THE STUDY ON VEGETATIVE PROPAGATION BY SHOOT CUTTINGS OF TEAK AND SOME OTHER COMMERCIAL TREE SPECIES TO ENHANCE GENETIC CONSERVATION

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ABSTRACT

The paper dealt with the upgrading of technology with respect to vegetative propagation of some commercial timber species of Myanmar. The species tested were Teak (***Tectona grandis* Linn.f**), Padauk (***Pterocarpus macrocarpus* Kurz**.), Yemane (***Gmelina arborea* Roxb**.) and Thinwin (***Millettia pendula* Benth**.). Three experiments were conducted a) to find out the response of different growth regulators at different levels of concentration, b) to find out the effectiveness of different types/ forms of commercial IBA compound and, c) to find out the amount of rooting in different species due to seasonal variations. The results of maximum rooting of 65 % for Teak was obtained by treatment with 100 ppm IBA and IAA, 78 % for Padauk by using 300 ppm NAA, 62.5 % for Thinwin by using 100 ppm IBA and IAA and 99.9 % for Yemane by using 400 ppm IAA and NAA.With the treatments of different forms of commercial IBA compound (A = solution, P = powder, R = root-fro, C = control), it was observed that the maximum rooting percent was 50 % with (P) in Teak, 65 % in Padauk, 72.5 % in Yemane and 84.9 % with (A) in Thinwin. The maximum rooting percent of 55.7 % was obtained in the hot season for Teak, 48.9 % in rainy season for Padauk, 68.8 % in the rainy season for Yemane and 69.9 % in the hot season for Thinwin. Based on the over all results of the experiments, the other timber species can also be propagated by shoot cutting.

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1. INTRODUCTION

Many developing countries are trying to replenish the degraded forest by planting with fast growing species.

The Forest Department is establishing, various kind of plantations such as, commercial, watershed management, industrial, and village supply plantation.

The problem arises annually in the establishment of plantations because of the difficulties of procuring and securing the good seeds. The seeds are usually collected wherever it is available, no matter what the seed source may be.

A special teak plantation program was started in 1998 with annual target of 20000 acres together with routine plantation of 30000 acres. The planting of such areas at least required more than 6500 baskets seeds. Therefore to obtain such large amount of seed became a problem for foresters all over the country.

However, with the view of obtaining good and sufficient seeds for annual planting, the Forest Department had established Seed Production Area (SPA) wherever necessary. But, problem still remains acquiring good and sufficient amount for all the plantations.

To solve the problem, various techniques had been sought, among which vegetative propagation could become the solution for mass production of good planting stocks.

In the process of grafting and budding, wounds are made, which in turn encourage the invasion of virulent pathogens. By taking advantages of the past experiences, this experiment is to use cuttings for the establishment of clonal orchard which is comparatively much cheaper and involved less work.

The experiment conducted here is to investigated various environmental factors influencing the development of shoots and roots of some commercial tree species from shoot cuttings.

Out of the many commercial species of timber other than Teak that are expected and exported from Myanmar, there are other species like, Padauk, Thinwin and Yemane. These are the most outstanding commercial timber species, fetching a very high price per cubicmeter. Because of the great demand, these species are being widely planted in most tropical countries where the climatic conditions are favourable.

Forest trees are usually propagated by seeds, seedlings and stumps but may by also propagated vegetatively. Vegetative propagation methods are also very useful tools in propagating forest tree, especially for cloning of desired quality trees in establishing seed orchards.

Being aware of the fact that, in the long term, mono-culture practices could be detrimental to biodiversity of natural habitat, the Forest Department has put on mixed planting of teak and some other commercial tree species like Padauk, Yemane and Thinwin.

The mixed planting experiments response in good growth of the tree species where the site condition is favourable. Therefore, these species have become important and planting of the good clonal materials has to be sought to in the future for mixed plantations.

Establishment of mixed plantation of teak and other commercial species need further research to which this research paper with its preliminary finding might serve the purpose.

2. OBJECTIVES

To establish genetically superior plantations of teak and some other commercially important tree species.

2.1. Specific Objectives

- To investigate the rooting ability of shoot cuttings
- To determine the effect of treatment of growth regulating substances (GRS) on shoot cuttings.
- To find out the effect of seasonal variation in rooting of shoot cuttings.
- To transfer the technology of vegetative propagation by shoot cuttings.

3. LITERATURE REVIEW

3.1. Vegetative Propagation by Cutting Methods in Forestry

There had been many literatures covering the subject of plant propagation by using cutting methods. The cutting methods used depend largely on the individual species. Type of cutting in these methods are stump coppice, branch materials, seedlings and seedling coppices. The use of growth regulators and their optimal level of concentrations is very important in proper root initiation. The environmental factors such as temperature, relative humidity, light and appropriate mineral proportion had to be manipulated until the most favorable condition was attained for the plant growth.

With the growing trend towards more forest plantations and genetic improvement of economic forest trees it has become necessary to develop quick and economical methods of producing planting material. Vegetative propagation and multiplication of the tree species, cutting is one of the appropriate methods for establishing the forest plantations. The method is also useful for the multiplication of clones in the tree improvement program.

Doo & Thida, (1989) also reported that, rooting could be obtained by branch cuttings from the old teak tree, and also from branch cuttings of 10 years old tree species like ***Leucaena leucocephala, Acacia auriculiformis, T. grandis,*** and ***G. arborea*** could be rooted.

The reproduction by vegetative propagation provides uniformity of growth and development because differences in the genetic constitution between trees are

minimum. In most cases, vegetatively propagated trees reach reproductive maturity much earlier than the trees grown from seeds (Hammet, 1973; Hartmann and Kester, 1983 and Hartmann et al., 1990).

In forestry, vegetative propagation is useful for replicating of clonal material and for the multiplication of planting stock for plantation purposes (Hartmann et al., 1990). Propagation by cutting is one of the most important forms of vegetative propagation employed by man (Hammet, 1973). This technique only uses a portion of a stem, branch, root, or leaf which is cut from the parent plant. The plant part will then be placed under specific favourable environmental conditions that could induce the formation of roots and shoots, which thus would produce a new independent plant.

3.2. Growth Hormones

The most widely used treatment was with aqueous solution of stimulants. Concentration of aqueous solution of growth stimulants and duration of treatment of the cuttings when treating cuttings with growth stimulants, the particular action of the individual preparation should by taken into account.

The most commonly used hormones with great success are indolebutyric acid (IBA), indole acetic acid (IAA), naphthalene acetic acid (NAA) and boric acid (B/A). The effectiveness of each hormone on rooting ability depends upon the application method, concentrations used and the duration of application. (Enright, 1957).

3.3. Environmental Conditions Influencing Rooting

Hartmann, (1990) mentioned that rooting ability of cutting could be affected by many factors. Among them were plant species, age of plant materials, stock plant management, nutrition and anatomical aspects. In addition to this, environmental and physical factor such as temperature, relative humidity, light, seasonal changes, pH, hormonal treatments, presence of leaves and source of cutting materials were some important factors in determining the rooting performance.

Aminah, (1991d) placed her enclosed mist system in a shade house with a relative light intensity about 50% of full sunlight.

The temperature of the sand and air was of considerable significance for rooting. The optimum temperature for the rooting of many tree and shrub species may fluctuate within the range of 18° C – 28°C.

Light was also of great significance in the rooting of summer cuttings as it was required for the synthesis of nutrients by the leaves. Cuttings of light-loving species (Crape myrtle, Syrian hibiscus, etc.) require stronger diffused light than do cuttings of shade-tolerant species (eg. Japanese aucuba, Gardenia, etc.)

For good rooting it was necessary to maintain a fairly high relative air humidity (95%) and a moderate sand humidity (60 % - 70 % of full water-holding capacity).

3.4. Misting System

Aminah & Dick. (1994) had published that the frequency of misting is important to the rooting success of some species. Lo, (1985) found, with *S. macrophylla,* that continuous mist resulted in 80 % rooting, whereas misting alternate hours during the day and continuously during the night gave 70 % rooting, and misting alternate hours during the day and no mist at night gave 15%. She attributed the depth of cuttings in the latter treatment to water stress experienced by the cuttings during the night.

In hot weather, cuttings were given a little water morning and evening from the watering can with a fine screen, and four to five times during the day, the leaves were sprayed with an automizer or "Automax" sprayer giving a fine mist. (Aminah, 1991d)

3.5. Rooting Media

Many researcher had utilized coarse to medium river sand as a medium for mist propagation system (Momose1978, Lo 1985, Aminah (1991a, 1991c) and non-mist systems (Muckadell & Malim, 1978).

River sand in Malaysia was reported by Aminah (1991 a) to contain a range of particle sizes approximately 60 % < 2 mm and 40 % > 2 mm.

This medium was favorable, because water drains freely and the base of the cutting did not became waterlogged.

Pollisco, (1994) mentioned that the rooting media consisted of a 1:1 ratio of coconut coir and river sand by sundrying for one week. Before planting, the media were saturated saturate the medium with water and further sterilized it by pouring Benlate solution into the potted mixture in the hiko trays.

Komissarov, (1969) reported that summer cuttings, either after or without treatment with growth stimulants, were planted in previously prepared hotbeds or green houses.

4. MATERIALS AND METHODS

4.1. Sequences of Vegetative Propagation of Teak by Cutting

There were 8 steps in the sequences of vegetative propagation of teak by cutting as shown in Plate 1.

Step 1 involved the collection of clones or propagules obtained from Step 2. (selected superior trees).

In Step 2 and Step 3, the clones were reproduced by vegetative propagation techniques either by grafting, budding or branch cutting for the establishment of clonal seed orchard or hedge garden.

The procedure involved in this experiment began from Step 4 as explained in the Plate 1, assuming that, the seeds or the plant parts raised in nursery were obtained from good seed source. Thus, from Step 5, subsequence procedure involved the establishment of hedge garden. Then the shoot cuttings were obtained from the garden and planted in the chamber.

After the development of shoots and roots, the plants were hardened before outplanting in the field.

There were three experiments in this study.

Experiment I. The response of different concentration levels of five treatments.
Experiment II. The effectiveness of different forms of commercial IBA compound.
Experiment III. The effect of seasonal variation in different species.

4.2. Experiment. I: The Response of Different Concentration Levels of Five Treatments.

4.2.1. Construction of chambers for the experiment

There were different types of chambers, such as Plastic Chamber (PC), Portable Plastic Chamber (PPC), and Glass Box Chamber (GBC) were used.

The PC, size of (10ft x 7ft x 7 ft) was constructed with wooden framework and PPC, size of (10ft x 4ft x 3ft) was made of bamboo frame. Some parts of the roof were covered with transparent plastic sheet to enable plants to receive sunlight inside the chamber. The GBC, size of (5ft x 2ft x 2 ft) was used as a propagator, the top and the end sides of the chamber were covered with transparent glass sheet and wet gunny sack to permit sufficient light and to maintain high humidity.

Seedlings were cut and the leafless cuttings were put in the PPC or PC. The shoot cutting treatments were investigated in GBC.

4.2.2. Rooting media

In this experiment, oven-dried river sand was used as rooting media. In additional to the sand, soil mixture, burnt husk, rice hull and coconut husk were mixed and tried as alternative media. When the shoot cuttings were planted in the media and placed in the (PPC) or (GBC).

4.2.3. Preparation of the rooting hormones

The stock solutions of hormones were prepared by using 100 mg of hormone making up to 100, 200, 300, 400 and 500 ppm in a litre of distilled water. The fresh stock solution was always used.

Dipping methods were used in this experiment. The levels of the concentration and growth hormones used in this experiment were 100-500 ppm IBA; 100-500 ppm IAA; 100-500 ppm NAA; 100-500 ppm B/A; 5% Root fro; and 30000 ppm IBA powder and untreated as the control. These hormones were obtained in the powder form produced by the product of Sigma Chemical Company, USA. Except only Root fro and mixture of compound powder of IBA were obtained from Thialand.

4.2.4. Preparation of cutting materials

In experiment one, ***Tectona grandis*** Linn.f. (Teak), ***Gmelina arborea*** Roxb. L. (Yemane), ***Pterocarpus macrocarpus*** Kz. (Padauk), and ***Millettia pendula*** Benth. (Thinwin) were tested. Teak seeds were collected from Phyu region, and Padauk, Yemane and Thinwin seeds were obtained from Yezin and raised in the nursery bed. Stock plant (seedlings) were raised under semi- shade in the nursery. The shoot cutting materials were taken from the healthy stock plants which were free from disease and insect attack.

Material for propagation was obtained from the seedlings after 3 to 11 months. The size of cuttings were about (2-3) inches made from the terminal shoot portion of seedlings. A total of 4000 seedlings from the four selected species of different ages and sources were taken for the research except Teak all other species were from one source i.e Yezin.

A secateur was used for shoot cuttings. The average length of the shoot cuttings of Teak was (55) mm and (3.4) mm in diameter, Padauk was (83.7) mm and (2.2) mm in diameter, Yemane was (75.5) mm and (3.6) mm in diameter and Thinwin was (52.2) mm and (1.7) mm in respectively.

The leaf area retained on each cuttings was about one-third leaves in order to reduce transpiration rate. The basal end of the stem cuttings were cut diagonally in order to facilitate in planting.

Each treatment consisted of 50 cuttings and with 10 cuttings from each species. These cuttings were planted in four blocks in oven-dried river sand.

The prepared shoot cuttings were treated with different levels of hormone and different concentration of plant growth substances.

The experiments were conducted in GBC or PPC and which were under controlled condition of temperature, light and relative humidity.

4.2.5. Misting system

A fine spray of water droplets on the leave of cuttings every few minutes prevents them from wilting, but the evaporation of water from the leaves varies with the prevailing weather conditions. An automatic control system is needed if full advantage is to be taken of a mist system.

The shoot cuttings were subjected to misting at frequencies of one minute at an hourly intervals using hand-held sprayer or knap-sack sprayer. At the same time, wet gunny sacks along the sides and the transparent plastic sheets on the top and the end sides of the propagation bed were kept moist by watering with a fine spray every two to three hours. Between 60 to 95 % humidity and 25° C to 30° C temperature were maintained for the shoot cuttings.

Air temperature and relative humidity were measured by using dry and wet bulb thermometer and digital hygrometer was used to record the temperature and humidity for both inside and outside the areas of the propagation bed.

For each experiment, the temperature and relative humidity were recorded daily throughout the whole experiment.

The measurements were made three times a day i.e. 8:00 to 9:00 am, 12:00 to 1:00 pm and 4:00 to 5:00 pm (morning, noon, evening).

4.2.6. Treatment and planting of shoot cuttings

The seedlings were sprayed with fungicide and insecticide before collecting the cuttings. Shoots were then cut and collected for planting.

Prior to planting, the medium was kept moist. The shoot cuttings were dried with a towel at their basal end. Then they were dipped in respective hormones according to the planned experiment. And they were planted in the sand medium at the depth of 2.0 – 3.0 cm. The distance between cuttings and row were 5 cm and 10 cm respectively.

In the case of five treatments (IBA, IAA, NAA, 2,4-D and Control), five concentration levels of (100ppm to 500ppm) with 200 shoot cuttings (4 replicates of 50 each) were used in each treatment. Cuttings of these four species were planted in sand box container (18″ x 12″ x 6″) and kept in a glass box chamber at high relative humidity of about 95 %. Shoot cuttings were put under partial shade of plastic net (60% shade) to avoid sun scorch.

4.3. Experiment II: The Effectiveness of Different Forms of Commercial IBA Compound.

The experiment conducted was the same as previous procedure. The only difference was that, only one hormone was used with different concentration levels. The Growth Regulating Substances (GRS) used were of different forms of commercial IBA which were as follows; (A = 100ppm IBA solution), (P = 30000ppm IBA powder), (R = 5% Root fro with vitamins), and control (untreated). The experiments conducted were of 4 treatments with 4 species.

4.4. Experiment III: The Effect of Seasonal Variation in Different Species

In the seasonal variation experiments the seasons were divided into three periods. Hot season (March to May), rainy season (June to September) and cold season (November to January).

4.5. Observations, Assessment of Shoot Cuttings and Statistical Analysis

The observations for the condition of shoot cutting were made daily to record both the temperature and relative humidity from morning, noon to the evening. Weekly assessment was made on shoot cuttings two weeks after treatment. The dried and dead shoot cuttings and the shed leaves were removed from the sand box or sand bed immediately to prevent spread of fungus and diseases.

The shoot cuttings were uprooted from sand box two months after planting and observations were made and percentage of rooted cuttings and the length of roots per cutting were recorded. For Teak and Yemane observations were made after 35 to 45 days. As for Padauk and Thinwin observations were made within 60 days after planting.

The data recorded were survival and rooting percentage, number of shoot and root per cutting. The data obtained were statistically analyzed using one way analysis of variance (ANOVA), following a complete Randomized Design (CRD). Mean separation was by using Duncan Multiple Range Test (DMRT) and was analyzed only when ANOVA showed significant differences.

5. RESULTS

Rooting response varied with species, growth regulating substances (Growth Hormone), their concentration, different forms of commercial hormone compound and also the season of treatment.

The following results were obtained.

5.1. Experiment. I: The Response of Different Concentration Levels of Five Hormonal Treatments

5.1.1. Shoot cutting of teak

Of the five hormonal treatments of (IBA, IAA, NAA, 2,4 -D, Control) and the five concentration levels (100, 200, 300, 400, 500 ppm). 100 ppm IBA and IAA hormone treatment showed maximum rooting of 65%.

Although it was not significant in hormonal treatment, 100ppm concentration level was most effective compared to others.

Rooting occurred in untreated (control) which was (28%), but in 2,4 -D hormone treatment, the percentage of rooting was lower than control which was (14.5%). Among the treatments IBA hormone showed the best result (55.5%). Therefore, IBA should be given priority in using hormone. It was more effective than

other hormone. It was also observed that, the best treatment selected by DMRT was 100ppm IBA.

5.1.2. Shoot cutting of Padauk

Although two factors interaction (hormonal treatment and concentration level) was not significant, concentration level was highly significant. The 300ppm application rate was the most suitable in this experiment.

Mean comparison of original scale indicated that difference between the three hormonal treatments of IAA, B/A and control were not significant with regard to percentage of rooting (44.9%, 43.5%, 43.4%).

5.1.3. Shoot cutting of Yemane

Analysis of variance (Appendix. A, and Appendix. C, Table 4) indicated that hormonal treatment and concentration levels were highly significant at 1% level.

With treatment of various hormone (Growth Regulating Substance) the rooting occurred in shoot cutting treated with IBA, IAA, NAA, 2,4-D and control (untreated).

According to the bases on the original scale table, hormonal treatment of IBA, NAA, IAA had the same effect, (86.4%, 85.4%, 84.5%). Therefore, any hormone could be used with reliability.

Of the five concentration level of treatments (100 to 500ppm), 400ppm showed the highest survival rate of (81.9%), followed by 200ppm concentration level (75.9%).

With untreated (control), rooting percent was better than 2,4-D. Therefore, (untreated) control could be survived and rooted in shoot cutting of *G. arborea*.

5.1.4. Shoot cutting of Thinwin

There was significant in hormonal treatment at 1 % level. Of the four treatments (IBA, IAA, NAA, and control), mean comparison of original scale showed the percentage of rooting at IBA (58.49%), IAA (43%), NAA (37.5%) and control (34%).

IBA hormone was suitable for shoot cutting of Thinwin but Control (untreated) rooted better with 2,4-D hormone.

Analysis of variance indicated that difference between the five concentration levels of different hormone (GRS), 100ppm IBA concentration levels was more effective (62.49%), followed by IAA 100ppm (42.5%). The others were not significant. (Appendix. A).

5.2. Experiment II: The Effectiveness of Different Forms of Commercial IBA Compound

5.2.1. Shoot cutting of Teak

There was no significant in all the treatments. (Appendix - C) But with the four treatments of (A, P, R, C), it was observed that, the maximum rooting percentage was 50 % with P=T_2= IBA powder. (Figure. 7)

5.2.2. Shoot cutting of Padauk

In treatment with different forms of commercial IBA compound, P=T_2 (IBA powder) treatment was significant at 5 % level (65%) followed by 48% in R=T_3 (5% Root fro).

5.2.3. Shoot cutting of Yemane

Induction of rooting of shoot cuttings of *G. arborea* was highly significant in P=T_2 (IBA powder) was 73 % followed by R=T_3 (5% Root fro) at 68 % as shown in Figure 7.

5.2.4. Shoot cutting of Thinwin

In treatment with different forms of commercial IBA compound, A = T_1 (100ppm IBA solution) was highly significant which was 87 % followed by 75.7% in R = T_3 (5% Root fro). The others (P=T_2= Powder) and (C=T_4= control) were not significant in this experiment. (Table. 2 and Fig. 7)

5.3. Experiment III: The Effect of Seasonal Variation in Different Species

5.3.1. Shoot cutting of Teak

To test the effects of seasonal variation on rooting of shoot cuttings, the experiments were conducted during hot season, rainy season and cold season. The cuttings were treated with 100 ppm of IBA. Rooting percents were observed from March to May (Hot season) (55.7%), June to September (Rainy season) (49.6%) and November to January (Cold season) (38.5%). (Figure.8)

5.3.2. Shoot cutting of Padauk

The development of shoots treated with 100 ppm IBA was (48.9%) in rainy season, (43.1%) in cold season, and (12.5%) in hot season respectively.

5.3.3. Shoot cutting of Yemane

In the seasonal effect of rooting, the response of Yemane was better compared to Teak with a maximum of 68.8% rooting in rainy season followed by 65 % in cold season and 55% in hot season.

In the seasonal effect of rooting in Yemane, the percentage of rooting was more than other species.

5.3.4. Shoot cutting of Thinwin

The seasonal effect of rooting in Thinwin, were at a maximum of (69.9%) in hot season, 39% in rainy and 43 % in cold season.

Table (1) Data on Average Diameter and Length, the Age of Stock Plant and Shoot Cutting, and Duration of the Period of Rooting

Species	Average Diameter (mm)	Average Length (mm)	Age of Stock Plant (month)	Age of Shoot cutting (days)	Duration of the period of rooting (days)
Tectona grandis (Teak)	3.4	55	6	89	42
Millettia pendula (Thinwin)	1.7	52.2	5	95	64
Gmelina arborea (Yemane)	3.6	75.8	4	74	35
Pterocarpus macrocarpus (Padauk)	2.2	83.7	6	90	60

Table (2) Rooting % of Different Species with IBA Compound

Species	Solution	Powder	Root-fro	Control
Teak	33.2	50	36.8	34.2
Padauk	39.6	65	43.3	30.2
Yemane	55	72.5	67.5	50
Thinwin	84.9	51.2	73.8	35

Table (3) Rooting % of Different Species at Three Seasons

Species	Hot Season	Rainy Season	Cold Season
Teak	55.7	49.6	38.5
Padauk	12.5	48.9	43.1
Yemane	55	68.8	66.3
Thinwin	69.9	39.1	42.8

6. DISCUSSIONS

The present study demonstrated that Teak, Padauk, Yemane and Thinwin can be vegetatively propagated by shoot cutting of young seedlings in chamber.

The upper portion of the shoot had only one internode. In the shoot cutting of Teak experiment, the root and shoot developed within 28 – 45 days. After 40 to 60 days (approximately 2 months) the maximum of rootlets were 2 to 7 per shoot cutting for Teak. In the root and shoot ratio, the root growth was found to be faster

than shoot growth. In some cases, root growth was observed although there was no new shoots. The development of shoot cuttings of Thinwin, Teak and Yemane of which Yemane with 3.6 mm diameter had better development than the other two. (See Table 1.)

Thinwin which had one pair of leaf when planted had a poor development of roots. There were only 2 to 3 rootlets, and also had a poor new shoot development. (Plate 9.)

In the trial of Yemane and Padauk, there were no different in diameter of shoot cutting, but the shoot development of Yemane and Padauk were much better than Teak and Thinwin.

There were 2 to 3 pairs of leaf, and the shoot length of Padauk was 20 to 50 mm longer. The average root growth of Padauk was 2 to 4 rootlets and Yemane 7 to 10 rootlets. After the development of root and when the four species were planted in soil mixture, the growth of both shoots and roots were vigourous.

6.1. Effect of Plant Growth Regulators

Hartmann, (1990) demonstrated that plant hormones, especially auxin whether endogenous or exogenous have a great effect on improving the rooting percentage, hastening root initiation and increasing the number of root produced on cuttings.

The results obtained in the experiment I, where shoot cuttings of Teak rooting of 65% at the concentration level of 100 ppm IBA and NAA was the best compared to other species tested. The result was the same as mentioned by Hartmann (1990).

Shoot cuttings of Padauk rooted much more vigorously at the concentration levels of 300ppm IBA and 300 ppm NAA which was better than treated Teak. With the five growth hormone tested, the concentration of 500ppm resulted in the poor growth of root.

Yemane showed the best result of rooting among the four species tested. It was also observed that the species rooted best at a concentration levels of 200ppm and 400ppm IBA (Fig.7 b, d). It was also observed that the untreated (control) Yemane also rooted considerably. It could be concluded that no growth hormone was required in the rooting of Yemane shoot cuttings, but the temperature and relative humidity should be regularly adjusted according to the required optimum conditions.

With the concentration levels of 200 ppm IBA, 63 % of rooting occurred in Thinwin. However, when compared to Padauk and Yemane, the rooting was less. (Fig. 5b, 6b, 7b, 8b)

In the experiment one, it was found that Yemane and Padauk rooted more than 70% where as Teak and Thinwin rooted only 60 %.

In the experiment two, when different forms of commercial IBA compound were used, T_2 (P = IBA powder) produced the best rooting compared to T_1,T_3,and T_4.

Yemane showed the best rooting at 60-73 %. Treatment with T_1, Thinwin rooted 84 % followed by 73 % with T_3 (R = 5% Root fro).

The use of different kind of hormones in the experiments indicated that, IBA powder (Thailand) and Root fro (Thailand) were as effective as hormone obtained from USA (Sigma Co.Ltd). When the expenditure were compared IBA from Thailand were mach cheaper and could be sufficiently obtained from the market for experiment. It was therefore advisable to use only cheap and easily available IBA.

However, with respect to the degree of rooting and shoot bud development, those treated with 500ppm IBA had better results compared to those in untreated cuttings (control).

Pollisco, (1994) reported that, in all species, hormone requirement was emphasized. *Dendrocalamus grandiflorus* had 4.4% rooting in the untreated cuttings, 44.44% rooting at 500ppm IBA and 50% at 1000ppm IBA which may just be good results considering its being a difficult – to – root species. However, with respect to the degree of rooting and shoot bud development, those treated with 500ppm IBA had better results compared to those in untreated cuttings (control).

Surendran & Seethalakshimi (1987) working on some important tree species came to the conclusion that all the three factors i.e. GRS their concentration and season have considerable effect on induction of rooting in cutting. They also reported that a treatment of IBA 100 ppm in May was most effective for Teak, while NAA 100ppm in April gave best result for Yemane.

Snow (1938), Snow (1941), Grace (1939), Thimann and Delisle (1939), Edgerton (1944), Overbeck and Gregory (1945) and Enright (1958) were observed that season of taking the cuttings, nutrient status and hormonal relation were some other factor of considerable importance.

Nutrient materials were of importance in rooting not only in relation to their ratio with auxin, but also in terms of the amount of substrate present for the actual growth of roots.

Doo and T. Mundt, (1989) also reported the same effect with propagules tried from the old teak trees.

The present experiment was different in that young apical shoot from young seedlings were used instead of using old propagules.

IBA was physiologically more active than IAA; NAA was similar to IAA in its activity, but more toxic and therefore applied in weaker concentrations.

Uchimura,(1979) found that treatment with IBA was better than that with IAA and NAA for rooting of ***B. vulgaris*.**

Seethalakshmi el at. (1983) also found that coumarin, NAA and a mixture of coumarin and IAA gave the highest percentage of rooting in the case of ***B.balcoa*.** NAA and B/A showed better sprouting and rooting than the control in the case of ***B.balcoa*.**

Choummaravong, (1989) reported that IBA 50 and 100 µg stimulated better rooting responses. However, the untreated cutting (control) gave the best survival percentages and also produced higher rooting percentage than some cuttings, which were treated with IBA 100 and NAA 100, 150 µg. It means that the lower level concentrations of auxin (viz: Seradix 2, IBA 50 and 100 µg) used in his study had been found reliable in stimulating the adventitious root production in *Azadirachta excelsa* cuttings.

Among the hormones used IBA was found to be the most effective. It has been generally used in vegetative propagation work because it was nontoxic over a wide concentration range and it has been reported to be effective in tropical hardwood species such as ***S. platyclados*** and ***S. acuminata*** Alias (1984), ***Dipterocarps spp***. Srivastava et al., (1986), ***A. mangium*** and ***S. leprosula*** Ng (1988), ***S. leprosula*** and ***S. curtisii*** (1992), ***S. acuminata*** Ling (1993), *A. mangium*, ***A. auriculiformis*** and ***L. diversifolia*** Ding (1993).

This may account for the results reported by Jen (1984). He observed that when the relative humidity in the propagation system was low, rooting only occurred when cuttings of ***S. macrophylla*** received 50 ppm IBA(16%) and no cuttings with 0, 100, 150 or 200ppm IBA rooted.

Surendran & Seethalakshimi, (1987) found that, a treatment of IBA 100ppm in May was most effective for ***T. grandis*** while NAA 100ppm in April gave best results for ***G. arborea, L. leucocephala*** was comparatively easy to root and a treatment of IAA 100ppm in September gave profuse rooting and sprouting. For root induction in sprigs of ***C. equiselifolia*** treatment with IBA 10 or 50 ppm; in control only callus formation was observed.

Some other researcher also stated similar finding on *A. mangium* and *S. curtisii* that higher doses of hormonal treatments could reduce the growth of shoots. They showed that at lower concentration of hormone as well as control increase the shoot growth.

Similarly, in this study, the experiment with four species of shoot cuttings and with five concentration levels indicated that cutting treated with low level of hormone rooted best compared to other higher concentration level of hormone. Untreated shoot cutting (control) also showed good result in rooting compared to high concentration level. Example as indicated were 100ppm IBA and 100ppm NAA and 400ppm NAA in Thinwin.

6.2. Cutting Position

In this study, seedlings were raised from the seeds and after 3 – 4 months the cuttings were obtained from the seedlings. The shoot cuttings were obtained from two position, terminal and basal position of Padauk and Yemane. Only terminal shoots were obtained from the other two species, Teak and Thinwin. With terminal

shoot cutting, there was a good growth of roots from Yemane and Padauk but very few from Padauk basal shoots.

6.3. Effect of Seasonal Variation

Surendran & Seethalakihimi, (1987) indicated that, all the three factors, i.e, growth regulating substance, their concentration and seasonal effect had considerable effect on induction of rooting in cuttings. A treatment of 100ppm IBA in May was most effective with ***T. grandis*** while 100 ppm NAA planted in April gave best result for ***G. arborea*** and ***L. leucocephala.***

Comparatively, ***G. arborea*** and ***L. leucocephala*** were easy to root with a treatment of 10 ppm IBA in September which resulted in profuse rooting and sprouting.

In this study, Teak planted in May i.e., hot season, produced the best result of rooting, and the survival percentage was also high. This demonstrated similar outcome of result mentioned by Surendran & Seethalakihimi. But in the case of Yemane and Padauk, the rooting per cent and survival percentage were higher in rainy season and cold season.

White (1947), studied the effect of seasonal variation on the rooting of branch cuttings in some bamboo species. His results showed that the average rooting percentage was at a maximum in December (15.8%), 10.5 % in June, 3.3 % in September.

March and April was found to be the best for the preparation of branch cutting of Teak (Doo & Thida Mundt, 1989 –1991). It was known from experience that the optimum time is often before growth initiation in the plant' cycle.

Snow (1938), Snow (1941), Grace (1939), Thimann and Delisle (1939), Edgerton (1944), Overbeck and Gregory (1945) and Enright (1958) observed that season of taking the cuttings, nutrient status and hormonal relation were some other factors of considerable importance.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The result of the experiments indicated that planting stock of ***Tectona grandis, Pterocarpus macrocarpus, Gmelina arborea*** and ***Millettia pendula*** could be raised through shoot cuttings. It can be successfully rooted when using appropriate cutting materials by manipulated with favorable environmental conditions. Among the specific conclusions drawn from this study include:

1. The result of the experiment indicated that among the five hormonal treatments, IBA was the best growth stimulants (hormones).
2. Among the treatments with different concentration levels, 100ppm IBA and 100ppm IAA resulted in the increased of rooting percent significantly for

shoot cutting of Teak. As for Padauk treatment with 300ppm IBA and NAA showed the best rooting. In the case of Yemane, there was little difference in the root development whether treated with high or low concentration levels. Hence, in the case of Yemane treatment with growth stimulants (hormones) was not necessary. The species could be vegetatively propagated on its own provided the environmental conditions were favourable. Of all the species tested Yemane and Padauk rooted better than Thinwin and Teak.

3. The commercial IBA tested showed that Powder and Root-fro was better than the IBA production from Sigma company. It was advisable that for mass production of planting stock Root-fro should be used.
4. With the effect of seasonal treatments it was found that a reduction of temperature and high humidity during rainy and cold season result better than hot season. There was also better root development of Yemane and Padauk during those seasons. In the case of Teak and Thinwin, a higher temperature during hot season was better for rooting.
5. The highest temperature in the chamber was 40ºC in hot season and the lowest temperature was 20º C in cold season. During the experiment, shoot cuttings could be wilted and dried up when the temperature was very high. Therefore, temperature and relative humidity should be manipulated to obtain optimal conditions.
6. With the experience through the experiment conducted it was advisable that the temperature of (25 ^{0}- 28 ^{0} C) and relative humidity of (70 - 95 %) should be maintained during the process of propagation.

7.2. Recommendations

Based on the results obtained in the present study, the following recommendations are made and should be considered for future research work.

1. Other tests such as cutting position and different sizes of cutting and test for correlation between cuttings, watering and different media should be conducted.
2. Effect of environmental factors, such as air and media temperature, light intensities and relative humidity on rooting performance of some commercial species of cuttings (coppice from hedge garden / shoot / stem) should be studied in more detail.
3. Effect of carbohydrate and nitrogen (CHO/N ratio) content on rooting performance of cuttings and the cause of mortality of cuttings in the rooting beds should be further investigated.

4. It would be extremely beneficial if more studies are made on the morphological, anatomical and physiological changes, which are induced by cutting's environments. This will enhance the information on appropriate choice of suitable plant materials.
5. Awareness of the fact that temperature and humidity are the most important factors in vegetative propagation especially when cutting materials are used as propagules. Therefore, the most appropriate temperature and humidity should be regulated during the process of propagation.
6. Juvenile sources should be used for cuttings, to ensure better rooting.
7. To obtain juvenile cutting materials, the establishment of hedge garden (clonal garden) and raising stump coppice seedlings are needed.
8. Other species like ***Xylia xylocarpa*** (Pyinkado) where collection of it seeds are difficult, should be given priority for further research on vegetative propagation.

Appendix A

Experiment I

Table (1) Analysis of Variance (ANOVA) Based on Rooting Percentage of Different Species in Different Concentrations.

Concentration Level	Teak			Padauk			Yemane			Thinwin		
	SS	F-Value	CV %	SS	F-Value	CV %	SS	F-Value	CV %	SS	F-Value	CV %
100 ppm	4207.99	3.95*	34.16	950.97	4.33*	17.9	6879.65	9.81**	30.69	6448.61	6.35**	72.85
200 ppm	3158.07	5.50**	30.2	865.66	< 1	38.44	11541.34	8.50**	33.12	5030.94	14.18**	36.51
300 ppm	996.82	< 1	79.49	581.06	1.34 ns	21.9	8884.09	15.51**	17.82	719.56	< 1	34.41
400 ppm	2355.54	3.01 ns	48.6	1426.05	1.15 ns	35.97	12424.28	16.51**	19.76	2355.54	3.01 ns	48.6
500 ppm	2250.90	6.89**	25.93	162.05	< 1	6.44	2083.01	2.51 ns	24.52	478.75	< 1	32

* = significant at 5 % level
* * = significant at 1 % level
ns = not significant

Appendix. B

Experiment (I) The Response of Different Concentration Levels of Five Treatments

Table (1) C x T Table of Means for Teak (%), Based on Original Scale (AVE. OVER. 4 REPS)

Concentration (C)	Treatment (T)					
	IBA	IAA	NAA	2, 4 - D	Control	C - mean
100 ppm	65.0 a	65.0 a	40.0 a	15.0 a	32.5 a	43.5 a
200 ppm	60.0 a	45.0 a	55.0 a	7.5 a	30.0 a	39.5 a
300 ppm	45.0 a	32.5 a	37.5 a	17.5 a	27.5 a	32.0 a
400 ppm	52.5 a	57.5 a	25.0 a	17.5 a	27.5 a	35.9 a
500 ppm	55.0 a	50.0 a	30.0 a	15.0 a	22.5 a	34.5 a
T- MEAN	55.5	49.9	37.5	14.5	28.0	37.09

In a column, means followed by a column letter are not significantly different at the 5 % level by DMRT.

Table (2) C x T Table of Means for Padauk (%), Based on Original Scale (AVE. OVER. 4 REPS)

Concentration (C)	Treatment (T)					
	IBA	AA	NAA	B/A	Control	C - mean
100 ppm	72.5 a	60.0 a	50.0 a	47.5 ab	40.0 ab	54.0 a
200 ppm	60.0 a	52.5 a	67.5 a	50.0 ab	40.0 ab	53.9 a
300 ppm	75.0 a	57.5 a	77.5 a	60.0 a	72.5 a	68.5 a
400 ppm	69.9 a	40.0 a	65.0 a	40.0 ab	49.9 a	52.9 a
500 ppm	20.0 b	15.0 b	25.0 b	20.0 b	15.0 b	19.0 b
T- MEAN	59.49	44.99	56.99	43.50	43.49	49.69

In a column, means followed by a column letter are not significantly different at the 5 % level by DMRT.

Table (3) C x T Table of Means for Yemane (%), Based on Original Scale (AVE. OVER. 4 REPS)

Concentration (C)	Treatment (T)					
	IBA	IAA	NAA	2, 4 -D	Control	C - mean
100 ppm	77.5 a	74.9 a	65.0 a	10.0 b	52.5 a	55.99
200 ppm	94.9 a	94.9 a	94.9 a	20.0 b	74.9 a	75.99
300 ppm	82.5 a	92.5 a	87.5 a	15.0 b	87.5 a	72.99
400 ppm	92.5 a	99.9 a	99.9 a	22.5 b	94.9 a	81.99
500 ppm	84.9 a	65.0 b	75.0 ab	12.5 c	55.0 b	58.49
T- MEAN	86.49	85.49	84.49	16.0	72.99	69.09

In a column, means followed by a column letter are not significantly different at the 5 % level by DMRT.

Table (4) C x T Table of Means for Thinwin (%), Based on Original Scale (AVE. OVER. 4 REPS)

Concentration (C)	Treatment (T)					
	IBA	IAA	NAA	2, 4 -D	Control	C - mean
100 ppm	62.5 a	42.5 ab	32.5 b	0.002 c	32.5 b	34.00
200 ppm	62.5 a	45.0 a	32.5 a	2.502 b	32.5 a	35.00
300 ppm	55.0 a	47.5 a	60.0 a	2.500 b	42.5 a	41.50
400 ppm	60.0 a	40.0 ab	27.5 b	0.005 c	32.5 ab	32.00
500 ppm	52.5 a	40.0 a	35.0 a	0.005 b	30.0 a	31.50
T- MEAN	58.49	43.00	37.50	1.003	34.00	34.80

In a column, means followed by a column letter are not significantly different at the 5 % level by DMRT.

Appendix.C (A, P, R, C)

Table (1) Analysis of Variance for Shoot Cutting of Thinwin Based on Values Transformed to Arcsine [Sqr (X/100)]

SV	DF	SS	MS	F
TREATMENT (T)	3	3186.0086	1062.0029	5.03 *
ERROR	12	2535.2200	211.2683	
TOTAL	15	5721.2286		

* = significant at 5% level

Table (2) Analysis of Variance for Shoot Cutting of Padauk Based on Values Transformed to Arcsine (Sqr(X/100))

SV	DF	SS	MS	F
TREATMENT (T)	3	1208.4788	402.8263	3.95 *
ERROR	12	1223.6760	101.9730	
TOTAL	15	2432.1548		

* = significant at 5% level

Table (3) Analysis of Variance for Shoot Cutting of Yemane Based on Values Transformed to Arcsine (Sqr(X/100))

SV	DF	SS	MS	F
TREATMENT (T)	3	476.1047	158.7016	1.39 ns
ERROR	12	1366.5536	113.8795	
TOTAL	15	1842.6583		

ns = not significant

Table (4) Analysis of Variance for Shoot Cutting of Teak Based on Values Transformed to Arcsine (Sqr(X/100))

SV	DF	SS	MS	F
TREATMENT (T)	3	424.9005	141.6335	1.69 ns
ERROR	16	1344.0636	84.0040	
TOTAL	19	1768.9641		

ns = not significant

Appendix . D

Table (1) Analysis of Variance for the Effect of Seasonal Variation

Based on Values Transformed to Arcsine (Sqr(X/100))

SV	DF	SS	MS	F
TREATMENT	35	40499.946	1157.141	10.01 **
SPECIES (S)	3	3288.362	1096.121	9.48 **
MONTH (M)	8	12074.551	1509.319	13.05 **
SxM	24	25137.034	1047.376	9.06 **
ERROR	108	12488.229	115.632	
TOTAL	143	52988.175		

** = significant at 1% level

Table (2) S x N Table of Means for Rooting Response (%)
Based on Original Scale
(AVE. OVER 4 REPS)

	SPECIES (S)				
SEASON (N)	Teak	Thinwin	Yemane	Padauk	N-MEAN
Hot	55.7500 a	69.9175 a	55.0000 a	12.5000 b	48.2919
Rainy	49.6281 a	39.1463 b	68.7581 a	48.9175 a	51.6125
Cold	38.5344 a	42.8125 b	66.3125 a	43.1405 a	47.7000
S-MEAN	47.9708	50.6254	63.3569	34.8527	49.2014

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

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