EFFECTS OF CONTAINER TYPE, FERTILIZER, AND AIR PRUNING ON THE PREPARATION OF SEEDLINGS FOR FOREST RESTORATION

NATENAPIT JITLAM

A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY

GRADUATE SCHOOL
CHIANG MAI UNIVERSITY

JULY 2001

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23 July 2001

ACKNOWLEDGEMENTS

This thesis could not have been completed without help from many people. Firstly, thank Ach. Vilaiwan Anusansunthorn, my supervisor, for giving me a chance to study and work with FORRU. She always solved many problems and supported me to do many things, with kindness for me. Ach. Stephen Elliott, was my thesis supervisor, thanks to him for correcting my thesis many times. Ach. Maxwell, helped me to understand the correct drawing of botanic pictures and provided guidelines for seedling descriptions, thank him for correcting my thesis and providing useful recommendations.

Puttipong, helped me very much with data analysis and computer problem. Many thanks for his willpower. Suwaree, had many recommendations. Jampee and Thonglao, helped me to collect seeds, take care my seedlings in the nursery and also, helped me to collect data. Chardsak, Rungtiwa, Greuk, Panee, Supawan, Wangworn and Narumon are thanked for good advice and powerful. I also thank Amanda for corrected my thesis.

Doungporn, my kind friend, given many statistic books to me and tried to make me understand statistics and many friends that I can not said in here thank for powerful and make me happy from everybody.

I thank BRT (Biodiversity Research and Training Program) for financial support of my thesis, Shell Forestry Ltd. supported my course fees. I also thank everybody in Microbiology Laboratory for use of the balance. I thank the Agriculture Faculty Chiang Mai University for providing meteorological report.

Finally, I thank my family. They have given me an opportunity to study and given me encouragement and understanding all the time. They have also supported me with money and equipment for writing the thesis.

Natenapit Jitlam

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INTRODUCTION

The highest rates of land use change in the world are found in the tropics. The Food and Agriculture Organization of the United Nations (FAO) estimated that during the period 1981-1990, 17 million hectares of forest were converted to other uses each year, of which about half was in the moist tropical zone (FAO, 1990). Forest biodiversity in Thailand is rapidly disappearing, mostly due to deforestation. In 1960, forest cover was 53% (Bhumibamon, 1986). It had been reduced to 25.28% by 1998 (Rojanapaiwong, 2000). In reality, remaining natural forest cover might be as low as 20% or even less (Leungaramsri and Rajesh, 1992). Between 1990 and 1995, Thailand's average rate of deforestation was approximately 2.6% (FAO, 1997) and Chiang Mai province had a deforested area of more than 6,513 km^2 in 1985 (GRID, 1988). The government realizes the importance of forests and has tried to restore them. The Forestry Policy, decided by the Council of Ministers on 3 November 1985, fixed the target forest area at not less than 40% of the country or 1.298 million km^2. Of this area, conservation forest was designated at 25% and economic forest at 15% (Budget Bureau, 1995). An appropriate goal of forest ecosystem rehabilitation is to facilitate, accelerate and direct natural succession processes so as to increase biological productivity, reduce rates of soil erosion, increase soil fertility including soil organic matter and increase biotic control over biogeochemical fluxes within the recovering ecosystem (Parrota, 1991).

According to the Budget Bureau (1995), most plantations by the Royal Forest Department (RFD) in Thailand have involved planting fast-growing monoculture plantations of pines, teak and eucalyptus which are easier to manage than mixed species plantations (Lamb and Lawrence, 1993). The value of such plantations for diversity and conservation is low. Monoculture plantations are the quickest method to rapidly restore tree cover, but are threats to native plants and animal species (Harshorn, 1983). After realization that such plantations are of low value for wildlife conservation and watershed protection, attitudes towards reforestation changed. Planting native tree species is now recommended for reforestation projects. This change in policy could not be implemented effectively since there was a lack of knowledge about how to select, grow and plant seedlings of native tree species (Elliott *et al.*, 1996). In plantations established by the Royal Forestry Department (RFD), under National Development Plans 5-6, the average survival of planted trees during the first year was 72.1%, lower than the 80% target (Budget Bureau, 1995). There was waste in planting poor quality seedlings (World Bank, 1993), since planting stock quality is essential to reforestation success (Wightman, 1997). High quality seedlings can establish well and grow fast after out planting (Milamo and Spencer, 1985). Therefore, it is necessary to develop more efficient methods to produce and maintain trees. More cost-effective methods to produce large numbers of trees with high performance must be developed.

The new knowledge generated by my project included the effects of container type, air pruning and fertilizers on tree seedling propagation of native tree species. This project results can also produce high quality seedlings and help increase biodiversity in Thai forests by bringing about more effective implementation of forest restoration.

Hypothesis

This research tested the hypothesis that seedlings grown in root trainers, with air pruning (raised 45 cm above the ground) will be more vigorous than when raised untreated on the ground. The project also investigated whether using either osmocote or soluble fertilizer during seedling propagation results in different seedling performance in the nursery.

Objectives

The objective of this research was to determine optimum container type and size, root pruning methods and fertilizer application regimes to maximize performance of seedlings of three native tree species, grown in nurseries for restoring natural forests to deforested areas. This research focused on nursery growth, shoot per root ratio, and the cost of the various methods to balance ecological and economic considerations for developing the most effective nursery management method and methodology.

Limitations of the study

This research included 3 native species (*Artocarpus lakoocha* Roxb. (Moraceae), *Balakata baccata* (Roxb.) Ess. (Euphorbiaceae) and *Horsfieldia thorelii* Lec. (Myristicaceae)) at the Forest Restoration Research Unit (FORRU) nursery. The applicability of the results of this project to other species is unknown. This project examined performance of seedlings only in the nursery for 10 months (October 1999 to August 2000). Although it is likely that nursery performance is correlated with field performance, monitoring of seedlings after planting out would be needed to confirm whether the effects of the treatments described here carries on after the seedlings are planted.

Study site description

Doi Suthep-Pui National Park, Chiang Mai, Thailand was established on 14 April 1981 and is under the jurisdiction of the National Parks Division of the Royal Forest Department. Doi Pui, the highest peak has an elevation of 1,685 m. The National Park covers an area of 261 km^2 (Maxwell,1988).

The Forest Restoration Research Unit (FORRU) was established in November 1994 at the headquarters of Doi Suthep-Pui National Park (18 ° 50′ N 98° 50′ E) at about 1,000 m elevation amidst primary evergreen seasonal, hardwood forest on granite bedrock. (Elliott *et al.*, 1997). The annual rainfall during October 1999 and August 2000 was about 117.37 mm and average temperature was 19.15 °C (Figure 1.).

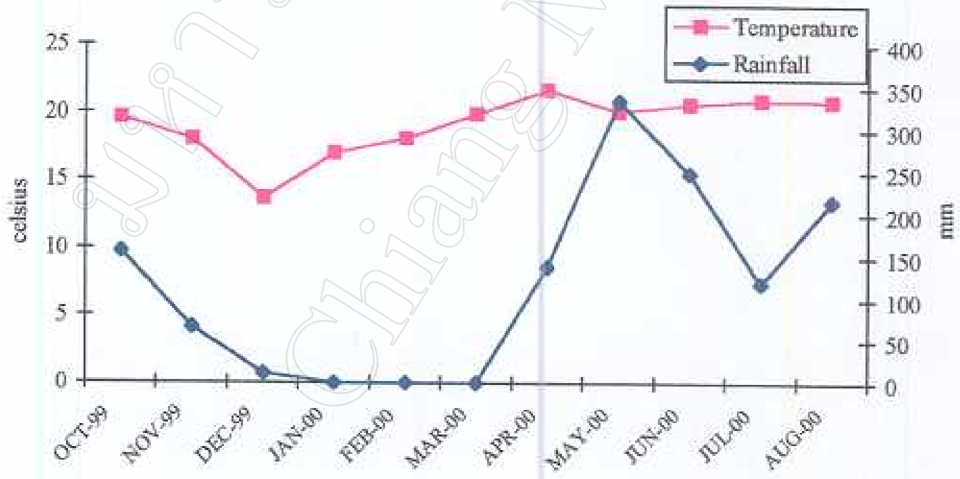

Figure 1. Average monthly temperature and rainfall at Chang Kian Station

Source: Meteorological report 1999-2000, Chang Kain Station, Faculty of Agriculture, Chiang Mai University.

LITERATURE REVIEW

Deforested areas are being rehabilitated, wherever possible, by natural succession. If natural succession can not achieve the target, planting may be necessary (Bruening,1996), but successful reforestation programs largely depend on the availability of high quality planting stock (Josiah and Jones, 1992). There are many methods of forest restoration.

The framework species method was first defined by Goosem and Tucker (1995). It was developed in Queensland, Australia for re-establishing rainforest ecosystems. Framework tree species are those which "capture the site" by rapidly shading out weeds and attracting birds and bats, which bring in the seeds of a wide range of additional tree species. The principal advantage of this method is that it involves only one planting and is a self-sustaining approach which relies on the local gene pool to increase species and life form diversity. The principal disadvantage of the method is that it relies on native vegetation being close enough to provide a seed source.

Pioneer tree species are fast growing, short lived species (Bruenig,1996), capable of invading bare sites, which become established in the early stages of succession (Helms,1998). They may grow in low and high light intensity but show a considerable stimulation after transfer from low light to high light conditions (Luttge,1997). Pioneer species are important to the framework species method for several reasons: their rapid growth suppresses weeds and forms a cool, shady microclimate beneath the canopy; their ability flower and fruit from a very early age, providing food for wildlife; they rapidly contribute to leaf litter and re-establish nutrient cycles and when pioneer species die and fall, they create light gaps and they assist lateral and upward growth of adjacent trees. Fallen logs and branches create ground habitat for wildlife. Fast growth rates increase the vertical growth of adjacent slower growing species. This may have an effect on the future structure of the new forest, by ensuring that these slower-growing species reach their full potential height and structural capacity. Many of the birds, which feed on these species can travel across open areas between patches of native forest. If the framework species method is used, pioneer species should comprise 30% of the total trees planted. Using this method, natural regeneration generally begins within two years of plot establishment (Goosem and Tucker,1995).

The Forest Restoration Research Unit has been testing the suitability of the framework species approach for reforestation by planting mixture of 20 - 30 native tree species in the north of Thailand (FORRU, 2000).

The Maximum Diversity Method or Miyawaki Method

These two methods use the same principle for reforestation. They attempt to recreate the species composition of the original forest as quickly as possible by collecting seeds and seedlings of climax species, raising them in a nursery and after adaptation, by planting the young trees on adequately prepared sites (Miyawaki, 1993). These methods use as many native species as possible, based on the potential of the natural vegetation. Seedlings with well-developed root systems up to 80 cm tall are planted. The soil is prepared and adequate drainage provided.

Organic fertilizers and mulching with rice straw is used. Two or three years after, planting no further management is needed (Fujiwara,1993).

Goosem and Tucker (1995) said that the disadvantage of this method is the intensive maintenance required because of the slower growth of the climax species.

Nursery Management

Seedling quality is determined by two factors: firstly the genetic make–up of the parent stock and secondly the seedling's immediate environment, i.e. nursery conditions and practices (World Bank, 1993).

Transplanting seedlings into containers (pricking out) is carried out after expansion of the 1st leaf pair. Roots can be pruned to fit the depth of the hole in the containers. Some tree species grow very fast in the nursery . If these species are potted too early, they will be too tall by planting time. Sometimes tall seedlings do not have enough roots to support many leaves. When these seedlings are planted in the field, they may grow slowly or even die because the roots cannot supply the leaves with enough water. The tops of seedlings (shoot) that have grown too tall should be cut before planting (Wightman, 1999). Josiah (1992) recommended using a sharp knife or scissors to trim the top leaves and the roots of plants raised in containers. Root pruning should be done regularly as soon as the root begin to grow through the bottom of the containers into the soil of the nursery. As soon as the roots begin to grow out of the containers, the containers should be moved, cutting the roots off with knife or a pair of scissors. The frequency of root pruning will depend on the species and its rate of growth which may vary from once a month to once a week. Jaenicke (1999) recommend root pruning twice a month. It is easy enough to check when root pruning is necessary by lifting the containers up. If there is resistance, root pruning is needed. Root pruning makes seedlings deficient in water, so root pruning should be followed immediately by watering. Periodic checks are better than a rigid timetable. During root pruning, the opportunity can be taken to grade plants according to size and get rid off weeds (Jackson, 1987).

The right amount of light is critical for healthy development of seedlings. Too much shade, for example, leads to etiolated and elongated of seedlings and makes them weak and prone to fungal disease. Too much light leads to scorching and drying out of tender tissue. Good quality shade cloth provides durable and uniform shade to the seedlings. Shade should be used permanently installed. Plants can be used from one shade level to another (Jaenicke, 1999).

During transportation of seedlings from the nursery to the planting site, seedlings should not be handled by the stem. In a truck, seedlings should be covered by canvas or shade cloth to protect them from wind damage (FORRU, 1998).

The Target Seedling Concept

The target seedling concept involves specific physiological and morphological characteristics that can be quantitatively linked with reforestation success (Rose and Haase, 1995). There is a negative relationship between survival and height of seedlings. Shorter seedlings are preferred for arid sites and taller seedlings are better in areas with high weed competition. Quality seedlings targeted for different sites may look different from each other, but they all have one thing in common: a well-developed root system with many root tips, from which new roots can quickly develop. In areas with adverse environments, such as dry, flooded, saline, or nutrient-deficient sites, only well-developed plants have a good chance of survival. For dry areas, seedlings should have a deeper root system. For weedy sites, larger plants are better because they can quickly out grow weeds (Jaenicke, 1999).

No single characteristic determines seedling quality. It is a combination of height, diameter, nutrition, health, root size, and root shape. Together, these characteristics determine how well a plant will establish itself in the field. They directly affect the rate of survival (Wightmam,1999).

Seedling quality depends on:

1. the ability to produce new roots quickly,
2. a well developed root system,
3. sun-tolerant foliage,
4. a large root collar diameter,
5. a balanced shoot : root ratio,
6. good carbohydrate reserves,
7. an optimum mineral nutrition content, and
8. the establishment of adequate mycorhizal or rhizobium infection (Jaenicke,1999).

Many seedling characteristics, such as shoot : root ratio are difficult to observe and require destructive sampling. The shoot : root ratio is important for seedling survival (Romero *et al.*, 1986). The ratio varies with conditions of the internal and external plant environment (Kolek and Kozinka, 1992) and has been used to express a morphological balance (Wightman, 1997). Many different suitable shoot per root ratios indicate a healthy plant have been reported, *e.g.* 1 : 1 to 1 : 2 (Jaenicke,1999), but Sirilak (1997) recommended 1 : 3 or 1: 2 and 1 :4 depending on species or nursery practices.

Quality tree seedlings have the following characteristics:

1. They are healthy, vigorously growing, and free of diseases.
2. They have a robust and woody single stem, free of deformities.
3. The stem is sturdy and has a large root collar diameter.
4. The crown is symmetrical and dense.
5. They have a dense root system with many fine, fibrous hairs with white root tips.
6. They have a root system free of deformities (Figure 1).
7. They have a balance between shoot and root mass.
8. Their leaves have a healthy, dark green color.
9. They can survive short periods without water.
10. They can tolerate full sunlight (Wightman, 1999).

Many reforestation projects determine seedling quality by height. The Forest Restoration Research Unit uses seedlings up to 50 – 60 cm tall, 30 cm for faster growing species (FORRU, 1998) and FAO (1989) reported that seedlings 15 – 40 cm tall, with a woody tap root have a higher survival rate than smaller seedlings with poor root systems. Most tree seedlings have a straight, slightly tapering main root and a large mass of fibrous roots. Healthy roots are not bent, crossed, or damaged. Knotted and bent roots are common in plants that have been left in the nursery too long or have been pricked out carelessly. These plants cannot survive in the field because damaged or deformed roots die back and become vulnerable to disease and termite attacks (Jaenicke, 1999). Root systems with a high percentage of fibrous root and a large surface are can efficiently absorb nutrients and water (Rose and Haase, 1995). Boudoux (1972) reported that root growth is determined more by container diameter than height. This was confirmed for *Pinus ponderosa* by Tinus (1974). Hocking and Mitchell (1975) showed that growth of seedlings in larger diameter containers is better than in smaller diameter containers although the containers had similar (Romero *et al.*, 1986).

Mycorrhiza are good for plants. They are beneficial fungi associated with the epidermis and cortex of roots. These fungus absorb nutrients from the soil, while the host plant provides the fungus with carbohydrates, amino acids, vitamins, and other organic substances. Infected mycorrhizal plants are more tolerant of drought and other stresses than non-infected plants (Moore and Clark, 1995).

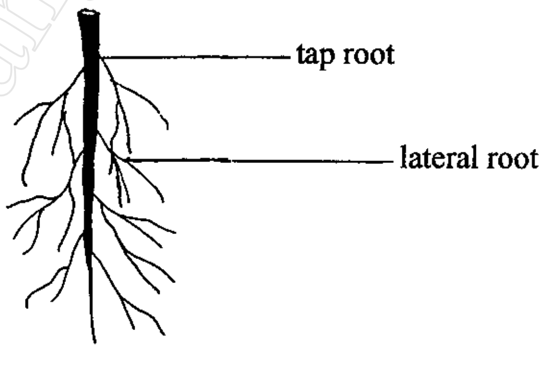

Figure 2. A good root system, where the tap root is straight with fine root hairs (Wightman,1999)

Root Deformations

Root deformities can be caused by poor pricking out from the germination bed into containers (Figure 3). Deformities generally occur within the first 10 cm under the surface of the soil. Seedlings are often squeezed into holes that are too short for the root system. When roots stuffed forcefully into bags, curl upwards. Since roots always eventually grow downwards, the roots bends back in completing a loop (Figure 3). These plants should be culled because they will never grow well in the field.

Figure 3. Root deformed by poor pricking out. The tap root was stuffed into a hole too small and the main root has twisted upwards (Wightman, 1999).

Figure 4. Root deformed by careless pricking out. The tap root is bent close to the surface of the container (Wightman, 1999).

Root deformities can also be caused by the bag. Smooth plastic bags cause the main root to coil or spiral along the side or the bottom of the bag. This inevitably happens when plants are left in the nursery too long. It can also happen to plants that are only a few centimeters tall. Some plants commonly develop roots before they begin shoot growth. So even plants with small shoots may have long roots that are coiled at the bottom of the bag (Figure 4). These roots should be cut off immediately before planting (Wightman, 1999).

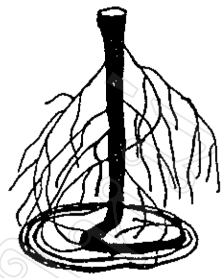

Figure 5. A spiraled root system, coiled at the bottom of the container (Wightman, 1999).

Roots can be characterized by their position and extent of deformation according to Menzie's Top Root Score (Chavasse, 1978; Zangkum,1998).

score	tap root condition
1	strong, dominant, well developed tap root
2	stunted, slightly malformed, but still a definite tap root
4	tap root distinctly hooked
6	tap root quite badly hooked, but downward development still present
8	tap root severely deformed into two or more fracture zones, but growth still downward
10	tap root dose not come below a horizontal plane, subtract one point for each strong sinker present

Containers

The size and vigor of seedlings in a nursery also depends on container size and nursery practices (Rabeendran and Jeyasingam, 1995). The optimum size of container depends on plant species, but the maximum size of seedlings in containers is determined by container size (Ffolliott *et al*, 1995). Containers have been found to reduce costs, improve seedling root morphology and vigor, increase post-planting performance and maximize program effectiveness and impact. Poly-bags are initially cheaper than root trainers, but they can usually be used only once, require large amounts of soil, are difficult to handle due to their size and weight, are poorly aerated, discourage lateral root development, and occupy large areas in the nursery. Most root trainers are reusable and durable, usually lasting 5 or more years, but are initially expensive and require a rack system for support (Josiah, 1992).

Poly-Bags

Poly-bags (polythene) are used worldwide because of their low cost, apparent simplicity and convenience (World Bank,1993) and if they are made from locally available materials, they may be more affordable. Plant development depends on the quality of the substrate more than the size of the bag. While small bags can be used with a nutrient rich substrate like compost, plants in small bags cannot stay in the nursery as long as plants in large bags (Wightman,1999). FAO (1989) reccommend that the minimum diameter should be 5 cm and height 15 cm.

A common problem with poly-bags is that roots tend to grow in spirals once they meet the smooth inner surface. This will inevitably lead to plants with restricted growth with poor resistance to stress and wind. The discarded poly-bags are a problem for nursery waste management, as they do not decay and are often burned, producing air pollution (Jaenicke, 1999).

Root Trainers

Root trainers are usually rigid containers with internal vertical ribs, which direct roots straight down to prevent spiral growth. The latest developments also encourage lateral air root pruning through vertical slits. Seedlings grown in root trainers have more vigorous and rapid root growth than seedlings grown in poly-bags. Out planting survival and, more importantly, long-term survival are much better. Plants grown in root trainers are often ready for planting when they are substantially smaller than those from conventional poly-bags. This helps to reduce space requirements in the nursery and transport costs to the field (Jaenicke, 1999).

Root trainers have been used to successfully grow high quality trees. They come in many shapes and sizes, but all have two characteristic in common; *viz.* vertical ribs and a big hole at the bottom. The vertical inner ribs direct the roots straight down as they grow, thus avoiding root deformities. The containers are set on frames above the ground, so that air circulates around the bottom hole. Roots are air-pruned as they emerge from the container. This natural pruning of the main roots encourages secondary root growth so that eventually the volume of the root trainer is filled with a 'plug' of fibrous roots. When the tree is planted in the field, the pruned roots continue to grow (Wightman, 1999).

Thapa *et al.* (1990), studied in the nursery techniques for four multipopose trees of Nepal. Experiments with *Artocarpus lakoocha, Bauhinia variegata, Dalbergia latifolia*, and *D. sissoo*, all showed significantly better seedling height, root collar diameter, and biomass production in 7.3 x 17.5 cm flats containing the growing medium of forest soil and farm yard manure.

Sunanta (1992), studied in growth of selected forest tree seedlings in different container sizes and potting media in Thailand and reported that, the container is positively correlated with seedling growth only in the case of fertilized media. The cost of producing 10,000 seedling varies from 171 to 183 US$ in *Hiko Boxes,* a type of root trainer, 34.5 cm long x 21.5 cm wide x 10.0 cm deep, 311 to 314 US$ in 10 x 15 cm black plastic bags and 452 to 523 US$ in 15 x 20 cm black plastic bags.

Rabeedran & Jeyasingam (1995) studied the effects of pot size and mulch on planting stock of exotic and indigenous species in Sri Lanka. Experiments with four sizes of poly-bag, *viz.* a) 10 x 22 cm b) 14 x 22 cm c) 10 x 44 cm and d) 20 x 22 cm, showed that wider pots are preferable for raising seedlings. Their recommendation was that rainforest seedlings should be grown up to 60-90 cm tall in 1 liter (approximately 20 cm deep) bags or similar containers. Plants of this size rapidly establish and dominate the site (Kooyman, 1996).

Zangkum (1998) reported that seedlings grown in REX trays were of significantly higher quality than those grown in other containers. A cost-benefit analysis showed that REX trays are beneficial for use on a wide scale for forest restoration in Thailand. REX trays have been studied in several nurseries and good results have been obtained. Root development of seedlings grown in these trays is generally much better than of seedlings grown in plastic bags and root deformation is reduced. REX trays are generally used in conjunction with air pruning.

For air pruning, the trays should be arranged so that there is a distance of more than 30 cm from the ground (Kamizore, 1998). Good aeration is needed for root development, since roots need more air than the stem and the leaves (Valli, 1995) for nutrient absorption because nutrient uptake requires energy, this comes from root respiration (Ignatioff and Page, 1968)

Boontawee *et al.* (1999) reported growth in terms of average height of 4 - month old seedlings of *Melia azedarach* Linn. (Meliaceae), which were planted in 4 x 6 , 5 x 8 and 6 x 8 inch plastic containers height equal to 14.63, 23.90 and 35.18 cm. From ANOVA, there were significantly differences among the container sizes. Average stem diameters at ground level of 0.26 , 0.30, and 0.46 cm were recorded at the same time as height and there were highly significant differences, but the differences among sizes of containers were not significant in terms of root : shoot ratio.

Fertilizer

Shade, water, and nutrients are all important for plant growth, development (Ignatioff and Page, 1968) and interact to produce healthy plants. A plant that grows in full light with abundant moisture and which receives all 13 basic nutrients will grow fast and have dark green leaves. Some species grows slowly in the shade may turn yellow. This does not mean that plants do not tolerate full sun – it might indicate a nutrient deficiency which did not show up in the shade because the plant did not have enough light to stimulate fast growth (Wightman, 1999).

When using soil or soil-based media, fertilizer might not be needed immediately because the substrate has residual fertility. During the production phase, seedlings need addition of balanced nutrients, but too much fertilizer can cause harmful toxic effects, burning the plants or making them grow too tall and weak (Ignatioff and Page,1968). Also, plants that do not have enough fertilizer grow slowly and become sickly. Root can take up nutrients only in dissolved form

(FAO,2000). Before applying fertilizer, the seedlings, should be watered since fertilizer can burn the roots if the soil is too dry. After fertilizer application the seedlings should be sprayed with water to wash fertilizer from the leaves so they are not burned (Josiah,1992). For large plants 1.5 to 2 tablespoons of soluble fertilizer (20-20-20) in a 3 gallon (15 litres) watering can is recommended, which can fertilize about 1,200 plants. Josiah, (1992) recommended beginning fertilizer application 2-3 weeks after germination or 1 to 2 weeks after transplanting. Alternatively slow-release fertilizers can be used, such as "Osmocote". Elliott *et al.* (1998) recommended adding about 10 granules (approximately 0.3 g) of slow - release "Osmocote" fertilizer (NPK 15 : 15 : 15) to the surface of the potting mixture in each container every 3 months.

Inorganic Fertilizers

Inorganic fertilizers are divided into single fertilizer, compound fertilizers, and full fertilizers. They can be applied by broadcasting or by mixing with irrigation water (fertigation). Fertilizers are commonly known by their main nutrients N, P, and K. The numbers on the bags show the percentages of these components. For example 20-10-10 fertilizer contains 20% of nitrogen, 10% off phosphorus, usually in the form of P_2O_5[2] and 20% of potassium, usually in the form of K_2O[3] (Jaenicke,1999).

Granular inorganic fertilizers and controlled-release fertilizers provide an attractive alternative to granular fertilizers. The release rate depends on water availability and soil temperature. Controlled-release fertilizers are more expensive than conventional soluble fertilizers, but they have several advantages:

1. The danger of over-fertilizing is reduced as the release of fertilizers is gradual.
2. Fertilizing is necessary only occasionally, sometimes only once in a season.
3. A balanced fertilizer mixture is provided at all times as the plants get what they need at different growth stages.

- Nutrients do not leach from the substrate since the plants receive all nutrients applied .

In products using the "Osmocote" technology, resins based on natural organic oils, such as soybean or linseed oil, are used to coat the fertilizer. Different thickness of resin coating are applied to the base fertilizer to achieve different release periods. Water enters the granule and dissolves the nutrients and they pass through the coating at a rate controlled by the soil temperature. As temperatures fluctuate, the rate of nutrient release changes, matching plant demand as growth rates rise and fall in correlation with these changes. The resin coating remains intact throughout the life of the product. When all nutrients are expended, the coating dissolves. There are products for specific markets, such as ornamentals, vegetables, and nursery production. The granules last from 3-4 to 16-18 months, depending on the soil temperature. Their estimated life is based on an average temperature of 21°C, release rates change by about 25 % for every 5°C. In tropical environments, with an average soil temperature of 28°C, a product labeled four months would last roughly three months (Jaenicke, 1999).

MATERIALS AND METHODS

Species selected :-

1) *Artocarpus lakoocha* Roxb.	(Moraceae)	760 seedlings
2) *Balakata baccata* (Roxb.) Ess.	(Euphorbiaceae)	760 seedlings
3) *Horsfieldia thorelii* Lec.	(Myristicaeae)	760 seedlings

Seedlings were grown in three container types :

1) 2.2 x 5.2 in (5.5 x 13 cm) JICA (REX) tray (300 cm^3)	33 trays
2) 2.5 x 9.0 in (6.25 x 22.5 cm) black plastic bag (800 cm^3)	760 bags
3) 3.0 x 7.0 in (7.5 x 17.5 cm) black plastic bag (850 cm^3)	760 bags

Fertilizers

1) "Osmocote", slow releasing (14-14-14)	1.368 kg
2) soluble fertilizer, granules (15-15-15)	2.850 kg

Materials

1) forest soil from Doi Suthep-Pui National Park	741,000 cm^3
2) coconut husk	370,500 cm^3
3) peanut husk	370,500 cm^3

4) plastic baskets (32 cm wide x 39 cm long x 9.5 cm high)

5) grid tables (90 cm wide x 180 cm long x 45 cm high)

6) oven

7) balance

8) Digital Lux meter (model BEHA 93421 IQ 0114SE)

Equipment for collection data

1) venier

2) ruler (cm)

3) pen

4) notebook

5) camera

Experimental Design

A randomized complete block design (RCB) was used. The experiment tested 12 treatments which were replicated in three blocks. Each block represented every treatment, randomly arranged (Figure 14).

Treatment Design

T1: raised – REX tray - "Osmocote"

T2: raised – REX tray – soluble fertilizer

T3: raised – plastic bag (2.5" x 9") - "Osmocote"

T4: raised – plastic bag (2.5" x 9") - soluble fertilizer

T5: raised – plastic bag (3" x 7") - "Osmocote"

T6: raised – plastic bag (3" x 7") - soluble fertilizer

T7: ground – REX tray - "Osmocote"

T8: ground – REX tray – soluble fertilizer

T9: ground – plastic bag (2.5" x 9") - "Osmocote"

T10: ground – plastic bag (2.5" x 9") - soluble fertilizer

T11: ground – plastic bag (3" x 7") - "Osmocote"

T12:ground – plastic bag (3" x 7") – soluble fertilizer

Randomized Complete Block Design

Block 1	Block 2	Block 3
T 3	T 9	T 3
T 5	T 7	T 1
T 1	T 11	T 5
T 4	T 10	T 6
T 2	T 8	T 2
T 6	T 12	T 4
T 9	T 1	T 10
T 11	T 3	T 12
T 7	T 5	T 9
T 10	T 6	T 11
T 8	T 4	T 7
T 12	T 2	T 8

Methods

Seed germination methods

Native tree species, framework species or potential framework species, with a medium to large seeds, used more than 1 year for preparation and low quality in the nursery such as *Artocarpus lakoocha* Roxb. and *Horsfieldia thorelii* Lec. from Doi Suthep – Pui National Park were studied.

Artocarpus lakoocka Roxb. (Moraceae) is a large deciduous tree, distributed in tropical Himalayas, India, and Thailand (Hooker, 1988). In Thailand occurs in evergreen forest at elevation of between 1,000 to 1,100 m (Maxwell, 2001). The mature trees are about 18 m high. Leaves thinly coriaceous, above glabrous or puberulous and reticulate beneath. Flower – head shortly peduncled, pubescent and oblong seeds (Hooker, 1988). The flowers bloom in September to October, fruiting in January to June (Maxwell, 2001).

Seeds were collected on 15 July 1999 from a single tree at Doi Suthep - Pui National Park headquaters c. 1,050 m, 16 m in height and 148 cm GBH. Ripe compound fruits, were collected from the ground, and the seeds soaked in water overnight. Seeds averaging 10 mm long were sown in plastic baskets on 16 July 1999, at least 1 cm apart, with 250 seeds per basket. The germination rate was 42.5% over 40-60 days. Seedlings were pricked out and transplanted into containers when they had 2 fully expanded leaves or were 6 - 8 cm tall.

Balakata balakata (Roxb.) Ess. (Euphorbiaceae) is a large size evergreen tree, found in primary and disturbed dipterocarp forest, bamboo forest, secondary forest, mixed deciduous forest, also along streams and on hill and slope (Esser, 1999) distributed in Thailand, east Himalayas and north India to Indo-China, southern China, Myanmar, peninsular Malaysia and Sumatra (FORRU, 2000). In

Thailand occurs in mixed evergreen + deciduous, seasonal forest or seasonal evergreen forest, often grown along streams at low elevations, elevation of between 400 to 1,350 m (Maxwell, 2001). The mature trees are about 26 m high with a girth at breast high of up to 60 cm. The bark dirty yellow with deep longitudinal cracks and fissures inner bark fibrous. Leaves are spirally arranged, blades elliptic to oblong, apex acuminate and base acute or obtuse. Inflorescent in terminal whorls and in the axils of few upper most leaves. Two type of inflorescent: purely staminate one, regularly branched with long branches (5-7 cm long) and bisexual ones, hardly branched and with shorter branches (2-3 cm long) (Esser,1999). Fruit fleshy drupes with white sap. The unripe seed is green and ripens to dark red-purple to black (FORRU, 2000). The flowers bloom in February to August, fruiting in September (December) (Maxwell, 2001).

Seeds from a single tree were collected on 18 September 1999 at Doi Suthep – Pui National Park near the side of the road to Monthathan waterfall, c. 1,050 m, 24 m high and 300 cm GBH. Ripe black were collected from the ground, each contained two black seeds. The seeds were soaked in water overnight to remove the pericarp and the remaining white tissue was scrubbed off by hand. Scarification by hand accelerated germination by accelerating water absorption (care was taken not to remove too much of the testa since this increased risk of fungal infection) and soak in water over night again. Seeds (average length 5 mm) were sow in plastic baskets on 20 September 1999, at least 1 cm apart, with 400 seeds per basket. The germination rate was 75% over 30-45 days. Seedlings were transplanted into containers when they had 2 leaves or were 8 -12 cm tall.

Horsfieldia thorelii Lec. (Myristicaeae) is an uncommon and medium-sized evergreen tree, distributed in central and northern Thailand and Indo-China (FORRU, 2000). In Thailand occurs in bamboo + deciduous, mixed evergreen + deciduous, and evergreen forest, often in disturbed areas at elevation of between 550 to 1,500 m (Maxwell, 2001). The mature trees are about 21 m high with a girth breast at high of about 75 cm. The bark thin and finely lenticellate and becoming thickened and roughly vertically cracked and ridged in older. Leaves are simple and spirally arranged, elliptic – oblong to oblong, broadest at or somewhat above the middle base attenuate, top acute-acuminate. (Wlide, 1984). Flowers are numerous in unisexual inflorescence, male inflorescence 6-21 cm long and female ones with fewer flowers and up to 2 cm long (FORRU, 2000). The flowers bloom in February to April, fruiting in March to May (Maxwell, 2001).

Seeds were collected from a single tree on 23 June 1999 at Anuchon camp opposite Doi Suthep Temple c.1,050 m, Doi Suthep – Pui National Park, 14 m height and 168 cm GBH. Fallen fruits with orange aril on the seeds were collected from the ground. The aril and brown testa were removed by hand and the seeds soaked overnight. Seeds (average length 33 mm) were sown in plastic baskets on 24 June 1999, at least 2 cm from apart, with 150 seeds per basket. The germination rate was 25% over 21-75 days. Seedlings were transplanted into containers when they had 2 leaves or were 10 - 13 cm tall.

The germination medium was forest soil, coconut husk, and peanut husk mixed in the ratio of 2 : 1 : 1.

Experimental methods

All seedlings were transferred into three types of containers: two different sizes of plastic bags 2.5 x 9 in. and 3 x 7 in. and REX tray root trainers. Half of the containers were raised 45 cm off the ground on wire grids, while the rest were placed on the ground. There were three blocks *viz.* open , 100% exposure (light intensity averaged 12,170 to >20,000 lux), medium, 80% exposure (light intensity averaged 7,700 to >20,000 lux) and deep shade, 50% exposure (light intensity averaged 2,400 lux). For the ground treatments roots were pruned every 3 months. Two fertilizer treatments were applied, *viz.* soluble fertilizer (NPK 15-15-15), 1.5 tablespoons of soluble fertilizer in a 15 litters (3 gallon) watering can applied every 15 days and sloe release fertilizer "Osmocote" (NPK 14-14-14), about 10 granules placed on the surface of the media in the containers every 3 months. Watering was done by using a rubber hose every day.

Table1. Fertilization and root pruning regimes.

Date	*A. lakoocha*			*B. baccakata*			*H. thorelii*		
	osmocote	soluble	pruning	osmocote	soluble	pruning	osmocote	soluble	pruning
01 Oct 99	+	+	-	-	-	-	+	+	-
15 Oct 99	-	+	-	-	-	-	-	+	-
01 Nov 99	-	+	-	-	-	-	-	+	-
15 Nov 99	-	+	-	-	-	-	-	+	-
01 Dec 99	-	+	-	-	-	-	-	+	-
15 Dec 99	-	+	-	-	-	-	-	+	-
01 Jan 00	+	+	+	+	+	-	+	+	+
15 Jan 00	-	+	-	-	+	-	-	+	-
01 Feb 00	-	+	-	-	+	-	-	+	-
15 Feb 00	-	+	-	-	+	-	-	+	-
01 Mar 00	-	+	-	-	+	-	-	+	-
15 Mar 00	-	+	-	-	+	-	-	+	-
01 Apr 00	+	+	+	+	+	+	+	+	+
15 Apr 00	-	+	-	-	+	-	-	+	-
01 May 00	-	+	-	-	+	-	-	+	-
15 May 00	-	+	-	-	+	-	-	+	-
01 Jun 00	-	+	-	-	+	-	-	+	-
15 Jun 00	-	+	-	-	+	-	-	+	-
01 Jul 00	+	+	+	+	+	+	+	+	+
15 Jul 00	-	+	-	-	+	-	-	+	-
01 Aug 00	-	-	-	-	+	-	-	-	-
01 Aug 00	-	-	-	-	+	-	-	-	-

Remark: + = done / applied
- = not done / applied

Data collection

Data were collected over the periods :

- *Artocarpus lakoocha* Roxb. October 1999 – July 2000
- *Balakata baccata* (Roxb.) Ess. January 2000 – August 2000
- *Horsfieldia thorelii* Lec. October 1999 – July 2000

Balakata baccata (Roxb.) Ess. seeds were collected late, so data were delay.

Ten seedlings per treatment per block per species were randomly selected for the following measurements :

1. seedling height ;measured from ground level to the apical bud
2. seedling stem basal diameter

Ten seedlings per treatment per block per species were harvested at the end of the experiment for measurement of the following

1. shoot : root ratio by dry mass
2. root morphology; condition of roots adapted from Mensie's and Wightman scores

score	tap (primary) root condition
1	strong, straight, dominant, well developed tap root
2	tap root severely deformed into two or more fracture zones, but growth still downward
3	tap root twisted close to the surface of the container

4 tap root twisted upwards, but downward development still present

5 tap root straight ascending, but coiled at the bottom

6 tap root twisted upward and coiled at the bottom

Statistical analysis

Data on height, basal diameter, shoot : root ratio, and relative growth rate (RGR) for height and basal diameter were tested for differences among blocks and among treatments for each species using ANOVA and LSD test (least significant difference) for divide treatments with less than 10 sample and for more than 10 treatments using SNK test (Student-Newman Keals). Chi–squre test for analysis value data (SPSS for Windows Release 6.0).

Relative Growth Rate (RGR) percent per year

$$\frac{LN\,H2 - LN\,H1}{T2 - T1} \times 365 \times 100$$

H1 = first height (cm) or basal diameter (mm)

H2 = final height (cm) or basal diameter (mm)

T1 = start time (day)

T2 = final time (day)

Seedling Quality Index (SQI) = standardized value (of height X basal diameter X root dry weight X shoot /root ratio X root score)

The value of each parameter was divided by the maximum mean recorded to give a standardized value of 0-1 for each characteristic (Zangkum, 1998), for shoot / root ratio divided the minimum mean.

production costs (bath per seedling per season in nursery)

= container price + medium + fertilization + root pruning + labor

The best treatment was identified by balancing seedling performance with production costs using the benefit value which is seedling quality index / production cost

Figure 6. Seeds and seedlings of *Artocarpus lakoocha* Roxb. 1, 3, 5 and 12 days after germination.

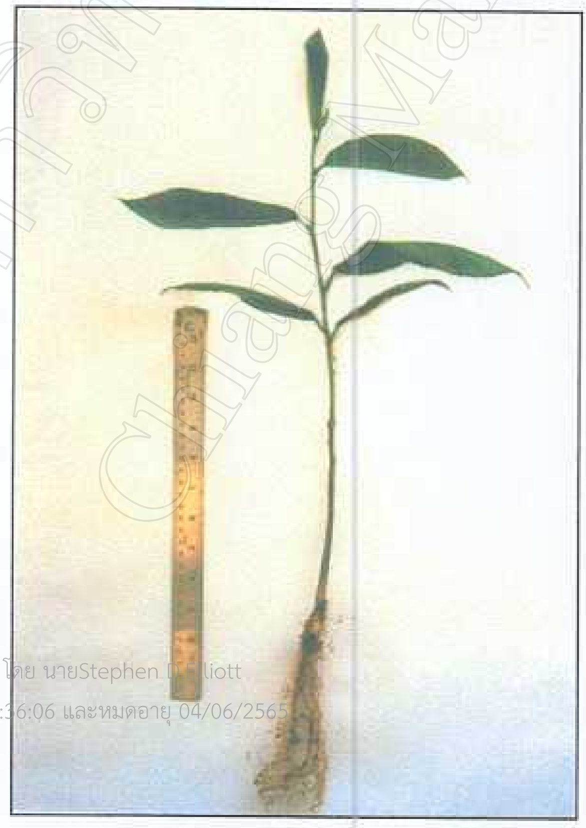

Figure 7. Seedling of *Artocarpus lakoocha* Roxb. 12 months after germination.

Figure 8. Seeds and seedlings of *Balakata baccata* (Roxb.) Ess. 1, 2, 4, 5, 7 and 10 days after germination.

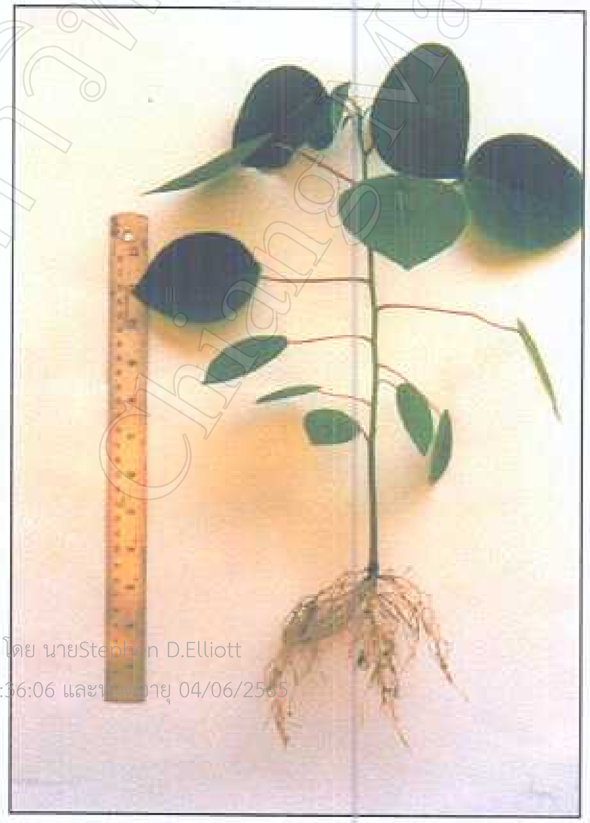

Figure 9. Seedling of *Balakata baccata* (Roxb.) Ess. 2 months after germination.

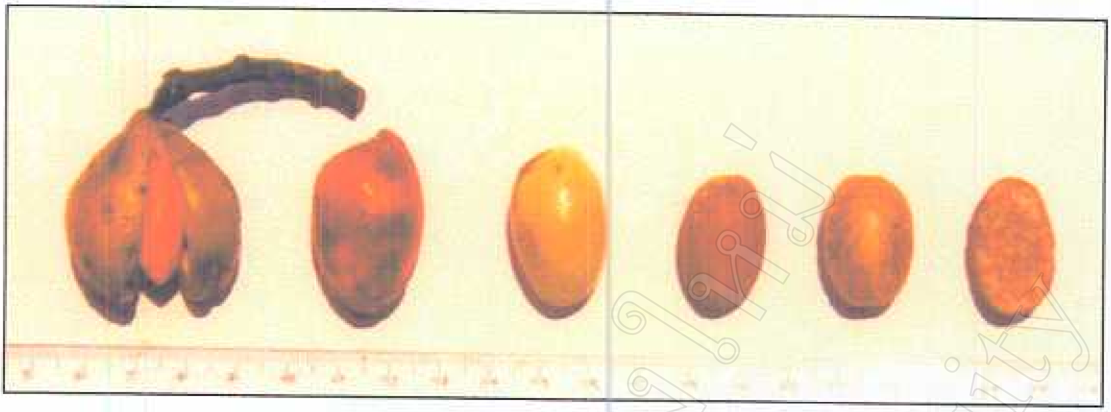

Figure 10. Capsule and seeds of *Horsfieldia thorelii* Lec.

Figure 11. Seedling of *Horsfieldia thorelii* Lec. 12 months after germination.

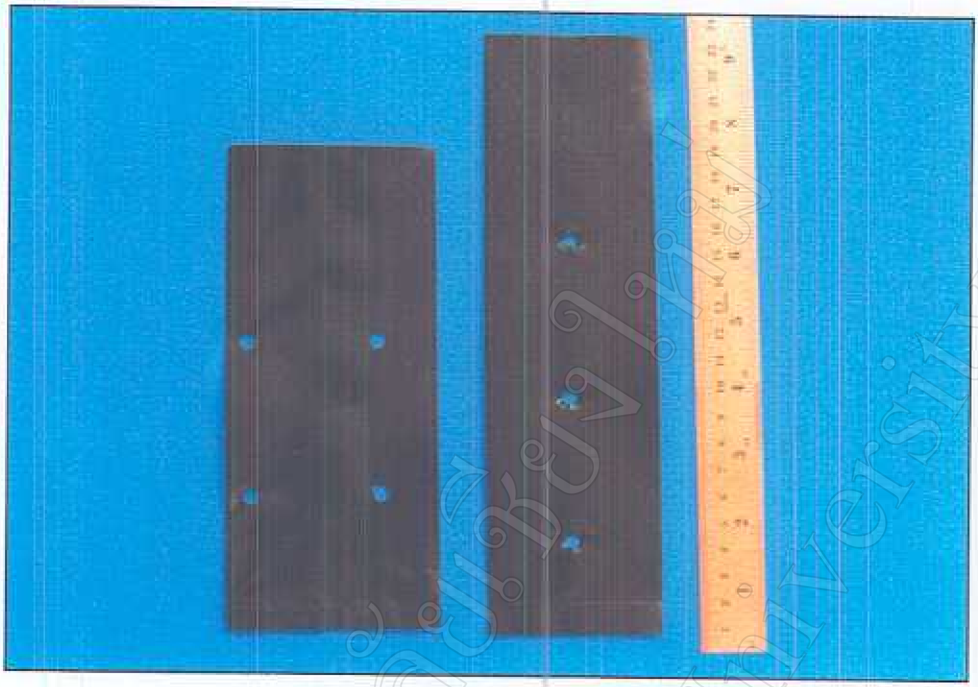

Figure 12. Left: plastic bag 3 × 7 in, right: 2.5 × 9 in

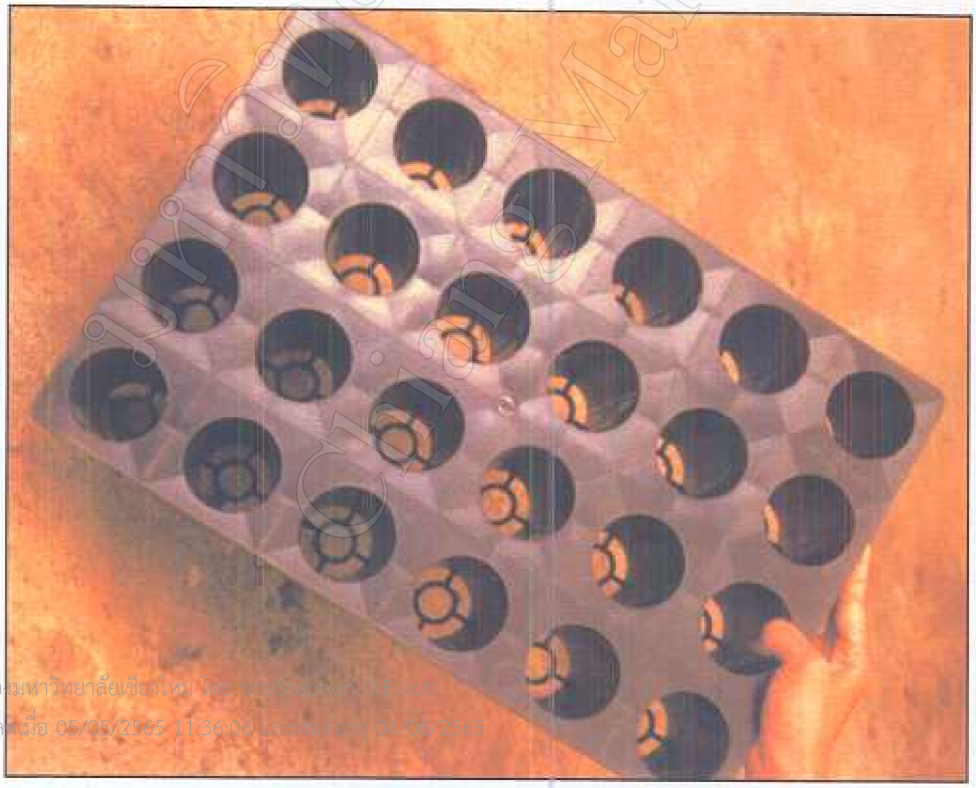

Figure 13. JICA (REX) tray

Figure 14. Experiment design was in randomized blocks in the FORRU nursery on January 2000.

RESULTS

Artocarpus lakoocha **Roxb.**

Mean height of seedling at first potting : 8.77 ± 2.31 cm

Mean height of seedling after 10 months : 28.87 ± 13.36 cm

Survival of seedlings after 10 months : 91.67%

RGR of basal diameter (Figure 18 and Table 3) was highest with T12 (135.45 ± 49.92). Interpretation of all factors (Table 7 and Appendix I, Table 19) showed that containers had a significant ($p<0.01$) effect with plastic bags 3 x 7 in. (122.29 ± 51.11) and 2.5 x 9 in. (112.39 ± 45.26) resulting in a higher mean than REX Trays. The effects of block were also significant ($p<0.01$) with open (124.20 ± 42.50) and medium exposure (119.64 ± 42.50) having higher means than deep shade.

RGR of height (Figure 18 and Table 3) was highest with T5 (182.45 ± 96.25). Interpretation of all factors (Table 7 and Appendix I, Table 20) showed that containers had a significant ($p<0.01$) effect, with plastic bags 3x7 in resulting in the highest mean (168.30 ± 77.00). The effects of block was also significant ($p <0.01$). Medium exposure (186.60 ± 62.60) and open (177.60 ± 64.97) resulted in higher means than deep shade.

Final basal diameter (Figure 19 and Table 3) was highest with T5 (0.531 ± 0.148 cm). Interpretation of all factors (Table 7 and Appendix I, Table 21) showed that block had a significant effect ($p<0.01$) with open (0.50 ± 0.13 cm) and medium exposure (0.48 ± 0.14 cm) resulting higher means than deep shade. Container had a significant effect ($p<0.01$) with plastic bags 3x7 in. (0.50 ± 0.17cm) resulting in the highest mean.

Final height (Figure 20 and Table 3) was highest with T11 (35.717 ± 19.583cm). Interpretation of all factors (Table 7 and Appendix I, Table 22) showed that block had a significant ($p<0.01$) effect with medium exposure (34.46 ± 12.46 cm) and open (34.03 ± 12.11 cm) resulting in higher means than deep shade. Fertilizer also had a significantly effect, with "Osmocote" (30.59 ± 15.20 cm) resulting in a higher mean than soluble fertilizer.

Shoot/root ratio dry weight (Figure 21 and Table 3) was lowest with T7 (1.04 ± 0.428 g). Interpretation of all factors (Table 7 and Appendix I, Table 23) showed that block had a significant ($p<0.01$) effect with open (1.12 ± 0.59 cm) and medium exposure (1.48 ± 0.81 cm) resulting in lower means than deep shade. Container type also had a significant effect ($p<0.01$) with REX trays (1.24 ± 0.63 cm) resulting in the lowest mean. Root pruning method had a significant effect ($p<0.05$) with root pruning by hand (1.43 ± 0.77) resulting in a lower mean than root pruning by air.

***Balakata baccata* (Roxb) Ess.**

Mean height of seedling at first potting : 11.09 ± 4.80 cm

Mean height of seedling after 10 months : 51.49 ± 18.06 cm

Survival of seedlings after 10 months : 68.6%

RGR of basal diameter (Figure 22 and Table 4) was highest T12 (215.10 ± 53.59). Interpretation of all factors (Table 8 and Appendix I, Table 24) showed that block was significant ($p<0.01$) with medium exposure (198.75 ± 52.69) and open (187.57 ± 53.59) resulting in higher means than deep shade. Container had a significant ($p <0.01$) effect with plastic bags 3 x 7 in. (193.24 ± 65.91) resulting in the highest mean. Root pruning by hand (190.91 ± 58.88) resulted in a higher mean than root pruning by air.

RGR of height (Figure 22 and Table 4) was highest with T5 (351.93 ± 112.64). Interpretation of all factors (Table 8 and Appendix I, Table 22) showed that block had a significant ($p<0.01$) effect with medium exposure (301.27 ± 105.12) resulting in the highest mean. Container had a significant ($p<0.01$) effect with plastic bags 3 x 7 in. (309.99 ± 116.77) resulting in the highest mean and "Osmocote" fertilizer (287.37 ± 106.75) resulted in a higher mean than soluble fertilizer.

Final basal diameter (Figure 23 and Table 4) was highest for 2 treatments, T4 (0.66 ± 0.13 cm) and T10 (0.66 ± 0.16 cm). Interpretation of all factors (Table 8 and Appendix I, Table 26) showed that block had a significant ($p<0.01$) effect with open (0.60 ± 0.15 cm) and medium exposure (0.59 ± 0.15 cm) resulting in a higher mean than deep shade. Container had significant ($p<0.05$) effects with plastic bags 2.5 x 9 in. (0.61 ± 0.14 cm) resulting in the highest mean and soluble fertilizer (0.90 ± 0.16 cm) had a higher mean than "Osmocote".

Final height (Figure 24 and Table 4) was highest the with T10 (62.03 ± 8.91 cm). Interpretation of all factors (Table 8 and Appendix I, Table 27) showed that block was significant ($p<0.01$) with medium exposure (57.78 ± 19.20 cm) resulting in the highest mean. Container had a significant ($p<0.01$) effect with plastic bags 2.5 x 9 in. (56.56 ± 18.08 cm) resulting in a higher mean. Root pruning by hand (53.54 ± 18.46 cm) had a higher mean than root pruning by air.

Shoot/root ratio of dry weight (Figure 25 and Table 4) had the lowest mean with T5 (0.72 ± 0.71). Interpretation of all factors (Table 8 and Appendix I, Table 28) showed that block had a significant ($p<0.01$) effect, with medium exposure (4.12 ± 1.90) resulting in the lowest mean. Container type was also significant ($p<0.01$) with REX trays (5.23 ± 3.87) resulting in the lowest mean. Fertilizer type was significant ($p<0.05$), with soluble fertilizer (1.43 ± 0.77) resulting in a lower mean than "Osmocote".

***Horsfieldia thorelii* Lec.**

Mean height of seedling at first potting :	13.39 ± 2.48 cm
Mean height of seedling after 10 months :	30.73 ± 8.98 cm
Survival of seedlings after 10 months :	91.67%

RGR of basal diameter (Figure 26 and Table 5) was highest with T5 (77.5 ± 33.15). Interpretation of all factors (Table 9 and Appendix I, Table 29) showed that block had a significant ($p<0.01$) effect with medium exposure (65.40 ± 29.59) and open (64.37 ± 34.95) resulting in higher means than deep shade. Root pruning by air (66.59 ± 33.02) resulted in a significantly higher mean than root pruning by hand.

RGR height (Figure 26 and Table 5) was highest with T5 (132.66 ± 54.42). Interpretation of all factors (Table 9 and Appendix I, Table 30) showed that block had a significant ($p<0.01$) effect with medium exposure (126.03 ± 39.78) and open (115.96 ± 46.96) resulting in having higher means than deep shade. Container had a significant ($p<0.01$) effect, with plastic bags 3 x 7 in (124.27 ± 45.22) resulting in the highest mean.

Final basal diameter (Figure 27 and Table 5) was highest with T5 (0.71 ± 0.15 cm). Interpretation of all factors (Table 9 and Appendix I, Table 31) showed that block had a significant ($p<0.01$) effect, with medium exposure (0.67 ± 0.10 cm) and open (0.65 ± 0.12 cm) having higher means than deep shade. Container also had a significant ($p<0.01$) effect, with plastic bags 3 x 7 in. (0.66 ± 0.13 cm) having the highest mean. Root pruning by air (0.66 ± 0.12 cm) resulted in a significantly higher mean than root pruning by hand.

Final height (Figure 28 and Table 5) was highest with T11 (35.25 ± 9.20 cm). Interpretation of all factors (Table 9 and Appendix I, Table 32) showed that block had a significant ($p<0.01$) effect, with medium exposure (35.98 ± 8.7 cm) resulting in the highest mean. With regard to container, plastic bags 3 x 7 in. (33.51 ± 9.95 cm) resulted in the highest mean. "Osmocote" (31.78 ± 9.23 cm) resulted in a significantly higher mean than soluble fertilizer.

Shoot / root ratio based on dry weight (Figure 29 and Table 5) was lowest with T8; (1.52 ± 0.45) and T10; (1.52 ± 0.37) Interpretation of all factors (Table 9 and Appendix I, Table 33) showed that a block had a significant ($p<0.01$) effect with open (1.53 ± 0.39) resulting in the lowest mean. Fertilizer type had a significant ($p<0.01$) effect with soluble fertilizer (1.62 ± 0.44) resulting in a lower mean than "Osmocote". Root pruning had a significant effect ($p< 0.01$) with by hand pruning (1.65 ± 0.56) resulting in a lower mean than root pruning by air.

Seedling Quality Index

The seedling Quality Index (SQI) (Table 14) for *Artocarpus lakoocha* was highest with plastic bags 3 x 7 in.+ "Osmocote" + root pruning by hand (0.352). SQI for *Balakata baccata* (Table 15) was highest with plastic bags 2.5 x 9 in. + soluble fertilizer + root pruning by hand (0..376). SQI for *Horsfieldia thorelii* (Table 16) highest with REX tray + "Osmocote" + root pruning by air (0.479).

Highest SQI averaging across all study species (Table 17) was in plastic bags 3 x 7 in + "Osmocote" + root pruning by air (0.577) and plastic bags 3 x 7 in + "Osmocote" + root pruning by hand (0.579).

Benefit value

Benefit value (Table 18), which relates seedling characteristics with production costs per seedling per season, was highest for *Artocarpus lakoocha* with REX trays + "Osmocote" + root pruning by hand (0.408) for *Balakata baccata* with plastic bags 2.5 x 9 in + soluble fertilizer + root pruning by hand 0.560) and for *Horsfieldia thorelii* with REX trays + "Osmocote" + root pruning by hand (0.529).

Highest benefit value averaging across all study species was showed in REX trays + soluble fertilizer + root pruning by hand (0.547).

Root Score (characteristic)

Root score 1: tap root straight and physically strong growing downwards to the bottom of containers (Figure 30).

Root score 2: branching tap root or very sinuous sometime without a tap root, but roots still grow downwards to the bottom of container (Figure 31).

Root score 3: tap root start vertically growing downwards and go down to bottom of container when touch inner surface of container (Figure 32).

Root score 4: tap root twisted upwards, but development straight down to the bottom of container (Figure 33).

Root score 5: tap root straight upward but coiled like container shape at bottom (Figure 34).

Root score 6: tap root hooked at start and coiled shape like bottom of container at bottom (Figure 35).

For *Artocarpus lakoocha* T1 resulted in the lowest mean root score of 2.4 (Table 11).

For *Balakata baccata* T5 resulted in the lowest mean root score of 2.1 (Table 12).

For *Horsfieldia thorelii* T1 resulted in the lowest mean root score of 1.333 (Table 13).

REX trays, the highest root score frequency was root score 1, with plastic bag 2.5 x 9 in , the highest root score frequency was root score 3 and plastic bag 3 x 7 in, the highest root score frequency was root score 2.

The best root characteristics were obtained with REX trays and root pruning by air.

Total Costs

The cheapest treatment (Table 2) was REX trays, with root pruning by hand and soluble fertilizer, 0.646 baht per seedling per season.

Seedlings Description

Artocarpus lakoocha **Roxb. (MORACEAE)**

The description is based on seedling grown at Forest Restoration Unit nursery. The large seedlings 10 months old, 37 cm tall (CMU Herbarium, voucher Jitlam S129b1), small seedlings 25 - 56 days old, 8 - 14 cm tall (CMU Herbarium, voucher Jitlam S129b2), very small in liquid collection 1-25 days old, 1-10 cm tall. The stage of development are in Figure 15.

germination:	hypogeal (*Horsfieldia* type (de Vogel, 1979))
testa:	thin, brown with darker brown lines
endosperm:	smooth, cream
cotyledons:	plano-convex, cream, 10 -15 x 8 – 10 mm
cotyledonary petiole:	distinct, white, 4 mm long, 2 mm thick
epicotyl:	often paired or branched above the base, one frequently aborting; straight, green; with 4 spirally arranged, scale-like/subulate prophylls, 1 mm long, all parts finely white hispidulous
cotyledonary leaves:	minute, inside the seed
seedling leaves:	spiral, simple, blade ovate, apex acuminate, base obtuse, finely serrulate, midnerve distinct, secondary veins pinnate, subopposite, 5 on each side of the midrib, arching, finer veins reticulate, spsrely and finely hispidulous on bloth sides, stipules, liner, hispidulous, 1.5 mm long
hypocotyl:	none

roots: radicle straight, thin, sinuous white, 1 mm diameter, after 5 days, becoming yellow, secondary roots, fibrous, white, becoming yellow with age, branching

Balakata baccata **(Roxb) Ess. (EUPHORBIACEAE)**

The description is based on seedling grown at Forest Restoration Unit nursery. The large seedlings 8 months olds, 28-32 cm tall (CMU Herbarium, Voucher Jitlam S015b1), small seedlings 2-18 days old, 2-6 cm tall, (CMU Herbarium, Voucher Jitlam S015b2), small and very small seedling in liquid collection 1-25 days old, 1-10 cm tall. Stage of development are in Figure 16.

germination: epigeal

testa: hard, black; tegument firm, soft, white

cotyledon: cryptocotyledonary, thick, white, disappear after germinate 2-3 days

epicotyl: initially reflexed and becoming straight 5 days after germination, green and becoming red or pink with age

cotyledonary leaves: opposite, blades elliptic both ends rounded, entire, main venation, obscure, with 5-6 parallel veins, forking near the tips, finer venation indistinct, 7 x 12 mm, light green or cream becoming green with age, petiole 2-3 mm long

embryo leaves: opposite, simple, blades ovate; apex acute, base rounded; entire, 9 x 12 mm, in older nodes becoming elliptic; apex acute, base peltate, 17 x 28 mm, midnerve with, primary vein soft 5-6 pairs of opposite, distinct, secondary vein finely, reticulate, above dark green, below light green, petiole light green, 8 mm long, grablous

seedling leaves: spiral, morphologically similar to the embryo leaves, but larger

hypocotyl: base white, middle pink or dark red, apex light green root: radicle stightly sinuous, cream becoming pale yellow , straight with age, 1 mm diameter after 20 days

Horsfieldia thorelii Lac. (MYRISTICACEAE)

The description is based on seedling grown at Forest Restoration Unit nursery.The large seedlings 10 months olds, 28-35 cm tall (CMU Herbarium, Voucher Jitlam S236b1). Liquid collection age 5 days and 30 days, 8 and 40 cm tall. Stage of development are in Figure 17.

germination: hypogeal (_Horsfieldia_ type (de Vogel, 1979))

teata: hard, mottled brown and gray, 0.5 mm thick

cotyledons: not seen, microscopic, remaining in the seed

endosperm: ruminate, white with brown lines

cotyledonary petiole: stout, 8 mm long, 5 mm thick, brown after 30 days

epicotyl: straight, stout, green, glabrous; with 3-4 spirally arranged, scale-like/subulate prophylls, lowest one 4 mm long, these becoming green and larger distally

hypocotyl: hardly distinct, represented by a dark brown ring between the insertion of the cotyledonary petiole and top of the radical

seedling leaves: spirally arranged, simple, spaced; blades elliptic apex obtuse, base acute, entire; midnerve distinct, flat dorsally, raised ventrally; secondary veins pinnate, subopposite, 6-7 on each side of the midrib; arching; finer veins reticulate; glossy dark green dorsally, glossy green underneath; petioles light green, 4-5 mm long; very immature leaf parts with fine, brown, stellate indumentum, glabrescent

stipules: none

roots: radical straight, stout, light brown, 3 mm diameter after 30 days; secondary roots fibrous, 1 mm diameter

Figure 15. Various stages of *Artocarpus lakoocha* Roxb. seedlings

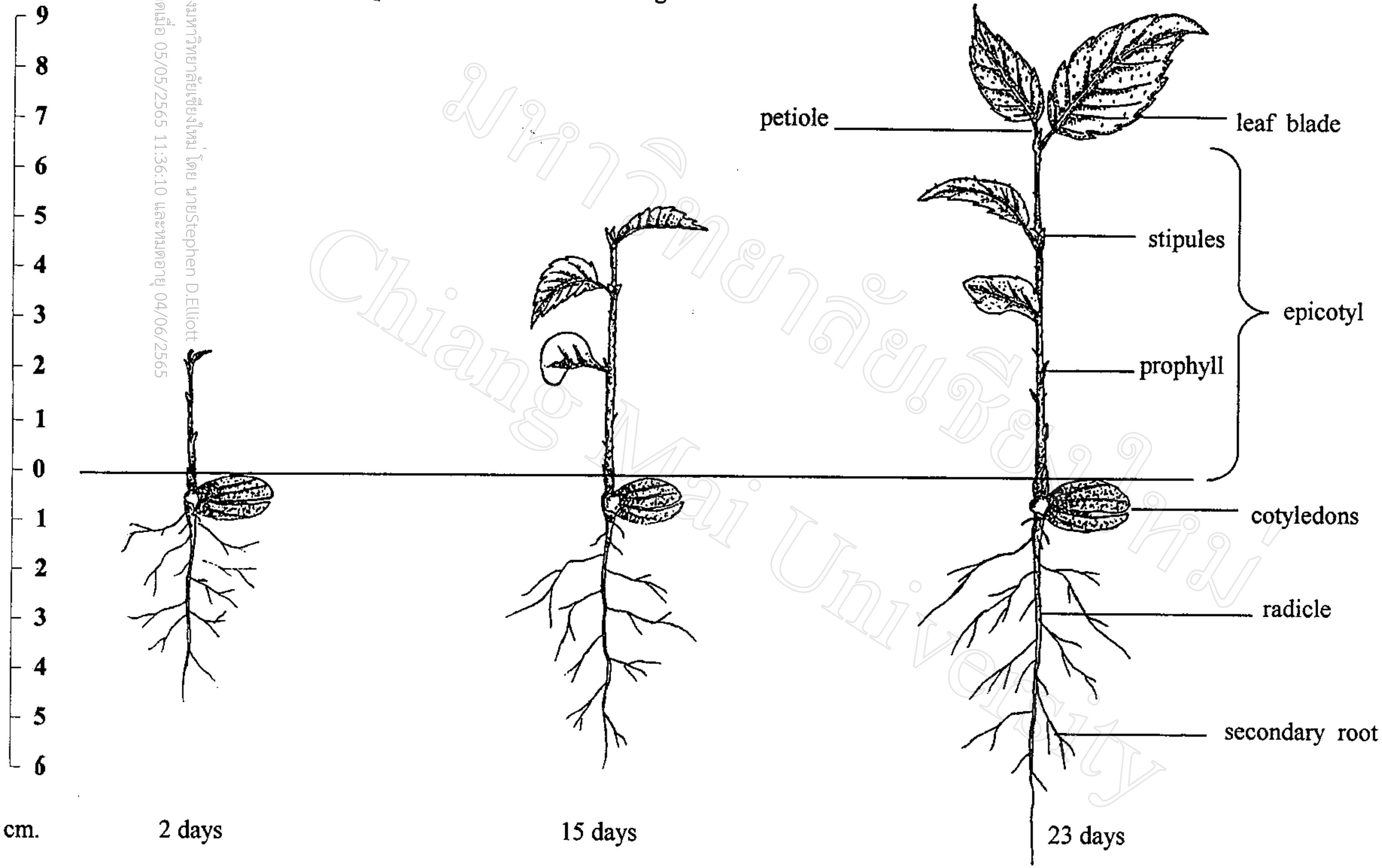

Figure 16. Various stages of *Balakata baccata* (Roxb.) Ess. seedlings

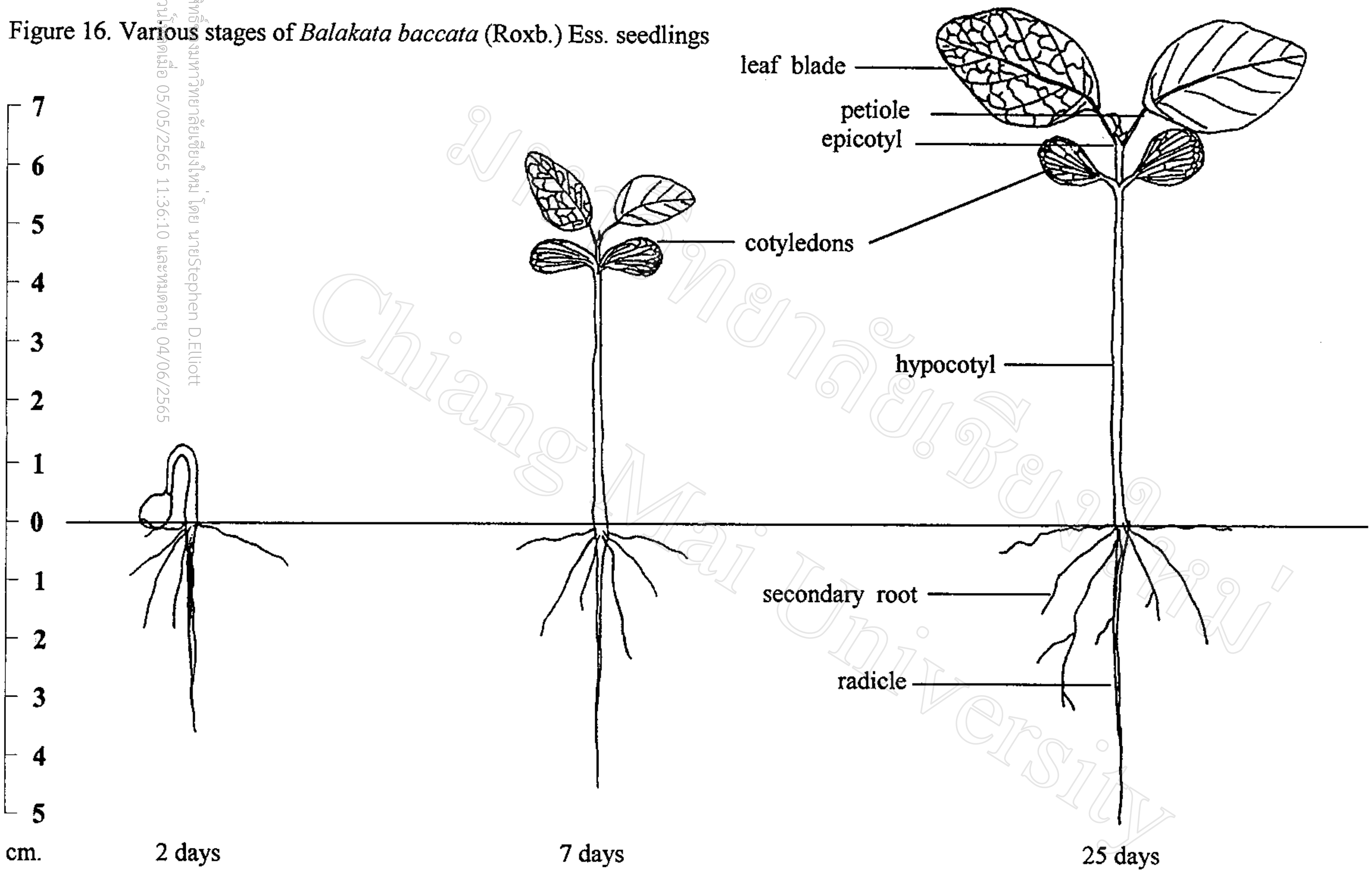

Figure 17. Various stages of *Horsfieldia thorelii* Lec. seedlings

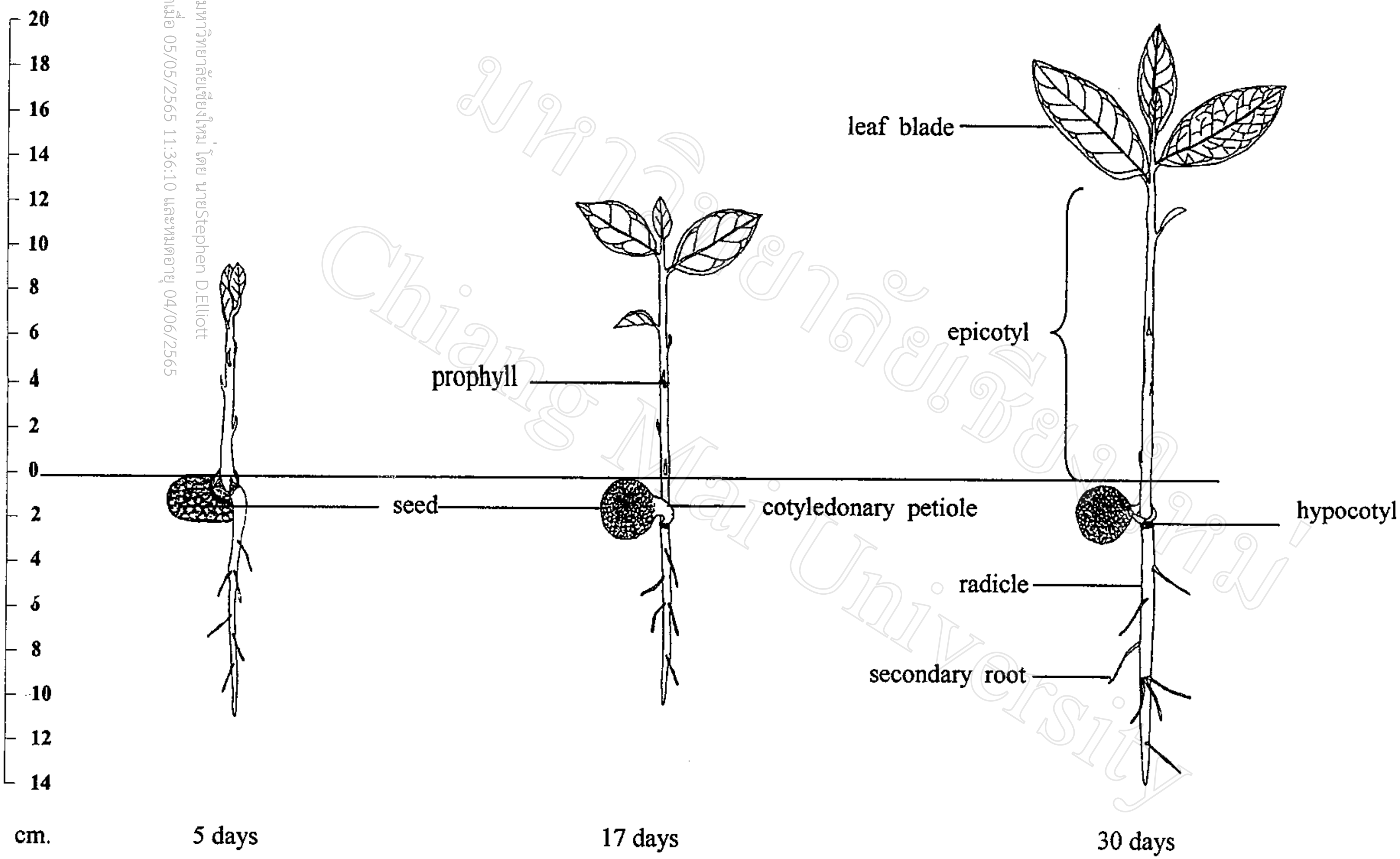

Figure18. Relative Growth Rate (RGR) of basal diameter and height percent per year of *Artocarpus lakoocha*.

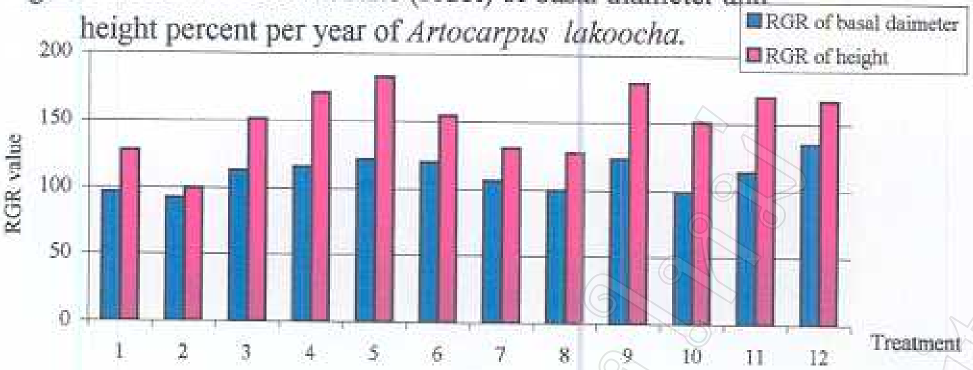

Figure 19. Final basal diameter of *Artocarpus lakoocha*.

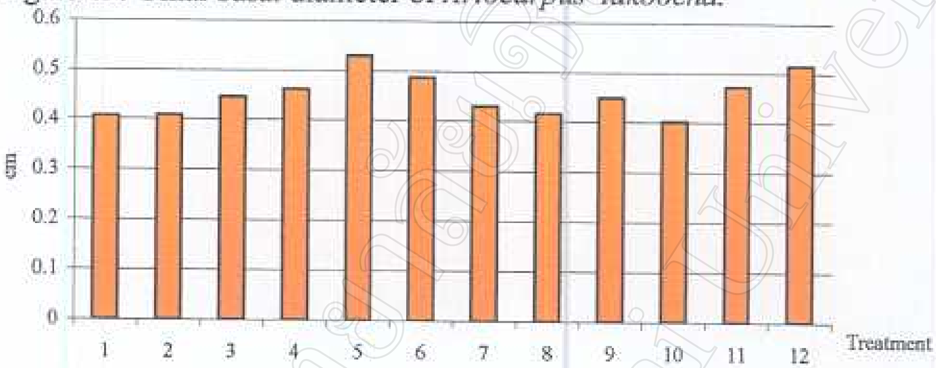

Figure 20. Final height of *Artocarpus lakoocha*.

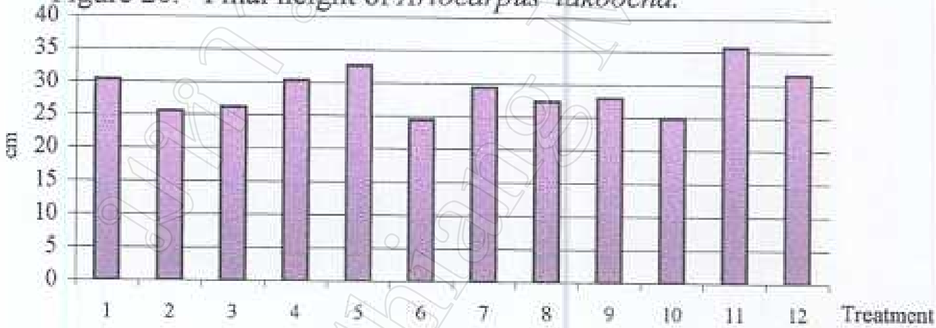

Figure 21. Shoot/root ratio of *Artocarpus lakoocha*.

Figure 22. Relative Growth Rate (RGR) of basal diameter and height percent per year of *Balakata baccata.*

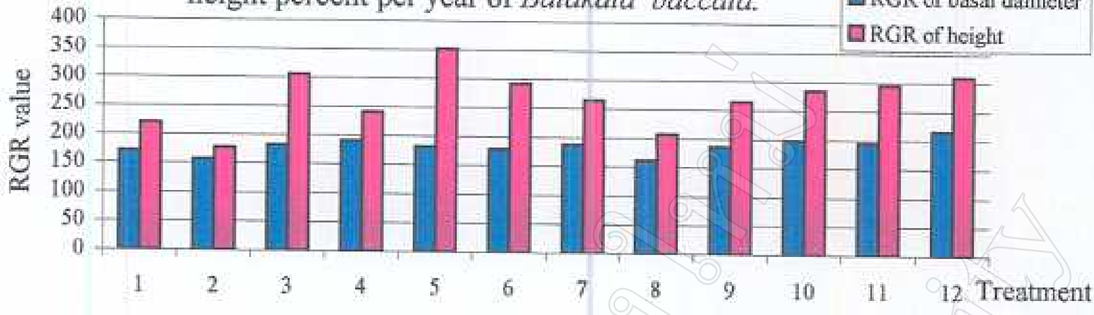

Figure 23. Final basal diameter of *Balakata baccata.*

Figure 24. Final height of *Balakata baccata.*

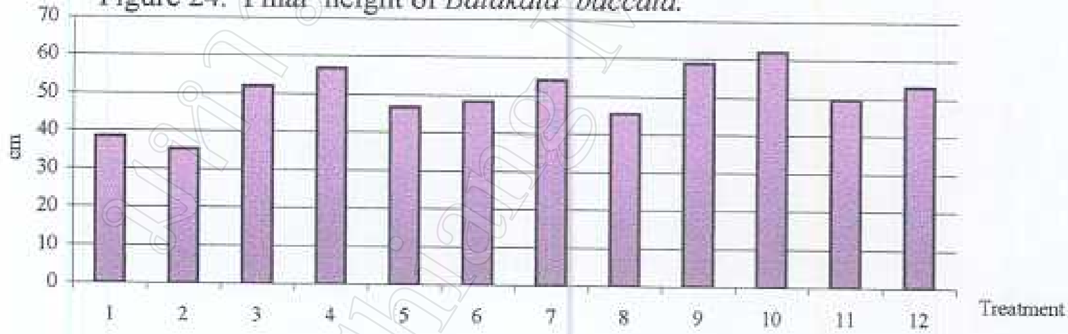

Figure 25. Shoot / root ratio of *Balakata baccata.*

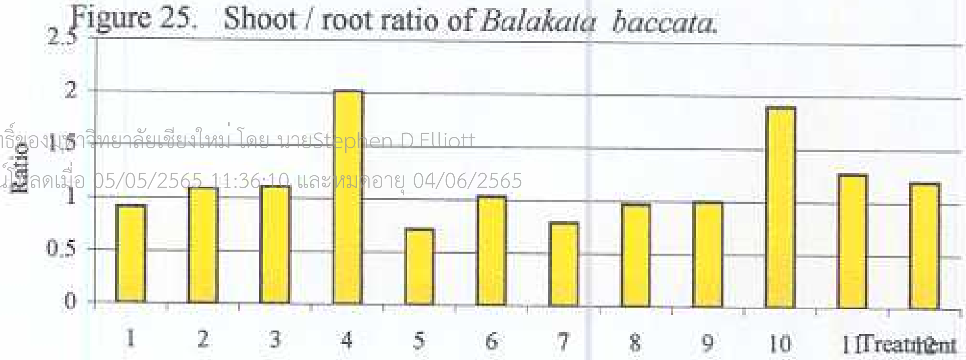

Figure 26. Relative Growth Rate (RGR) of basal diameter and height percent per year of *Horsfieldia thorelii.*

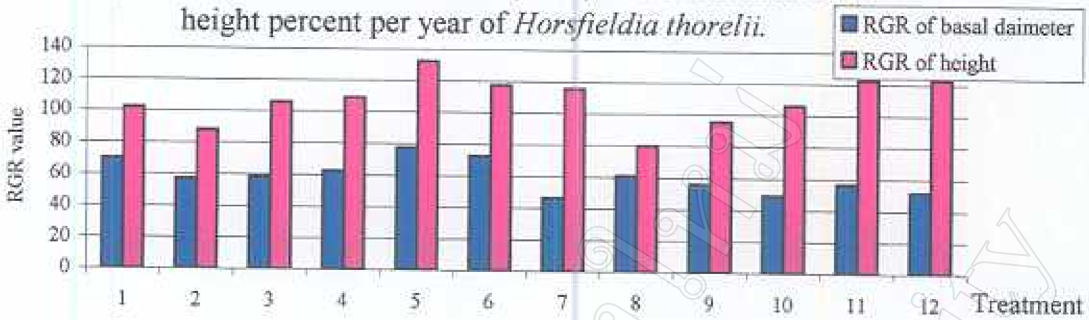

Figure 27. Final basal diameter of *Hosfieldia thorelii.*

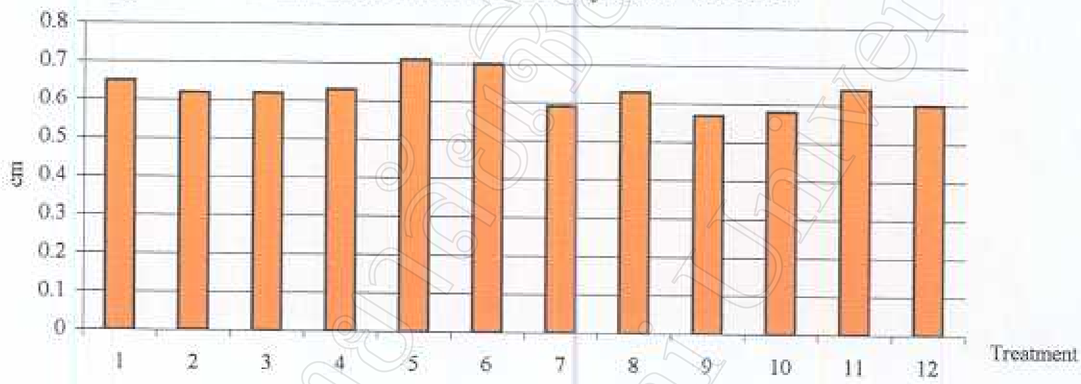

Figure 28. Final height of *Horsfieldia thorelii.*

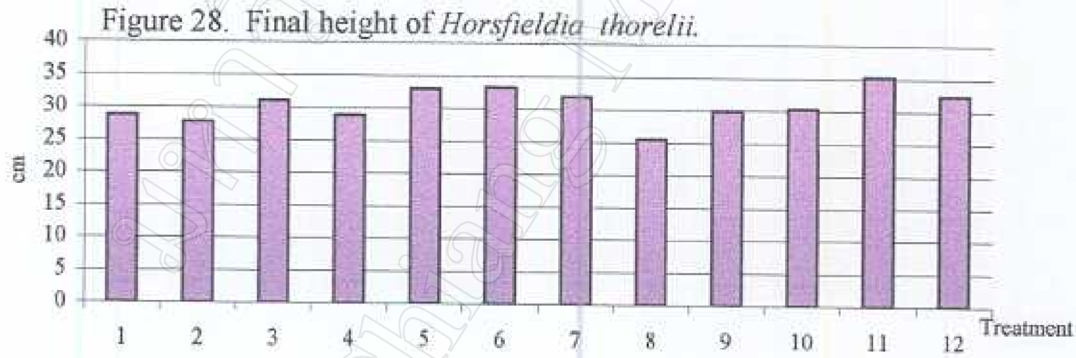

Figure 29. Shoot / root of *Horsfieldia thorelii.*

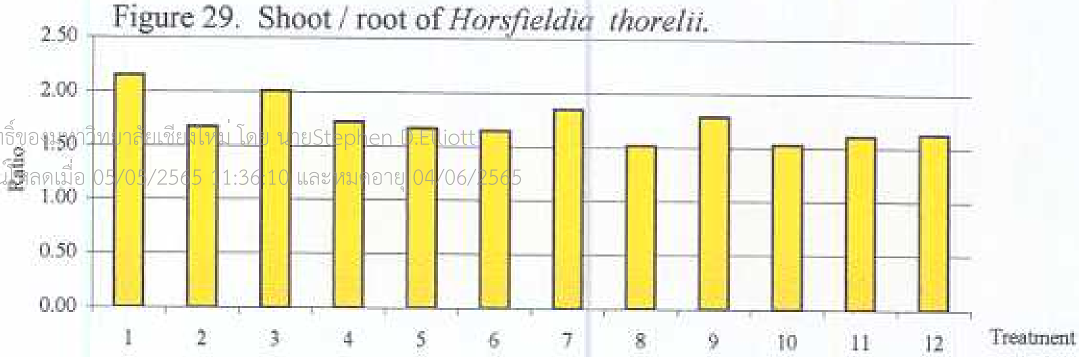

Figure 30. Root score 1

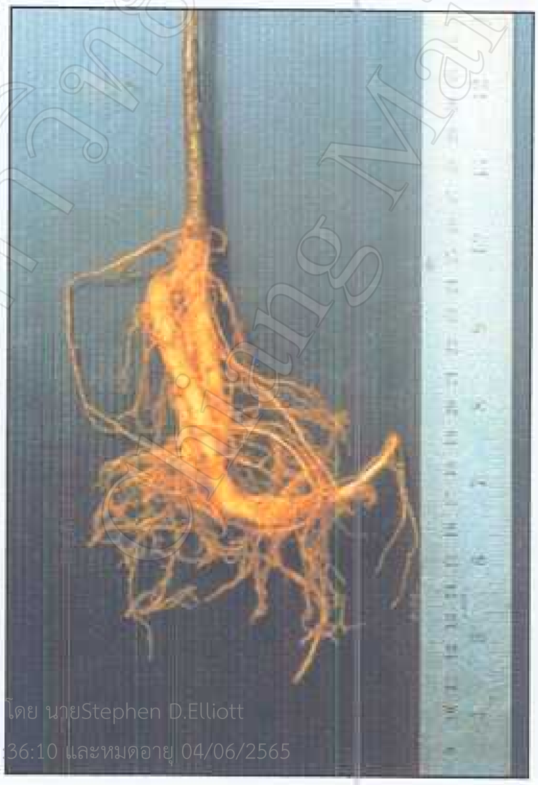

Figure 31. Root score 2

Figure 32. Root score 3

Figure 33. Root score 4

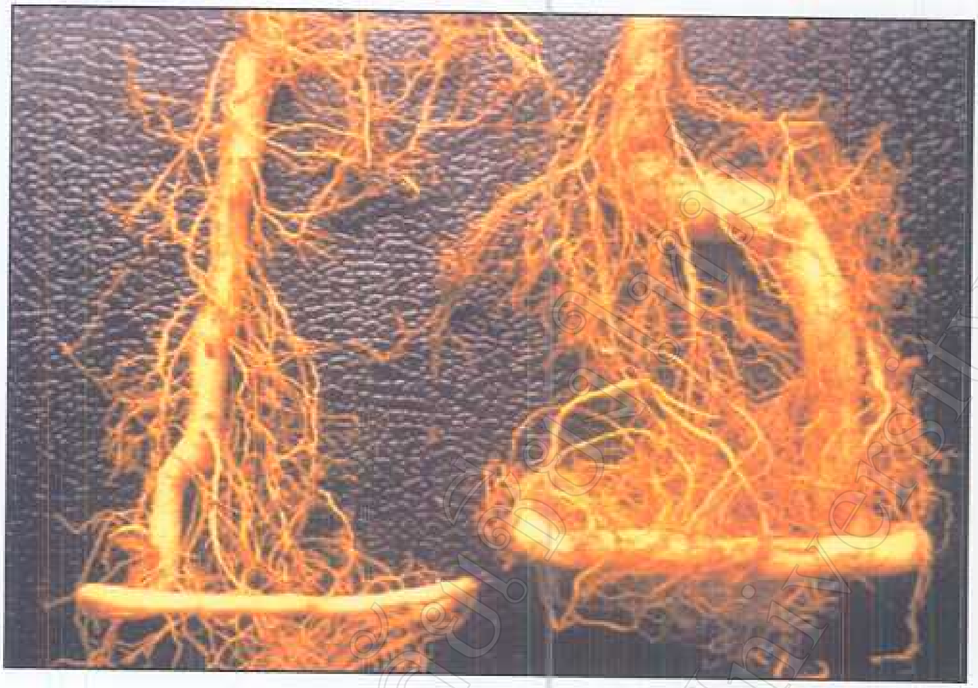

Figure 34. Root score 5

Figure 35. Root score 6

Table 2. Total cost: baht per seedling per season

Treatment	Container	Media	Fertilizer	Root Pruning	Labour Cost	Total
T1: raised + REX tray + osmocote	0.243	0.1671	0.18	0.347	0.1689	1.106
T2:raised + REX tray + soluble fertilizer	0.243	0.1671	0.0375	0.347	0.1928	0.987
T3:raised + plastic bag 2.5x9 in + osmocote	0.127	0.4456	0.18	0.242	0.2404	1.235
T4:raised + plastic bag 2.5x9 in + soluble fertilizer	0.127	0.4456	0.0375	0.242	0.2643	1.116
T5:raised + plastic bag 3x7 in + osmocote	0.144	0.4736	0.18	0.347	0.2404	1.385
T6:raised + plastic bag 3x7 in + soluble fertilizer	0.144	0.4736	0.0375	0.347	0.2643	1.266
T7: ground + REX tray + osmocote	0.243	0.1671	0.18	0.0054	0.1689	0.764
T8:ground + REX tray + soluble fertilizer	0.243	0.1671	0.0375	0.0054	0.1928	0.646
T9:ground + plastic bag 2.5x9 in + osmocote	0.127	0.4456	0.18	0.104	0.2404	1.097
T10:ground + plastic bag 2.5x9 in + soluble fertilizer	0.127	0.4456	0.0375	0.104	0.2643	0.978
T11:ground + plastic bag 3x7 in + osmocote	0.144	0.4736	0.18	0.104	0.2404	1.142
T12:ground + plastic bag 3x7 in + soluble fertilizer	0.144	0.4736	0.0375	0.104	0.2643	1.023

Table 3. Growth parameters of *Artocarpus lakoocha* Roxb. with 12 treatments. Data were analized by SNK and Duncan test with significance level 0.05.

Treatment	Number	RGR diamete % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)		
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	Number
T1	26	96.64ab	37.10	127.26ab	67.99	0.407a	0.103	30.327	11.455	1.29ab	0.549	30
T2	30	92.06a	35.16	99.77a	39.57	0.409a	0.072	25.600	5.892	1.34ab	0.866	30
T3	23	112.82ab	47.97	151.64ab	81.93	0.446ab	0.131	26.217	12.389	1.76b	0.868	30
T4	26	116.16ab	39.90	170.79b	81.55	0.462ab	0.112	30.327	14.236	1.73b	1.040	30
T5	28	121.68ab	55.42	**182.45b**	96.25	**0.531b**	0.184	32.554	17.163	1.76b	0.960	30
T6	30	119.89ab	51.50	154.44ab	50.23	0.487ab	0.159	24.450	7.714	1.61ab	0.941	30
T7	29	105.99ab	37.24	130.53ab	51.25	0.43ab	0.099	29.397	10.384	**1.04a**	0.428	30
T8	28	99.91ab	31.87	127.44ab	53.84	0.416b	0.068	27.321	9.848	1.29ab	0.586	30
T9	25	123.28ab	44.52	179.67b	93.81	0.449ab	0.133	27.900	16.682	1.85b	0.973	30
T10	28	98.83ab	50.78	150.81ab	82.29	0.401a	0.132	24.893	11.993	1.39ab	0.564	30
T11	30	113.42ab	47.69	170.09b	86.46	0.473ab	0.160	35.717	19.583	1.69b	0.946	30
T12	27	**135.45b**	49.92	167.04b	69.16	0.516ab	0.163	31.556	14.256	1.35ab	0.718	30

Table 4. Growth parameters of *Balakata baccata (Roxb.) Ess.* with 12 treatments. Data were analized by ANOVA and SNK test with significance level 0.05

Treatment	Number	RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)		
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	Number
T1	10	170.39ab	36.72	220.33ab	69.70	0.50a	0.05	38.5ab	12.03	0.92ab	0.78	13
T2	9	156.75a	34.86	176.21a	62.12	0.522ab	0.09	35.22a	13.61	1.09ab	0.64	11
T3	26	182.05ab	40.23	306.13bc	103.41	0.56ab	0.13	52.13abc	19.09	1.11ab	0.92	21
T4	23	190.96ab	45.63	240.61ab	109.66	**0.66b**	0.13	56.91c	18.74	2.02b	1.73	21
T5	27	180.85ab	53.21	**351.93c**	112.64	0.49a	0.11	46.82abc	16.06	**0.72a**	0.71	21
T6	19	177.17ab	42.55	291.75bc	127.62	0.55ab	0.15	48.39bc	11.63	1.03ab	0.83	19
T7	24	186.99ab	42.41	264.68abc	86.74	0.51ab	0.11	54.13abc	15.06	**0.79a**	0.74	20
T8	22	160.90ab	30.93	207.03ab	85.05	0.57ab	0.08	45.57c	10.89	0.97ab	0.76	21
T9	21	185.82ab	69.34	264.18abc	88.00	0.55ab	0.14	58.88c	21.55	1.00ab	1.90	21
T10	18	198.06ab	30.82	284.44bc	122.82	**0.66b**	0.16	**62.03c**	8.91	1.90b	1.21	21
T11	25	193.87ab	74.44	294.74bc	129.91	0.55ab	0.19	49.64abc	22.45	1.27ab	0.92	18
T12	23	**215.10b**	77.20	310.61bc	92.58	0.57ab	0.22	53.26bc	22.19	1.20ab	1.18	19

Table 5. Growth parameters of *Horsfieldia thorelii* Lac.with 12 treatments. Data were analized by ANOVA and SNK test with significance level 0.05 .

Treatment	Number	RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)		
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	Number
1	26	70.01ab	23.94	102.01abc	51.78	0.65abc	0.08	28.71ab	9.65	2.15c	1.05	30
2	27	56.99ab	26.64	88.04ab	36.66	0.62ab	0.06	27.76ab	6.16	1.68ab	0.47	30
3	26	58.61ab	37.06	105.92abc	48.99	0.62ab	0.09	31.06ab	10.21	2.01bc	0.75	30
4	30	62.63ab	38.01	109.14abc	50.80	0.63ab	0.13	28.83ab	7.87	1.73abc	0.40	30
5	30	**77.5b**	33.15	**132.66c**	54.42	**0.71c**	0.15	32.97b	10.18	1.67ab	0.36	30
6	28	72.66ab	33.66	117.77bc	43.91	0.70bc	0.13	33.29b	9.20	1.65ab	0.44	30
7	26	46.34a	23.45	115.82abc	32.33	0.59a	0.10	31.94ab	7.01	1.85abc	0.59	30
8	27	60.81ab	32.05	80.28a	45.35	0.63ab	0.09	25.53a	7.29	**1.52a**	0.45	30
9	25	55.84ab	27.52	95.46abc	45.79	0.57a	0.10	29.94ab	7.73	1.79abc	0.83	30
10	29	49.11a	32.15	106.24abc	27.91	0.58a	0.11	30.33ab	7.07	**1.53a**	0.37	30
11	30	56.63ab	26.62	122.83bc	35.16	0.64ab	0.11	**35.25b**	9.20	1.61ab	0.47	30
12	26	51.65ab	28.83	123.32bc	46.35	0.60a	0.09	32.45ab	11.40	1.63ab	0.47	30

Table 6. Average for all study species in growth parameters of with 12 treatments. Data were analized by ANOVA and SNK test with significance level 0.05 .

Treatment	Number	RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)		
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	Number
1	62	97.37ab	46.81	131.68a	73.36	0.523ab	0.14	30.97ab	11.18	1.79ab	0.92	73
2	66	86.54a	45.21	105.40a	50.45	0.512a	0.12	27.60a	7.96	**1.70a**	0.83	71
3	75	118.02b	66.21	189.35c	118.74	0.547ab	0.14	36.88bc	18.25	2.61bc	1.90	81
4	79	117.61bc	66.22	167.71bc	96.81	0.582ab	0.15	37.50bc	18.55	2.28abc	1.80	81
5	75	117.42bc	61.16	**200.95c**	120.59	**0.596b**	0.18	35.95bc	15.46	2.82c	2.16	81
6	77	116.85bc	58.96	174.99c	101.42	0.578ab	0.17	33.57abc	13.14	2.42abc	1.80	79
7	79	110.97bc	66.22	166.44bc	88.31	0.506a	0.12	37.747bc	15.53	3.89abc	1.96	80
8	77	103.52ab	50.83	133.64ab	79.48	0.534ab	0.12	31.91abc	12.71	2.00abc	1.28	81
9	71	119.47bc	70.74	175.01c	102.96	0.525ab	0.13	37.78bc	20.95	2.82c	2.04	81
10	75	103.42ab	69.95	165.65bc	105.50	0.533ab	0.17	35.91bc	17.71	2.20abc	1.73	81
11	85	117.04bc	75.35	190.07c	113.35	0.553ab	0.17	**39.65c**	18.65	2.49abc	1.91	78
12	76	**130.89c**	85.14	194.18c	105.98	0.560ab	0.16	37.89bc	18.81	2.14abc	1.49	79

Table 7. Growth parameters of Artocarpus lakoocha Roxb. in different type of block, container, root pruning and fertilization Analized by ANOVA and LSD test with significance level 0.05.

		RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Block	1	87.52b	39.50	81.80b	49.63	0.38b	0.10	17.20b	5.51	1.92b	0.89
	2	**124.20a**	42.50	**177.60a**	64.98	**0.50a**	0.13	**34.03a**	12.11	**1.12a**	0.59
	3	**119.67a**	46.05	**186.60a**	62.35	**0.48a**	0.14	**34.46a**	15.84	1.48b	0.81
Container	1	98.56b	35.29	120.87b	54.37	0.46b	0.09	28.09	9.59	**1.24a**	0.63
	2	**112.39a**	46.26	**163.16a**	84.64	0.44b	0.13	27.31	13.87	1.69b	0.89
	3	**122.29a**	51.11	**198.30a**	77.00	**0.50a**	0.17	31.03	15.70	1.60b	0.90
Root pruning	1	109.77	46.00	147.07	75.66	0.46	0.14	28.18	12.14	1.58b	0.89
	2	112.41	45.42	153.78	75.72	0.45	0.14	28.55	14.45	**1.43a**	0.77
Fertilization	1	112.25	45.65	157.05	82.73	0.46	0.14	**30.59a**	15.20	1.57	0.86
	2	110.01	65.78	144.19	67.88	0.45	0.13	27.24b	11.13	1.45	0.81

Remarks:

Remarks:	Block	1 = deep shade	2 = open	3 = medium
	Container	1 = REX tray	2 = plastic bag 2.5 x 9 in.	3 = plastic bag 3 x 7
	Root pruning	1 = by air	2 = by hand	
	Fertilization	1 = "Osmocote"	2 = soluble fertilizer	

Table 8. Growth parameters of Balakata baccata (Roxb.) Ess. in different type of block, container, root pruning and fertilization Analized by ANOVA and LSD test with significance level 0.05.

		RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Block	1	164.12b	44.69	240.75b	117.76	0.48b	0.11	43.83b	17.30	6.82b	4.08
	2	**187.57a**	53.59	265.85b	101.73	**0.60a**	0.15	49.73b	17.08	**4.16a**	2.02
	3	**198.75a**	52.69	**301.27a**	105.12	**0.59a**	0.15	**57.78a**	19.20	**4.12a**	1.90
Container	1	171.99b	279.74	226.52b	85.37	0.53b	0.10	46.82b	15.15	**3.84a**	2.20
	2	**188.13a**	338.22	274.24b	107.31	**0.60a**	0.14	**56.56a**	18.08	5.43b	3.87
	3	**193.27a**	439.00	**309.99a**	116.77	0.54b	0.18	52.42b	17.52	4.95	2.08
Root pruning	1	**0.10a**	6.87	277.01	115.68	0.56	0.13	48.87b	17.28	5.94	3.67
	2	0.09b	6.63	571.33	105.72	0.57	0.16	**53.54a**	18.46	4.86	2.19
Fertilization	1	185.7	53.63	**287.37a**	106.75	0.53b	0.14	51.23	19.07	5.29b	2.41
	2	186.24	51.85	258.95b	112.05	0.59a	0.16	51.77	16.96	**4.51a**	3.42

Remarks:

Remarks:	Block	1 = deep shade	2 = open	3 = medium
	Container	1 = REX tray	2 = plastic bag 2.5 x 9 in.	3 = plastic bag 3 x 7
	Root pruning	1 = by air	2 = by hand	
	Fertilization	1 = "Osmocote"	2 = soluble fertilizer	

Table 9. Growth parameters of Horsfieldia thorelii Lac. in different type of block, container, root pruning and fertilization. Analized by ANOVA and LSD test with significance level 0.05.

		RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Block	1	49.96b	27.47	82.77b	38.68	0.57b	0.09	24.85b	5.62	1.89b	0.76
	2	**64.37a**	34.95	**115.96a**	46.96	**0.65a**	0.12	31.00b	8.50	**1.53a**	0.39
	3	**65.41a**	29.59	**126.03a**	39.78	**0.67a**	0.10	**35.98a**	8.70	1.80b	0.57
Container	1	58.25	27.73	96.30b	43.77	0.62b	0.09	28.45	7.86	1.80	0.72
	2	56.57	34.08	104.50b	43.87	0.60b	0.11	30.00	8.19	1.77	0.64
	3	64.92	32.16	**124.27a**	45.22	**0.66a**	0.13	33.51	9.95	1.64	0.43
Root pruning	1	**66.59a**	33.02	109.79	49.52	**0.66a**	0.12	30.48	9.11	1.82b	0.65
	2	53.43b	28.67	107.78	41.69	0.60b	0.10	30.99	9.96	**1.65a**	0.56
Fertilization	1	61.16	30.50	113.30	46.62	0.63	0.12	**31.78a**	9.23	1.85b	0.73
	2	59.05	35.69	104.44	44.58	0.63	0.11	29.73b	8.64	**1.62a**	0.44

Remarks:				
	Block	1 = deep shade	2 = open	3 = medium
	Container	1 = REX tray	2 = plastic bag 2.5 x 9 in.	3 = plastic bag 3 x 7
	Root pruning	1 = by air	2 = by hand	
	Fertilization	1 = "Osmocote"	2 = soluble fertilizer	

Table 10. Average growth parameter of all species in different types of block, container, root pruning and fertilization.

		RGR diameter % per year		RGR height % per year		final diameter (cm)		final height (cm)		shoot/root ratio (dry weight)	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Block	1	90.92b	57.02	119.22c	95.65	0.42b	0.15	26.36c	13.98	2.70b	2.03
	2	**118.02a**	64.46	177.16b	91.44	**0.62a**	0.24	36.96b	13.81	**2.00a**	1.56
	3	**124.68a**	69.24	**200.02a**	102.09	**0.59a**	0.22	**41.94a**	17.43	**2.26a**	1.53
Container	1	100.03b	53.99	135.48b	77.91	0.52b	0.16	32.35b	12.85	**1.98a**	1.36
	2	114.81b	68.19	**174.48a**	105.96	**0.55a**	0.23	**37.02a**	18.76	2.48b	1.88
	3	**120.45a**	70.99	**189.97a**	110.46	**0.57a**	0.27	**36.84a**	16.81	2.47b	1.86
Root pruning	1	109.90	59.59	163.86	102.83	0.56	0.16	34.02b	15.12	2.30	1.70
	2	114.19	70.76	171.06	101.50	0.54	0.15	**36.86a**	17.63	2.34	1.77
Fertilization	1	113.99	65.72	**177.20a**	106.65	0.54	0.15	**36.73a**	17.16	2.50b	1.89
	2	110.24	65.48	157.98b	96.62	0.55	0.15	34.24b	15.76	**2.13a**	1.54
Species	1	111.10b	45.66	150.46b	75.65	0.45c	0.23	28.87b	13.36	**1.50a**	0.84
	2	**185.96a**	52.67	**273.82a**	110.00	0.56b	0.24	**51.49a**	18.06	1.74b	0.61
	3	60.09c	31.6	108.39c	45.59	**0.64a**	0.17	31.60b	8.84	4.53c	1.10

Remarks:				
	Block	1 = deep shade	2 = open	3 = medium
	Container	1 = REX tray	2 = plastic bag 2.5 x 9 in.	3 = plastic bag 3 x 7
	Root pruning	1 = by air	2 = by hand	
	Fertilization	1 = "Osmocote"	2 = soluble fertilizer	

Table 11. Mean of root scores (characteristic) in different treatment of *Artocarpus lakoocha* Roxb. data were analized by Chi-squre test.

treatment	root pruning	container	fertilizer	number	mean	Standard diviation	Chi-squre	Degree of Freedom	Sig
T1	by air	root trainer	osmocote	30	2.4	1.4527	7.8	2	0.0202
T2			soluble	30	2.8667	1.33218	15.333	3	0.0016
T3		2.5 x 9 in	osmocote	30	2.8333	0.91287	28.333	4	0
T4			soluble	30	2.8	0.76112	20.667	3	0.0001
T5		3 x 7 in.	osmocote	30	3.3	1.08755	29.2	5	0
T6			soluble	30	3.2333	1.19434	23.2	5	0.0003
T7	by hand	root trainer	osmocote	30	2.7333	1.41259	17.467	3	0.0006
T8			soluble	30	2.6667	1.49328	12.6	2	0.0018
T9		2.5 x 9 in	osmocote	30	2.6667	0.88409	23.867	3	0
T10			soluble	30	3.2333	1.04	69.6	5	0
T11		3 x 7 in.	osmocote	30	3.733	1.65952	4.4	5	0.4934
T12			soluble	30	3.8333	1.46413	4.33	4	0.3628

Table 12. Mean of root scores (characteristic) in different treatment of *Balakata baccata* (Roxb.) Ess. data were analized by Chi-squre test.

Treatment	Root pruning	Container	Fertilizer	Number	Mean	Standard diviation	Chi-squre	Degree of Freedom	Sig
T1	by air	root trainer	osmocote	13	2.76923	1.01274	0.6923	1	0.4054
T2			soluble	11	2.36364	1.43337	4.6364	3	0.2004
T3		2.5 x 9 in	osmocote	21	2.57143	0.50709	0.4286	1	0.5127
T4			soluble	21	2.80952	0.87287	10.2857	2	0.0058
T5		3 x 7 in.	osmocote	21	2.19048	0.98077	29.4762	3	0
T6			soluble	19	2.31579	0.47757	2.5789	1	0.1083
T7	by hand	root trainer	osmocote	21	2.61905	1.07127	25.9048	4	0
T8			soluble	21	3.28571	1.00712	16.9048	3	0.0007
T9		2.5 x 9 in	osmocote	21	2.38095	0.86465	6.2381	3	0.1006
T10			soluble	21	2.71429	0.56061	10.2857	2	0.0058
T11		3 x 7 in.	osmocote	18	2.27778	0.57451	8.333	2	0.0155
T12			soluble	19	2.21053	0.41885	6.3684	1	0.0116

Table 13. Mean of root scores (characteristic) in different treatment of *Horsfieldia thorelii* Lac. data were analized by Chi-squre test.

treatment	root pruning	container	fertilizer	number	mean	Standard diviation	Chi-squre	Degree of Freedom	Sig
T1	by air	root trainer	osmocote	30	1.333	0.5467	20.6	2	0
T2			soluble	30	1.4	0.6146	16.8	2	0.0002
T3		2.5 x 9 in	osmocote	30	2.033	0.96431	6	3	0.116
T4			soluble	30	1.8	0.71438	4.2	2	0.1225
T5		3 x 7 in.	osmocote	30	2.667	0.99424	13.467	3	0.0037
T6			soluble	30	2.033	0.96431	6	3	0.116
T7	by hand	root trainer	osmocote	30	1.667	0.7581	5	2	0.0821
T8			soluble	30	1.533	0.57135	12.2	2	0.0022
T9		2.5 x 9 in	osmocote	30	2.033	0.80872	17.733	3	0.0005
T10			soluble	30	2.233	1.19434	.3.33	3	0.343
T11		3 x 7 in.	osmocote	30	3.533	0.68145	13.4	2	0.0012
T12			soluble	30	2.933	1.31131	18.533	3	0.0003

Table 14. Seedling Quality Index (SQI) of *Artocarpus lakoocha* Roxb.

Treatment	Root pruning	Container	Fertilizer	Standardised value					SQI
				Height	Diameter	Root dry weight	Shoot/root	Root degree	
T1	by air	REX trays	osmocote	0.849	0.766	0.397	0.806	1.000	0.208
T2			soluble	0.716	0.770	0.448	0.773	0.837	0.160
T3		2.5 x 9 in	osmocote	0.734	0.840	0.546	0.596	0.847	0.170
T4			soluble	0.849	0.870	0.512	0.601	0.857	0.195
T5		3 x 7 in.	osmocote	0.911	1.000	0.781	0.591	0.727	0.306
T6			soluble	0.685	0.917	0.611	0.645	0.742	0.184
T7	by hand	REX trays	osmocote	0.823	0.810	0.544	1.000	0.878	0.318
T8			soluble	0.765	0.783	0.430	0.806	0.900	0.187
T9		2.5 x 9 in	osmocote	0.781	0.940	0.469	0.562	0.900	0.174
T10			soluble	0.697	0.756	0.529	0.962	0.742	0.199
T11		3 x 7 in.	osmocote	1.000	0.891	1.000	0.615	0.643	0.352
T12			soluble	0.884	0.972	0.801	0.770	0.626	0.332

Table 15. Seedling Quality Index (SQI) of *Balakata baccata* (Roxb.) Ess.

Treatment	Root pruning	Container	Fertilizer	Standardised value					SQI
				Height	Diameter	Root dry weight	Shoot/root	Root degree	
T1	by air	REX trays	osmocote	0.621	0.758	0.456	1.000	0.791	0.169
T2			soluble	0.568	0.791	0.541	0.780	0.927	0.176
T3		2.5 x 9 in	osmocote	0.840	0.848	0.548	0.398	0.852	0.132
T4			soluble	0.917	1.000	1.000	0.344	0.780	0.246
T5		3 x 7 in.	osmocote	0.755	0.742	0.354	0.343	1.000	0.068
T6			soluble	0.780	0.833	0.504	0.431	0.946	0.134
T7	by hand	REX trays	osmocote	0.873	0.773	0.391	0.372	0.836	0.082
T8			soluble	0.735	0.864	0.481	0.577	0.667	0.118
T9		2.5 x 9 in	osmocote	0.949	0.833	0.497	0.365	0.920	0.132
T10			soluble	1.000	1.000	0.943	0.494	0.807	0.376
T11		3 x 7 in.	osmocote	0.800	0.833	0.628	0.400	0.962	0.161
T12			soluble	0.859	0.864	0.610	0.489	0.991	0.219

Table 16. Seedling Quality Index (SQI) of *Horsfieldia thorelii* Lec.

Treatment	Root pruning	Container	Fertilizer	Standardised value					SQI
				Height	Diameter	Root dry weight	Shoot/root	Root degree	
T1	by air	REX trays	osmocote	0.742	0.908	1.000	0.710	1.000	0.479
T2			soluble	0.738	0.878	0.782	0.900	0.952	0.434
T3		2.5 x 9 in	osmocote	0.828	0.882	0.934	0.760	0.656	0.340
T4			soluble	0.775	0.952	0.808	0.880	0.741	0.389
T5		3 x 7 in.	osmocote	0.882	1.000	0.777	0.910	0.500	0.312
T6			soluble	0.878	0.958	0.765	0.660	0.656	0.279
T7	by hand	REX trays	osmocote	0.812	0.817	0.860	0.820	0.667	0.312
T8			soluble	0.657	0.871	0.704	1.000	0.870	0.350
T9		2.5 x 9 in	osmocote	0.832	0.784	0.832	0.850	0.656	0.302
T10			soluble	0.847	0.814	0.709	0.990	0.597	0.289
T11		3 x 7 in.	osmocote	1.000	0.904	0.746	0.940	0.377	0.239
T12			soluble	0.770	0.810	0.759	0.930	0.455	0.200

Table 17. Total Seedling Quality Index (SQI) for these three species.

Treatment	Root pruning	Container	Fertilizer	Standardised value					SQI
				Height	Diameter	Root dry weight	Shoot/root	Root score	
T1	by air	REX trays	osmocote	0.690	0.881	0.466	0.813	1.000	0.230
T2			soluble	0.746	0.883	0.548	0.886	0.884	0.283
T3		2.5 x 9 in	osmocote	0.868	0.913	0.719	0.761	0.892	0.387
T4			soluble	0.889	0.996	0.822	0.709	0.880	0.454
T5		3 x 7 in.	osmocote	0.908	1.000	0.883	0.879	0.819	**0.577**
T6			soluble	0.829	0.969	0.849	0.864	0.818	0.483
T7	by hand	REX trays	osmocote	0.878	0.866	0.600	1.000	0.905	0.413
T8			soluble	0.776	0.890	0.604	0.997	0.872	0.362
T9		2.5 x 9 in	osmocote	0.940	0.871	0.692	0.797	0.916	0.413
T10			soluble	0.948	0.910	0.827	0.815	0.796	0.462
T11		3 x 7 in.	osmocote	1.000	0.970	1.000	0.822	0.726	**0.579**
T12			soluble	0.861	0.930	0.783	0.903	0.716	0.405

Table 18. Benefit value (Seedling Quality Index (SQI)/Cost) of *Artocarpus lakoocha, Balakata baccata* and *Horsfieldia thorelii.*

Treatment	Cost	*Artocarpus lakoocha*		*Balakata baccakata*		*Horsfieldia thorelii*		Total	
		SQI	benefit value	SQI	benefit value	SQI	benefit value	SQI	benefit value
T1	1.1059	0.208	0.188	0.060	0.054	0.479	0.433	0.230	0.208
T2	0.9873	0.160	0.162	0.103	0.104	0.434	0.440	0.283	0.286
T3	1.2354	0.170	0.138	0.268	0.217	0.340	0.275	0.387	0.313
T4	1.1168	0.195	0.175	0.460	0.411	0.389	0.348	0.454	0.407
T5	1.3854	0.306	0.221	0.198	0.143	0.312	0.225	0.577	0.416
T6	1.2668	0.184	0.145	0.256	0.202	0.279	0.220	0.483	0.381
T7	0.7809	0.318	**0.408**	0.192	0.246	0.312	0.399	0.413	0.529
T8	0.6623	0.187	0.282	0.125	0.189	0.350	**0.529**	0.362	**0.547**
T9	1.0974	0.174	0.159	0.343	0.312	0.302	0.276	0.413	0.377
T10	0.9788	0.199	0.203	0.548	**0.560**	0.289	0.295	0.462	0.472
T11	1.1424	0.352	0.308	0.358	0.313	0.239	0.209	0.579	0.506
T12	1.0238	0.332	0.324	0.286	0.279	0.200	0.195	0.405	0.396

DISCUSSION

Benefit value

The results showed that REX trays resulted in the highest benefit values which are agreement with Zangkum (1998). Zangkum also reported that seedlings grown in REX trays were of significantly higher quality than those grown in other containers. This contrasts with my results which showed that, plastic bags 3 x 7 in had higher quality seedlings. Zangkum did not use plastic bags of this size.

There was no relationship between seedling quality and benefit value. Treatments resulting in seedlings of high quality often had low benefit values because of the high price of some of the equipment necessary, such as wire grid tables. Using wire grid tables improves seedling quality, but results in low benefit values. Reducing the cost of the wire grid tables could significantly increase the benefit value of air pruning.

Containers

For the same container type *e.g.* plastic bags, large containers produce higher quality seedling than smaller ones. This agrees with the results of Boudoux (1972) who note that root growth is more affected by container diameter than by container height. Tinus (1974) also reported similar results using *Pinus ponderosa.* Hocking and Mitchell (1975) showed that growth of seedlings in containers with bigger diameters was better than in smaller diameter containers although all containers had similar volumes (Romero *et al.*, 1986)

The most suitable container for *Artocarpus lakoocha* Roxb., *Balakata baccata* (Roxb) Ess., and *Horsfieldia thorelii* Lec. is plastic bags 3x7in which produced higher quality seedlings than in other container types. This is in agreement with the results of Thapa *et al* (1990) who reported that *Artocarpus lakoocha* Roxb. had a significantly better quality in this sized bag. But bigger container size used more space in the nursery and transport.

Fertilizer

Most seedlings failed to grow to a plantable height within one year after germination with the exception of *Balakata baccata* (Roxb) Ess.. The average height of seedlings planted by FORRU is usually 50-60 cm or not less than 30 cm for fast – growing pioneers (Elliott *et al*, 1998) For *Artocarpus lakoocha* Roxb. and *Horsfieldia thorelii* Lec. growth accelerated by increasing the amount of fertilizer or target fertilizer application to the period of maximum growth rate for *Artocarpus lakoocha* Roxb. of 120-240 days after transplanting and *Horsfieldia thorelii* Lec. 60-120 days or 180-240 days after transplanting (Appendix IV).

Root pruning

A wire grid table is not necessary when using plastic bags. Although roots can grow through the hole in the bottom of the plastic, the tap root often tends to coil around the bottom of a plastic bag.

Root pruning by air may cause problems if watering is not carried out frequently enough. Containers on the ground can get moisture from the soil, so if root pruning by air is used, watering should be increased.

Balakata baccata had a low percent of survival because the seedlings were infected by bacteria causing damping off (Figure 36) starting at the base of the stem, which wide spread to other seedlings. Caterpillars (Figure 37) were also a serious pest. They lived hid under the leaves and ate the leaves and shoots, but seedlings produced new leaves after 10-14 days. Damping off could be solved by using chemicals or by pricking out earlier and move isolate from other seedlings. For the problem of caterpillars, is not necessary to use chemicals, since they can be removed by hand. Seedlings should be frequently inspected for signs of caterpillar damage.

Figure 36. Dampimg off in *Balakata baccata* (Roxb.) Ess.

Figure 37. Caterpillar in *Balakata baccata* (Roxb.) Ess.

CONCLUSIONS

1. REX trays placed on the ground with soluble fertilizer add produced the highest quality seedlings per unit cost this method is recommended for all three species tested.
2. Plastic bags of 3 x 7 in with "Osmocote", also produced high quality seedlings.
3. REX trays promoted better root morphology than using with plastic bags of both sizes.
4. Root pruning could not help to promote good root systems.
5. The fertilizer type had no significant effect on seedling quality. Either soluble or "Osmocote" method is equally effective, but soluble fertilizer is cheaper than "Osmocote", as determine by price and labor costs.
6. These three species, should be grown in high light conditions. Deep shade clearly depressed seedling growth.

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สุเมษ ศิริลักษณ์ , 2540. การเพาะชำกล้าไม้ระบบถาดเพาะชำ ศูนย์ส่งเสริมการเพาะชำกล้าไม้และปลูกป่า ฯ ที่ 4 (นครราชสีมา) สำนักส่งเสริมการปลูกป่า กรมป่าไม้.

APPENDIX I: ANOVA analysis

Table 19. ANOVA of Relative Growth Rate (RGR) of basal diameter of *Artocarpus lakoocha* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	119982.685	6	19997.114	11.792	.000	
Block	86704.375	2	43352.188	25.564	.000	**
Container	33373.405	2	16686.703	9.840	.000	**
Fertilize	124.519	1	124.519	.073	.787	ns
Root pruning	834.900	1	834.900	.492	.483	ns
Explained	119982.685	6	19997.114	11.792	.000	
Residual	565833.713	323	1751.807			
Total	685816.398	329	2084.548			

LSD Test

Block:	open (124.20 ± 42.50)	=	medium shade (119.67 ± 42.50)	>	under shade (87.51 ± 39.49)
Container:	bag 3 x 7 in. (122.29 ± 51.11)	=	bag 2.5x 9 in. (112.39 ± 45.26)	>	REX tray (98.57 ± 35.29)

Table 20. ANOVA of Relative Growth Rate (RGR) of height of *Artocarpus lakoocha* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = $p < 0.01$, * = $p < 0.05$, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	893637.914	6	148939.652	56.566	.000	
Block	724944.725	2	362472.363	137.663	.000	**
Container	158220.254	2	79110.127	30.045	.000	**
Fertilize	8405.902	1	8405.902	3.192	.075	ns
Root pruning	5648.173	1	5648.173	2.145	.144	ns
Explained	893637.914	6	148939.652	56.566	.000	
Residual	989224.256	323	3062.614			
Total	1882862.170	329	5722.985			

LSD Test

Block:	medium shade (186.60 ± 62.60)	=	open (177.60 ± 64.97)	>	under shade (81.80 ± 49.63)
Container:	bag 3 x 7 in. (168.30 ± 77.00)	>	bag 2.5 x 9 in. (163.16 ± 84.64)	>	REX tray (120.84 ± 4.37)

Table 21. ANOVA of final basal diameter of *Artocarpus lakoocha* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.
** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	1.288	6	.215	14.763	.000	
Block	.839	2	.420	28.852	.000	**
Container	.444	2	.222	15.275	.000	**
Fertilizer	.003	1	.003	.207	.650	ns
Root pruning	.006	1	.006	.405	.525	ns
Explained	1.288	6	.215	14.763	.000	
Residual	4.761	323	.015			
Total	6.049	329	.018			

LSD Test

Block:	open (0.50 ± 0.13)	=	medium shade (0.48 ± 0.14)	>	under shade (0.38 ± 0.10)
Container:	bag 3 x 7 in. (0.50 ± 0.17)	>	REX tray (0.42 ± 0.09)	=	bag 2.5x 9 in. (0.44 ± 0.13)

Table 22. ANOVA of final height of *Artocarpus lakoocha* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	22547.637	6	3757.939	38.569	.000	
Block	20671.666	2	10335.830	106.079	.000	**
Container	910.822	2	455.411	4.674	.053	ns
Fertilizer	663.237	1	663.237	6.807	.010	**
Root Pruning	221.218	1	221.218	2.270	.133	ns
Explained	22547.637	6	3757.939	38.569	.000	
Residual	36169.394	323	111.98			
Total	58717.031	329	178.471			

LSD Test

Block:	medium shade	=	open	>	under shade
	(34.46 ± 12.46)		(34.03 ± 12.11)		(17.20 ± 5.51)
Fertilizer:	osmocote	>	soluble		
	(30.59 ± 15.20)		(27.24 ± 11.13)		

Table 23. ANOVA of shoot per root ratio of *Artocarpus lakoocha* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	54.840	6	9.140	16.472	.000	
Block	38.016	2	19.008	34.256	.000	**
Container	13.638	2	6.819	12.289	.000	**
Fertilizer	1.218	1	1.218	2.194	.139	ns
Root Pruning	1.969	1	1.969	3.549	.060	*
Explained	54.840	6	9.140	16.472	.000	
Residual	195.871	323	0.555			
Total	250.711	329	0.698			

LSD Test

Block:	under shade (1.92 ± 0.89)	>	medium shade (1.48 ± 0.81)	>	open (1.12 ± 0.59)
Container:	bag 2.5x9 in (1.69 ± 0.89)	=	bag 3x7 in (1.60 ± 0.90)	>	REX trays (1.24 ± 0.63)
Root pruning:	air (1.58 ± 0.89)	>	hand (1.43 ± 0.77)		

Table 24. ANOVA of relative growth rate (RGR) of basal diameter of *Balakata baccata* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.
** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	88900.611	6	14816.768	6.226	.000	
Block	58653.220	2	29326.610	12.324	.000	**
Container	35246.246	2	17623.123	7.406	.001	**
Fertilizer	.598	1	.598	.000	.987	ns
Root pruning	13869.193	1	13869.193	5.828	.017	**
Explained	88900.611	6	14816.768	6.226	.000	
Residual	565896.609	230	2460.420			
Total	654797.220	236	2774.564			

LSD Test

Block:	medium shade	=	open	>	under shade
	(198.75± 52.69)		(187.57 ± 53.59)		(164.12 ±44.69)
Container:	bag 3 x 7 in.	>	bag 2.5x 9 in.	>	REX tray
	(193.27 ± 65.91)		(188.13 ± 48.08)		(171.98 ± 38.78)
Root pruning:	hand	>	air		
	(190.91 ± 58.55)		(179.62 ± 43.49)		

Table 25. ANOVA of relative growth rate (RGR) of height of *Balakata baccata* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	513009.844	6	85501.641	9.489	.000	
Block	205774.634	2	102887.317	11.419	.000	**
Container	314807.484	2	157403.742	17.470	.000	**
Fertilizer	50540.095	1	50540.095	5.609	.019	*
Root pruning	122.269	1	122.269	.014	.907	ns
Explained	513009.844	6	85501.641	9.489	.000	
Residual	2342402.147	230	10184.357			
Total	2855411.992	236	12099.203			

LSD Test

Block:	medium shade (301.27±105.12)	>	open (265.85 ±101.73)	=	under shade (240.75±17.76)
Container:	bag 3 x 7 in. (309.99±116.77)	>	bag 2.5 x 9 in. (274.24±107.31)	>	REX tray (226.52±85.37)
Fertilizer:	osmocote (287.37±106.75)	>	soluble (258.96±112.05)		

Table 26. ANOVA of final basal diameter of *Balakata baccata* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	1.194	6	.199	13.822	.000	
Block	.726	2	.363	25.232	.000	**
Container	.399	2	.199	13.849	.000	**
Fertilizer	.194	1	.194	13.447	.000	**
Root pruning	.038	1	.038	2.641	.106	ns
Explained	1.194	6	.199	13.822	.000	
Residual	3.934	230	.017			
Total	5.128	236	.022			

LSD Test

Block:	open (0.60 ± 0.15)	=	medium shade (0.59 ± 0.15)	>	under shade (0.48 ± 0.11)
Container:	bag 2.5x 9 in. (0.61 ± 0.14)	>	REX tray (0.53 ± 0.11)	=	bag 3 x 7 in. (0.54 ± 0.18)
Fertilizer:	soluble (0.90 ± 0.16)	>	osmocote (0.53 ± 0.14)		

Table 27. ANOVA of final height of *Balakata baccata* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	16474.385	6	2745.731	11.602	.000	
Block	10032.822	2	5016.411	21.197	.000	**
Container	7562.146	2	3781.073	15.977	.000	**
Fertilizer	42.128	1	42.128	.178	.674	ns
Root pruning	2566.114	1	2566.114	10.843	.001	**
Explained	16474.385	6	2745.731	11.602	.000	
Residual	60526.577	230	236.159			
Total	77000.962	236	326.275			

LSD Test

Block:	medium shade (57.78 ± 19.20)	>	open (49.73 ± 14.08)	>	under shade (43.83 ± 17.30)
Container:	bag 2.5x 9 in. (56.56 ± 18.08)	>	bag 3 x 7 in. (52.42 ± 17.52)	>	REX tray (46.82 ± 15.15)
Root pruning:	hand (53.54 ± 18.46)	>	air (48.87 ± 17.28)		

Table 28. ANOVA of shoot per root ratio of *Balakata baccata* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	437.396	6	72.899	10.291	.000	
Block	297.034	2	148.517	20.966	.000	**
Container	70.047	2	35.024	4.944	.008	**
Fertilizer	35.675	1	35.675	5.036	.026	*
Root pruning	0.186	1	0.186	0.026	.872	ns
Explained	437.396	6	72.899	10.291	.000	
Residual	1551.354	219	7.084			
Total	1988.750	225	8.839			

LSD Test

Block:	under shade (6.82 ± 4.08)	>	open (4.16 ± 2.02)	>	medium shade (4.12 ± 1.90)
Container:	bag 3 x 7 in. (5.43 ± 2.08)	>	bag 2.5 x 9 in. (5.23 ± 3.87)	>	REX tray (3.84 ± 2.20)
Fertilizer:	osmocote (5.29 ± 2.41)	>	soluble (4.51 ± 3.42)		

Table 29. ANOVA of relative growth rate (RGR) of basal diameter *Horsfieldia thorelii* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	34704.151	6	5784.025	7.108	.000	
Block	15885.612	2	7942.806	9.760	.000	**
Container	4161.537	2	2080.768	2.557	.079	ns
Fertilize	308.697	1	308.697	.379	.538	ns
Root pruning	13998.770	1	13998.770	17.202	.000	**
Explained	34704.151	6	5784.025	7.108	.000	
Residual	293760.601	323	909.476			
Total	328464.752	329	998.373			

LSD Test

Block:	medium shade	=	open	>	under shade
	(65.40 ± 29.59)		(64.37 ± 34.95)		(49.36 ± 37.47)
Root pruning:	air	>	hand		
	(66.59± 33.02)		(53.48 ± 28.67)		

Table 30. ANOVA of relative growth rate (RGR) of height of *Horsfieldia thorelii* percent per year. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.
** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	164639.450	6	27439.908	18.412	.000	
Block	112452.999	2	56226.499	37.727	.000	**
Container	46074.984	2	23037.492	15.458	.000	**
Fertilize	6126.914	1	6126.914	4.111	.053	ns
Root pruning	264.039	1	264.039	.177	.674	ns
Explained	164639.450	6	27439.908	18.412	.000	
Residual	519113.663	323	1607.136			
Total	683753.113	329	2078.277			

LSD Test

Block:	medium shade (126.03 ± 39.78)	=	open (115.96 ± 46.96)	>	under shade (82.77 ± 38.69)
Container:	bag 3 x 7 in. (124.27 ± 45.22)	>	bag 2.5 x 9 in. (104.50 ± 43.87)	=	REX tray (96.30 ± 43.77)

Table 31. ANOVA of final basal diameter of *Horsfieldia thorelii* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	1.052	6	.175	20.266	.000	
Block	.588	2	.294	33.992	.000	**
Container	.213	2	.107	12.328	.000	**
Fertilize	.002	1	.002	.226	.635	ns
Root pruning	.239	1	.239	27.607	.000	**
Explained	1.052	6	.175	20.266	.000	
Residual	3.180	323	0.010			
Total	4.232	329	0.013			

LSD Test

Block:	medium shade (0.67 ± 0.10)	=	open (0.65 ± 0.12)	>	under shade (0.57 ± 0.09)
Container:	bag 3 x 7 in. (0.66 ± 0.13)	>	REX tray (0.62 ± 0.09)	=	bag 2.5x 9 in (0.60 ± 0.11)
Root pruning:	air (0.66 ± 0.12)	>	hand (0.60 ± 0.10)		

Table 32. ANOVA of final height of *Horsfieldia thorelii* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD result.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	8705.878	6	1450.980	30.510	.000	
Block	6875.068	2	3437.534	72.283	.000	**
Container	1506.248	2	753.124	15.836	.000	**
Fertilize	339.524	1	339.524	7.139	.008	**
Root pruning	30.369	1	30.369	.639	.425	ns
Explained	8705.878	6	1450.980	30.510	.000	
Residual	16989.822	323	52.600			
Total	25695.700	329	78.102			

LSD Test

Block:	medium shade (35.98 ± 8.70)	>	open (31.00 ± 8.50)	>	under shade (24.85 ± 5.62)
Container:	bag 3 x 7 in. (33.51 ± 9.95)	>	bag 2.5x 9 in. (30.00 ± 8.1894)	>	REX tray (28.45 ± 7.86)
Fertilizer:	osmocote (31.78 ± 9.23)	>	soluble (29.73 ± 8.64)		

Table 33. ANOVA of shoot per root ratio of *Horsfieldia thorelii* under different treatments over ten months. Significant differences were further analyzed using the LSD Test. Mean final height is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	16.925	6	2.821	8.562	.000	
Block	8.306	2	4.153	12.606	.000	**
Container	1.729	2	0.865	2.625	.074	ns
Fertilize	4.476	1	4.476	13.587	.000	**
Root pruning	2.414	1	2.414	7.326	.007	**
Explained	16.925	6	2.821	8.562	.000	
Residual	116.297	353	0.329			
Total	133.222	359	0.371			

LSD Test

Block:	under shade (1.89 ± 0.76)	=	medium shade (1.80 ± 0.57)	>	open (1.53 ± 0.39)
Fertilizer:	osmocote (1.85 ± 0.73)	>	soluble (1.62 ± 0.44)		
Root pruning:	air (1.82 ± 0.65)	>	hand (1.65 ± 0.56)		

Table 34. ANOVA of final height of the three native tree species. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	118640.179	8	14830.022	104.716	.000	
Block	31770.582	2	15885.291	112.167	.000	**
Container	3205.651	2	1602.825	11.318	.000	**
Fertilizer	804.663	1	804.663	5.682	.017	*
Root pruning	996.560	1	996.560	7.037	.008	**
Species	73108.181	2	36554.091	258.111	.000	**
Explained	118640.179	8	14830.022	104.716	.000	
Residual	125759.837	888	141.621			
Total	244400.016	896	272.768			

LSD Test

Block:	medium shade	>	open	>	under shade
	(41.94 ± 17.43)		(36.93 ± 13.81)		(26.36 ± 13.98)
Container:	bag 2.5 x 9 in.	=	bag 3 x 7 in.	>	REX tray
	(37.02 ± 18.76)		(36.84 ± 16.81)		(32.35 ± 12.85)
Fertilizer:	osmocote	>	soluble		
	(36.73 ± 17.16)		(34.24 ± 15.76)		
Root pruning:	hand	>	air		
	(36.86 ± 17.63)		(34.02 ± 15.12)		
Species:	*B. baccata*	>	*H. thorelii*	=	*A. lakoocha*
	(51.49 ± 18.06)		(30.60 ± 8.84)		(28.87 ± 13.36)

Table 35. ANOVA of relative growth rate (RGR) of basal diameter of the three native tree species. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	2360211.999	8	295026.500	175.283	.000	
Block	132329.122	2	66164.561	39.310	.000	**
Container	46116.171	2	23058.085	13.699	.000	**
Fertilizer	476.003	1	476.003	.283	.595	ns
Root pruning	2.206	1	2.206	.001	.971	ns
Species	093190.302	2	1046595.151	621.810	.000	**
Explained	2360211.999	8	295026.500	175.283	.000	
Residual	1494630.024	888	1683.142			
Total	3854842.024	896	4302.279			

LSD Test

Block:	medium shade (124.68 ± 69.24)	=	open (118.02 ± 64.46)	>	under shade (90.92 ± 57.02)
Container:	bag 3 x 7 in. (120.45 ± 70.99)	=	bag 2.5 x 9 in. (114.81 ± 68.19)	>	REX tray (100.03±53.99)
Species:	*B. baccata* (185.96 ± 52.67)	>	*A. lakoocha* (111.10 ± 45.66)	>	*H. thorelii* (60.09 ± 31.6)

Table 36. ANOVA of relative growth rate (RGR) of height of the three native tree species. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = p < 0.01, * = p < 0.05, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	5182172.014	8	647771.502	138.019	.000	
Block	840933.464	2	420466.732	89.588	.000	**
Container	399680.762	2	199840.381	42.579	.000	**
Fertilizer	53911.306	1	53911.306	11.487	.001	**
Root pruning	990.415	1	990.415	.211	.646	ns
Species	3561396.902	2	1780698.451	379.409	.000	**
Explained	5182172.014	8	647771.502	138.019	.000	
Residual	4167693.720	888	4693.349			
Total	9349865.735	896	10435.118			

LSD Test

Block:	medium shade (200.02 ± 102.09)	>	sun (177.16 ± 91.44)	>	under shade (119.22± 95.65)
Container:	bag 3 x 7 in. (189.97 ± 110.46)	=	bag 2.5 x 9 in. (174.48 ± 105.96)	>	REX tray (135.48± 77.91)
Fertilizer:	osmocote (177.20 ± 106.65)	>	Soluble (157.98 ± 96.62)		
Species:	*B. baccata* (273.822 ± 110.00)	>	*A. lakoocha* (150.46 ± 75.65)	>	*H. thorelii* (108.39± 45.59)

Table 37. ANOVA of basal diameter of the three native tree species. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD results.

** = $p < 0.01$, * = $p < 0.05$, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	13.003	8	1.625	51.827	.000	
Block	5.897	2	2.948	94.015	.000	**
Container	.394	2	.197	6.274	.002	**
Fertilizer	.035	1	.035	1.116	.291	ns
Root pruning	.026	1	.026	.815	.367	ns
Species	6.434	2	3.217	102.583	.000	**
Explained	20.918	71	.295	9.394	.000	
Residual	27.379	873	.031			
Total	48.297	944	.051			

LSD Test

Block:	open (0.62 ± 0.24)	=	medium shade (0.59 ± 0.22)	>	under shade (0.42 ± 0.15)
Container:	Bag 3 x 7 in. (0.57 ± 0.27)	=	bag 2.5 x 9 in (0.55 ± 0.23)	=	REX tray (0.52 ± 0.16)
Species:	*H. thorelii* (0.64 ± 0.17)	>	*B. Baccata* (0.56 ± 0.24)	>	*A. .lakoocha* (0.45 ± 0.23)

Table 38. ANOVA of shoot per root ratio of the three native tree species. Significant differences were further analyzed using the LSD Test. Mean RGR is included in the LSD result.

** = $p < 0.01$, * = $p < 0.05$, ns = not significant.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig of F	Significant
Main Effects	1629.500	8	203.688	158.578	.000	
Block	103.993	2	51.996	40.481	.000	**
Container	28.523	2	14.261	11.103	.000	**
Fertilizer	30.558	1	30.558	23.790	.000	**
Root pruning	0.035	1	0.035	0.027	.870	ns
Species	1472.125	2	736.063	573.051	.000	**
Explained	1629.500	8	203.688	158.578	.000	
Residual	1202.257	936	1.284			
Total	2831.758	944	3.000			

LSD Test

Block:	under shade	>	medium shade	=	open
	(2.70 ± 2.03)		(2.26 ± 1.53)		(2.00 ± 1.56)
container:	bag 2.5 x 9 in.	=	bag 3 x 7 in	>	REX tray
	(2.48 ± 1.88)		(2.47± 1.86)		(1.98 ± 1.36)
Fertilizer:	osmocote	>	Soluble		
	(2.50 ± 1.89)		(2.13 ± 1.54)		
Species:	*B. baccata*	>	*H. thorelii*	>	*A. lakoocha*
	(4.53 ± 2.10)		(1.74 ± 0.61)		(1.50± 0.83)

APPENDIX II: Number and percent of root score

Table 39. Number and percent of root score in different root pruning method and was analized by Chi-squre test

Root pruning	root score 1		root score 2		root score 3		root score 4		root score 5		root score 6		Total
	number	percent	number	percent	number	percent	number	percent	number	percent	number	percent	number
by air	115	55.02	140	51.47	127	51.84	75	40.11	4	33.33	5	25	466
by hand	94	44.98	132	48.53	118	48.16	112	59.89	8	66.67	16	75	480
Total	209	100	272	100	245	100	187	100	12	100	21	100	946

Table 40. Number and percent of root score in differect container type and was analized by Chi-squre test

Container	root score 1		root score 2		root score 3		root score 4		root score 5		root score 6		Total
	number	percent	number	percent	number	percent	number	percent	number	percent	number	percent	number
REX tray	126	60.29	71	26.1	22	8.98	86	46	0	0	0	0	305
2.5 x 9 in	52	24.88	98	36.03	142	57.96	24	12.83	5	41.67	3	14.29	324
3 x 7 in.	31	14.83	103	37.87	81	33.06	77	41.18	7	58.33	18	85.71	317
Total	209	100	272	100	245	100	187	100	12	100	21	100	946

Chi-squre test

root score	number	DF	root pruning Chi-squre	root pruning Significance	container Chi-squre	container Significance
1	209	1	2.11	0.1463	71.4928	0
2	272	1	0.2353	0.6276	6.5368	0.0381
3	245	1	0.3306	0.5653	88.1714	0
4	187	1	7.3209	0.0068	36.0107	0
5	12	1	1.3333	0.2482	0.3333	0.5637
6	21	1	5.7619	0.0164	10.7143	0.0011

APPENDIX III: Production cost analysis per seedling per season.

CONTAINER

REX Tray

Cost		50	baht /tray	
Transplantation		20	baht/tray	
24 cells : 1 tray				
1 cell	70/24	=	2.92	baht/seedling/ 12season
1 cell	2.92/12	=	0.243	baht/ seedling/season

Plastic bag 2.5" x 9"

Cost	30	baht/kilogram		
One kilogram has	236	bags		
Cost of 1 bag	30/236	=	0.127	baht/seedling/season

Plastic bag 3" x 7"

Cost	30	baht/kilogram		
One kilogram has	208	bags		
Cost of 1 bag	30/208	=	0.144	baht/seedling/season

MEDIA

Forest Soil	1,685,500	cm^3	=	1,000	baht
	1	cm^3	=	0.00059	baht/ cm^3
Coconut husk	98,400	cm^3	=	50	baht
	1	cm^3	=	0.000508	baht/ cm^3

Peanut husk	46,300	cm^3	=	25	baht
	1	cm^3	=	0.00054	baht/cm^3

Volume used

REX Tray	300	cm^3
Plastic bag 2.5" x 9"	800	cm^3
Plastic bag 3" x 7"	850	cm^3

Potting media cost / seedling / season

REX Tray

Use forest soil	150 cm^3 x 0.00059	=	0.0885	baht
Use coconut husk	75 cm^3 x 0.000508	=	0.0381	baht
Use peanut husk	75 cm^3 x 0.00054	=	0.0405	baht
		=	0.1671	baht/seedling/season

Plastic bag 2.5" x 9"

Use forest soil	400 cm^3 x 0.00059	=	0.236	baht
Use coconut husk	200 cm^3 x 0.000508	=	0.1016	baht
Use peanut husk	200 cm^3 x 0.00054	=	0.103	baht
		=	0.4456	baht/seedling/season

Plastic bag 3" x 7"

Use forest soil	425 cm^3 x 0.00059	=	0.2508	baht
Use coconut husk	212.5 cm^3 x 0.000508	=	0.1080	baht
Use peanut husk	212.5 cm^3 x 0.00054	=	0.1148	baht
		=	0.4736	baht/seedling/season

FERTILIZER

"Osmocote"	1,000 g	=	150	baht
	0.3 g	=	0.045	baht / seedling
use 4 time for season 0.045 x 4		=	0.18	baht / seedling / season
Soluble fertilizer	1,000 g	=	15	baht
	1.5 tablespoon (22.5 g)	=	0.3375	baht / 180 seedlings
use 20 time for season0.3375 x 20		=	0.0375	baht / seedling / season

ROOT PRUNING

by air pruning

Table size 90 x 180 cm (16,200 cm^2) = 1,000 baht

REX Tray	size 30 x 45 cm	=	1,350	cm^2
	12 trays	=	288	seedlings / table
	1 seedling	=	3.47	baht / seedling
	10 season / table	=	0.347	baht / seedling / season

plastic bag 2.5" x 9"

bottom size	=	39.06	cm^2
	=	414	seedlings/ table
1 seedling	=	2.42	baht / seedling
10 season / table	=	0.242	baht / seedling / season

plastic bag 3" x 7"

bottom size	=	56.25	cm^2
	=	288	seedlings / table
1 seedling	=	3.47	baht / seedling
10 season / table	=	0.347	baht / seedling / season

by hand

Labor wages	1 day (8 hrs.)	=	28,800	seconds
	1 day	=	150	baht
	1 second	=	0.0052	baht / second

REX Tray

24 seedlings	time consuming for cut root	25	seconds
1 seedling	time consuming for cut root	1.042	seconds

1.042 x 0.0052 = 0.0054 baht / seedling / time

root pruning 4 times per season 0.0054 x 4 = 0.022 baht / seedling / season

Plastic bag 2.5" x 9"

1 seedling time consuming for cut root 5 seconds

5 x 0.0052 = 0.026 baht / seedling / time

root cutting 4 time per season 0.026 x 4 = 0.104 baht / seedling / season

Plastic bag 3" x 7"

1 seedling time consuming for cut root 5 seconds

5 x 0.0052 = 0.026 baht / seedling / time

root cutting 4 time per season 0.026 x 4 = 0.104 baht / seedling / season

LABOR COST

for seed collection

1,000	seeds	=	100	baht
1	seed	=	0.1	baht/seed

Labor wages	1 day (8 hrs.)	=	150	baht
	8 hrs.	=	28,800	second
	1 second	=	0.0052	baht/second

for filling containers

REX Tray 1.25 second / seedling x 0.0052 baht/second

= 0.0065 baht / seedling

Plastic bag 2.5" x 9" 15 second / seedling x 0.0052 baht/second

= 0.078 baht / seedling

Plastic bag 3" x 7" 15 second / seedling x 0.0052 baht/second

= 0.078 baht / seedling

for fertilization

"Osmocote"	20	seedlings	consuming time		60	second
	1	seedling	consuming time	=	3	second

3 x 0.0052 = 0.0156 baht / seedling / time

use 4 time for season 0.0156 x 4 = 0.0624 baht / seedling / season

Soluble fertilizer	360	seedlings	consuming time	300 second
	1	seedling	consuming time	= 0.83 second

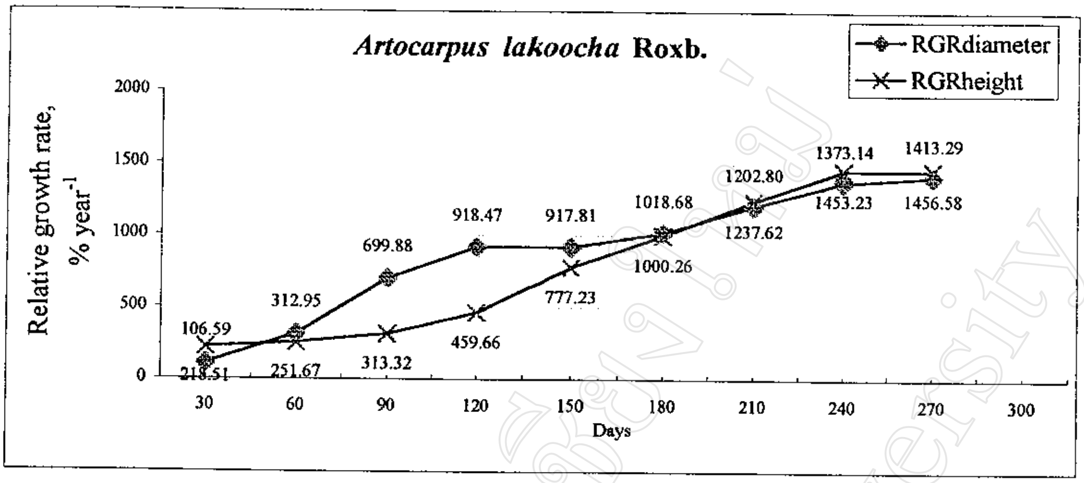
0.83 x 0.0052 = 0.0043 baht / seedling / time

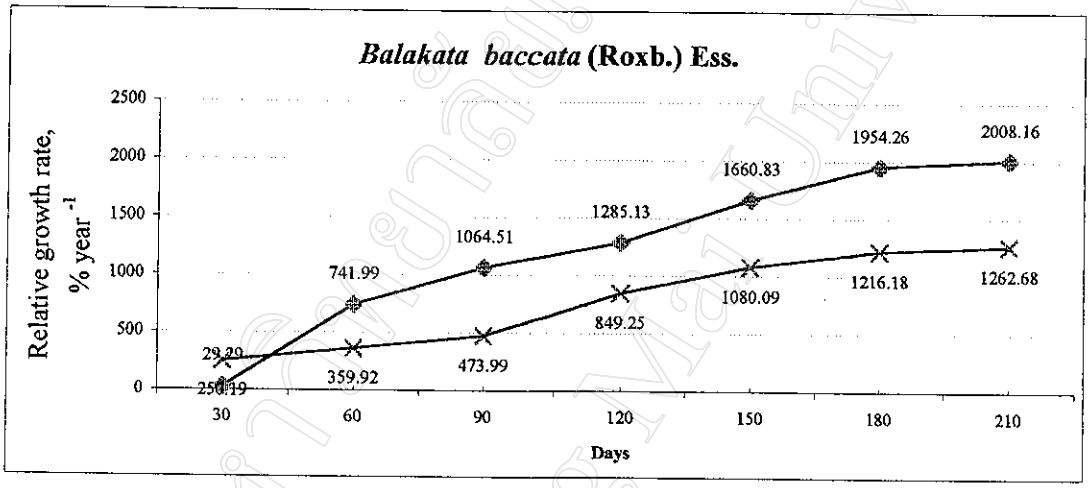
use 20 time for season0.0043 x 20 = 0.0863 baht / seedling / season

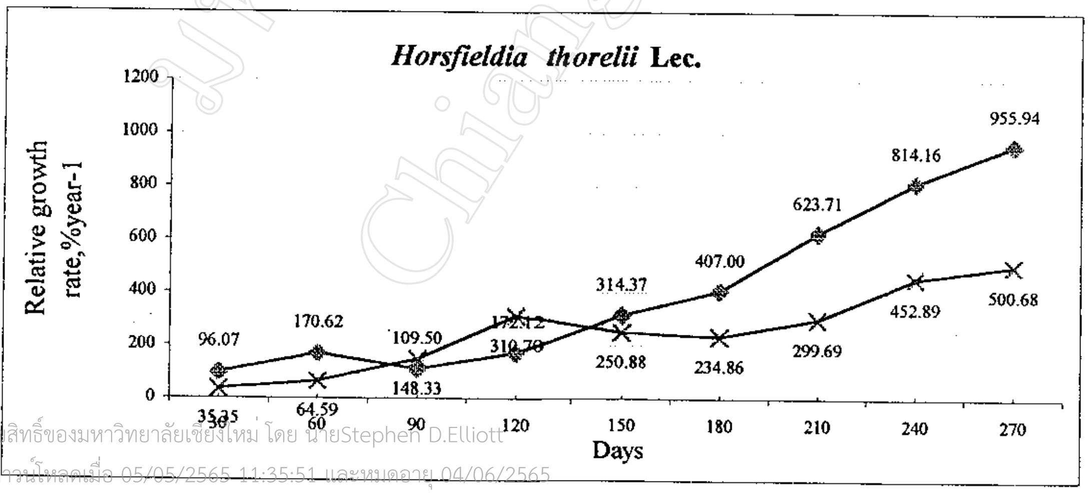
Total of labor cost = seed collection+ filling containers + fertilization

1. raised+REX tray+"Osmocote"	=0.1+0.0065+0.0624	=	0.1689
2. raised+REX tray+normal fertilizer	=0.1+0.0065+0.0863	=	0.1928
3. raised+plastic bag (2.5" x 9")+"Osmocote"	=0.1+0.078+0.0624	=	0.2404
4. raised+plastic bag (2.5" x 9")+soluble	=0.1+0.078+0.0863	=	0.2643
5. raised+plastic bag (3" x 7")+"Osmocote"	=0.1+0.078+0.0624	=	0.2404
6. raised+plastic bag (3" x 7")+soluble	=0.1+0.078+0.0863	=	0.2643
7. ground+REX tray+"Osmocote"	=0.1+0.0065+0.0624	=	0.1689
8. ground+REX tray+normal fertilizer	=0.1+0.0065+0.0863	=	0.1928
9. ground+plastic bag (2.5" x 9")+"Osmocote"	=0.1+0.078+0.0624	=	0.2404
10. ground+plastic bag (2.5" x 9")+soluble	=0.1+0.078+0.0863	=	0.2643
11. ground+plastic bag (3" x 7")+"Osmocote"	=0.1+0.078+0.0624	=	0.2404
12. ground+plastic bag (3" x 7")+soluble	=0.1+0.078+0.0863	=	0.2643

APPENDIX IV: RGR curve in which the percentage growth per year is graphed against age days.







CURRICULUM VITAE

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Work Experience

1998-1999	Old Chiang Mai Culture Center
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