaf Development at 4WAP of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	1.6004	0.80020		
MEDIUM	5	6.0913	1.21826	8.80	0.0001
CUTS	1	1.1378	1.13778	8.21	0.0090
MEDIUM*CUTS	5	3.1318	0.62636	4.52	0.0055
Error	22	3.0472	0.13851		
Total	35	15.0085			

Grand Mean 1.1056   CV 33.66

6. ANOVA Table for Leaf Development at 5WAP of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	2.2906	1.14528		
MEDIUM	5	6.3700	1.27399	5.40	0.0022

CUTS	1	0.6697	0.66967	2.84	0.1062
MEDIUM*CUTS	5	3.1066	0.62132	2.63	0.0518
Error	22	5.1901	0.23591		
Total	35	17.6269			

Grand Mean 1.4658 CV 33.14

7. ANOVA Table for Leaf Development at 6WAP of Ixora

Source	**DF**	**SS**	**MS**	**F**	**P**
REPLICATION	2	4.9829	2.49145		
MEDIUM	5	13.1448	2.62896	8.06	0.0002
CUTS	1	2.4492	2.44922	7.51	0.0119
MEDIUM*CUTS	5	4.0048	0.80097	2.46	0.0651
Error	22	7.1747	0.32612		
Total	35	31.7564			

Grand Mean 1.7186 CV 33.23

8. ANOVA Table for Leaf Development at 7WAP of Ixora

Source	**DF**	**SS**	**MS**	**F**	**P**
REPLICATION	2	7.2904	3.64521		
MEDIUM	5	11.6520	2.33040	5.35	0.0023
CUTS	1	1.8769	1.87690	4.31	0.0499
MEDIUM*CUTS	5	4.4321	0.88641	2.03	0.1133
Error	22	9.5912	0.43597		
Total	35	34.8426			

Grand Mean 2.0222 CV 32.65

9. ANOVA Table for Leaf Development at 8WAP of Ixora

Source	**DF**	**SS**	**MS**	**F**	**P**
REPLICATION	2	6.4875	3.24375		
MEDIUM	5	12.7281	2.54562	5.40	0.0022
CUTS	1	2.4806	2.48062	5.26	0.0318

MEDIUM*CUTS	5	4.7968	0.95936	2.03	0.1132
Error	22	10.3764	0.47165		
Total	35	36.8694			

Grand Mean 2.0564 CV 33.40

10. ANOVA Table for Leaf Development at 9WAP of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	3.8653	1.93263		
MEDIUM	5	11.8798	2.37596	4.31	0.0070
CUTS	1	1.6002	1.60023	2.90	0.1026
MEDIUM*CUTS	5	2.1295	0.42591	0.77	0.5799
Error	22	12.1325	0.55148		
Total	35	31.6073			

Grand Mean 2.1375 CV 34.74

11. ANOVA Table for Leaf Development at 10WAP of Ixora

Source	DF	SS	MS	F	P
REPLICATION	2	4.4339	2.21697		
MEDIUM	5	12.0994	2.41988	3.89	0.0112
CUTS	1	1.1025	1.10250	1.77	0.1969
MEDIUM*CUTS	5	3.3824	0.67649	1.09	0.3953
Error	22	13.6977	0.62262		
Total	35	34.7159			

Grand Mean 2.1028 CV 37.52

Appendix 1.1: ANOVA tables for stem cutting propagation of Ficus

1. ANOVA Table for Days to Sprouting of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.03807	0.01903		
MEDIUM	5	0.16877	0.03375	2.92	0.0361

CUTS	1	0.00694	0.00694	0.60	0.4467
MEDIUM*CUTS	5	0.09766	0.01953	1.69	0.1792
Error	22	0.25447	0.01157		
Total	35	0.56590			

Grand Mean 2.9950 CV 3.59

2. ANOVA Table for Survived Cuttings of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.04335	0.02168		
MEDIUM	5	0.75863	0.15173	4.05	0.0093
CUTS	1	0.00722	0.00722	0.19	0.6647
MEDIUM*CUTS	5	0.12283	0.02457	0.66	0.6601
Error	22	0.82365	0.03744		
Total	35	1.75568			

Grand Mean 0.8375 CV 23.10

3. ANOVA Table for Rooted Cuttings of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.10115	0.05058		
MEDIUM	5	0.49130	0.09826	2.82	0.0407
CUTS	1	0.00000	0.00000	0.00	1.0000
MEDIUM*CUTS	5	0.26010	0.05202	1.49	0.2321
Error	22	0.76585	0.03481		
Total	35	1.61840			

Grand Mean 0.8233 CV 22.66

4. ANOVA Table for Root Length (cm) of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.9631	0.48154		
MEDIUM	5	2.3882	0.47764	1.30	0.2993
CUTS	1	0.4075	0.40747	1.11	0.3034
MEDIUM*CUTS	5	1.0678	0.21357	0.58	0.7134
Error	22	8.0730	0.36695		
Total	35	12.8996			

Grand Mean 0.9581 CV 63.23

5. ANOVA Table for Leaf Development at 4WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	2.5542	1.27712		
MEDIUM	5	6.8978	1.37956	2.09	0.1046
CUTS	1	3.1270	3.12700	4.75	0.0404
MEDIUM*CUTS	5	4.1719	0.83438	1.27	0.3134
Error	22	14.4943	0.65883		
Total	35	31.2452			

Grand Mean 2.1914 CV 37.04

6. ANOVA Table for Leaf Development at 5WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	1.3752	0.68761		
MEDIUM	5	2.4562	0.49123	0.72	0.6175
CUTS	1	2.4911	2.49114	3.64	0.0697
MEDIUM*CUTS	5	4.6841	0.93682	1.37	0.2745
Error	22	15.0725	0.68511		
Total	35	26.0791			

Grand Mean 1.5892 CV 52.08

7. ANOVA Table for Leaf Development at 6WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.8856	0.44279		
MEDIUM	5	2.1383	0.42765	1.11	0.3834
CUTS	1	2.2600	2.26001	5.87	0.0241
MEDIUM*CUTS	5	2.4561	0.49122	1.28	0.3097
Error	22	8.4720	0.38509		
Total	35	16.2120			

Grand Mean 1.0911 CV 56.87

8. ANOVA Table for Leaf Development at 7WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.65741	0.32870		
MEDIUM	5	1.55748	0.31150	1.87	0.1417
CUTS	1	0.05063	0.05063	0.30	0.5875
MEDIUM*CUTS	5	2.20966	0.44193	2.65	0.0510
Error	22	3.67413	0.16701		
Total	35	8.14930			

Grand Mean 0.8497 CV 48.09

9. ANOVA Table for Leaf Development at 8WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.45212	0.22606		
MEDIUM	5	1.29112	0.25822	2.18	0.0932
CUTS	1	0.07023	0.07023	0.59	0.4494
MEDIUM*CUTS	5	1.76113	0.35223	2.98	0.0336
Error	22	2.60448	0.11839		
Total	35	6.17907			

Grand Mean 0.8325 CV 41.33

10. ANOVA Table for Leaf Development at 9WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.30617	0.15309		
MEDIUM	5	1.41506	0.28301	3.04	0.0312
CUTS	1	0.15734	0.15734	1.69	0.2074
MEDIUM*CUTS	5	1.72922	0.34584	3.71	0.0138
Error	22	2.05129	0.09324		
Total	35	5.65909			

Grand Mean 0.8244 CV 37.04

11. ANOVA Table for Leaf Development at 10WAP of Ficus

Source	DF	SS	MS	F	P
REPLICATION	2	0.82095	0.41047		
MEDIUM	5	1.85283	0.37057	2.32	0.0780
CUTS	1	0.44890	0.44890	2.81	0.1080
MEDIUM*CUTS	5	1.25833	0.25167	1.57	0.2088
Error	22	3.51758	0.15989		
Total	35	7.89860			

Grand Mean 0.8700 CV 45.96

Appendix 1.2: ANOVA tables for stem cutting propagation of Thuja

1. ANOVA Table for Survived Cuttings of Thuja

Source	DF	SS	MS	F	P
REPLICATION	2	1.99209	0.99604		
MEDIUM	5	0.40975	0.08195	0.78	0.5754
CUTS	1	0.07023	0.07023	0.67	0.4226
MEDIUM*CUTS	5	0.34466	0.06893	0.66	0.6607
Error	22	2.31418	0.10519		
Total	35	5.13090			

Grand Mean 1.6647 CV 19.48

2. ANOVA Table for Rooted Cuttings of Thuja

Source	DF	SS	MS	F	P
REPLICATION	2	0.10792	0.05396		
MEDIUM	5	2.01640	0.40328	4.12	0.0086
CUTS	1	0.02151	0.02151	0.22	0.6437
MEDIUM*CUTS	5	0.88639	0.17728	1.81	0.1518
Error	22	2.15108	0.09778		
Total	35	5.18330			

Grand Mean 1.1017 CV 28.38

3. ANOVA Table for Root Length (cm) of Thuja

Source	DF	SS	MS	F	P
REPLICATION	2	1.5505	0.77526		
MEDIUM	5	13.3768	2.67535	6.94	0.0005
CUTS	1	0.8867	0.88674	2.30	0.1437
MEDIUM*CUTS	5	1.5236	0.30473	0.79	0.5681
Error	22	8.4850	0.38568		
Total	35	25.8227			

Grand Mean 1.5375 CV 40.39

Appendix 2.0: ANOVA tables for air-layering propagation of Ixora

1. ANOVA Table for Days to Root Emergence of Ixora Air-Layers

Source	DF	SS	MS	F	P
MEDIUM	5	42.175	8.4349	0.81	0.5649
Error	12	125.076	10.4230		

Total	17	167.251

Grand Mean 3.1344   CV 103.00

2. ANOVA Table for Survived Air-Layers of Ixora

Source	DF	SS	MS	F	P
MEDIUM	5	0.00000	0.00000	M	M
Error	12	0.00000	0.00000		
Total	17	0.00000			

Grand Mean 1.2200   CV 0.00

3. ANOVA Table for Rooted Air-Layers of Ixora

Source	DF	SS	MS	F	P
MEDIUM	5	0.24565	0.04913	0.68	0.6472
Error	12	0.86700	0.07225		
Total	17	1.11265			

Grand Mean 0.9083   CV 29.59

4. ANOVA Table for Root Length per Air-Layer of Ixora

Source	DF	SS	MS	F	P
MEDIUM	5	2.3775	0.47550	0.49	0.7800
Error	12	11.7239	0.97699		
Total	17	14.1014			

Grand Mean 1.3689   CV 72.21

Appendix 2.1: ANOVA tables for air-layering propagation of Ficus

1. ANOVA Table for Days to Root Emergence of Ficus Air-Layers

Source	DF	SS	MS	F	P
MEDIUM	5	7.8228	1.56457	0.64	0.6733
Error	12	29.2913	2.44094		
Total	17	37.1142			

Grand Mean 3.8872 CV 40.19

2. ANOVA Table for Survived Air-Layers of Ficus

Source	DF	SS	MS	F	P
MEDIUM	5	0.13005	0.02601	0.60	0.7013
Error	12	0.52020	0.04335		
Total	17	0.65025			

Grand Mean 1.1350 CV 18.34

3. ANOVA Table for Rooted Air-Layers of Ficus

Source	DF	SS	MS	F	P
MEDIUM	5	0.13005	0.02601	0.60	0.7013
Error	12	0.52020	0.04335		
Total	17	0.65025			

Grand Mean 1.1350 CV 18.34

4. ANOVA Table for Root Length per Air-Layer of Ficus

Source	DF	SS	MS	F	P
MEDIUM	5	3.5387	0.70774	1.26	0.3429
Error	12	6.7526	0.56272		
Total	17	10.2913			

Grand Mean 2.1022 CV 35.68

Appendix 2.2: ANOVA tables for air-layering propagation of Thuja

1. ANOVA Table for Days to Root Emergence of Thuja air-layers

Source	DF	SS	MS	F	P
MEDIUM	5	112.202	22.4404	8.78	0.0011
Error	12	30.672	2.5560		
Total	17	142.874			

Grand Mean 2.2139 CV 72.21

2. ANOVA Table for Survived Air-Layers of Thuja

Source	DF	SS	MS	F	P
MEDIUM	5	0.63580	0.12716	2.93	0.0588
Error	12	0.52020	0.04335		
Total	17	1.15600			

Grand Mean 0.9367 CV 22.23

3. ANOVA Table for Rooted Air-Layers of Thuja

Source	DF	SS	MS	F	P
MEDIUM	5	0.63580	0.12716	2.93	0.0588
Error	12	0.52020	0.04335		

Total	17	1.15600

Grand Mean 0.9367   CV 22.23

4. ANOVA Table for Root Length (cm) of Air-Layers of Thuja

Source	DF	SS	MS	F	P
MEDIUM	5	8.31400	1.66280	19.61	0.0000
Error	12	1.01760	0.08480		
Total	17	9.33160			

Grand Mean 1.0467   CV 27.82

Appendix 3.0 Equipments for measuring environmental data

Micronta LCD Indoor/Outdoor Thermometer/Hygrometer Model No. 63-867

ThermoTrace Infrared Thermometer Model No. 15030