VEGETATIVE PROPAGATION OF *Dipterocarpus zeylanicus* (HORA) BY CUTTINGS

By

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DECLARATION

The work is described in this thesis was carried out by me at the Faculty of Applied Sciences under the supervision of Dr. D.M.S.H.K.Ranasinghe and Dr.K.K.D.S.Ranaweera. A report on this has not been submitted to any other University for another degree.

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AFFECTIONATELY DEDICATED TO
MY EVERLOVING
MOTHER AND FATHER

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ABSTRACT

Dipterocarpus zeylanicus, an endemic tree in Sri Lanka offers great potential for bridging the gap between supply and demand of timber in the country. However, at present it has not been widely used as a plantation species. Establishment of plantation by seeds has proved somewhat difficult due to low viability, etc. Genetically uniform planting stock can be obtained rapidly through vegetative propagation.

With the above objective in mind an experiment was conducted to propagate stem cuttings of *D. zeylanicus* using a variety of rooting hormones under both mist and non mist conditions. In all the instances, cuttings of 15 cm length and 0.3-0.4 mm basal diameter with two and half leaves were used. The hormone concentrations used were; Indole Butyric Acid (IBA) 500ppm, 1000ppm and 1500ppm and the commercial hormone Secto (NAA+fungicide). Control did not have any hormone treatments. 5 sets of cuttings were used for each hormone treatment. The medium used was sand. The experiment was conducted under two conditional environments; under an automatic mist and in a non mist polypropagator, a low cost alternative that has also designed to maintain a high humidity through water manipulation.

After the experimental period of 10 weeks, there was a marked difference between the mist and non mist conditions in percentage survival of cuttings. In all the treatments, % survival was higher under mist. In terms of percentage rooting, the cuttings under the non mist propagator did not show rooting at all although callusing was observed in all the treatments at varying success levels. Among the rooting treatments, the highest percentage rooting (38.39%) was shown in the control without rooting hormones closely followed by other hormone treatments. However, the treatment 1000ppm of IBA showed the lowest percentage rooting (11.11%).

From these results, it can be concluded that *D.zeylanicus* can be effectively propagated by stem cuttings under mist conditions.

CONTENTS

		Page number
ABSTRACT		I
ACKNOWLEDGEMENT		II
LIST OF FIGURES		IV
LIST OF TABLES		V
LIST OF PLATES		VI
CONTENTS		VII
ABBREVIATIONS		IX
CHAPTER 1		
1.0	INTRODUCTION	01
1.1	Objectives	02
CHAPTER 2		
2.0	LITERATURE REVIEW	03
2.1	Family-Dipterocarpaceae	03
2.1.1	Distribution of family Dipterocarpaceae	04
2.1.2	Family characteristics	05
2.2	*Dipterocarpus zeylanicus*	06
2.2.1	Distribution and ecology	06
2.2.2	Botanical description	06
2.3	Importance of the Dipterocarps	07
2.4	Vegetative propagation	10
2.4.1	Vegetative propagation by cuttings	12
2.4.2	Non-mist poly propagation	16
2.4.3	Mist propagation	16
2.4.4	Use of growth hormones	17
2.5	Vegetative propagation of *Dipterocarpus. zeylanicus*	18
2.6	Importance of the vegetative propagation of the Dipterocarps	18

CHAPTER 3

3.0 MATERIALS AND METHOD 20
3.1 Experimental site 20
3.2 Non-mist propagator 20
3.3 Propagating beds under Mist condition 20
3.4 Preparation of chemicals 21
3.5 Specimen collection 21
3.6 Preparation of cuttings 21
3.7 Experimental design 22
3.8 Experiment under mist condition 22
3.9 Experiment under non-mist condition 22
3.10 Experiment period 22
3.11 Data collection 22
3.12 Data analysis 23

CHAPTER 4

4.0 RESULTS AND DISCUSSION 28
4.1 Results 28
4.2 Discussion 32

CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS 34

REFERENCES 35

APPENDIX

Appendix 1 39
Appendix 2 45
Appendix 3 49

ABBREVIATIONS

cm -centi meter
FAO -Food and Agricultural Organization
ha -hectare
IAA -Indole Acetic Acid
IBA -Indole Butyric Acid
IUCN -International Union for Conservation Nature
km^2 -square kilo meter
m^2 -square meter
m^3 -cubic meter
mai -mean annual increment
ml -mili leter
mm -mili meter
NAA -Napthalene Acetic Acid
ppm -parts per million

LIST OF FIGURES

Figure 3.1:	Randomized design of non-mist propagator (Block II)	24
Figure 3.2:	Randomized design of mist propagator (Block I)	24

LIST OF TABLES

2.1	Dipterocarpacae genera and number of species present in Sri Lanka	04
2.2	Threat status of Sri Lankan Dipterocarps	04
3.1	Environmental conditions through out the rooting period	23
4.1	Average data on survival, rooting, callusing from non rooted cuttings, average number of roots/cuttings, average length of roots/cuttings, maximum length of roots/cutting in *Dipterocarpus zeylanicus* under mist conditions	28
4.2	Average data on survival, rooting, callusing from non rooted cuttings, average number of roots/cuttings, average length of roots/cuttings, maximum length of roots/cutting in *Dipterocarpus zeylanicus* under non-mist conditions	29
4.3	Average data on % survived, % rooted, number of roots/cuttings, maximum length of roots/cutting, and average length of roots/cuttings against different treatments in different replications with the cuttings of *Dipterocarpus zeylanicus* under mist condition	30

LIST OF PLATES

3.1	Cutting under mist	25
3.2	Non mist poly propagator	25
3.3	Cuttings in non-mist propagator (after 8 weeks period)	26
3.4	Used hormones (Secto and IBA)	26
3.5	Prepared cutting for planting	27
4.1	Cuttings that had the longest roots (for each treatment)	31
4.2	Callus formed on the cutting	31

CHAPTER 1

1.0 INTRODUCTION

The world forest cover is being declined at an alarming rate. The annual average decline of the forest cover during the period of 1991-1995 was about 0.3%. This figure is higher for tropical forests. Average annual depletion of natural forests in Asia between 1990 and 1995 was 8.9%. (World Resource Institute, 1998).

Sri Lanka has a land area of 65610 km^2. In 1881, out of that extent, 84% was under high forest cover (Nanayakkara, 1987). In 1961, 44% or 2.87 million ha of the land area was covered by high forest (Sahajananthan, 1987). However, the forest cover of the country rapidly decreased due to number of reasons. The rate of deforestation in Sri Lanka was about 42000 ha. per annum for the 1970's and 1980's (Pushparajah, 1987). Average annual percent declination of total forests in 1980-1990 and 1990-1995 is subsequently 1.0% and 1.1%. Average annual percent depletion of natural forests in 1980-1990 and 1990-1995 was 1.4% and 1.2% respectively (World Resource Institute, 1998).

A wide range of factors contributes to deforestation and forest degradation. One of the main underlying causes is the poverty, which is the often combined with landlessness and poor land tenure system. The other main causes of forest destruction are large agricultural and settlement projects, reservoir and hydropower projects, shifting cultivation, and conversion of natural forests to plantations and arable lands. In mid 1970's, annual consumption of wood and wood products for all purposes was equal to about 1.2m^3/ha of closed forests. This is closed to the very roughly estimated mean annual increment for those forests of 1.1m^3/ha/a (King, 1975).

Establishment of man made forest plantations helps to compensate this loss of forest cover and to meet part of the present and future demand of timber, fuel wood, and other forest products. Raising plantations will also help to improve quality of environment and reduce forest related natural hazards.

In early 90's, the total extent of man-made plantations in Sri Lanka is 139000 ha. Average annual percent change between 1980 and 1990 is 6% (World Resource Institute, 1998). In 1995, total extent of plantations under the Forest Department was 131309ha (Department of Census and Statistics, 1998). Sri Lankan forest plantations consist of mostly of monocultures. The number of species used is also a very few. Extent of polyculture plantations under the Forest Department in 1995 was 10659 ha (Department of Census and

Statistics, 1998). All the other forest plantations were monocultures. Indigenous hardwood species, having good timber qualities, have not been tried in large scale. Teak, Margosa, *Eucalyptus* species and *Pinus* species are the major contributors of the forest plantations of Sri Lanka.

Dipterocarpus zeylanicus (Hora), which is the tree species in the present study, is endemic to Sri Lanka. It offers great potential for industrial and commercial exploitation. It is an important timber tree and can be considered as a medium heavy timber. *D. zeylanicus* wood is an important plywood species of the island as some other Dipterocarps in the other countries. It is also used for railway sleepers and as a construction timber (FAO, 1985).

At present, there are no large-scale plantations of *D. zeylanicus* in Sri Lanka. Some nurseries of the Forest Department produce plants for distribution among villagers as part of social forestry programme. In this connection, plants were obtained by seeds collected from natural forests.

Collection and storage of *D. zeylanicus* seeds are somewhat difficult and time consuming, apart from being an expensive method. Stored fruits of Dipterocarps lost their viability rapidly (Yap, 1981). The lack of dependable supply of seeds can be overcome by the application of vegetative propagation method.

Vegetative propagation is widely used in forestry projects especially for man made plantations. Genetic uniformity and similar growth and form for planting stock can be obtained by vegetative propagation. The multiplication of desired hybrids are possible without segregation of characters. There are several other advantages including possibility to utilize maximum genetic gains in a shorter time. It also helps to decrease rotation and increase yield and quality of timber.

1.1 OBJECTIVES OF THE STUDY

The objective of this study is to assess the most appreciate method of propagation of *Dipterocarpus zeylanicus* by cuttings. A series of hormone levels were applied under both mist and non mist conditions in this regard.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 FAMILY DIPTEROCARPACEAE

Primary rain forest trees, having evergreen conditions and contributes in enormous sizes to make family Dipterocarpaceae.

Earlier there were three subfamilies in the family Dipterocarpaceae namely Dipterocarpoidae, Monotoidae and Pakaraimoidae. Dipterocarpoidae was the largest subfamily while Pakaraimoidae had one genus with one species (Jacobs, 1981). Subfamily Monotoidae contains African species and Pakaraimoidae was an American subfamily. Kostermans (1985) have demonstrated that Monotoidae from Africa and Pakaraimoidae from America represent a family different from Asian Dipterocarpoidae. Since the subfamily Monotoidae and Pakaraimoidae has been separated from the Dipterocarpoidae, the family Dipterocarpaceae is restricted to the tropical Asia (Kostermans, 1992).

Genera of Diptrocarpaceae can be distinguished into two basic groups according to the chromosome number. Those are known as 7 (*Shorea*, *Hopea*) and 11 (*Dipterocarpus*, *Vatica*, *Stemonoporus*).

According to the Revised handbook to the Flora of Ceylon (1980) there are 15 genera with 580 species all over the Asian tropics. According to Ashton (1980) 7 genera with 45 Dipterocarp species are in Sri Lanka.

Kostermans (1992) identified 18 genera with about 580 species of Dipterocarps in the recent studies. Nine genera with 58 species can be seen in Sri Lanka and all these species are endemic to the island. Of the nine genera, two are endemic namely *Doona* and *Stemonoporus*. Earlier, those were under *Shorea* as sections. (Kostermans, 1992). Sri Lankan species belong in to each genus are listed in the table 2.1.

Table 2.1. Dipterocarp genera and number of species present in Sri Lanka.

Genera	Number of species
Dipterocarpus	4
Suneptea	1
Vatica	4
Vateria	1
Hopea	4
Shorea	6
Doona	10
Balanocarpus	2
Stemonoporus	26

According to IUCN, Out of 58 species of Sri Lankan Dipterocarps, 53 are listed as threatened species in Sri Lanka (IUCN Sri Lanka, 2000). Threat status according to the IUCN is given in table 2.2.

Table 2.2. Threat status of Sri Lankan Dipterocarps.

Globally threatened species				Nationally threatened species	
Endangered	Indeterminate	Vulnerable	Rare	Threatened	Highly threatened
14	7	7	7	26	27

However, *Dipterocarpus zeylanicus* is not listed as threatened.

2.1.1 DISTRIBUTION OF FAMILY DIPTEROCARPACEAE

Family Dipterocarpaceae can be considered as a purely Asiatic family and it is confined to the South and South East Asia (Bawa and Hudley, 1991). This family is distributed from India through Bangladesh, Burma, South China, Thailand and Indochina to Malesia (Malaysia, Indonesia, Philippines, New Guinea) up to the Entrecosteaux islands (Kostermans, 1992).

In Sri Lanka, species of family Dipterocarpaceae is restricted mainly to the wet zone occurring only in primary rain forests. No species are known to occur in secondary forests

exclusively. Dipterocarps occur below 1600m altitude. Concentration of the species in appearance below 300-400m above mean sea level.

Species of this family occur in 14 of the 23 districts of the island and concentration is clearly in the wet South Western part of the country (Jacobs, 1981).

2.1.2 FAMILY CHARACTERISTICS

Family characteristics of Dipterocarpaceae are described by Kostermans (1992) as follows in his book named 'A Handbook of the Dipterocarpaceae of Sri Lanka'.

Mostly tall, rarely very small (Stemonoporus), usually evergreen trees, often buttressed with rather smooth to flaky to fissured bark, usually with an indumentum of unicellular stellate or simple hairs or of scales. Sometimes multicellular long stalked (Vateria) or capitate (Dipterocarpus) hairs. Branching first monopodial, later sympodial in emergent species. Leaves spirally arranged, simple with entire or sinuate, but not crenate margins with a more or less pronounced geniculate petiole, penninerved, rarely obscurely triplinerved, often with hairy domatia in the axils between midrib and lateral ribs, tertiary nerves reticulate or scalariform. Stipules large or small, persistent or fugacious, leaving short to amplexicaul conspicuous scars. Inflorescence paniculate, usually racemes, terminal, or axillary sometimes reduced to a single flower. Bracts and bracteoles paired, tiny or large, persistent or fugacious. In *Stemonoporus moonii* numerous stipules on the apical branches. Flowers second or distichous, bisexual, actinomorphic, scented, nodding. Calyx persistent, 5-merous, 2-5 sepals usually greatly enlarged in fruit, erect, wing like; sepals either free to base, imbricate in bud, remaining so or becoming valvate in fruit, or fused at base, forming a cup, enclosing more or less the nut, free or agnate to it. Corolla 5-merous, contorted, bases of petals connate, the corolla falling as a rosette, or free. Stamens (in Ceylon species) 10 to many, 1-3 verticillate, hypogynous or subperigynous, centrifugal; anthers erect with (2-) 4 pollensacks, opening by longitudinal slits (in *Stemonoporus pseudomonoporus*), usually laterally dehiscent, connective protruded into a long and slender or short and thick appendage or appendages; filaments always narrowly triangular, flattened, free or connate at base, often cohering with the petals when falling. Pollen grains 2 celled at anthesis. Ovary superior or semi inferior, 3-, rarely 2- locular; style sometimes thickened at its base into a stylopodium; stigma obscure or prominent, lobed. Ovules 2 (-3) in each loculament, axillary, pendulous, usually anatropous, bitigmate with ventral raphe and superior micropyle. Fruit dehiscent or not, one-seeded with woody or thin pericarp aliform erect enlarged sepals, or sepals thinner, pressed to the base of the fruit or patent, not much enlarged, or woody, hard,

pointing downwards (Vatica), pericarp splitting irregularly (part of stemonoporus) or by longitudinal valves. Polygonum type of embryo sac development; endosperm of the nuclear type. Ripe seeds usually without endosperm, oily, cotyledons usually unequal with one more or less including the other, laminar, or fleshy, entire or lobed and folded enclosing the radicle. Germination is epigeal or hypogeal. Wood with resin channels.

2.2 *Dipterocarpus zeylanicus*

Dipterocarpus zeylanicus belongs to genus *Dipterocarpus*, which have about 69 species in Asia (Kostermans, 1992). Three other endemic *Dipterocarpus* species are occur with *Dipterocarpus zeylanicus* in Sri Lanka.

D. zeylanicus is an important and common tree species in the lowland and wet evergreen forests. It is called Hora in Sinhala. This was formerly identified as a *D. indicus.* After that Thwaites identified it as a *D. turbinatus.*

2.2.1. DISTRIBUTION AND ECOLOGY

A common species found in the lowland wet evergreen forests where it occurs generally widespread below 1000m altitude (Kostermans, 1992; Ashton, 1980; FAO, 1985). It is distributed in wet and intermediate zones and often extends to lowland semi evergreen forests (Andrews, 1961).

Gregarious mixed Dipterocarp forests with characteristic forest type can be seen specially on riverbanks and well drained alluvium. *Dipterocarpus zeylanicus* is also occurring in a few scattered localities on permanently moist, well drained soils in the intermediate zone as Lunugala, Moneragala, Madulkelle and Matale (FAO, 1985; Ashton, 1980; Kostermans, 1992).

In the wet evergreen forests that have stratification, the top canopy consists essentially of Dipterocarps among which this species is predominant. In the semi evergreen forests, this species occupying the emergent layer. Flowering occurs in February and is fairly regular.

2.2.2. BOTANICAL DESCRIPTION

Usually *D. zeylanicus* is an evergreen tree and it can be sized up to 40m tall and 135cm dbh or 4m in girth. Low rounded buttresses can be seen when mature. Dense crown is hemispherical, tending to remain oblong and monopodial if isolated. Pale orange-brown bark initially smooth and pale verrucose lanticeolate and irregular flaky.

Young parts more or less densely, evenly buff pubescent, and caducous on midrib below petiole. Twig and raceme persistent on buds, outside of stipules, ovary and part of corolla exposed in bud elsewhere fugacious.

Twigs are thick, 6-10mm in diameter, becoming dark brown with prominent pale amplexicaul stipules scars. Leaf bud is lanceolate and acute. It is up to 15 x 6mm in size.

Leaves are subaggregate and thickly coriaceous. Leaf shape is ovate to elliptic (in young trees). Size of leaves can be changed from 10 x 7.5cm to 23 x 14cm. Broad tapering acumen and obtuse to sub cordate base can be seen. 15-18 pairs of straight, close ascending ribs are present. They are prominent beneath and narrowly depressed above. Petioles are 2-5cm long and ca.2-3mm in diameter.

Raceme up to 14cm long and at bases its up to 3mm in diameter. When it fruit, auxillary with long branches, hanging in dense pendent masses from near the ends of the twigs. Flower buds are fusiform and up to 25 x 8mm in size. 15 stamens are present and connectival appendage shorter than anther. Style and stylopodium are columnar and pubescent in the basal two thirds. Flowers are purplish red in color.

Fruit calyx tube is subglobulose and up to 25cm in diameter with 5 more or less prominent or becoming smooth or drying. The two long wings are lorate, obtuse and up to 33 x 3cm in size. They are tapering to ca. 8mm wide at the subauriculate base. The three short lobes are relatively large oblong, obtuse and up to 3 x 2cm in size.

Young tree leaves are elliptic and lamina up to 45 x 16cm in size with up to 22 pairs of ribs. Ribs and midribs are in beneath; petiole and twig are persistently pubescent.

2.3. IMPORTANCE OF DIPTEROCARPS

Major importance of Dipterocarp species is its timber value. Dipterocarp species constitute about 70% of the commercial stock in the tropical forest of the South Asia (Zabala, 1993). Most of the volume of commercial hardwood taken from South East Asian tropical rain forests comes from the family Dipterocarpaceae. Dipterocarp wood makes up 25% of the world trade of hard wood (Smits, 1987). Their use in reforestation is reasonably justified, because, they already have taken an important place in the domestic and world trade in hard wood. They produce long, straight boles and have good wood qualities.

Most of the heartwoods of Dipterocarps can be categorized as a resistant or moderately resistant to the decay as the *Dipterocarpus zeylanicus*. But, some species like *Dipterocarpus glanduloses* (Dorana) are subjected to severe insect attacks (Vivekanandan,). However, few species of insects and diseases are known to affect Dipterocarps.

According to the decay resistance of wood, different uses can be obtained from those species. Normally, Dipterocarps can be considered as a medium heavy timber and they absorb preservatives easily (Kostermans, 1992).

D. zeylanicus is an important timber tree (Kostermans, 1992; Ashton, 1980). It is extensively used for railway sleepers (FAO, 1985) and as a general purpose construction timber (FAO, 1985; Ashton *et.al.*, 1997). This timber is also used for construction of railway wagons and in marine works as jetty piles (FAO, 1985). Dipterocarps are suitable for furniture and cabinet making, but not for superior furniture. Hora wood is an important plywood species of the island (FAO, 1985; Ashton *et.al.*, 1997) as some other Dipterocarp species in the other South Asian countries.

The family holds potential for forestry under a very broad spectrum of tree growth. However, this potential is restricted into the primary rain forests. Both selective felling method and clear cutting and replanting method can be used for silviculture.

The anticipated depletion of the natural forests has forced foresters to consider the potential of plantation to maintain levels of wood production. A possible alternative strategy for increasing the harvestable fraction of the forest is to plant valuable and fast growing trees in plantations.

Dipterocarp trees growing in plantations are performing better than trees in either primary forests or secondary forests (Tan *et.al.*, 1987). The results of the study that was done by Tan *et.al.* (1987) by using *Shorea* species, show that one particular species growing in plantation can achieve mai (in diameter) of about 0.91 cm with range 0.72-1.22 cm per year. At this rate of growth a period of about 45 years is required to produce commercial logs with a diameter of 45 cm dbh. According to this study, they mention that 40-50 year cycle is technically feasible way to produce timber.

Richard *et.al* (1987) showed that some Dipterocarp species has a growth rate of 1.8 cm per year. If this high growth rate can be sustained this tree could reach commercial size in only 25 years from the time of seed germination.

Dipterocarpus alatus cultivated in small plantations shows promising growth and it is reached an average girth of 50 cm (Smitinand and Santisulc, 1981). *Dipterocarpus tuberculatus* have reached 43 cm in 15 years while *Shorea obtusa* gain 39 cm in 15 years (Smitinand and Santisulc, 1981).

Dipterocarp species can also be planted as roadside trees. It gives scenic beauty and commercial value. Some species shows growth of 180 cm of girth in 50 years when planted as roadside trees (Smitinand and Santisulc, 1981).

Not only do most species of Dipterocarps have good timber value, some also yield products useful to people. However, these species are never cultivated by the local people.

Chemicals that can be obtained from Dipterocarps are important in several ways. Most species have oleoresins (balms, resins). Their volatile portion consists mainly of sesquiterpenes such as humilenes, caryophyllenes, copaenes elements and guajenes. The resin fractions of the oleoresins are compounds of triterpenoids and usually consist of neutral and acid components. Some attention has been paid to the phenolic constituents of leaves, bark and seeds. Dipterocarps tend to produce proanthocyanidins and gallic acid derivatives. These polyphenolic compounds are building stones of condensed and hydrolysable tannins, both types of tannins are representing in species characteristic ratios and amount in many species. Seed fats (oils) of Dipterocarps are characterized by strong dominance of stearid and oleic acid (Kostermans, 1992).

The oleoresin of *Dipterocarpus kerrii* has traditionally been used by Malaysian villagers for caulking boats, for torches and for medicinal and other minor purposes (Burkill, 1935). Essential oils from the oleoresin have been used as fixatives in perfumes by essential oil manufacturers in Singapore (Gianno, 1986). However, the resinous fraction of the oleoresin has not been exploited commercially (Ibrahim *et.al.*, 1987).

Most of the Dipterocarps have medicinal value. *Dipterocarpus zeylanicus* is using from ancient time for many disorders. Several parts of the tree are used for medicine. The heartwood of the tree is used along with some other ingredients for fever (Roberts, 1931).

The greenish grey gum resin that yields from trunk is used on chronic ulcers, sinuses and fistulae. Internally it acts as a diaphoretic and expectorant, and useful in the treatment of pharyngitis, tonsillitis, bronchitis and pneumonia (Roberts, 1931; Jayaweera, 1980). It has antiperiodic properties of some value and administered with other antiperiodics gives good results (Roberts, 1931).

Dipterocarps provide a number of indirect advantages in addition to its direct uses.

Some Dipterocarp forests contain vast number of tropical fruit trees and their wild relatives. Also these forests contain a considerable portion of the world's Rattan resources (Jacobs, 1981). It will give additional value to the Dipterocarp forests in the economic as well as in the biological point of view.

High level of phenols and tannins are contained in litter of the Dipterocarps. This probably influences plant species composition in these forests as well as microbiological processes above and in the ground (Smits 1987). It helps to improve nutritional condition in the forest.

2.4. VEGETATIVE PROPAGATION

The propagation is the controlled perpetuation of plants. The objectives in propagation are both to increase the number of plants and to preserve the essential characters of the plant. Propagation can be obtained by two methods namely sexual propagation and asexual propagation.

Seeds are used in sexual propagation and it is the common method for self-pollinated plants. There are some disadvantages in seed propagation although trees have several deviations in seeds for dispersion and germination. Genetic variations occur in seeds that obtained from cross-pollinated plants and therefore the plant grown from seed may not exactly duplicate the characteristics of its parents. And many undesirable characters may be seen. Some plants take long time to grow from seeds to maturity (Kumar, 1995).

Asexual or by vegetative means in which specialized vegetative structures of the plants are involved. Vegetative propagation is the production of new plant directly from vegetative parts of existing ones, not from seeds. For many plants vegetative propagation is a natural process. But for others, it is an artificial one. Vegetative propagation can be achieved in several ways by involving adventitious or dormant buds.

Vegetative propagation gives number of advantages.

- Large number of plants can be obtained from a single stock. The long life cycle of trees makes the development of superior varieties a lengthy process. The vegetative propagation methods are potentially useful for replicating clonal material and for the multiplication of stock.
- The plants will be genetically identical to parent stock and consequently, the growth and form will be uniform. Thus, it provides an opportunity to harness and exploit genetic variation directly.
- Vegetative propagation methods are very useful when trees are not producing seeds or if the seeds are not viable.
- It permits multiplication of desirable hybrids without segregation of characters.
- It helps to utilize maximum genetic gains in shortest time.
- Vegetative propagation helps to make an investment in trees more attractive by increasing yield and quality, and shortening rotation.

Despite the advantages of the methods of vegetative propagation, it has its own limitations and disadvantages too.

- Very careful operations with great practice and skill are required for vegetative propagation.
- A large number of species do not root even in controlled conditions of the rooting is not satisfactory. Suitable condition should be supplied for success. Otherwise it will give inferior growth.
- Vegetative propagation is easier with young trees, but becomes more difficult as tree age.
- Mixing of genes in gene pool is restricted.
- The physiological and environmental factors play an important role in the vegetative propagation. Status of those factors is different for different species. Therefore, each and every species should be experimented separately for physiological and environmental factors.

The ultimate goal of vegetative propagation is to obtain the best planting stock with highest quality. In vegetative propagation methods, greater genetic gain and greater uniformity can be achieved unlike in sexual propagation. Plants can be raised almost throughout the year by this technique. Plantable stock for some species can be obtained in shorter time than that required by seed origin plants.

Many tropical trees flower and fruit rarely. Some tree species have seeds that do not have good storing ability. Some seeds are subjected to attack of pests and diseases severely. Therefore, better stock cannot be obtained from these species through seed propagation. Vegetative propagation is the best solution to get stock from this type of species.

There are two basic vegetative propagation methods namely macro propagation and micro propagation. The macro propagation involves the use of the relatively large piece of plant tissues as compared to micro propagational or tissue cultural methods that involve the use of a very small piece of tissue or a single cell.

Macro propagation is achieved by several methods with the use of different body of the Parent plant. Methods, which use root suckers, coppice, cuttings and layering, grafting and budding are some of those vegetative propagation methods.

In propagating and growing young nursery plants, five fundamental environmental factors (light, water, temperature, gasses and mineral nutrients) should be controlled. Various types of propagating structures are used to maintain suitable environmental conditions for plants. Shed roofs, shade houses, propagating frames, misting units, green houses, mist chambers and growth area chambers are the major propagating structures. All these structure helps to optimize environmental factors that are necessary for growth and development of propagating plants.

2.4.1. VEGETATIVE PROPAGATION BY CUTTINGS

Use of cuttings is one of the easiest, cheapest and best methods of multiplying the stock. Any portion viz. stems, roots or branch, leafs and leaf buds can be taken as cuttings. The cuttings can be of softwood, hard wood or semi hardwood depending upon the species and lignin content (Kumar, 1999).

A large number of Bamboo species can be propagated by use of rhizome cuttings (E.g. *Bambusa arundinacea, B. vulgaris, Dendrocalamus strictus*). Root or shoot or stump cuttings can be used for species such as *Tectona grandis, Bombax ceiba, Gmelina arborea* and *Dalbergia sisso*. Root section cuttings or thongs are used to raise plants like *Bombax ceiba, Artocarpus indica*, etc. (Kumar, 1999). Begonia species are the best example for that propagation by leaf cuttings. A number of plant species including berry species and *Rhododendron* can be propagated by leaf bud cuttings (Hartman *et. al.*, 1993).

Stem cuttings can be divided in to four groups, according to the nature of the wood used: hardwood, semi hardwood, softwood and herbaceous.

Leafy or leafless cuttings can be used for propagation. Leafy cuttings should be smaller and must be taken from softer shoots, because they would dry out very quickly. They need to keep in a humid poly propagator or under mist until they root and take up sufficient water. Most species of trees can be rooted with leafless cuttings. Moist and lightly shaded conditions are enough to root.

Large numbers of Dipterocarp species are successfully tested for vegetative propagation by leafy cuttings. *Shorea polembanica, S. leprosula, Vatica pauciflora, Hopea mangarawan* (Halle and Kamil, 1981), *Anisoptera scaphula, Shorea bracteolata, Dipterocarpus chartaceus* (Srivastava and Manggil, 1991) are some of the species that achieved high rooting percentage by using leafy stem cuttings.

The rooting response is greatest in young seedlings and declines with age. It should be noted that very lignified or woody cuttings do not sprout and at the same time very herbaceous cuttings tend to be susceptible to drying out. The correct time of collecting cuttings is just before they start their active growth period. Age of the parent trees can be varying from three months to 3-4 years old.

Memose (1978) achieved best results with cuttings from juvenile plants in his experiments with Dipterocarps in Malaysia. Hall and Kamil (1981) reported that *Vatica pauciflora* cuttings taken from 3-4 years old saplings were successfully rooted with IBA in Indonesia. Srivastava and Manggil (1991) achieved high rooting success in some Dipterocarps with young parent plants in Malaysia. The species and age of the plants were *Anisoptera scaphula* (27 months), *Shorea bracteolata* (12 months), *Sorea leprosula* (10 months), and *Dipterocarpus chartaseus* (10 months). *Shorea selanica* and *S. leprosula* were successfully rooted in Indonesia when the parent plants were 12-16 months old seedlings (Masano, 1992). Darus Ahmad (1992) achieved about 90-100% rooting in Dipterocarps under mist condition with one-year-old parent plants in Malaysia. Species tested are *Dipterocarpus baudii, Hopea odorata, Shorea bracteolata, S. leprosula, S. ovalis, S. parviflora, S. platyclados, S. Singkanang.*

Size of the cuttings, which used to propagate, can vary too. For leafless cuttings, sometimes 1-2 m poles are used to root. This capacity is used to establish live fences for example in

Cassia siamea, Gliricidia sepium, etc. However, some scientists mention that the ideal length to root is usually 15-40 cm with a basal diameter of about 5-30 mm. (Longman, 1993).

10-12 cm long cuttings were rooted with 90-100% success in Dipterocarps *(Anisoptera marginata, Shorea smithiana, S. laevis, S. leprosula, S. ovalis, S. blanco* and *S. pauciflora*) by the bubble bath method (Smits and Yasman, 1988). *Shorea leprosula* and *S. selanica* were successfully tested (60% of rooting) with 10-12 cm long cuttings (Masano, 1992). About 90-100% rooting has obtained from Dipterocarpus, Hopea and Shorea species with the top shoot cuttings about 10cm long (Darus, 1992). Marked rooting success was observed in *Dipterocarpus chartaceus* (60%), *Shorea bracteolata* (100%), *Anisoptera scaphula* (80%), and *Shorea leprosula* (40%) with the 10cm long cuttings (Srivastava and Manggil, 1981). 15-20 cm long cuttings of five Dipterocarp species were examined and got high rooting percentage (80%) by Hall and Kamil (1981).

There should be at least a pair of leaves in one nodal stem cutting. If long cuttings are used the lower leaves should be removed from the cuttings whereas upper leaves are retained. Leaf area of the cutting is also a very important factor. Greater the leaf area greater the transpiration and therefore water loss. By trimming excess leaves and clipping off half of the leaves transpiration can be minimized.

Smits and Yasman (1991) used cuttings of Dipterocarps with three half leaves for propagation by the bubble bath method. Some of the Dipterocarp cuttings were successfully rooted with three half leaves (Masano, 1992), three full leaves (Darus, 1992), 1-2 pairs of leaves (Paler and Alcobar, 1991) and few leaves (Halle and Kamil, 1981).

The cuttings should be taken out from aerial parts of the parent plant. Top portion or vertical (orthotropic) shoots of seedlings should be collected by using a very sharp pruning shear. Only orthotropic shoots must be collected, because plagiotropic cuttings seldom develop into vertical growing trees (Zabala, 1994).

Response of terminal cuttings can be attributed for the higher concentration of endogenous root promoting growth regulators like auxins in the terminal buds (Hertman and Kester, 1993). Martin and Guillot (1982) also reported the superiority of terminal cuttings over middle or basal cuttings. The rooting of terminal cuttings has an added advantage because of one cut end thus reduces the possibility of infection by disease causing organisms during or after rooting phase (Srivasuki *et.al.*, 1991).

The cut of the basal end should be made oblique to ensure greater surface for absorption. Clipping must be done with the sharp pruning shear to minimize tissue damage (Srivastava and Manggil, 1981). Cuttings root best when the basal 3mm of the cutting contains a node (Zabala, 1993).

The ability of cuttings to root varies with the tree species and also time at which cuttings is taken, with other factors. During collection, it is very important that the cuttings should not be put into a moistureless condition. Therefore, cuttings should be collected early morning, possibly before 9 'o' clock and should be put into a bucket with water as soon as taken out from the parent plant. Cuttings should be prepared and treated for rooting immediately after collection.

The rooting medium should have good aeration, high water holding capacity and should be well drained. And also it should be free from harmful pathogens. Washed sand, mixture of sand or sand mixture with peat moss are mostly used rooting media. The pH of medium should be nearly 6.5 to 7.

Some Dipterocarps were successfully tested in media such as peat washed river sand mixture (Smits, 1987; Srivastava and Manggil, 1981), Sand and peat moss (Halle and Kamil, 1981), Sand (Hall and Kamil, 1981; Darus, 1992).

Conditions under which the cuttings are rooted determine the rooting percentage or success. Some of the major conditions that are needed for rooting success can be mentioned as follows. (Longman, 1993).

- Very high humidity.
- Moderately low light intensity.
- Equable temperature.
- Protection from wind, heavy raindrops, pests and diseases.

To provide above conditions, propagating structures like mist chambers, green houses, Shade houses, etc. are used.

2.4.2. NON MIST POLY PROPAGATION

Poly propagator is used when non-mist conditions are supplied. It does not require an electrical supply and sophisticated instruments. This method is not expensive like mist propagation and suitable for rural areas. Poly propagators are simpler to operate, with less risk of breakdown and can be used either for small or large-scale propagation (Longman, 1993).

This poly propagator consists of a simple fiberglass box covered with polythene lid and the base is watertight. Successive layers of large stones, small stones and gravel of about 20 cm thickness and thereafter 3-4 cm rooting medium were placed in a propagator. The propagator is filled with water to a just below a rooting medium. Due to this design, rooting medium is always under moisture, because of capillary rise of water. Above 90% relative humidity can be obtained in this type of propagators. Many of the tropical plants were successfully propagated in non-mist poly propagators. Cuttings of the *Azadirachta indica* were successfully propagated by this method (Majeedh, 1995). For *Ochreinauclea missionis* of Rubiaceae, which is extremely rare species, 91.1% of rooting success was obtained in poly propagator (Jose *et.al.*, 1995). Some of the Dipterocarps were also tested in poly propagators.

2.4.3. MIST PROPAGATION

Mist propagation technique is now being increasingly used in the practice of forestry for propagating species that are difficult to root (Gupta and Joshi, 1984). The mist tends to lower the temperature of the shoot through,

- The evaporation of mist that cools the air.
- The small drops of water acting as a screen to the sun's rays.
- The water temperature often being lower than the propagator.

Due to high humidity in the mist chamber, air is cooled and supplied an equable temperature to cuttings. Mist chambers further afford protection against unfavorable weather conditions such as rain, hail, drought and frost.

Mist is produced by passing water under pressure through mist jets that are very small specially made holes. System consist a water supply, electric pump, a filtration system, a mist controller, a set of mist nozzles or jets (Longman, 1993). In mist chambers, it is possible to maintain humidity conditions about 95-100% by water spray.

Hall and Kamil (1981) achieved high rooting success with the misting only in the morning (7.00-8.00am) and in the afternoon (4.00-5.00pm). Darus (1992) achieved 90-100% rooting with automatic mist. Mist spray of 30 seconds duration at 5 minute intervals from 6.00am to 6.00pm is used. Srivastava and Manggil (1981) obtained high rooting for five Dipterocarp species with intermittent spray of mist. Misting was done in day time for five minute in half hour intervals and hourly intervals.

2.4.4. USE OF GROWTH HORMONES

Stem or leaves are not rooting portions like root system of the tree. Therefore, there should be some initiator to induce tissues of stem cuttings to produce roots. Although ethylene is a naturally occurring plant hormone, the use of synthetic root promoting hormones greatly help in root initiation of cuttings. The auxins such as IAA, IBA, NAA, etc. are of great value in stimulating root formation (Kumar, 1999).

Different concentrations of hormones give different results. The rate of success to those auxins can vary between species. Therefore experiments are needed to find the proper auxin and its concentration for each species.

These treatment agents can be used as a talc powder or as a solution. It is better, if cuttings can be treated just after the collection. Cuttings should be planted immediately after the treatment with growth regulators.

Kumar (1999) mentions some chemicals as successful rooting hormones. Those are Indole Acetic Acid (IAA), Indole Butyric Acid (IBA), Indole 3 Propionic Acid (IPA), Gibberlic Acid (GA), Naphthalene Acetic Acid (NAA), Absorbic Acid and Seradix.

IBA is the mostly used growth regulator. It has used for vast number of tropical trees for rooting of cuttings. In most of the cases, IBA promotes more roots in terms of numbers (Nautiyal *et.al.*, 1992). IBA is more successful in rooting mature stem cuttings (Pari and Khara, 1992).

For Teak, IBA shows best results, when compared to IAA, NAA and mixture of IBA and NAA with the concentrations of 100 and 200 ppm (Nautiyal *et.al.*, 1992). Reddy and Srivasuki (1990) showed that IBA was better than IAA and IPA for rooting cuttings of red sanders. For *Ochreinauclea missionis*, a very rare and highly threatened species, IBA in 1000 ppm was the best than the IAA and NAA. For IBA, with increase in concentration (2000,3000 ppm)

both rooting and numbers of roots were adversely affected (Jose *et.al.*, 1995). Best results were obtained from IBA 200 ppm solutions with 24 hour treatment time for *Woodfordia fruiticosa* of family Lythraceae (Bhaguna *et.al.*, 1988).

Most of the Dipterocarps had been tested with several hormones including IBA. Smits and Yasman (1988) achieved about 90-100% rooting for *Anisoptera marginata, Shorea smithiana, S. laevis, S. leprosula, S. ovalis, S. blanco* and *S. pauciflora* with the treatment of IBA 100 ppm for a one-hour period. Fifty percent rooting was achieved in the treatment of IBA at 1000 ppm concentration (30 minute treatment time) for *Shorea selanica* and *S. leprosula* (Masano, 1992). About 80% rooting success of *Vatica pauciflora* was obtained when 2000 ppm of IBA was treated for a 3-5 seconds (Halle and Kamil, 1981). Srivastava and Manggil (1981) tested four Dipterocarps with talc preparations of IBA in 100 ppm, 500 ppm, 1000 ppm and 2000 ppm. Highest rooting percentage (80%) was obtained in cuttings treated with 1000 ppm of IBA.

2.5. VEGETATIVE PROPAGATION OF *Dipterocarpus zeylanicus*

Most of the Dipterocarps were tested for vegetative propagation. From that, vast numbers of Malaysian Dipterocarps were successfully propagated. Research into the propagation of Dipterocarps was also carried out in Indonesia, Philippines and India.

Dipterocarpus zeylanicus was not tested for vegetative propagation in Sri Lanka. It is only propagated through seeds. Nurseries of Forest Department collect the seeds from natural forests and gets seedlings from those seeds for their planting programs. And also they collect wildlings from forests as planting materials.

2.6 IMPORTANCE OF THE VEGETATIVE PROPAGATION OF THE DIPTEROCARPS.

Because of the logging boom in the 1970's the fragile ecosystem of the Dipterocarp forest has been disturbed and their very existence has been threatened. It is of extreme urgency, therefore, to adopt sustainable measures to conserve, restore and enrich the Dipterocarp forest to make it more viable for economic and ecological considerations. It is more economical, when plantations are maintained.

For conservation or commercial plantations, there should be a method to supply good planting stock to plant. There are, however, some problems in the production of planting stock of Dipterocarps by seeds. Those are irregularity of seed supply due to irregular flowering and fruiting, short viability period of seeds, and lack of seed storage and handling

facilities that have hampered restoration enrichment activity for the regeneration of the Dipterocarp forest (Zabala, 1993).

Methods of collecting, testing and storage of Dipterocarp seeds are not sufficient to supply good seeds continuously. Because, most Dipterocarps fruit infrequently (Yap, 1981). Among Dipterocarps in general, two contrasting classes of flowering behaviors have been described. In most years, only a small proportion of trees flower in any population and this is called 'sporadic' flowering. In other years, flowering reaches a highly synchronized peak in which a large proportion of trees flowers in phase with each other. This is usually described as 'gregarious' or general flowering (Ng, 1981). However, flowering and fruiting of *Dipterocarpus zeylanicus* is fairly regular. Flowering is in January to February and fruiting during April and May. Therefore, uniform supply of seeds cannot be obtained throughout the year.

Dipterocarp fruits distribute throughout the forest with high dispersal potential. Collection of fruits or seedlings from natural forest is very difficult activity since Dipterocarp forests being as a closed forests. This practice is time consuming and need high labor force. For silvicultural purposes, seedlings should be supplied continuously with less labor force and by cheaper method.

Most species of Dipterocarps exhibit little or no dormancy and germination is immediate when suitable conditions are available (Yap, 1981). Therefore, collection of even age seedlings or fruits with same status is difficult.

Stored fruits of Dipterocarps lost their viability rapidly and different species responded to different conditions. The storability of Dipterocarp seeds shows a range of variability. To get better results from storing fruits, greater air spaces that improve ventilation is needed (Yap, 1981).

By using vegetative propagation method, above difficulties can be eliminated. It offers uniform growth and development, and maintains the parity of the parent stock (Srivastava and Manggil, 1981). Out of all the methods of vegetative propagation, the rooting of stem cuttings is popular as the techniques ensures fast multiplication and provides large number of propagules in a short time span (Reddy and Srivasuki, 1990). The most economical method is the use of rooted branch cuttings as they have undifferentiated tissues that permit root primordia (Nanda *et.al.*, 1970).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

The experimental part of the study was conducted under the mist and non-mist conditions. Non-mist condition was given in propagator, which was placed in the garden of the University of Sri Jayawardenapura. Mist condition was given in green house of the University of Sri Jayawardenapura.

3.2 NON MIST PROPAGATOR

The experiment under non-mist condition was carried out in a poly propagator. The propagator was made out of a translucent fiberglass box with a lid made by polythene and wood. The base of the propagator was watertight and there were two pipes at the bottom as an inlet and outlet of water. The base of the box was covered with a thin layer of sand. Then a layer of large stone (6-10 cm in diameter) was laid to a depth of 10 to 15 cm. Then small stone of 3-6 cm in diameter and gravel of 0.5-1.0 cm in diameter were packed consequently to a total depth of 20 cm. Medium sand as a rooting medium formed the uppermost layer. It was about 3-5 cm in depth. Water was added to the propagator up to the base of rooting medium, which kept it moist, by capillarity. Water level in the propagator was observed regularly and maintained at a particular level.

3.3 PROPAGATING BEDS UNDER MIST CONDITION

Mist condition was given in the green house. Nine large plastic trays were used as propagating beds. Dimensions of trays are 17"x13"x2.5". About ten holes were made at bottom of the trays to drain excess water. Then trays were filled with medium sand as a rooting medium. Plates were arranged in a certain manner and misting units were placed to provide mist to the beds. Two misting nozzles were used. Distance between 2 nozzles was 1.2m. Sensor of the unit sensitive to relative humidity and temperature was placed in one plate that locates in between the two nozzles. Then A/C current was supplied to the unit. Water was supplied through pipes. Before the planting of cuttings beds were saturated with water. A regular observation was done to minimize the technical problems that can be obtained due to power failure or shortage in water supply.

3.4 PREPARATION OF CHEMICALS

Three solutions of IBA with different concentrations 500 ppm, 1000 ppm and 1500 ppm were prepared one-day prior to the collection of specimen to be treated. 250ml of solutions were prepared for each concentration. Required weights of the IBA powder were measured by the electronic balance to the watch glass. Then it was transferred into the volumetric flask through funnel. Sufficient amount of 0.1M NaOH solution is used to dissolve the powder. Then water was added to the flask and shaken well. Finally water was filled up to a mark of particular volume.

3.5 SPECIMEN COLLECTION

Shoot cuttings were obtained from even age seedlings of less than one year old. Those cuttings were collected from the Waga Forest Department nursery. Collection was done in the morning (9.00-10.00am) and transported to the University as soon as they were collected. In transportation, cuttings were placed in closed polythene bags to maintain high humidity. Some amount of water was also added to the bags to keep it moist.

3.6 PREPARATION OF CUTTINGS

Cuttings of 15 cm length were prepared. A slant cut was made to the basal end of the cutting. The basal cut was made just below a node. Diameter of the cuttings at the basal end was about 0.3-0.4 mm. One leaf was trimmed to half and 2 full leaves were retained. Excess leaves were removed.

Three sets of cuttings were treated with different concentrations of IBA i.e. 500 ppm, 1000 ppm, and 1500 ppm. Basal ends of the cuttings were dipped in the solutions for 10 seconds. Then those were planted immediately in the rooting medium.

One set of cuttings was treated with commercially available hormone called "Secto". It contains NAA as a rooting hormone. It was applied in powder form. Wet basal ends of cuttings were dipped in the powder. Then cuttings were shaken to remove excess powder of Secto. After that, cuttings were inserted in rooting beds.

One set of cuttings was planted without any treatment as a control.

Small polythene strips were tagged to the cuttings as identifying tags. Five different colors were used for each treatment.

Prepared cuttings were planted in randomized blocks of propagating beds. The depth of insertion in rooting medium was 2.0-3.0 cm.

3.7 EXPERIMENTAL DESIGN

A randomized design with three replicates was used for each condition. 30 cuttings were planted in one replicate (6 cuttings from one treatment).

3.8 EXPERIMENT UNDER MIST CONDITION

Three trays were used for one block and cuttings in each block were arranged randomly. Ten cuttings per tray were planted. There were 90 cuttings under mist condition. Five sets of cuttings with different treatments were used. From each set, 18 cuttings were planted.

Water was supplied as an intermittent mist. Automated misting unit determines the watering schedule according to the sensitivity of sensor to temperature and relative humidity.

3.9 EXPERIMENT UNDER NON MIST CONDITION

A randomized design with three replicates was conducted. Area of each block was equal to the area of block in mist propagator beds. Number of cuttings and treatments that do for the cuttings were same as the experiment under mist condition. Thirty cuttings were in each block and therefore 90 cuttings altogether in the non-mist propagator.

Water was supplied from inlet pipe of the propagator box. Regular observations were done and water level was maintained at particular level. Lid of the box was opened only in the mornings and evenings.

3.10 EXPERIMENT PERIOD

Cuttings were planted on 18th August of 2000 and rooting of cuttings was checked on 27th October of 2000. Within this 10 week period air temperature and bed temperature, and relative humidity were measured in both mist and non mist conditions.

3.11 DATA COLLECTION

At end of experiment period, data on % survival and % rooting were collected. Number of roots in cutting was counted and length of the each root was measured by Verniar caliper. Non-rooted, survived cuttings were checked for callus development.

3.12 DATA ANALYSIS

Data on percentage of survival, Percentage of rooting, number of roots/cutting, and average length of root/cutting, maximum length of root/cutting, were analyzed using analysis of variance. A mean comparison was done by Duncan's multiple range test. All analysis was carried out using SAS statistical package.

Average temperatures at mornings & evenings of bed and surround air and average relative humidity are given in table 3.1.

Table 3.1 Environment condition throughout the rooting period.

Mist condition			Non mist condition		
RH (%)	Temperature (^{0}c)		RH (%)	Temperature (^{0}c)	
	bed	air		bed	air
91	29.67	29.93	94.23	26.54	26.36

Fig.3.1 **Randomized design of non-mist propagator. (Block II)**

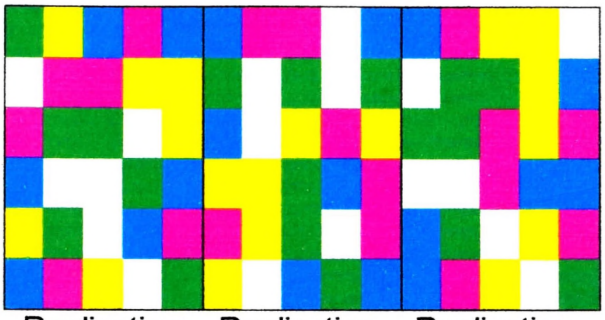
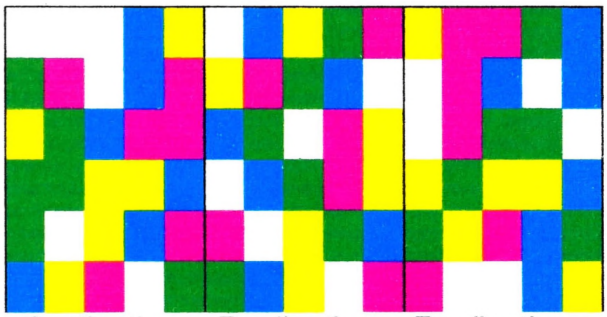


Fig .3.2 **Randomized design of mist propagator. (Block I)**



	Secto
	500ppm of IBA
	1000ppm of IBA
	1500ppm of IBA
	No treatment

Plate 3.1 Cuttings under mist.

Plate 3.2 Non mist poly propagator

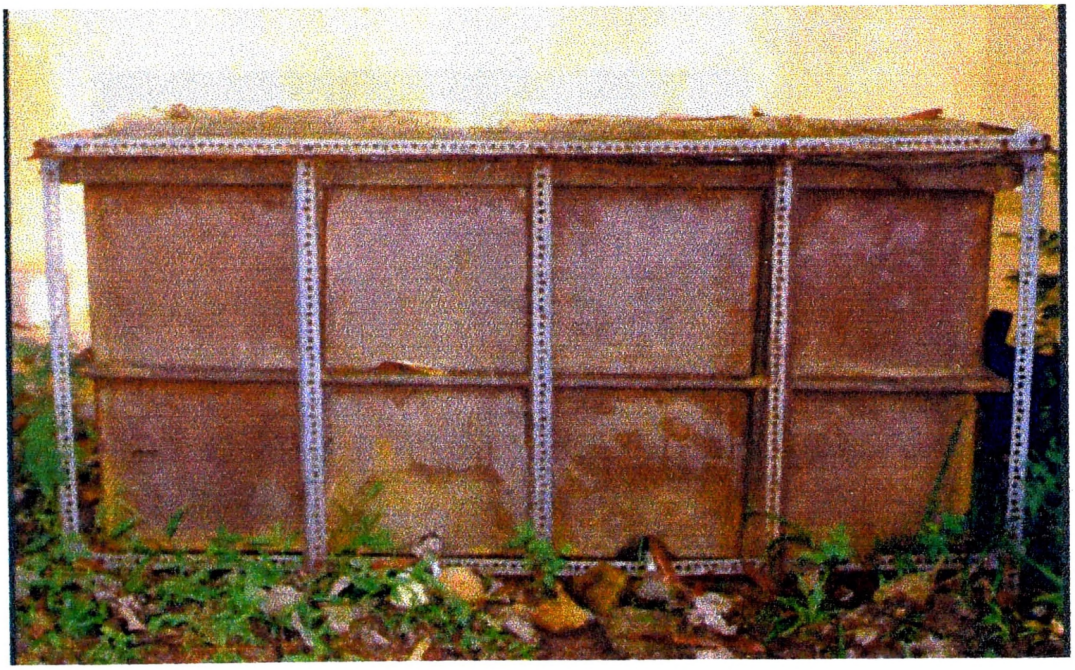


Plate 3.3 Cuttings in non-mist propagator (after 8 week period)

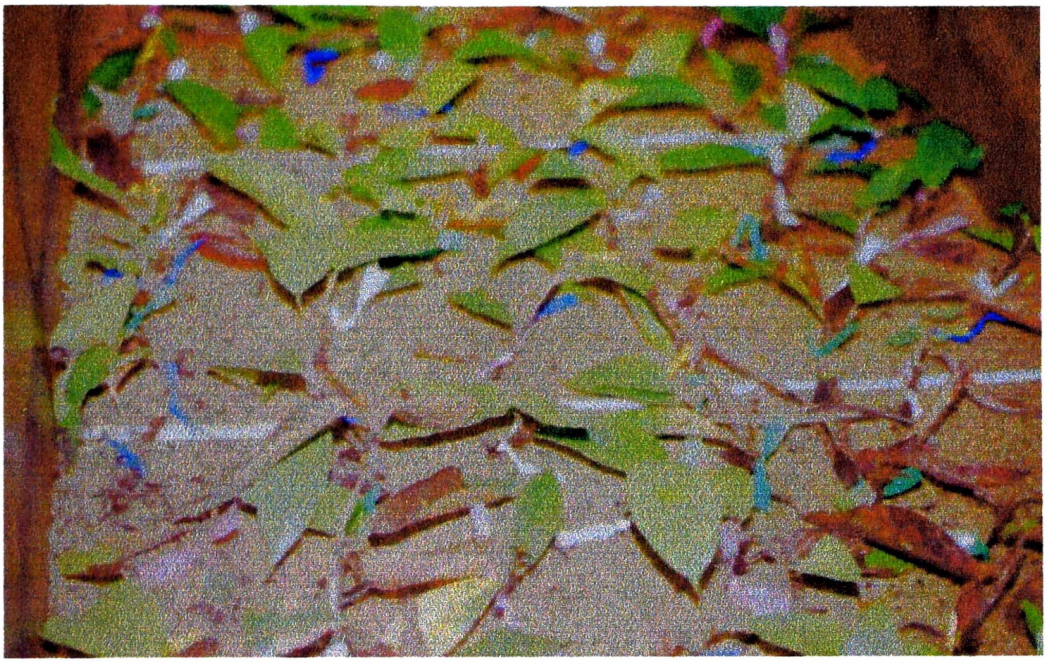


Plate 3.4 Used hormones (Secto and IBA)

Plate 3.5 Prepared cutting for planting

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

To compare rooting of cuttings obtained from two conditions and different hormone treatments after 1 weeks the average percentage survival, rooting percentage, callusing percentage for non-rooted cuttings, average number of roots per cutting, average length of roots per cutting and maximum length of roots per cutting were calculated. Those results are shown in table 4.1 and 4.2. The raw data are shown in Appendix I

Table 4.1:Average data on survival, rooting, callusing from non rooted cuttings, average number of roots per cutting, average length of roots per cutting, maximum length of roots per cutting in *Dipterocapus zeylanicus* under mist condition.

Treatment	% survived	% rooted	% callused	Avg. No. of roots/cut	Avg. length of roots/cut	Max. length of roots/cut
Control	100.00	38.39	72.73	4.43	11.05	20.90
Secto	94.44	27.78	92.31	4.80	8.37	15.96
500ppm of IBA	100.00	22.22	64.29	3.25	11.13	14.70
1000ppm of IBA	100.00	11.11	100.00	7.50	11.47	29.75
1500ppm of IBA	100.00	27.78	76.92	4.00	11.20	21.34
Total	98.89	25.56	82.09	4.48	10.63	19.62

Table 4.2: Average data on survival, rooting, callusing from non rooted cuttings, number of roots per cutting, length of roots per cutting, maximum length of roots per cutting in *Dipterocarpus zeylanicus* under non mist condition.

Treatment	% survived	% rooted	% Callused	Avg. no of roots /cutting	Avg. length of roots/ cutting	Max. length of roots/ cutting
Control	72.22	0	33.33	0	0	0
Secto	50.00	0	33.33	0	0	0
500ppm of IBA	83.33	0	50.00	0	0	0
1000ppm of IBA	61.11	0	50.00	0	0	0
1500ppm of IBA	66.67	0	44.44	0	0	0
Total	66.67	0	42.22	0	0	0

- % Callused and % callused from non-rooted cuttings are equal because of zero number of rooted plants.

According to table 4.1 and 4.2, there is no rooting in cuttings, which were placed under non mist condition while the cuttings placed under mist condition produced roots. Significant differences ($P<0.05$) were observed in percentage survived, percentage rooted, and percentage callused from non-rooted cuttings between mist and non mist conditions (Appendix 2,2A, 2B, 2C).

To compare rooting of cuttings with different hormone treatments, the average percentage survived, percentage rooted, number of roots per cutting, maximum length of root per cutting and average length of root per cutting for each treatment were calculated separately. Those results are shown in table 4.3.

Table 4.3:Average data on % survived, % rooted, number of roots/cutting, maximum length of root/cutting and average length of root/cutting against different treatments in different replications with the cuttings of *Dipterocarpus zeylanicus* under mist condition.

Replication	Treatment	% survived	% rooted	No.of roots/cut	Max. length of root/cut	Avg. length of root/cut
1	1	100.00	16.67	8.00	73.2	35.38
2	1	100.00	66.66	4.25	12.62	7.46
3	1	100.00	33.33	3.00	11.40	6.07
1	2	100.00	0.00	0.00	0.00	0.00
2	2	100.00	50.00	5.00	11.00	6.41
3	2	83.33	33.33	4.50	23.40	12.22
1	3	100.00	16.67	1.00	4.10	4.10
2	3	100.00	16.67	5.00	26.30	20.74
3	3	100.00	33.33	3.50	14.20	9.84
1	4	100.00	16.67	6.00	40.20	10.60
2	4	100.00	16.67	9.00	19.30	12.34
3	4	100.00	0.00	0.00	0.00	0.00
1	5	100.00	16.67	1.00	6.20	6.20
2	5	100.00	16.67	1.00	5.00	5.00
3	5	100.00	50.00	6.00	30.17	14.94

- 1,2 and 3 denotes replication I, II and III respectively.

Although statistically significant differences ($P<0.05$) were not observed in all parameters with different hormone treatments the average data showed the highest % rooting under control condition while the lowest was shown in the IBA 1000ppm concentration (Appendix 3, 3A, 3B, 3C, 3D, 3E). According to Duncan's multiple range test for every variable, the highest values were obtained with control (Appendix 3F, 3G, 3H, 3I, 3J)

Plate 4.1 **Cuttings that had the longest roots (from left: 500ppm of IBA, 1500ppm of IBA, Secto, 1000ppm of IBA and Control)**

Plate 4.2 **Callus formed on the cutting**

4.2. DISCUSSION

An attempt has been made in the present study to assess the optimum conditions for successful vegetative propagation of *Dipterocarpus zeylanicus* by stem cuttings. In the present study, the cuttings were placed in a poly propagator under non-mist condition and in a green house under mist condition. Care was taken to maintain high humidity and suitable temperature around the propagating beds in two conditions.

In the present study, cuttings that placed under the mist condition gave best results compared to cuttings under the non-mist condition. No roots were appeared in cuttings, which were placed under the non-mist condition. Roots were appeared under the mist condition but rooting percentage was 25.56%. Darus (1992) achieved 90-100%rooting. Srivastava and Manggil (1981) achieved 40-80% rooting for Dipterocarps under mist condition. Results of the present study showed somewhat lower values for rooting compared to previous studies for other Dipterocarps. Rooting ability of cuttings change mainly with the species and many other factors such as age of the parent plant, length of the cuttings, medium of the rooting bed, time period that allowed to root, etc. Therefore, these results cannot be compared with the previous studies of the other Dipterocarps.

Rooting was assessed after 10 weeks in the present study. Many scientists achieved successful rooting for Dipterocarps in 4-6 weeks (Darus, 1992), 60 days, 85 days and 90 days (Paler and Alcobar Jr., 1991). In experiments of Paler and Alcobar Jr. (1991), *Shorea negrosensis* cuttings have rooted (40-63%) after 85 days from planting with the treatment of high concentrations oh IBA (6000 ppm, 8000 ppm) and Rootone. *Shorea palosapis* rooted with 6000 ppm of IBA (41%) and 8000ppm of IBA (25%) after 90 days from planting. Cuttings of *Shorea polysperma* treated with IBA (6000 ppm and 8000 ppm) rooted to about 33% and control rooted to about 22%. The cuttings developed roots 90 days after planting. The treatment combinations applied to *Shorea contorta* cuttings resulted in rooting about 15% and 10% after 90 days from planting. After 120 days from planting, *Dipterocarpus grandiflorus* cuttings had not developed any roots.

Therefore, results of present study can be considered as in agreement with those results of previous studies. 82.09% cuttings from non-rooted cuttings were callused under mist condition, while non-mist condition gives 42.22% for that parameter. 82.09 is a higher value and therefore we can assume that if the rooting period is higher it may give higher rooting

percentage. However, there is no argument that mist condition is the best for vegetative propagation of *Dipterocarpus zeylanicus*.

In some species, root formation can be promoted by pretreatment with hormones before insertion in the rooting medium. Root setting hormones can be made from solution or powder of the active chemical such as IBA, IAA, etc. or it can be available under various chemical names such as Rootone, Seradix, Secto, etc. Hormones induce rooting of cuttings to different degrees. In the present study, the control treatment gave superior results for % survived % rooting, average number of roots/cutting, maximum length of root/cutting, average length of roots/cutting. This observation is in agreement with the experiment of Masano (1992) for vegetative propagation by cuttings of *Shorea selanica* and *S. leprosula*. He achieved 50% rooting with 1000 ppm of IBA and 60% rooting without any treatment.

CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS

From the present study the following conclusions could be arrived at.

- *Dipterocarpus zeylanicus* can be propagated vegetatively using terminal stem cuttings.
- *Dipterocarpus zeylanicus* has some rooting ability with or without hormone treatments.
- Mist propagation is the best method for rooting.

However, further studies should be carried out over a longer period for better results. Callus formation of non-rooted cuttings was high. It indicates that if experiment period is longer, rooting percentage may be higher.

This study was carried out with only one chemical hormone treatment. Suitability of other hormones, commercial treatments and combinations of treatments should be checked.

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APPENDIX 1

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
1	1	1	1	1	2	2			
1	1	1	2	1	2	1			
1	1	1	3	1	2	1			
1	1	1	4	1	2	2			
1	1	1	5	1	1	-	8	73.2	35.375
1	1	1	6	1	2	1			
1	1	2	1	1	2	1			
1	1	2	2	1	2	1			
1	1	2	3	1	2	1			
1	1	2	4	1	2	1			
1	1	2	5	1	2	1			
1	1	2	6	1	2	1			
1	1	3	1	1	2	1			
1	1	3	2	1	2	1			
1	1	3	3	1	2	1			
1	1	3	4	1	2	1			
1	1	3	5	1	2	1			
1	1	3	6	1	1	-	1	4.1	4.1
1	1	4	1	1	2	1			
1	1	4	2	1	2	1			
1	1	4	3	1	2	1			
1	1	4	4	1	2	1			
1	1	4	5	1	2	1			
1	1	4	6	1	1	-	6	40.2	10.6
1	1	5	1	1	2	1			
1	1	5	2	1	2	1			
1	1	5	3	1	1	-	1	6.2	6.2
1	1	5	4	1	2	1			
1	1	5	5	1	2	1			
1	1	5	6	1	2	1			
1	2	1	1	1	1	-	5	13	7.68

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
1	2	1	2	1	1	-	8	27.1	12.275
1	2	1	3	1	2	2			
1	2	1	4	1	1	-	1	7.2	7.2
1	2	1	5	1	1	-	3	3.2	2.667
1	2	1	6	1	2	1			
1	2	2	1	1	1	-	1	3.5	3.5
1	2	2	2	1	2	1			
1	2	2	3	1	2	1			
1	2	2	4	1	1	-	6	13.2	8.217
1	2	2	5	1	2	1			
1	2	2	6	1	1		8	16.3	7.525
1	2	3	1	1	2	2			
1	2	3	2	1	2	2			
1	2	3	3	1	2	1			
1	2	3	4	1	1	–	5	26.3	20.74
1	2	3	5	1	2	2			
1	2	3	6	1	2	1			
1	2	4	1	1	2	1			
1	2	4	2	1	2	1			
1	2	4	3	1	2	1			
1	2	4	4	1	2	1			
1	2	4	5	1	2	1			
1	2	4	6	1	1	-	9	19.3	12.344
1	2	5	1	1	2	2			
1	2	5	2	1	2	1			
1	2	5	3	1	1	-	1	5.0	5.0
1	2	5	4	1	2	1			
1	2	5	5	1	2	1			
1	2	5	6	1	2	1			
1	3	1	1	1	2	1			
1	3	1	2	1	2	1			
1	3	1	3	1	1	-	1	1.7	1.7

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
1	3	1	4	1	1	-	5	21.1	10.44
1	3	1	5	1	2	1			
1	3	1	6	1	2	1			
1	3	2	1	1	2	1			
1	3	2	2	1	2	1			
1	3	2	3	1	1	-	3	40.5	21.23
1	3	2	4	1	1	-	6	6.3	3.2
1	3	2	5	2					
1	3	2	6	1	2	1			
1	3	3	1	1	2	2			
1	3	3	2	1	1	-	2	7.1	5.05
1	3	3	3	1	2	1			
1	3	3	4	1	1	-	5	21.3	14.62
1	3	3	5	1	2	1			
1	3	3	6	1	2	2			
1	3	4	1	1	2	1			
1	3	4	2	1	2	1			
1	3	4	3	1	2	1			
1	3	4	4	1	2	1			
1	3	4	5	1	2	1			
1	3	4	6	1	2	1			
1	3	5	1	1	1	-	9	34.5	21.167
1	3	5	2	1	2	2			
1	3	5	3	1	2	2			
1	3	5	4	1	1	-	7	37.0	11.34
1	3	5	5	1	1	-	2	19.0	12.3
1	3	5	6	1	2	1			
2	1	1	1	2					
2	1	1	2	2					
2	1	1	3	1	2	2			
2	1	1	4	1	2	1			
2	1	1	5	1	2	1			

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
2	1	1	6	2					
2	1	2	1	2					
2	1	2	2	2					
2	1	2	3	1	2	1			
2	1	2	4	2					
2	1	2	5	2					
2	1	2	6	1	2	1			
2	1	3	1	1	2	1			
2	1	3	2	1	2	2			
2	1	3	3	1	2	2			
2	1	3	4	1	2	1			
2	1	3	5	1	2	1			
2	1	3	6	1	2	1			
2	1	4	1	2					
2	1	4	2	1	2	2			
2	1	4	3	2					
2	1	4	4	1	2	1			
2	1	4	5	2					
2	1	4	6	1	2	1			
2	1	5	1	2					
2	1	5	2	1	2	1			
2	1	5	3	2					
2	1	5	4	1	2	1			
2	1	5	5	1	2	1			
2	1	5	6	2					
2	2	1	1	1	2	2			
2	2	1	2	1	2	1			
2	2	1	3	1	2	2			
2	2	1	4	1	2	2			
2	2	1	5	1	2	1			
2	2	1	6	1	2	2			
2	2	2	1	1	2	1			

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
2	2	2	2	2					
2	2	2	3	1	2	1			
2	2	2	4	1	2	2			
2	2	2	5	1	2	2			
2	2	2	6	2					
2	2	3	1	1	2	2			
2	2	3	2	1	2	2			
2	2	3	3	1	2	1			
2	2	3	4	1	2	1			
2	2	3	5	2					
2	2	3	6	1	2	2			
2	2	4	1	1	2	1			
2	2	4	2	2					
2	2	4	3	1	2	1			
2	2	4	4	1	2	1			
2	2	4	5	1	2	1			
2	2	4	6	1	2	1			
2	2	5	1	1	2	1			
2	2	5	2	2					
2	2	5	3	1	2	1			
2	2	5	4	1	2	2			
2	2	5	5	1	2	1			
2	2	5	6	1	2	2			
2	3	1	1	1	2	2			
2	3	1	2	2					
2	3	1	3	1	2	2			
2	3	1	4	1	2	1			
2	3	1	5	2					
2	3	1	6	1	2	1			
2	3	2	1	1	2	1			
2	3	2	2	2					
2	3	2	3	2					

Block	Replicates	Treatment	Level	Survival	Rooting	Callusing	No. of roots	Max. length	Avg. length
2	3	2	4	1	2	2			
2	3	2	5	1	2	1			
2	3	2	6	2					
2	3	3	1	1	2	1			
2	3	3	2	2					
2	3	3	3	1	2	1			
2	3	3	4	1	2	2			
2	3	3	5	1	2	1			
2	3	3	6	2					
2	3	4	1	2					
2	3	4	2	2					
2	3	4	3	1	2	1			
2	3	4	4	1	2	2			
2	3	4	5	2					
2	3	4	6	1	2	1			
2	3	5	1	2					
2	3	5	2	1	2	1			
2	3	5	3	1	2	2			
2	3	5	4	1	2	2			
2	3	5	5	1	2	1			
2	3	5	6	2					

* For survival, callusing and rooting, 1 denotes 'YES' and 2 denotes 'NO'.

APPENDIX 2

Effect of mist and non-mist conditions and different growth hormones on percentage survived, percentage rooted and percentage callused (from non rooted cuttings).

Condition	Treatment	% survived	% rooted	% callused
1	1	100.0	38.39	72.73
1	2	94.44	27.78	92.31
1	3	100.00	22.22	64.29
1	4	100.00	11.11	100.00
1	5	100.00	27.78	76.92
2	1	72.22	0.00	33.33
2	2	50.00	0.00	33.33
2	3	83.33	0.00	50.00
2	4	61.11	0.00	50.00
2	5	66.67	0.00	44.42

Appendix 2A

Analysis of variance

Dependent variable: % survived

Source	DF	Anova SS	Mean Square	F value	Pr>F
Treatment	4	413.608660	103.402165	1.81	0.2895
Condition	1	2595.643210	2595.643210	45.48	0.0025

There is a significant difference between mist and non-mist conditions for % survived.

Appendix 2B.

Analysis of variance

Dependent variable: % rooted

Source	DF	Anova SS	Mean Square	F value	Pr>F
Treatment	4	203.885240	50.971310	1.00	0.5000
Condition	1	1633.028410	1633.028410	32.04	0.0048

There is a significant difference between mist and non-mist conditions for rooting ability.

Appendix 2C.

Analysis of variance

Dependent variable: % callused (from non-rooted cuttings)

Source	DF	Anova SS	Mean Square	F value	Pr>F
Treatment	4	550.374960	137.593740	0.94	0.5243
Condition	1	3807.571690	3807.571690	25.90	0.0070

There is a significant difference between mist and non-mist conditions for % callused (from non rooted cuttings).

Appendix 2D.

Duncan's multiple range test for variable % survived.

Alpha -0.05

DF -4

Critical range -13.29

Duncan grouping	Mean	N	Condition
A	98.888	5	1
B	66.666	5	2

*Means with the same letter are not significantly different.

Mist condition is better than non-mist condition with respect to % survived.

Appendix 2E.

Duncan's multiple range test for variable % rooted.

Alpha -0.05

DF -4

Critical range -12.56

Duncan grouping	Mean	N	Condition
A	25.558	5	1
B	0.00	5	2

*Means with the same letter are not significantly different.

Mist condition is better than non-mist condition with respect to % rooted.

Appendix 2F.

Duncan's multiple range test for variable % callused (from non rooted cuttings).

Alpha -0.05

DF -4

Critical range -21.31

Duncan grouping	Mean	N	Condition
A	81.246	5	1
B	42.220	5	2

*Means with the same letter are not significantly different.

Mist condition is better than non-mist condition with respect to % callused from non-rooted cuttings.

APPENDIX 3

Effect on growth hormones on percentage survived, percentage rooted, average number of roots/cutting, maximum length of roots/cutting and Average length of roots/cutting for mist condition.

Replication	Treatment	% survived	% rooted	No. of roots/cut	Max. length of root/cut	Avg. length of root/cut
1	1	100.00	16.67	8.00	73.2	35.38
2	1	100.00	66.66	4.25	12.62	7.46
3	1	100.00	33.33	3.00	11.40	6.07
1	2	100.00	0.00	0.00	0.00	0.00
2	2	100.00	50.00	5.00	11.00	6.41
3	2	83.33	33.33	4.50	23.40	12.22
1	3	100.00	16.67	1.00	4.10	4.10
2	3	100.00	16.67	5.00	26.30	20.74
3	3	100.00	33.33	3.50	14.20	9.84
1	4	100.00	16.67	6.00	40.20	10.60
2	4	100.00	16.67	9.00	19.30	12.34
3	4	100.00	0.00	0.00	0.00	0.00
1	5	100.00	16.67	1.00	6.20	6.20
2	5	100.00	16.67	1.00	5.00	5.00
3	5	100.00	50.00	6.00	30.17	14.94

Appendix 3A

Analysis of variance

Dependent variable: % survived

Source	DF	Anova SS	Mean square	F value	Pr>F
Treatment	4	74.10370667	18.52592667	1.00	0.4516

There is no significant difference between treatments for % survived.

Appendix 3B

Analysis of variance

Dependent variable: % rooted

Source	DF	Anova SS	Mean square	F value	Pr>F
Treatment	4	1221.844493	305.461123	0.82	0.5385

There is no significant difference between treatments for % rooted.

Appendix 3C

Analysis of variance

Dependent variable: Average number of roots/cutting

Source	DF	Anova SS	Mean square	F value	Pr>F
Treatment	4	15.51666667	3.87916667	0.41	0.8004

There is no significant difference between treatments for average number of roots per cutting.

Appendix 3D

Analysis of variance

Dependent variable: Maximum length of roots/cutting

Source	DF	Anova SS	Mean square	F value	Pr>F
Treatment	4	840.0672267	210.0168067	0.50	0.7391

There is no significant difference between treatments for maximum length of roots per cutting.

Appendix 3E

Analysis of variance

Dependent variable: Average length of roots/cutting

Source	DF	Anova SS	Mean square	F value	Pr>F
Treatment	4	190.6700267	47.6675067	0.52	0.7221

There is no significant difference between treatments for average length of roots per cutting.

Appendix 3F

Duncan's multiple range test for variable % survived

Alpha	-0.05			
DF	-10			
Number of means	-2	3	4	5
Critical range	-7.816	8.174	8.404	8.520

Duncan grouping	Mean	N	Treatment
A	100.00	3	1
A			
A	100.00	3	4
A			
A	100.00	3	3
A			
A	100.00	3	5
A			
A	94.443	3	2

- Means with the same letter are not significantly different.

Control is better than other treatments with respect to % survived.

Appendix 3G

Duncan's multiple range test for variable % rooted

Alpha	-0.05			
DF	-10			
Number of means	-2	3	4	5
Critical range	-34.95	36.55	37.57	38.09

Duncan grouping	Mean	N	Treatment
A	38.89	3	1
A			
A	27.78	3	5
A			
A	27.78	3	2
A			
A	22.22	3	3
A			
A	11.11	3	4

- Means with the same letter are not significantly different.

Control is better than other treatments with respect to % rooted.

Appendix 3H

Duncan's multiple range test for variable average number of root per cutting

Alpha	-0.05			
DF	-10			
Number of means	-2	3	4	5
Critical range	-5.613	5.870	6.035	6.119

Duncan grouping	Mean	N	Treatment
A	5.083	3	1
A			
A	5.000	3	4
A			
A	3.167	3	3
A			
A	3.167	3	2
A			
A	2.667	3	5

- Means with the same letter are not significantly different.

Control is better than other treatments with respect to average number of roots per cutting.

Appendix 3l

Duncan's multiple range test for variable maximum length of root/ cutting

Alpha	-0.05			
DF	-10			
Number of means	-2	3	4	5
Critical range	-37.35	39.06	40.15	40.71

Duncan grouping	Mean	N	Treatment
A	32.41	3	1
A			
A	19.83	3	4
A			
A	14.87	3	3
A			
A	13.79	3	5
A			
A	11.47	3	2

- Means with the same letter are not significantly different.

Control is better than other treatments with respect to maximum length of roots per cutting.

Appendix 3J

Duncan's multiple range test for variable average length of root/cutting

Alpha	-0.05			
DF	-10			
Number of means	-2	3	4	5
Critical range	-17.35	18.15	18.66	18.92

Duncan grouping	Mean	N	Treatment
A	16.293	3	1
A			
A	11.558	3	3
A			
A	8.713	3	5
A			
A	7.647	3	4
A			
A	6.210	3	2

- Means with the same letter are not significantly different.

Control is better than other treatments with respect to average length of roots per cutting.

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