THE EFFECTS OF CONTAINER TYPE AND MEDIA ON GROWTH AND MORPHOLOGY OF TREE SEEDLINGS TO RESTORE FORESTS

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN
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IN ENVIRONMENTAL SCIENCE

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EXAMINING COMMITTEE

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1 April 1998

Acknowledgements

I think I have to say that, before I start to thank anybody concerning my research studies, this is the first time that I have reached into the plant world. My background is zoology and I was never interested in plants before. It is said that the first time is the best time and I agree with this. I don't know much about the names of trees, their lives and their roles in forest ecosystem. I thought that all trees are simply trees and I suspected why somebody would devote himself to study about this. I care for all nature, both animals and the environment more than going deep into one part of these. However when I was looking for what I should do for my research studies, I started to become interested in forest restoration. I wanted to help to save my environment, since I live in Chiang Mai and I have seen Doi Suthep since I was very young. That is part of my life.

I am very grateful to Dr. Stephen Elliott (Acharn Steve), my main supervisor. He was the one who encouraged me to go into the forest, let me try to learn something new, lead me to discover other experiences that I would regret if I lost that chance. Moreover he always gave me the guidance on how to work and how to solve the problems that occur. Due to my ignorance about plants and forest ecosystems, he sacrified a lot for my work and preparation of my thesis. I think I couldn't complete my thesis without this support.

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ABSTRACT

Forest biodiversity in Thailand is fast disappearing because of deforestation. Restoring forests by planting native tree species can help promote biodiversity. The current nursery practices using plastic bags and forest soil, often result in poorly developed root systems. Producing high-quality planting stock can be achieved by using root-trainers. This research was conducted at the Forest Restoration Research Unit Nursery (FORRU), Doi Suthep-Pui National Park, Chiang Mai. Seeds of 4 species ; i) ***Spondias axillaris***, ii) ***Micromelum hirsutum*** , iii) ***Archidendron clypearia*** spp. ***clypearia*** var. ***clypearia*** and iv) ***Eugenia fruticosa*** (DC.) Roxb. were collected from Doi Suthep-Pui National Park and sown with 6 treatments (3 container types with 2 kinds of media). Containers included traditional plastic bags (with seeds germinated first in square cells and then transplanted into the bags) and 2 kinds of root-trainers: REX trays and tube cells. Media treatments were forest soil and mixed media (soil plus additional organic matter). The treatments were replicated in 3 randomized complete blocks. Physical and morphological characteristics; height and root collar diameter, root morphology; dry root weight, root-shoot ratio in

weight and degree of root spiraling were recorded over 6 months from June to December 1997. Seedlings, grown in REX trays were of significantly higher quality than those grown in the other containers. In addition, mixed media promoted better shoot growth and morphology than forest soil, but forest soil promoted better root morphology than mixed media. Furthermore the cost-benefit analysis showed that REX trays are the most beneficial for use on a wide scale for forest restoration in Thailand.

ชื่อเรื่องวิทยานิพนธ์ ผลของภาชนะบรรจุและดินปลูกที่มีต่อการเจริญเติบโตและสัณฐานของต้นกล้าเพื่อการฟื้นฟูป่า

ชื่อผู้เขียน นางสาว สุดารัตน์ ซางคำ

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บทคัดย่อ

ความหลากหลายทางชีวภาพของป่าในประเทศไทยกำลังลดลงอย่างรวดเร็วเนื่องมาจากการตัดไม้ทำลายป่า การฟื้นฟูป่าโดยการปลูกพันธุ์ไม้ชนิดที่พบในป่าสามารถช่วยส่งเสริมความหลากหลายทางชีวภาพได้ ในปัจจุบันเรือนเพาะชำทั่วไปนิยมใช้ถุงพลาสติกและดินจากป่าในการปลูกต้นกล้า ซึ่งมีผลทำให้ต้นกล้ามีระบบรากที่ไม่ดี การผลิตต้นกล้าที่มีคุณภาพจะประสบผลสำเร็จได้ด้วยการใช้ภาชนะคัดราก งานวิจัยนี้ได้ทำการศึกษาที่หน่วยวิจัยฟื้นฟูป่า (FORRU) อุทยานแห่งชาติ ดอยสุเทพ-ปุย จังหวัด เชียงใหม่ โดยทำการเก็บเมล็ดจากพันธุ์ไม้บนดอยสุเทพ 4 ชนิด คือ 1) **มะกอกห้ารู** (*Spondias axillaris*) 2) **หัสคุณ** (*Micromelum hirsutum*) 3) **ไครย้อย** (*Archidendron clypearia* spp. *clypearia* var. clypearia) และ 4) **หว้าขี้กวาง** (*Eugenia fruticosa* (DC.) Roxb.) ทำการทดลองด้วยวิธีทดสอบ 6 วิธี

คือ การเพาะต้นกล้าในภาชนะ3 ชนิดโดยใช้ดินปลูก 2 ชนิด วิธีการคือเพาะต้นกล้าแบบเก่าโดยเพาะในถาดเพาะสี่เหลี่ยมแล้วจึงย้ายต้นกล้าที่งอกไปปลูกในถุงพลาสติกสีดำ และการเพาะต้นกล้าในภาชนะคัดราก 2 ชนิด; ชนิดแรกเรียกว่า กระบะเรกซ์ (REX tray) และ หลอดคัดราก (tube cell) และการเพาะต้นกล้าด้วยดินปลูก 2 ชนิด คือ ดินจากป่า และดินปลูกที่ผสมสารอินทรีย์ ทำการทดลอง 3 ซ้ำโดยการสุ่มในบล็อก บันทึกลักษณะทางกายภาพและสัณฐาน ได้แก่ ความสูง เส้นผ่าศูนย์กลางโคนราก การบันทึกลักษณะทางสัณฐานวิทยาของราก ได้แก่ น้ำหนักแห้ง อัตราน้ำหนักของรากต่อลำต้น และการบิดงอและขดพับของราก เป็นเวลา 6 เดือน ตั้งแต่ เดือน มิถุนายน ถึงเดือน ธันวาคม 2540 ผลการศึกษาพบว่า ต้นกล้าที่ปลูกในภาชนะคัดรากชนิดกระบะเรกซ์ มีคุณภาพดีกว่าต้นกล้าที่ปลูกโดยภาชนะอื่นๆ นอกจากนั้น ดินปลูกผสม จะให้ต้นกล้าที่มีลักษณะสัณฐานของลำต้นและการเจริญเติบโตที่ดีกว่าดินจากป่า อย่างไรก็ตาม ดินจากป่า จะให้ต้นกล้าที่มีลักษณะสัณฐานของรากที่ดีกว่าดินปลูกผสม ยิ่งไปกว่านั้น การวิเคราะห์ต้นทุน-กำไร แสดงให้เห็นว่า การปลูกโดยใช้ภาชนะคัดรากชนิดกระบะเรกซ์ เป็นวิธีที่ให้ประโยชน์สูงสุดเพื่อการใช้อย่างกว้างขวางในการฟื้นฟูป่าในประเทศไทยต่อไป

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Abbreviation and Synonyms

A.. clypearia	:	*Archidendron clypearia*
Ca	:	Calcium
cm	:	centimetre
E. fruticosa	:	*Eugenia fruticosa*
g	:	gram
K	:	Potassium
km2	:	square kilometre
Mg	:	Magnesium
M. hirsutum	:	*Micromelum hirsutum*
ml	:	millilitre
mm	:	millimetre
N	:	Nitrogen
NGO	:	Non Government Organization
No.	:	number
OM	:	organic matter
P	:	Phosphorus
Rf	:	REX tray (root-trainer) with forest soil
Rm	:	REX tray (root-trainer) with mixed media
Tf	:	Tubecell (root-trainer) with forest soil
Tm	:	Tubecell (root-trainer) with mixed media
S. axillaris	:	*Spondias axillaris*
Sf	:	Squarecell/plastic bag with forest soil
Sm	:	Squarecell/plastic bag with mixed media

INTRODUCTION

Forest biodiversity in Thailand is fast disappearing mostly due to deforestation. Estimated forest cover, both plantation and natural, is 111,010 km^2 or 22.8 % of the country (FAO, 1997), down from 60 % in 1953 (Poffenberger and McGean, 1993). Unofficial estimates put Thailand's natural forest cover at less than 20 % (Leungaramsri & Rajesh, 1992). The rapid deforestation of mountainous areas in northern Thailand has caused rapid loss of biodiversity and degradation of water catchments. Satellite images revealed that the deforested area in the northern province of Chiang Mai more than doubled in a decade from 3,235 km^2 in 1975 to 6,513 km^2 in 1985 (GRID, 1988). The national forest policy is that 40 % of the country should be forested. Until recently most reforestation projects in Thailand involved planting fast growing monoculture plantations, such as pines and eucalyptus, since this was the quickest method of re-establishing tree cover. However, 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. In 1993, to celebrate His Majesty King Bhumibol Adulyadej's Golden Jubilee, the government, NGO's, and private sectors, became involved in reforestation projects to plant 50 millions trees on 8,273 km^2 of deforested land. The project specified use of a wide variety of native forest tree species. However, the policy could not be implemented effectively since there was lack of knowledge about how to grow and plant seedlings of native tree species (Elliott *et al.*,1996).

The Forest Restoration Research Unit (FORRU), a co-operative project between Chiang Mai University and Doi Suthep-Pui National Park, was established in November 1994 to investigate such techniques. It is situated at the headquarters of Doi Suthep-Pui National Park, Chiang Mai Province, northern Thailand (18° 50′ N, 98° 50 ′E) at about 1,000 m elevation. There are two kinds of forest there,viz. deciduous and evergreen, in a monsoon climate (Maxwell, 1988). The work of the first 3-years phase of the FORRU project (1994-97) was cataloging and describing the fruits, seeds, and seedlings of tree species found in the park. Seed germination trials and preliminary seedling planting trials in deforested areas have also been carried out. The second phase of the project is concentrating on 20-30 so called "framework species" to complement natural regeneration in deforested areas. The aim will be to develop efficient propagation systems, planting methods, and post-planting management systems to enable use of native tree species for reforestation of national parks (Elliott, 1997).

Rationale

Restoring forests by planting native tree species can help promote biodiversity (Wightman,1997). FORRU uses only native tree species for reforestation in the national park. Given that successful reforestation depends on the use of vigorous seedlings, attention must be paid to the quality of seedlings, seed sources, and nursery production techniques that affect seedling growth and morphology. Current nursery practices using plastic bags and forest soil with little organic matter often results in poorly developed root systems (Josiah *et al*, 1992). Producing high-quality planting stock can be achieved by using root-trainers, containers with vertical grooves to direct root growth vertically downwards and large holes in the bottom to allow air pruning. Seedlings that are grown in root-trainers have stronger and healthier root systems than those grown in plastic bags. Seedlings with strong root systems survive better after outplanting (Wightman 1998). In addition, tree seedlings need good soil especially a potting medium which is composed of a high percentage of organic matter, light in weight, very well drained and aerated, so that roots can grow well (Josiah, 1992).

Hypotheses

This research tested the effects of container types and potting media on growth of seedlings of native tree species in a nursery. It tested the hypotheses that seedlings grown in root-trainers will be of higher quality than those grown in the traditional way in black plastic bags and that seedlings grown in a mixed medium rich in organic matter will be of higher quality than those grown in forest soil. Seedling quality is determined by growth rate and seedling form, especially root mass and morphology.

Wightman (1997) has shown that the use of root-trainers is very effective for tree species in Costa Rica. However, different tree species are likely to respond in various ways. Because root-trainers are more expensive than plastic bags, it is necessary to test their effectiveness in Thailand with native tree species before deciding on whether or not to recommend their use on a wider scale.

Objectives

The objectives of this study were to investigate the influence of container type and growing medium on the survival, growth rate, and morphology of seedlings of native tree species raised in a nursery for the purpose of restoring natural forest ecosystems in protected areas. This study concentrated especially on the development of root systems, and the costs of the various methods tested and attempted to balance economic and ecological considerations in formulating recommendations for the improvement of forest restoration programs.

Future implications of the study

The results of this study will help implement and develop other knowledge about nursery techniques, especially of root morphology and root formation. In addition, the outcome of the study will provide appropriate nursery techniques to FORRU which will help in their goals. Furthermore, the results will also be available to future projects which should continue to monitor the seedlings grown in root-trainer containers when planted in degraded areas to determine the field performance of the seedlings which are raised by this technique.

Limitations of the study

The main goal of this study was to determine the effectiveness of root-trainers and mixed growing media to raise seedlings and provide target seedlings with physiological and morphological characteristics that can be quantitatively linked with reforestation success (Rose *et al.*, 1990). This study investigated only 4 species and only 2 types of root-trainers. The information obtained might not be applicable to every species. Furthermore, planting trials of these seedlings after hardening should be done. However I could not do this because of time constraints.

Site Description

This study was conducted at the Forest Restoration Research Unit Nursery (FORRU) at the headquarters of Doi Suthep-Pui National Park, Thailand (18° 50′ N, 98° 50′ E) at about 1,000 m elevation in primary evergreen, seasonal, hardwood forest on granite bedrock. The annual rainfall is usually about 1,000 mm at the base of the mountain and about 2,000 mm near the summit (1,685 m elevation). During the cool - dry season (November to February), the average temperature is 20-24°C, while it rises up to 30°C in April (Elliott, 1997).

LITERATURE REVIEW

General Reviews on Forest Restoration

Planting native tree species helps to accelerate forest restoration and promote biodiversity. To enhance local reforestation efforts, improved nursery production techniques must be developed and practiced. Tree planting programs will only be successful if there is a high seedling survival rate and if the trees grows vigorously. The physiological quality of seedlings can be improved by proper nursery techniques which can help them to handle stress after outplanting. In the past, many different container systems have been developed to produce seedlings for reforestation programs. With each new system, techniques changed and seedling quality improved. However, each of these containers has its own strong and weak points, depending on the objectives and conditions for reforestation (Milamo *et al.*, 1985). Current nursery practices using plastic bags and forest soils often results in planting stock with deformed roots, especially spiraled roots. Planting stock quality could be improved by using other types of containers and different potting media (Wightman, 1997).

Target Seedling Concept

The target seedling concept is the attainment specific physiological and morphological seedling characteristics which can be quantitatively linked with reforestation success (Rose *et al.*, 1990).

The basic goal of having quality seedlings is to achieve the best growth possible and have the highest amount of desired output. Seedling quality depends on two factors viz. genetics of the parent stock and physical traits. The goal of the target seedling program is to seek the optimization of all of characteristics for the greatest gain after outplanting. Target characteristics are based on morphological parameters, e.g. height, which is not always a reliable indicator of success without taking into account stem diameter and root volume. Other morphological characteristics are leaf area or leaf number, root weight, bud size or appearance, and disease infection. Furthermore physiological parameters are also involved, e.g. plant water potential, nutrients, photosynthesis, etc. Nevertheless, not all physiological characteristics can be used as target characteristics, but a conceptual understanding of mechanism is useful in the production of target seedlings.

Implementation of a target seedling program can be done by two steps: i) inventory and characterization; collecting physiological and morphological information on height, stem diameter, shoot weight or volume, root weight or volume, and other necessary parameters that the studies focus on, and then calculating the relationships of the parameters, e.g. root-shoot ratio and height-diameter ratio. These data are analysed by ststiscal tests to produce means, standard deviations and coefficients of variation, which can show the class of seedlings in each parameter. ii) Field testing, which continues doing the measurements in each parameter noted above, while signs of stress and mortality should be measured.

Root Characteristics

Root characteristics can be used to pinpoint target seedlings; high root growth capacity, fibrous root systems and long root systems can minimize mortality and growth shock due to moisture stress, nutrient deficiencies, and dessication after outplanting. Furtheremore, tolerance to root exposure can minimize the adverse effects of poor stock handling at the planting site. In addition, the box-pruned root system can minimize abnormalities in root form and reduce risks of root disease (Burdett *et al.* 1983). Roots can be characterized by their position and extent of deformation, according to Menzie's Tap root Score (Chavasse, 1978)

Score	Tap Root Condition
0	Strong, dominant, well developed tap root
2	Stunted, slighty 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 does not come below a horizontal plane. Subtract one point for each strong sinker present.

Container Systems

Plastic bags have been used to produce trees in Thailand for many years. They are chosen because they are cheap, appropriate for small nurseries in remote sites, and can be manufactured in-country. Yet plastic bags as nursery containers have a number of very serious technical and logistical disadvantages. They require large amounts of soil, are difficult to handle due to their size and weight, are poorly aerated, discourage lateral root development and caused root spiraling (Figure 1), and occupy much nursery space. Technical activities in the nursery are labor intensive, leading to high labor costs. Plastic bags are not considered reusable, and require constant replacement. Many nurseries using plastic bags throughout the tropics need regular root-pruning of their seedlings, since the root will be damaged when the seedlings are extracted for planting.

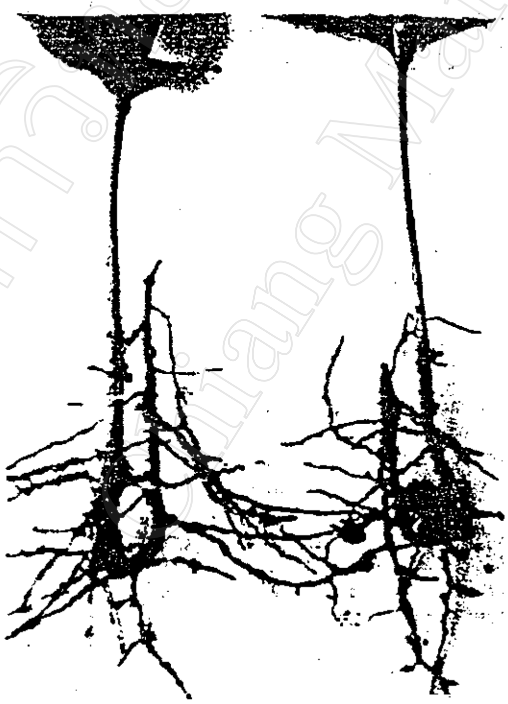


Figure 1. Spiraling roots formed while growing in a plastic bag (Josiah *et. al.*, 1992).

Container systems currently being used have been designed to address several critically important biological factors affecting seedling morphology and growth. Root-trainers lack sharp horizontal corners that distort root growth. Vertical ribs inside these containers direct root growth downwards, thus avoiding root spiraling, hence the name "root-trainer" and provide for air pruning of roots to encourage lateral root development (Josiah *et al*,1992).

By using root-trainers, roots follow vertical grooves, emerge from the drainage hole, and dry off (air pruning). Soon the seedlings have many roots, mostly in the grooves on the outside of the plug. Tap rooted plants that grow in root-trainers do not suffer shock when transplanted (Spencer, 1993).

Root-trainers have many advantages for nursery production systems and also for reforestation. Lateral root growth and orientation are excellent and they also encourage good root morphology.

Many reports exist worldwide which indicate better outplanting growth and survival when seedlings are produced by root-trainer systems (Josiah *et al*, 1992). Studies have shown that root-trainer grown seedlings have more vigorous and rapid root growth than seedlings grown in plastic bags. Outplanting survival is greatly increased and, more importantly, long-term survival is ensured (World Bank, 1993). Root-trainer systems in simplify nursery operations such as disease and insect control, handling, monitoring, and sampling. Also, the reusability of root-trainers can offset their initial higher costs when compared to plastic bags. Furthermore, root-trainers are smaller in volume than plastic bags, require less media, require a short time to fill, and are easy to fill. The seedlings grown in smaller, lighter root-trainers are less labor intensive in the nursery, occupy less space, have high survival rates upon outplanting and are much easier and cheaper to transport to the planting sites.

Root-trainers are considered to be expensive because usually they must be imported. Many of the containers currently available are only made in North America or Europe (Josiah *et al*, 1992). Nevertheless, with good planting stock from root-trainers, costs are saved when replanting in the planting site becomes unnecessary. When comparing production costs between root-trainers and plastic bags, all expenses should be considered in calculating costs per seedling. While costs are important, the long term financial advantages of high quality seedlings are of great importance and must be considered.

There are many different types of root-trainers on the market today and all of them have been designed to improve root growth and morphology. For example, individual cells in trays, with each seedling grown in its own cell are arranged in a rack or tray. Tubecells are preferred by researchers because of the ability to randomize seedlings in experiments. This system includes the ability to expand seedling growing space by separating the seedlings while it is easy to take unhealthy seedlings out and rearrange the remaining seedlings to take up the space.

Block containers are a single unit composed of many cells arranged within blocks, usually made of thick polyethylene. These containers are available in a variety of sizes and configurations. They are durable, lightweight, and easy to handle.

Potting media

A nursery potting medium has several functions, which are essential for good planting stock. The roots must be free to grow, but if soil is sticky and fine textured, the roots cannot push through and drainage is poor.

Seedling roots need a balanced amount of air and water to grow well. In order for seedlings to grow well, the potting medium must meet five criteria i) it must be lightweight ; ii) well-drained; iii) free of insects, diseases and weed seeds; iv) it should have a low clay content; v) it should be comprised of well-decomposed materials (Josiah, 1992).

The use of coconut husks as a potting medium in the production of forest tree seedlings has many advantages. The material is lightweight, porous and has excellent adhesive and cohesive properties. In addition, its high water-holding capacity reduces watering cost and labor. Seedlings grow faster and more vigorously than in other potting media. Other major advantages of using coconut husk as a potting medium is that seedlings can be lifted bare-rooted from the containers and transportation costs are less than when other potting media are used (Kijkar, 1991).

MATERIALS and EQUIPMENT

Species Studied:

Spondias axillaris Roxb. (Anacardiaceae)

Micromelum hirsutum Oliv. (Rutaceae)

Archidendron clypearia (Jack) Niels. spp. *clypearia* var. *clypearia* (Mimosoideae)

Eugenia fruticosa (DC.) Roxb. (Myrtaceae)

Equipment

REX trays (Figure 2, see Appendix 1)

Tubecell root-trainers (Figure 3, see Appendix 1)

Squarecell (germination tray - Figure 4)

Black plastic bags (500 ml.) (Figure 5)

Vernia calipper (mm)

Ruler (cm)

Oven (80 °C)

Balance (Mettler Toledo 205 g. - Type AE 200S SNR 1113281814 FNR 38690 04)

Materials

Forest soil from Doi pui

Peanut valve

Coconut husk

Figure 2. REX tray root-trainer

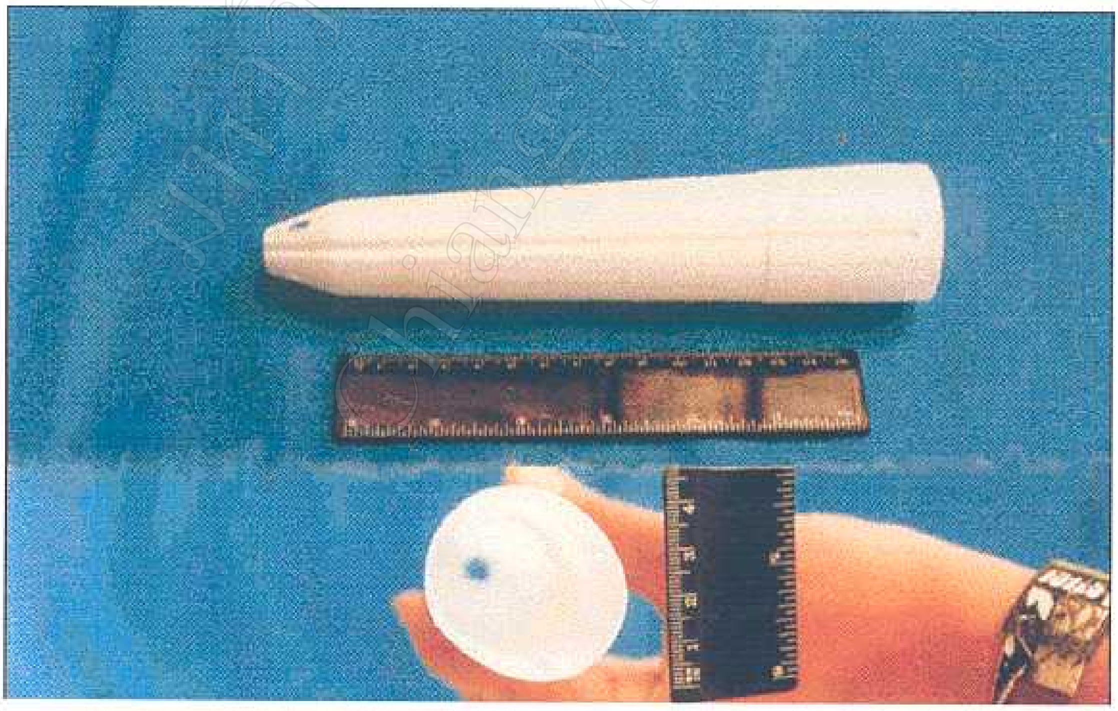


Figure 3. Tubecell root-trainer

Figure 4. Squarecell germination tray

Figure 5. Plastic bag with forest soil (left) and mixed media (right)

METHODOLOGY

Experimental Design

A Randomized Complete Block Design was selected. The experiment tested six treatments replicated in three blocks. Each block represents every treatment randomly arranged, by dividing into three types of containers; REX tray, tubecell, and squarecell each with two kinds of media; forest soil and mixed media (Figures 6-8).

Figure 6. Randomized Complete Block Design

Block 1

REX tray root-trainers - Tubecell root-trainers - Squarecell germination tray/Plastic bag

Block 2

Tubecell root-trainers - Squarecell germination tray/Plastic bag - REX tray root-trainers

Block 3

Squarecell germination tray/Plastic bag - REX tray root-trainers - Tubecell root-trainers

Figure 7. Overview of the experiment in the germination room

Figure 8. The randomized block design on three benches

Seed collection

In order to select appropriate species, the database of Chiang Mai University herbarium was consulted (CMU, 1997). The species were chosen based on these criteria: i) seeds were available at that season (May-June), ii) high germination rate, iii) low % mortality and iv) fast growing. Seeds of four species were collected in Doi Suthep-Pui National Park and sown in six treatments, i.e. three container types; tubecell root-trainer (individual cell), REX tray (block container), and squarecell (germination tray) with seedlings rapidly transferred to black plastic bags after germination and each with two different potting media,viz. forest soil and mixed media (forest soil : coconut husks : peanut valves = 1: 1: 1). The treatments were replicated in 3 randomized complete blocks. Each replicated treatment contained 24 plants.

Voucher specimens of the parent trees and specimens of seedlings at various stages of development (Zangkum s066b3, s089b2, s112b2 and s326b2) were made and deposited in Chiang Mai University Herbarium (CMU,1998).

Data collection

Soil parameters, such as N, P, K, soil texture, organic matter, and pH were analyzed in the Department of Soil Science, Faculty of Agriculture, Chiang Mai University

Physical and Morphological Information

Four seedlings of each treatment from each block were selected randomly and measured for physical and morphological seedling characteristics, viz. height, root collar diameter, number of leaves, and health score every month to determine the seedling growth and morphology.

Root Morphology

Four seedlings of each treatment and block were randomly selected after 4 and 6 months were sacrificed for sampling of dry mass and to examine root deformation, i.e. degree of root spiraling adapted from Mensie's score (see page 8 and Appendix 2), and root-shoot ratio in weight.

Data analysis

The main comparisons of interest were between seedlings grown in root-trainers and those grown in plastic bags. Other comparisons were between seedlings grown in forest soil and those grown in mixed media, which indicated the effects of the potting media.

Statistical analysis

The Randomized Complete Block Design is suitable to test for treatment differences, with great precision. In cases that the experiment involves a large number of treatments, it might not be possible to accomodate them all in a single homogeneous area. Treatments are, therefore, equally assigned to several uniform blocks and tests are performed to separate differences among blocks from differences among treatments. The treatments are allocated at random to the plots in the block. The randomized complete block design must have the same number of treatments in every block (Bailey, 1995).

Analysis of variance with *a priori* established contrasts were performed using the SPSS computer program to detect significant treatment differences.

4

RESULTS

Soil Analysis

Table 1. Soil Analyses based on single sample

Sample	pH	%O.M.	%N	%P	%K	%Ca	%Mg
Forest soil	5.45	10.96	0.562	47.50	60.00	550.0	30.00
Mixed media	5.83	12.35	1.082	50.00	587.5	625.0	70.00

Source of Sample: Forest soil : Doi Suthep-Pui National Park, Chiang Mai, Thailand

Mixed Media : Forest soil : Coconut husks : Peanut valves in ratio of 1:1:1

Analysing Date: 25 June 1997

Source: Main Laboratory, Department of Soil Science, Faculty of Agriculture, Chiang Mai University. Chiang Mai, Thailand

Table 1. shows that mixed media has more organic matter and nutrients than forest soil. This analysis supports the hypothesis that mixed media is more suitable for growing seedlings because more nutrients are available.

The following abbreviations of treatments are used throughout this thesis:

Rf : REX Tray (Root- trainer) with forest soil

Rm: REX Tray (Root- trainer) with mixed media

Tf : Tubecell (Root-trainer) with forest soil

Tm : Tubecell (Root-trainer) with mixed media

Sf : Squarecell /plastic bag with forest soil

Sm: Squarecell /plastic bag with mixed media

With these different alphabets are significantly different by ANOVA ($P < 0.05$), and sampled seedlings /treatment/block =4

A: group 1

B: group 2

C: group 3

D: group 4

Group means each number in the the same group has no least significance among the other numbers, that means no significant difference in the same group or same alphabets showing.

Germination and % Mortality

The numbers of germinated seedlings were recorded from sowing time for 3 months to determine the germination rate and % mortality [(Number of Deaths / Number of Germination) * 100].

Germination

Table 2. Germination rate in studied species

Treatment	*S. axillaris* Mean	SD	*M. hirsutum* Mean	SD	*A. clypearia* Mean	SD	*E. fruticosa* Mean	SD
REX tray+Forest soil	13.7	9.5	27AB	4.6	19.7	1.5	20.3	0.6
REX tray+Media	17.7	4.9	27.3AB	6.7	22.7	1.5	22.3	4.2
Tubecell+Forest soil	20.7	3.1	33.3B	4.2	15.3	4.7	20.3	4.7
Tubecell+Media	19.0	6.1	28.7 B	2.1	18.3	4.2	23.0	2.0
Square/P+Forest soil	12.3	10.7	18.3A	7.0	18.0	2.6	20.3	3.2
Square/P+Media	13.0	7.0	34.3B	5.7	23.7	3.1	25.0	2.6

In general, treatments had little effect on % germination, only one of the species tested. Only *Micromelum hirsutum* had significant differences in germination rate among treatments. Mixed media in squarecell/plastic bag had the highest number of germinated seedlings (Table 2)

Spondias axillaris seeds germinated from the 1st to the 9th week (Figure 9). The Analysis of Varience (ANOVA) showed no significant difference ($P<0.05$) between treatments (Appendix 4, Table1).

Micromelum hirsutum seeds germinated from the 1st to the 7th week (Figure 10). The ANOVA showed a significant difference ($P<0.05$) among treatments. Squarecells with forest soil had the lowest number of germinated seedlings while squarecells with mixed media and tubecells with both of media had the highest germination rate (Appendix 4, Table 2).

Archidendron clypearia seeds germinated from the 1st to the 12th week (Figure 11). Although mixed media consistently produced the highest germination rates, compared to forest soil in all container types, ANOVA showed that such differences were not significant ($P<0.05$) among treatments (Appendix 4, Table 3).

Eugenia fruticosa seeds germinated from the 1st to the 12th week (Figure 12). Again, mixed media resulted in higher germination rates in all container types but the differences were not significant ($P<0.05$) (Appendix 4, Table 4).

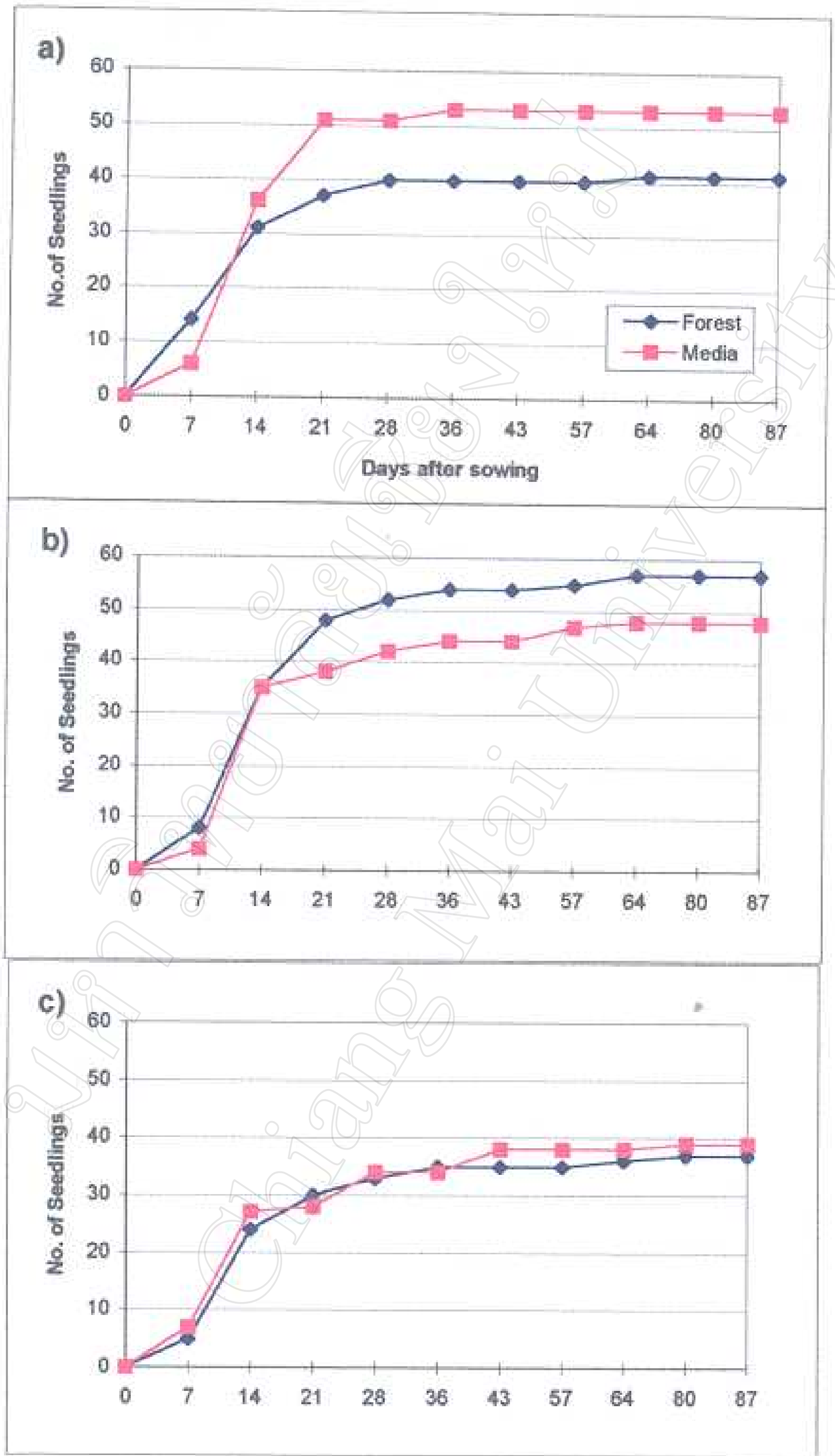


Figure 9. Germination of *Spondias axillaris*. a) Rex tray, b) tubecell,

c) squarecell/plastic bag

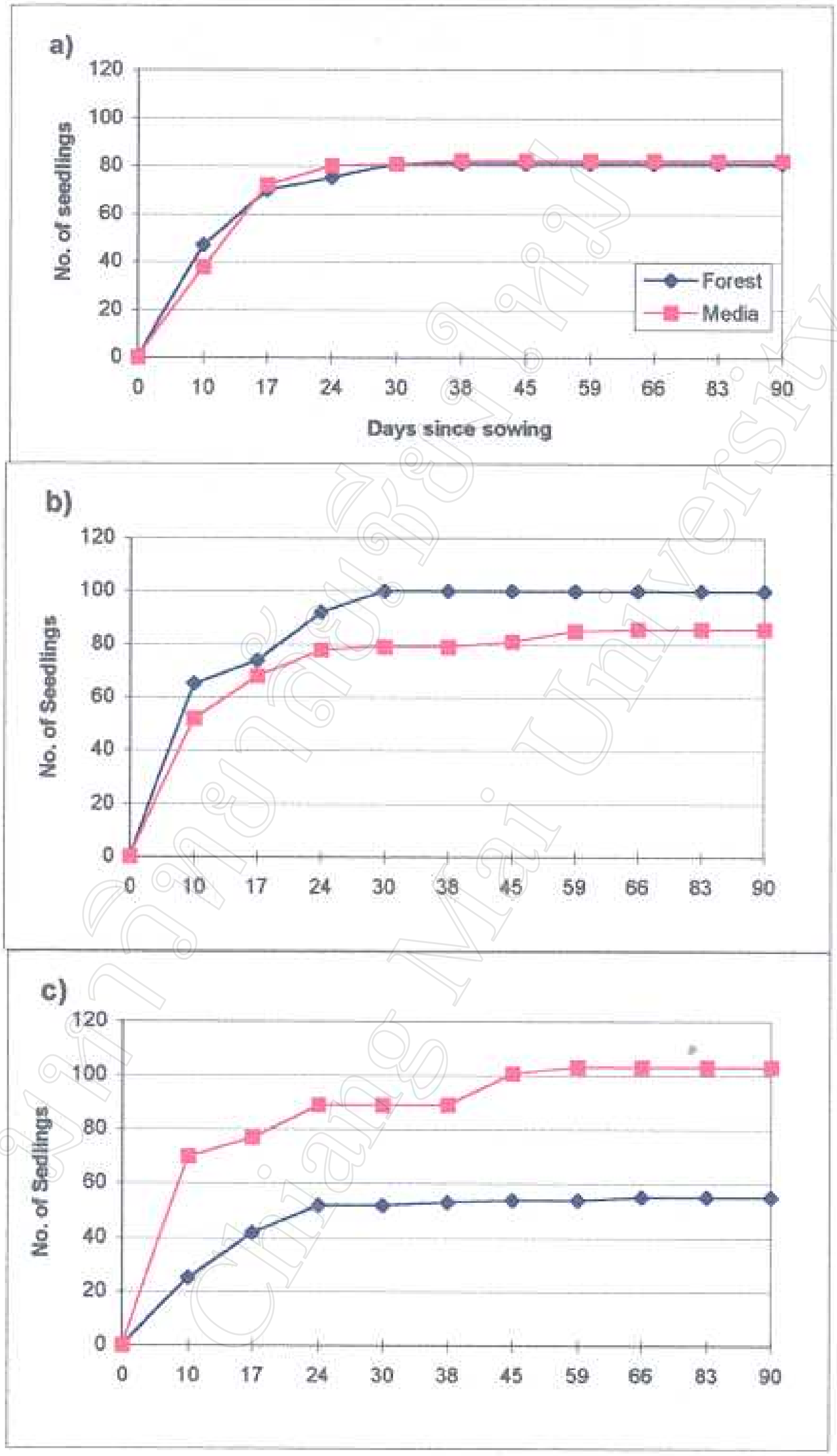


Figure 10. Germination of *Micromelum hirsutum*. a) Rex tray, b) tubecell,

c) squarecell/plastic bag

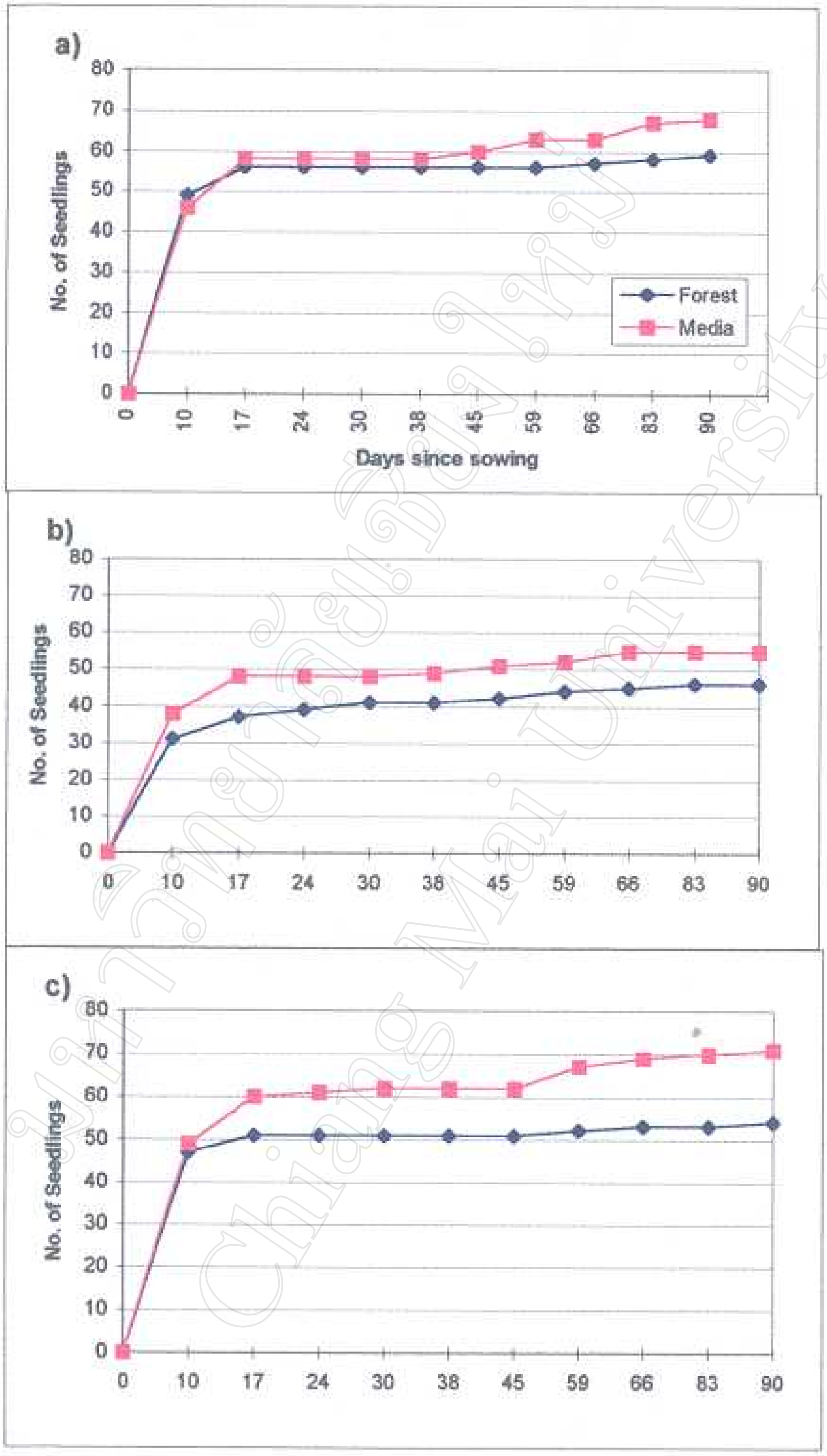


Figure 11. Germination of *Archidendron clypearia*. a) Rex tray, b) tubecell, c) squarecell/plastic bag

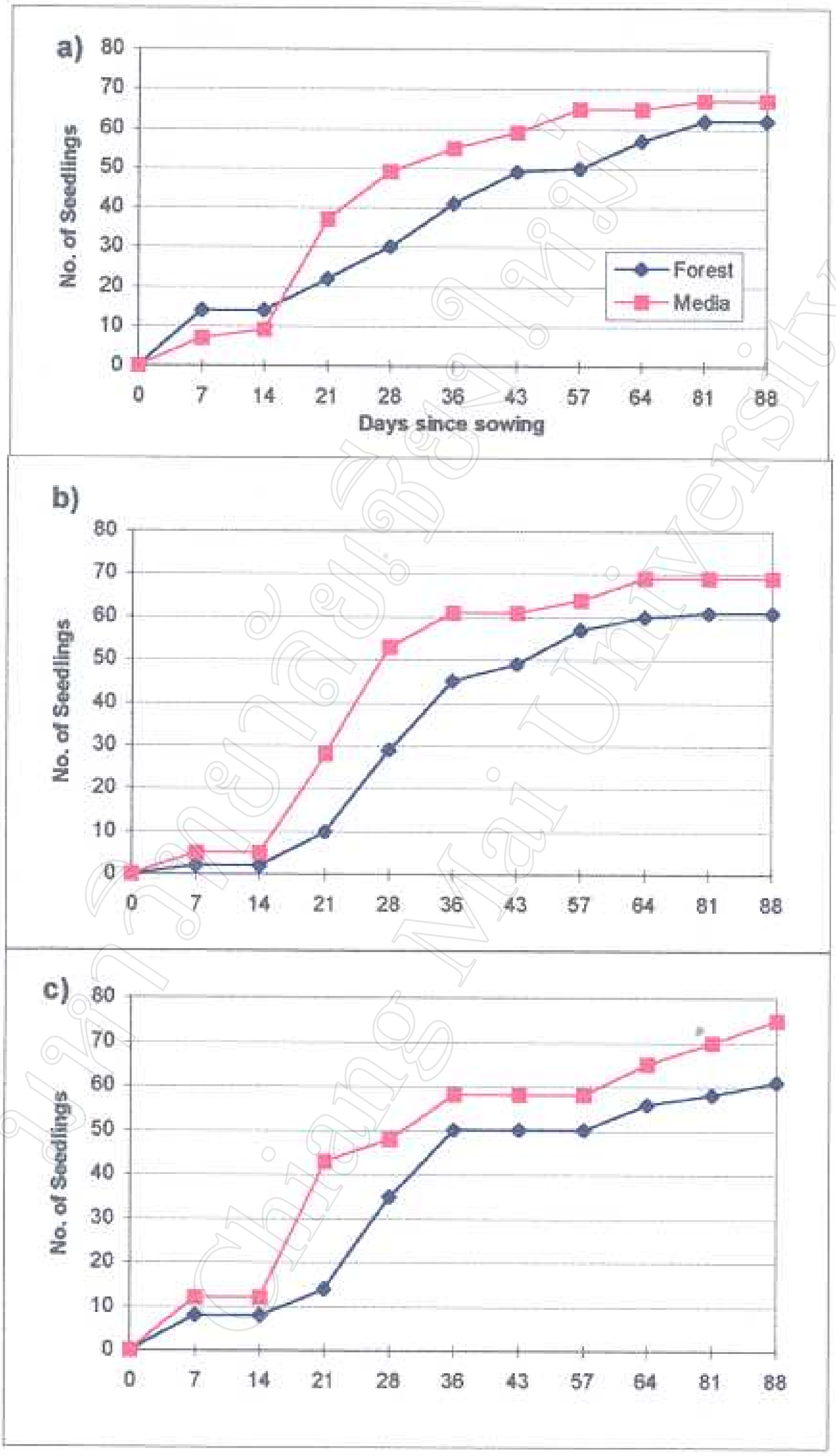


Figure 12. Germination of *Eugenia fruticosa*. a) Rex tray, b) tubecell, c) squarecell/plastic bag

% Mortality

Table 3. % mortality in studied species

Treatment	*S. axillaris* Mean	SD	*M. hirsutum* Mean	SD	*A. clypearia* Mean	SD	*E. fruticosa* Mean	SD
REX tray+Forest soil	12.9	11.4	9.74	14.2	26.0	24.0	0	0
REX tray+Media	21.6	14.7	6.57	5.19	29.3	14.7	1.75A	3.04
Tubecell+Forest soil	10.0	6.01	19.2	3.11	1.75	3.04	0	0
Tubecell+Media	21.0	32.4	12.6	4.60	14.7	2.58	1.45A	2.51
Square/P+Forest soil	11.0	14.8	5.75	6.02	23.8	3.33	0	0
Square/P+Media	11.5	6.9	19.3	8.08	16.8	4.30	13.1B	4.89

Similarly, treatments had little effect on seedling mortality during the first 90 days of the experiment (Table 3). Mortality of *Spondias axillaris* varied from 10% to 22% (Appendix 4, Table 5), while *Micromelum hirsutum* varied from 6% to 20% (Appendix 4, Table 6) and *Archidendron clypearia* had a little higher % Mortality from 1.8% to 29% (Appendix 4, Table 7).

Only *Eugenia fruticosa* showed significant differences ($P<0.01$) among treatments (Appendix 4, Table 8). Forest soil resulted in zero mortality whilst mixed media in squarecells caused significant mortality (13%) (Appendix 4, Table 9)

Comparisons of root morphology between 4 and 6 month-old seedlings of *Archidendron clypearia* spp. *clypearia* var. *clypearia*.

Archidendron clypearia was selected for a more detailed examination of root development. Three root morphological characteristics of *Archidendron clypearia* were studied using 4 seedlings sampled from each treatment, with data pooled from all blocks to determine: root dry weight, root-shoot ratio by dry weight, and degree of root spiraling.

Figures 13 shows shoot and root morphology of this species at about 4 months old (122 days) within three container types, each with 2 potting media, (in all cases seedlings grown in forest soil are displayed on the left and those from mixed media on the right). Seedlings grown in REX trays were bigger than those from other container types (20 cm, 10 cm and 15cm respectively). Roots in root-trainers, both REX trays and tubecells, were straight and more fibrous, whereas roots of seedlings grown in squarecell/plastic bags tended to be spiraled and crooked. In addition, roots in media were more branching than those in forest soil.

Root dry weight

Root dry weight seemed to depend primarily on the volume of the container. It was highest after 6 months in plastic bags (the largest container) and lowest in tubecells (the smallest container). Root dry weight increased rapidly after 4 months in REX trays and Squarecells when compare to tubecells. Root dry weight incresed about 0.5-6 g in forest soil and about 2-4 g in mixed media (Figure 14).

Root - Shoot Ratio in weight

In almost every container type (especially in REX tray with forest soil) the root - shoot ratio of *Archidendron clypearia* increased from 4 to 6 months. Only squarecell/plastic bags showed a reduction in root-shoot ratio in the same time period. (Figure 15).

Degree of root spiraling

Figure 16 shows that both root trainer types markedly reduced root spiraling compared with plastic bag. There was no root spiraling within 4 months in REX trays with both forest soil and mixed media, and tubecells with forest soil. Furthermore REX tray and tubecell root-trainers with forest soil showed no root spiraling even after 6 months.

a.

b.

c.

Figure 13. *Archidendron clypearia* root morphology in different containers : a. REX tray, b. tubecell, c. squarecell/plastic bag

Archidendron clypearia Root morphology

Figure 14. *Archidendron clypearia* Root Dry Weight At 4 Months and 6 Months Old

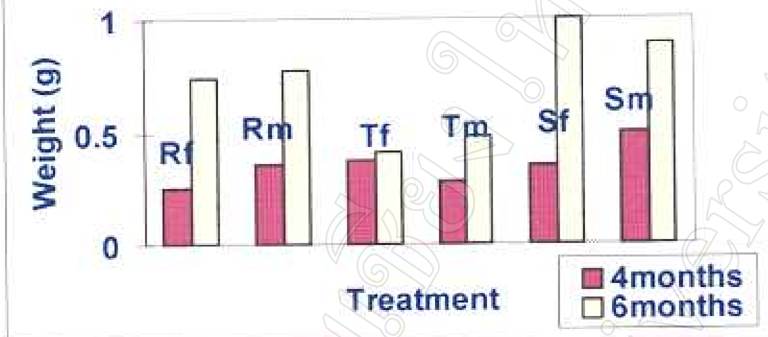


Figure 15. *Archidendron clypearia* Root - Shoot Ratio in Weight At 4 months and 6 Months Old

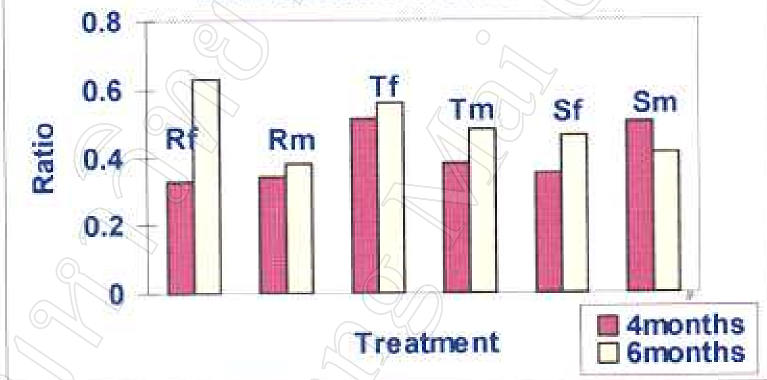
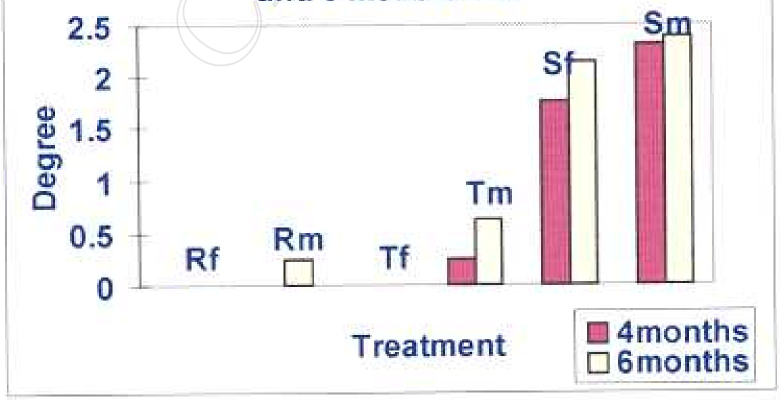


Figure 16. *Archidendron clypearia* Degree of Root Spiraling At 4 Months and 6 Months Old



Seedling Morphology

Plant growth by height

Because there were not enough seedlings of *Spondias axillaris* to study, seedling and root morphology were studied in the other 3 species. The growth curves of the three species showed fairly constant growth rates from the 2nd to 6th months, within 3 months seems like no effects from treatments. The effects of treatments became apparent by larger differences among treatments at later months (Figures 17-19).

Height growth of *Archidendron clypearia* and *Eugenia fruticosa* were also almost the same in every treatment in the 1st month. Differences among treatments became exagerated after the 3rd month, to the 6th months. Height growth was rather seperately divided between the 2 kinds of potting media (Figures 18-19).

Height at six months

There were significant differences among treatments in height at 6 months for *Micromelum hirsutum* and *Eugenia fruticosa* (Appendix 4, Tables 9 and 11). Seedlings grew tallest in REX trays with mixed media. Furthermore use of mixed media in every container resulted in significantly taller seedlings than forest soil (Figures 20 and 22).

However, *Archidendron clypearia's* mean height showed no significant difference among treatments (Figure 21, Appendix 4, Table10).

Root collar diameter at 6 months

The mean root collar diameter of seedlings of two species: *Archidendron clypearia* and *Eugenia fruticosa*, differed significantly among treatments. The mean root collar diameter of *Archidendron clypearia* was highest in squarecell/plastic bag with media (Appendix 4, Table 13),while in *Eugenia fruticosa* the highest mean was in squarecell/plastic bag and REX tray, with mixed media (Appendix 4, Table 14). In addition, the mixed media generally resulted in higher mean root collar diameter than forest soil (Figures 24 and 25).

Even though Figure 23 shows that squarecell/plastic bags with mixed media resulted in slightly higher mean root collar diameter than the other treatments, the differences were not significant in *Micromelum hirsutum* (Appendix 4, Table12).

Height growth chart

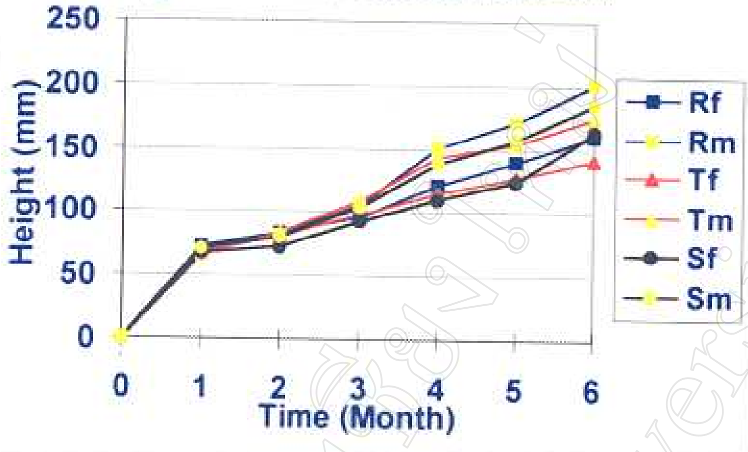


Figure 17. *Micromelum hirsutum*

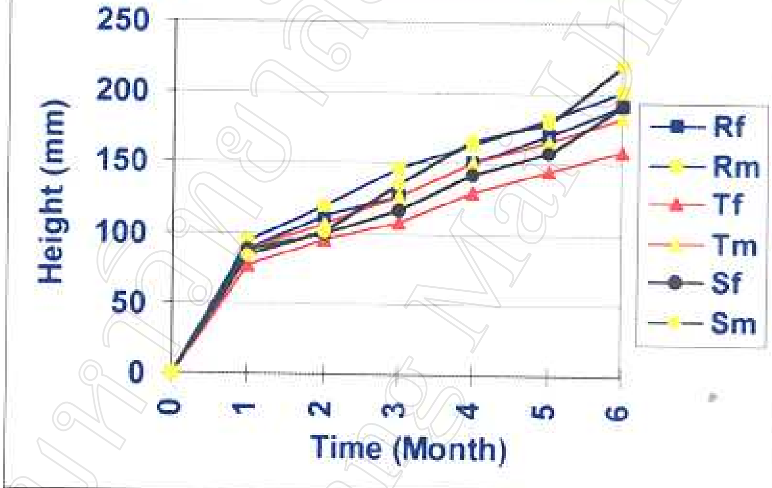


Figure 18. *Archidendron clypearia*

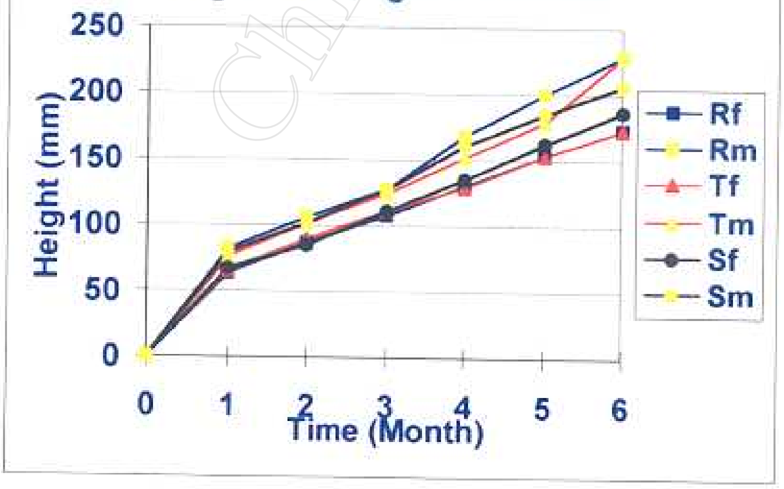


Figure 19. *Eugenia fruticosa*

Height at six months

Figure 20. *Micromelum hirsutum*

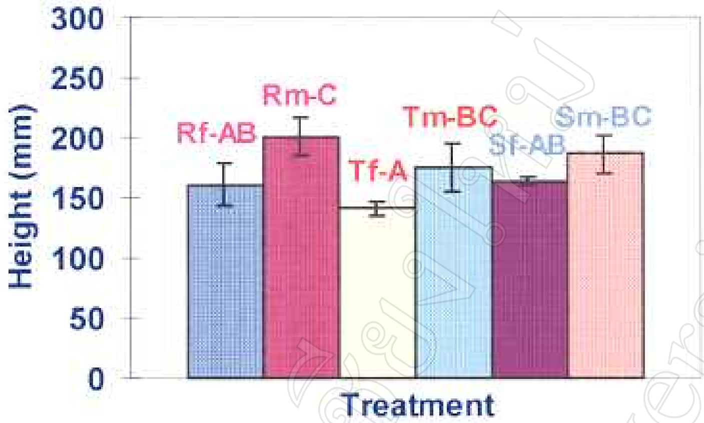


Figure 21. *Archidendron clypearia*

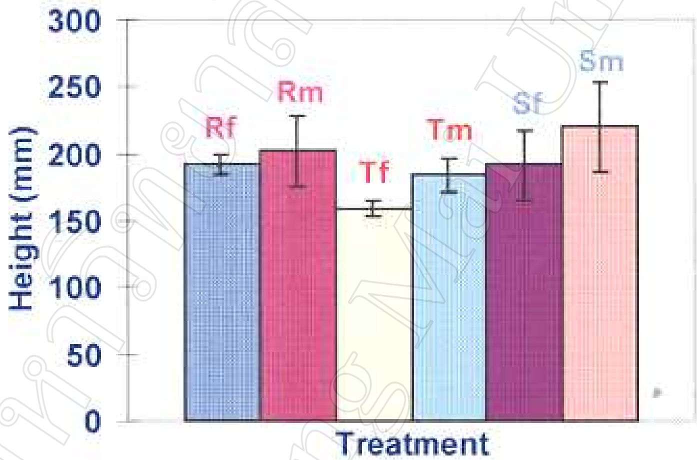
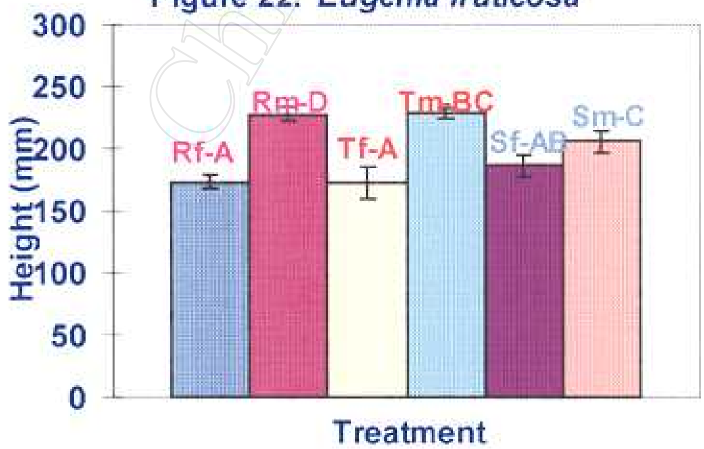
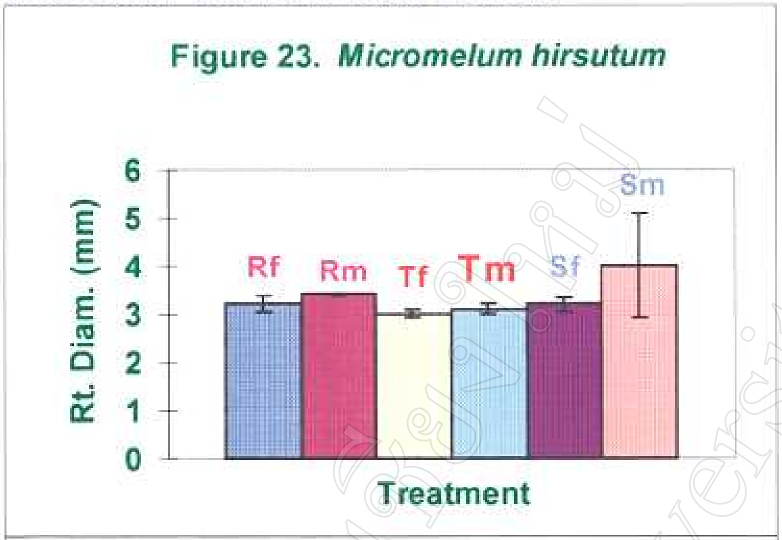
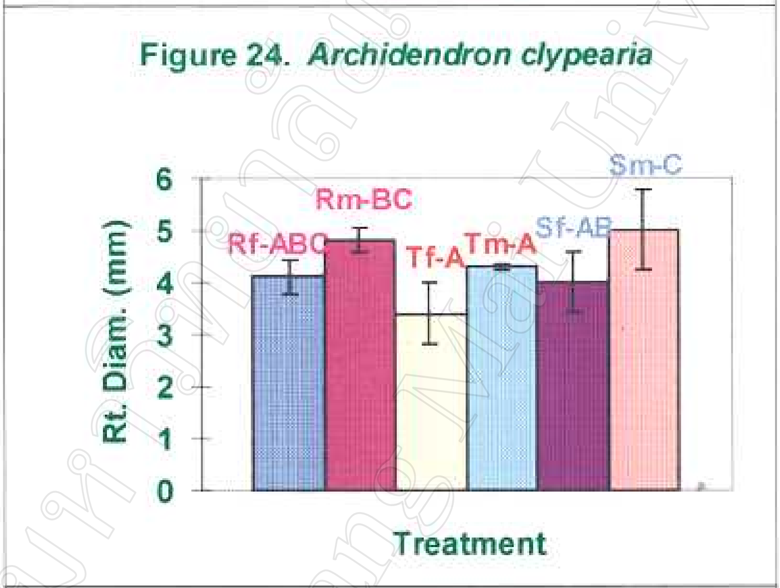


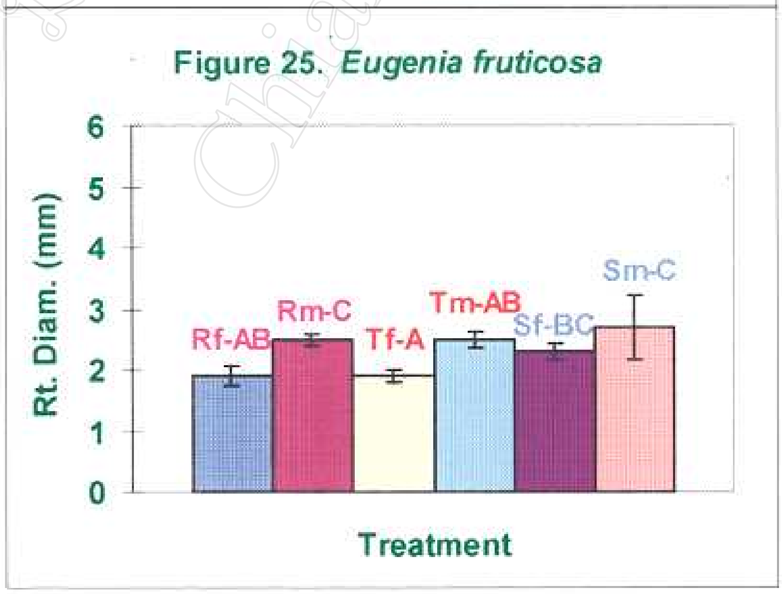
Figure 22. *Eugenia fruticosa*



Root collar diameter at six months







Root Morphology

Root dry weight at six months

In general mixed media resulted in higher mean root dry weight than forest soil. Especially in *Micromelum hirsutum* and *Eugenia fruticosa*, root dry weights with mixed media were about 0.5-3 times higher than with forest soil (Figures 26 and 28). Mean root dry weight was highest with REX trays with mixed media in *Micromelum hirsutum*, while it was highest in squarecell/plastic bags with mixed media in *Eugenia fruticosa* (Appendix 4, Table 15 and 17).

However, *Archidendron clypearia* presented another result. In squarecell/plastic bags with forest soil resulted in higher mean root dry weight than mixed media (Figure 27, Appendix 4, Table16).

Root-shoot ratio at 6 months

Mean root-shoot ratios in tubecell root-trainers were higher than with other container types. For *Micromelum hirsutum*, tubecells with forest soil resulted in higher values than with mixed media (Figures 29, Appendix 4, Table 19). Though *Archidendron clypearia* also presented a similar result (Figure 30), differences among treatments were not statistically significant in this species (Appendix 4, Table 19).

In *Archidendron clypearia*, squarecell/plastic bags with mixed media resulted in highest ratio. However root-trainers (both REX trays and tubecells) with forest soil still resulted in higher ratios than root-trainers with mixed media (Figure 30, Appendix 4, Table 20).

Degree of root spiraling at six months

For every species the highest degree of root spiraling occurred with squarecell/plastic bags with both forest soil and media, about 2-3 times more than with other containers ; root-trainer types. In addition, mixed media caused more root spiraling than forest soil for every species and every container type (Figures 32-34, Appendix 4, Tables 21-23).

Root dry weight at six months

Figure 26. *Micromelum hirsutum*

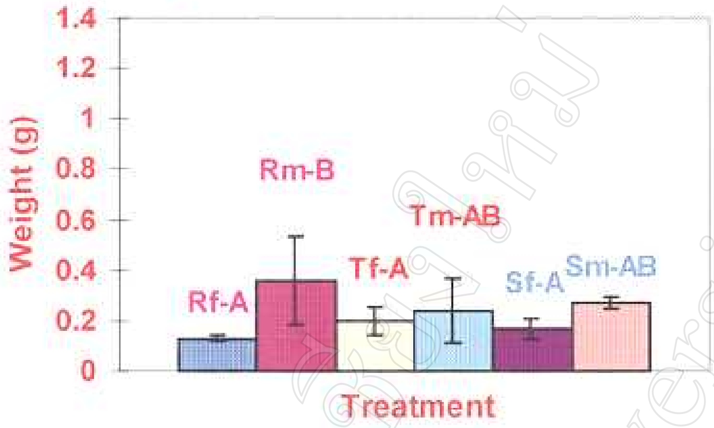


Figure 27. *Archidendron clypearia*

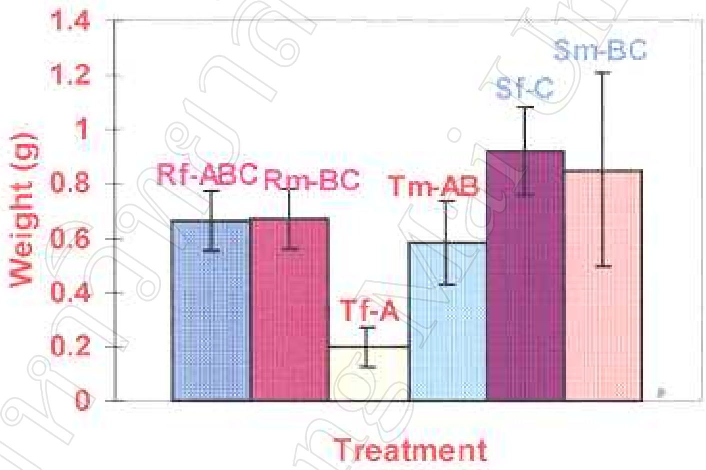
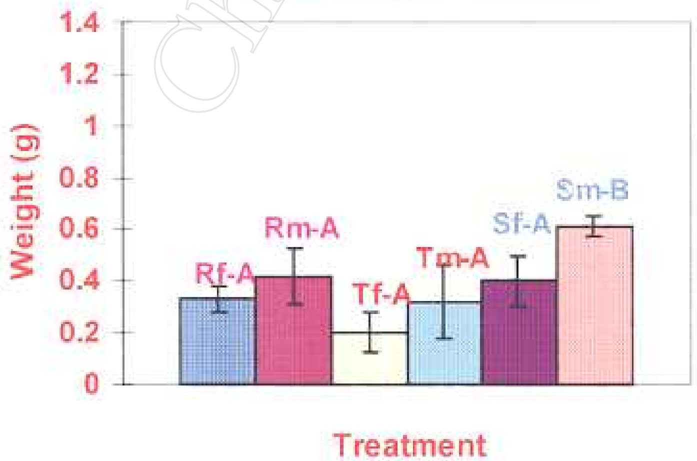


Figure 28. *Eugenia fruticosa*



Root-shoot ratio at six months

Figure29. *Micromelum hirsutum*

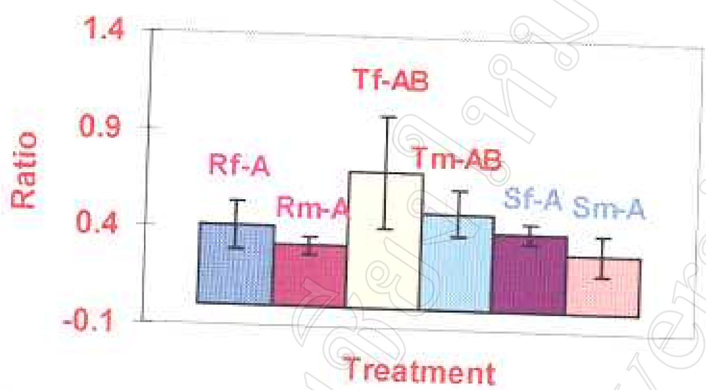


Figure30. *Archidendron clypearia*

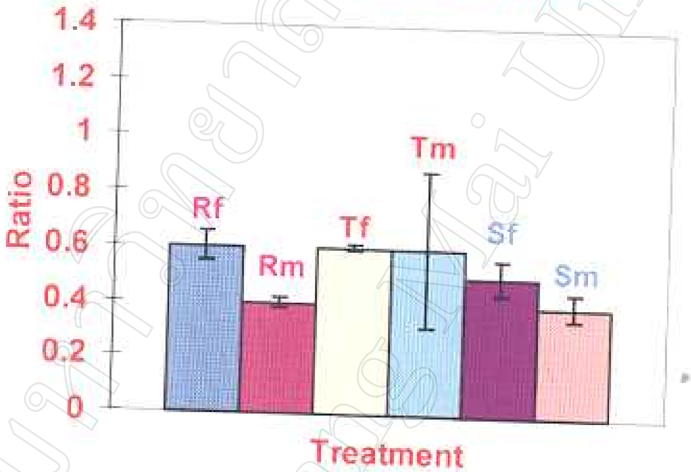
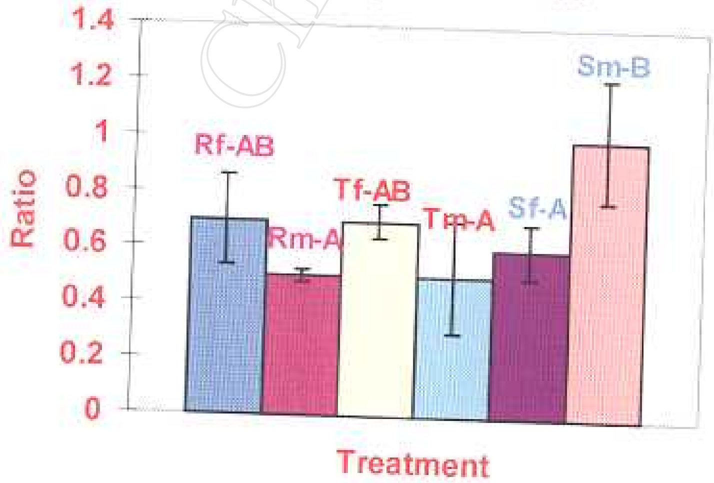


Figure 31. *Eugenia fruticosa*



Degree of root spiraling at six months

Figure 32. *Micromelum hirsutum*

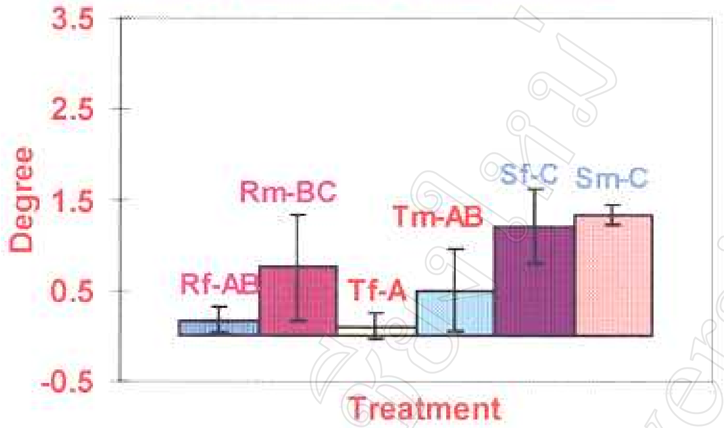


Figure 33. *Archidendron clypearia*

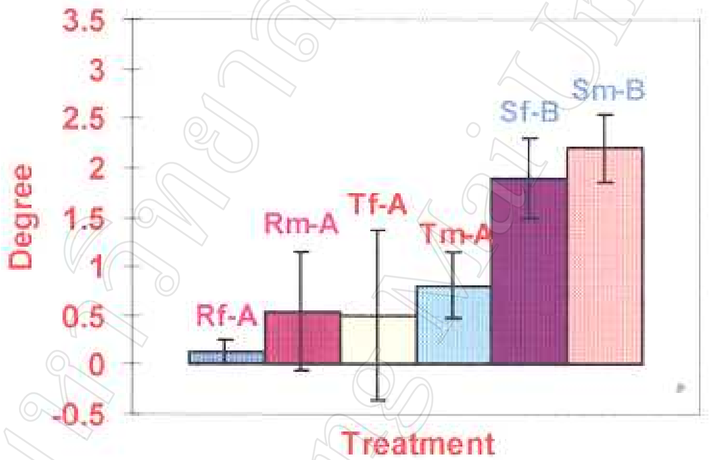
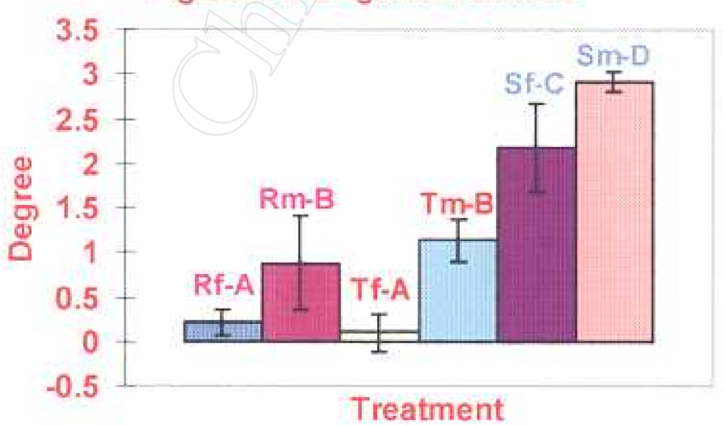


Figure 34. *Eugenia fruticosa*



Total Cost Per Seedling Per Season (see Appendix 5)

1. Containers

Rex Tray	0.243	Baht/seedling/season
Tubecell	3.08	Baht/seedling/season
Squarecell/ Plastic bag	0.240	Baht/seedling/season

2. Media

Rex Tray		
Forest soil	0.30	Baht/seedling/season
Media	0.24	Baht /seedling/season
Tubecell		
Forest soil	0.20	Baht/seedling/season
Media	0.16	Baht /seedling/season
Squarecell/ Plastic bag		
Forest soil	0.55	Baht/seedling/season
Media	0.44	Baht/seedling/season

3. Labor

Rex Tray	0.107	Baht/seedling/season
Tubecell	0.152	Baht/seedling/season
Squarecell/ Plastic bag	0.329	Baht/seedling/season

Total cost/seedling/season

Total cost/seedling/season = container cost + potting media cost + labor cost

Table 4. Total cost per seedling per season

Treatments	Cost			Total
	Container	Media	Labor	(Cost/seedling/season)
Rex Tray + Forest Soil	0.243	0.30	0.107	0.65
Rex Tray + Media	0.243	0.24	0.107	0.59
Tubecell + Forest Soil	3.08	0.20	0.152	3.43
Tubecell + Media	3.08	0.16	0.152	3.39
Total Old Method (S+P) FS	0.24	0.55	0.329	1.12
Total Old Method (S+P) M	0.24	0.44	0.329	1.01

Total Cost Per Seedling Per Season

Rex Tray + Forest Soil	**0.65**	**Baht/seedling/season**
Rex Tray + Media	**0.59**	**Baht/seedling/season**
Tubecell + Forest Soil	**3.43**	**Baht/seedling/season**
Tubecell + Media	**3.39**	**Baht/seedling/season**
Total Old Method (S+P) FS	**1.12**	**Baht/seedling/season**
Total Old Method (S+P) M	**1.01**	**Baht/seedling/season**

Benefit Value

In order to calculate the benefits of each seedling propagation per unit cost, it was first necessary to devise an overall mean index of seedling quality based the values of the most important seedling characteristics (target seedling characteristics) analysed in tables 9-23 in appendix 4 i.e. height, root collar diameter, dry root weight, root-shoot ratio in weight and degree of root spiraling. The value of each parameter was divided by the maximum value recorded to give a standardize value of 0-1 for each desirable characteristic. The five standardized values were then multiplied together to give an index of seedling quality (SQI).

Seedling Quality Index = Standardized Values of (Height * Root collar diameter* Root weight*Root-shoot ratio*Degree of Root spiraling)

The SQI divided by the unit cost of each treatment provided a useful measure of cost effectiveness.

Benefit Value = Seedling Quality Index / Total cost per seedling

S89 *Micromelum hirsutum* Oliv.

Treatment	**Benefit Value**
Rex Tray + Forest Soil	1.55
Rex tray + Media	1.15
Tubecell + Forest Soil	1.15
Tubecell + Media	0.23

Squarecell/plastic bag + Forest soil	0.16
Squarecell/plastic bag + Media	0.28

S112 ***Archidendron clypearia*** spp. *clypearia* var. *clypearia*

Treatment	**Benefit Value**
Rex Tray + Forest Soil	12.5
Rex tray + Media	3.04
Tubecell + Forest Soil	0.21
Tubecell + Media	0.34
Squarecell/plastic bag + Forest soil	0.58
Squarecell/plastic bag + Media	0.55

S326 ***Eugenia fruticosa*** (DC.) Roxb.

Treatment	**Benefit Value**
Rex Tray + Forest Soil	4.87
Rex tray + Media	1.81
Tubecell + Forest Soil	1.23
Tubecell + Media	0.12
Squarecell/plastic bag + Forest soil	0.36
Squarecell/plastic bag + Media	0.89

DISCUSSION

Methodology

All statistical analyses except one (root collar diameter of *Archidendron clypearia* ($P < 0.05$) Appendix 4, Table 13) revealed no significant differennce among the three replicate blocks. This shows that a single block would probably have been sufficient to show the same results. Similar tests on more species in the future could be greatly simplified by using single blocks rather than replicates.

Container type

REX trays were the best containers for almost all target seedling characteristics and for most species. REX trays provided not only better morphological characteristics but also good root formation. Wightman (1997) and Josiah and Jone (1992) also reported that root-trainers were more effective than plastic bags, and bigger root-trainers were more effective than smaller root-trainers. The two root-trainer types used in the experiment reported here had different volumes. Rex tray cells were larger (300 cm3) than tubecells (200 cm3). So the results of the experiments agreed with the results of other researchers. However comparisons between root-trainers and plastic bags of the same volume has not yet been done. REX trays and plastic bags had slightly different volumes (300 cm3 and 500 cm3 respectively), but tubecell root-trainers were much smaller than plastic bags (200 cm3). Consequently the volume of containers should also be considered.

Potting media

Potting media also influences seedling growth. Seedlings which grown in mixed media had better growth characteristics. Mixed media encouraged fibrous root growth which could absorb more nutrients and resulted in faster and stronger seedling growth. However root deformation (root spiraling) occured more with mixed media than with forest soil for each container type (Figures 32-34). Considering media, the heterogenous nature of the mixed media and the different ratio of each component might have caused the higher degree of root deformation. Mixed media caused more root spiraling. It might be possible that, because the media were not so finely mixed and the materials were still in big pieces, when roots touched the materials, roots became spiraled. In addition, the ratio of 1:1:1 (forest soil: coconut husk: peanut valve) might not be suitable. Though seedlings developed very good shoot characteristics, root morphology was poor. Root morphology is very important when outplanting. Root spiraling does not disappear, it grows as the tree grows and adult trees with spiraled roots are easily blown over by the wind. Seedlings with good root formation will grow well in the first rainy season after planting. Root development determines drought resistance in the dry season when seedlings are at risk of mortality (Slatyer, 1967 and Kramer *et. al.*, 1969).

Cost - Benefit Analysis

The analysis was based on FORRU nursery expences. Forest soil is taken from Doi Pui, so we need to calculate the cost of gasolene and labor to transport the soil from the road down to the nursery or in case of containers we need to transport REX trays from Khon kaen to Chiang Mai, thus the costs depend on circumstances at each nursery. The cost-benefit analysis showed that the balance between ecological and economical considerations depended on the cost and type of containers and media. Imported root-trainers might not be suitable to use because of the high cost and tax charged. From this study, considering benefit value, REX trays were considerably more economical than the other container types (Benefit Value, page 46-47). REX tray cells had higher volume and provided more nutrients so seedlings could grow fast and vigourusly. Furthermore, REX trays are available in Thailand and are not so expensive.

Limitations of the study

According to time constraints, this study did not continue until the time for outplanting. This experiment covered only seedlings grown in the nursery within 6 months and did not yet complete the objectives to restore forest. However this study did provide a basis for further study and guidelines to adapt and improve other nursery techniques.

Future implications

The results showed that REX tray root-trainers are a very effective container type for tree nurseries in Thailand, to help in restore forest. REX trays should be promoted for wider use. Nursery management should be improved and adapted for their use. Nursery managers can re-engineer their nurseries by trying to change to REX trays bit by bit. REX trays can be reused many times, though the initial cost is quite high, nurseries can save a lot in subsequent seasons. Nurseries would also have to prepare for storage and maintenance. Staff need to learn how to use and how to handle the new system for longer using period. Furthermore space in the nursery has to be considered. REX trays take up more space than tubecells but less than plastic bags, so the nurseries should calculate number of trays fit with space before making decision.

CONCLUSION

1. Root-trainer supported faster seedling growth and better seedling form than current nursery techniques using plastic bags.

2. Though mixed media facilitated development of better seedling morphology, root morphology was better in forest soil.

3. REX trays with forest soil provided the most efficient and cost effective method of producing native tree seedlings for forest restoration project.

4. REX trays were sufficiently effective with native Thai forest species to recommend their wider use to support forest restoration projects.

RECOMMENDATIONS

1. The experiment should be continue to monitor after outplanting in the degraded areas, to see the effectiveness of the recommended treatments under field conditions.

2. Further research is necessary to take into amount differences in container volumes.

3. Experiments should be carried out on a wider range of potting media.

4. Further experiments should be carried out to further improve the REX tray method e.g. rate and types of fertilizer application.

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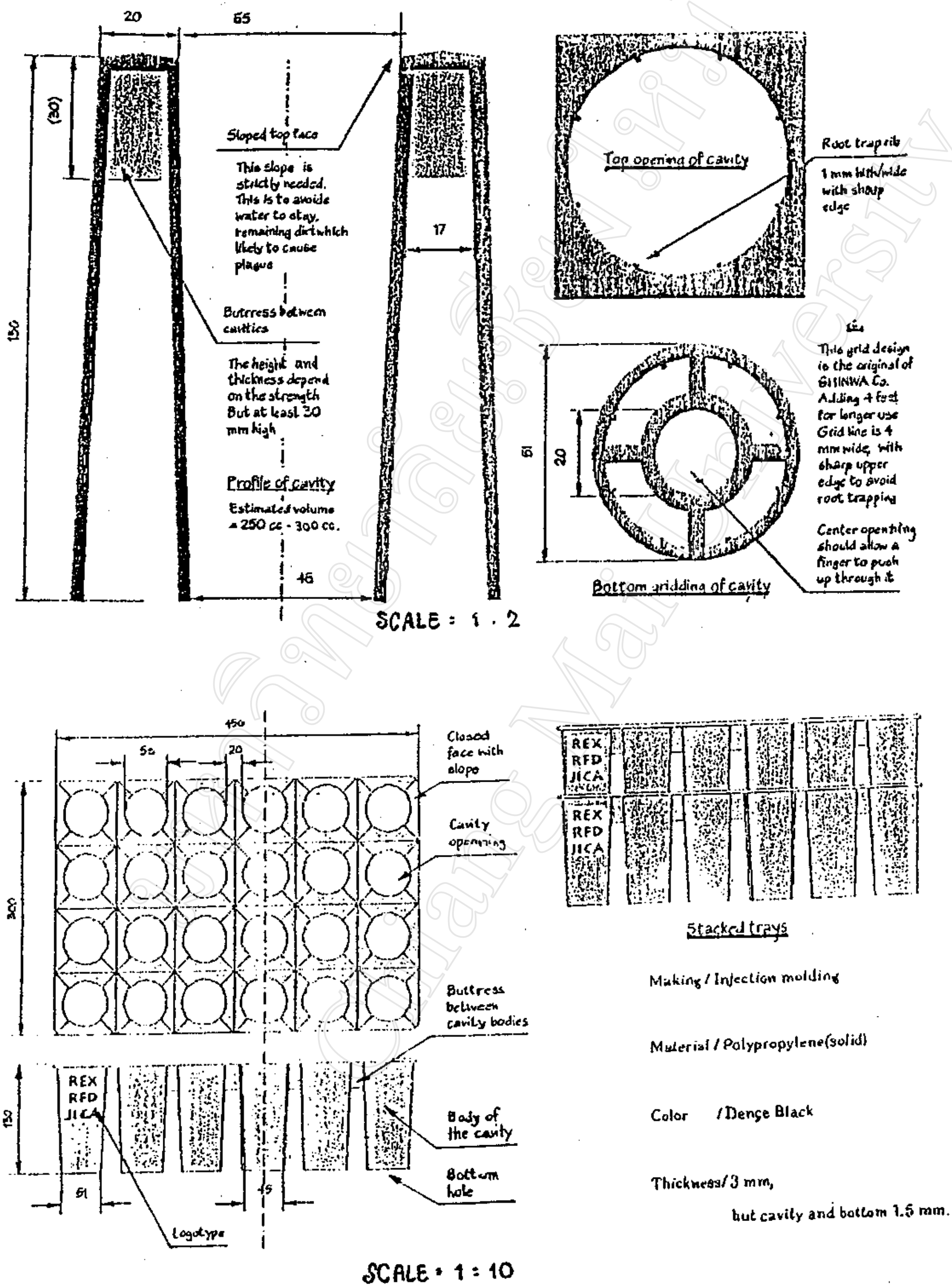
APPENDICES

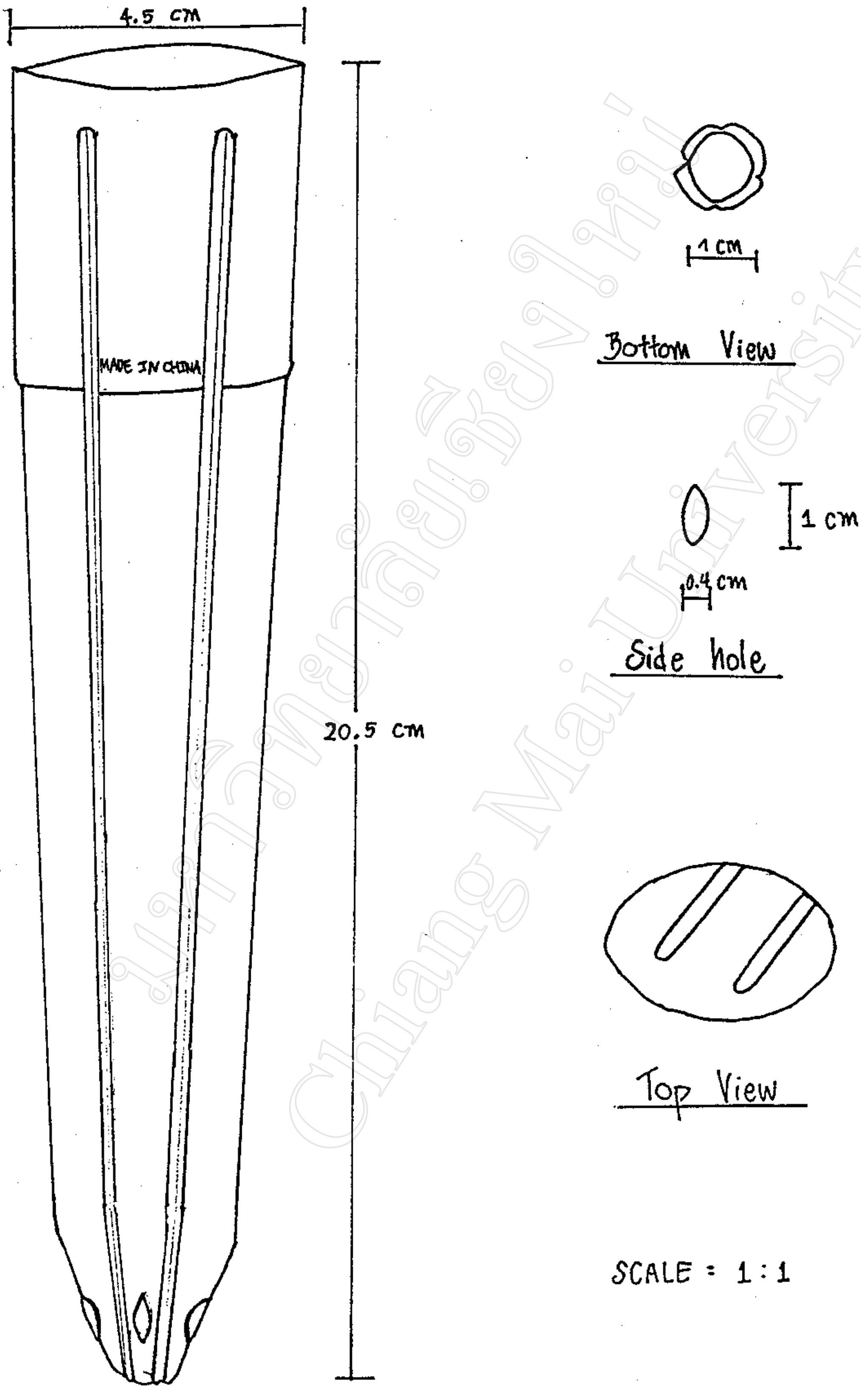
APPENDIX I: Root-trainer Diagram

REX tray root-trainer



Source: JICA, Mahasarakarm Nursery, Khon Kean.

Tube cell root-trainer



Source: Stuewe and Son's, Inc., Oregon, USA.

APPENDIX II: Degree of root spiraling scoring method

Scoring methods can provide a rapid and useful complement to more precise and quantitative measurements. They are especially appropriate when the parameters cannot be assessed by simple measurements, or time is limited. Furthermore, the data can be used to carry out statistical tests (e.g. Analysis of Variance) of significance (Longman *et. al.,* 1993).

Degree of root spiraling score adapting from menzie's tap root score :

Score	Tap Root Condition
0	Strong, dominant, well developed tap root
1	Slighty malformed
1.5	Tap root distinctly hooked
2	Tap root badly hooked, but growth still downwards
2.5	Tap root severely deformed into two or more fracture zones, but growth still downward
3	Tap root does not come below a horizontal plane. Subtract one point for each sinker present.

APPENDIX III: Seedling Descriptions

Spondias axillaris Roxb. (Anacardiaceae)

This description is based on seedlings examined on 9 September 1997, grown at the FORRU nursery, from 3 batches of seed, all collected from the same parent tree, at Doi Suthep-Pui National Park Headquarters, c. 1,050 m elevation, at different times (CMU Herberium, voucher s066b1- Zangkum s066b3). The 2 largest seedlings (29-30 months old, 38-46 cm tall) originated from seed collected on 6 March 1995 and germinated 21 March - 11 April 1995. Twenty medium sized seedlings (2-3 months old, about 23 cm tall) originated from seed collected on 2 June 1997 and germinated 9 June - 8 July 1997, while 40 very small seedlings (1-12 days old, up to 7-8 cm tall) originated from seed collected on 7 August 1997 and germinated on 28 August onwards.The first two seed batches were germinated in shade, while the last batch was germinated in sunny conditions.Various stages of development are illustrated in Figure 35.

Seedlings: cotyledons are raised above the soil surface (**epigeal**) and free of the fruit and seed walls (**phanerocotylar**).

Development: one to five tap roots emerge downwards through five holes in the sclerified pyrene. After the roots become anchored in the soil and begin to develop secondary roots, the hypocotyl elongates, arching upwards pulling the linear cotyledons free of the pyrene. The cotyledons spread horizontally.

Roots: Primary root at the cotyledon stage, white, about 1 mm in diameter, becoming cream coloured to light brown, 2.5 mm in diameter, fibrous, sinuous or straight in older seedlings. **Secondary roots:** fibrous, slender, sparsely branching, white when young, becoming light brown with age.

Stems: Hypocotyl (the part of the stem immediately below cotyledons) 6.5-7.0 cm long when cotyledons fully expanded; initially pink to light orangey-brown, turning light brown-red with age; at the 6-node stage or older, with raised lenticels which become more prominent and dense in older seedlings; with sparse, very short, white, unbranched hairs. **Epicotyl** (the part of the stem immediately above the cotyledons) 2.0-4.0 cm long, green (at first leaf pair stage) becoming light red-brown (similar to the hypocotyl) by the 5-6 node stage, silky in appearance, with round, raised lenticels apparent at the 6 node stage and older. **Internodes:** first internode 1.0-2.0 cm long; second 0.3-1.5 cm, higher node up to 3.5 cm long; similar to the epicotyl, youngest part green, becomong red to reddish brown with age; circular in cross-section, developing sparse, round, slightly raised lenticels. Stems of larger seedlings erect, slender. All stem parts with very short white hairs. **Axillary buds** (between the stem and the dorsal base of the petiole) ovate to conical, green with brownish apex, hairy, c. 1.0 mm long by c. 1.0 mm across.

Cotyledonary leaves two, opposite, linear, with acute to accuminate apex, margin entire and base decurrent, yellow when very young, turning green when fully expanded, often remaining yellowish towards the base, slightly fleshy, with dense, very short, white hairs on the upper surface, sparsely so on the under surface. **Venation** often not visible, sometimes 1-3 parallel veins on the upper and lower surfaces. **Cotyledonary petioles** absent. Cotyledons usually shed at the 2-5-node stage, leaving tiny scars on each side of the epicotyl - hypocotyl junction.

Leaves once pinnate, opposite at the first node, spiral on upper nodes, petiolate. Leaves at the first node always with 3 leaflets, those at the second node have 5 leaflets, higher nodes have 7-15 leaflets. Leaflets opposite, with a terminal leaflet, green on the upper surface, slightly pinkish underneath, hairy, lanceolate, margin serrate, apex acuminate, acute to cuneate at the base. **Venation** pinnate, midnerve sunken on the upper surface and raised on the lower surface. **Stipules** absent. **Petiole** (leaf stalk below the leaflets) green, hairy, 1.5-6.0 cm long, 1.0-2.0 cm in diameter. **Rachis** hairy, 1.0-15.0 cm long. **Petiolule** (leaflet stalks) green to red-purple, about 2.0 mm long, 0.5-1.0 mm in diameter on lateral leaflets, about 20.0 mm long, 0.5-1.0 in diameter for the terminal leaf. Both petiolules and rachis are red-green to red-purple, with short white sparse, minute hairs.

Branches rarely at 4-10th node.

Odour and sap not distinctive.

Micromellum hirsutum Oliv. (Rutaceae)

This description is based on 60 seedlings examined on 14 January 1998 (about 8 months old, 10.5-27.5 cm tall), grown at the FORRU nursery, all seeds collected from the same parent tree, in Doi Suthep-Pui National Park Headquarters, c. 1,050 m above sea level, at 27 May 1997 (CMU Herberium, voucher Zangkum s089b2). The seedlings originated from seeds sown on 30 May 1997 and germinated on 7-30 June 1997, in sunny conditions. Seedling specimens are kept at Chiang Mai University Herbarium (CMU Herberium, seedling specimens Zangkum s089b2). Various stages of development are illustrated in Figure 36.

Seedlings: epigeal enclosed by a black silky testa.**(Cryptocotylar)**

Roots: Primary root at the cotyledon stage, white; hairs minute, about 1.0 mm in diameter, becoming cream coloured, fibrous, sinuous or straight in older seedlings. **Secondary roots**: fibrous, slender, densely branching, white when young becoming cream with age.

Stems: Hypocotyl about 4 cm long when cotyledons fully expanded; initially light green with short brown hairs, after the 5node stage or older, becoming white to cream with lignification which becomes more prominent and dense in older seedlings;. **Epicotyl** 1.5-2.0 cm long, green with minute hairs (at first leaf pair stage), becoming white to cream (similar to the hypocotyl) by the 5-6 nodes stage and older. **Internodes**: first internode 1.0-2.0 cm long; second 0.5-3.0 cm, higher nodes up to 5.0 cm long;

similar to the epicotyl, youngest part green, becoming white to brown with age; circular in cross-section, developing dense, vertical, lignified striations. Stems of larger seedlings erect, slender. **Axillary buds** ovate to conical, green with brownish apex, hairy, about 1.0 mm long by about 1.0 mm across.

Cotyledonary leaves two, opposite, deltoid, with acute to accuminate apex, margin entire and petiolate, light green when young, turning green when fully expanded, hairless, venation palmate. **Cotyledonary petioles** green with minute hairs, 3-5mm long. Cotyledons usually shed at the 2-5-node stage, leaving tiny round scars on each side at the epicotyl - hypocotyl junction.

Leaves opposite at the first node, spiral at later nodes, paripinnate, compound, petiolate leaflets. Blades at 1-5 nodes decussate, green above, light green underneath, first leaflet obovate elliptic on higher ones apex mucronulate, margin entire, attenuate at the base. Blades after 5-6 nodes imparipinnate compound leaves, each green above, light green underneath, glossy when young, with minute white hairs, elliptic with mucronulate apex, margin entire, attenuate at the base. **Venation** pinnate, midnerve sunken on the upper surface and raised on the lower surface. **Stipules** absent. **Petioles** green, hairy, 2.5-3 cm long, **Rachis** (continuation of petiole) 3-5 cm long, **Petiolules** yellow-green, hairy, 3-5 mm long.

Branches not yet formed

Odour and sap not distinctive.

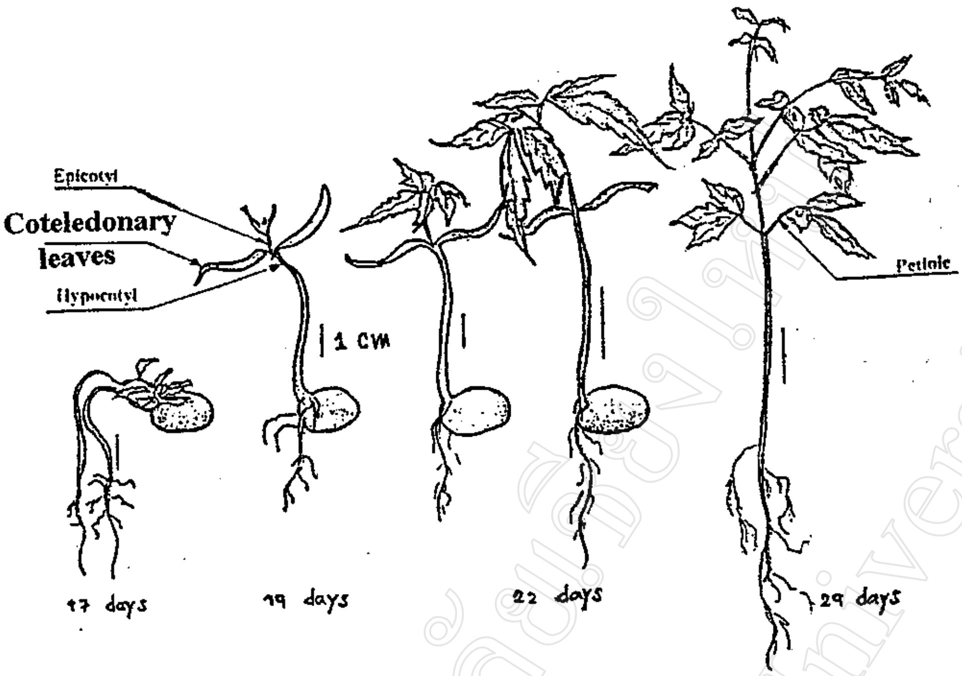


Figure 35. Various stages of *Spondias axillaris* seedling

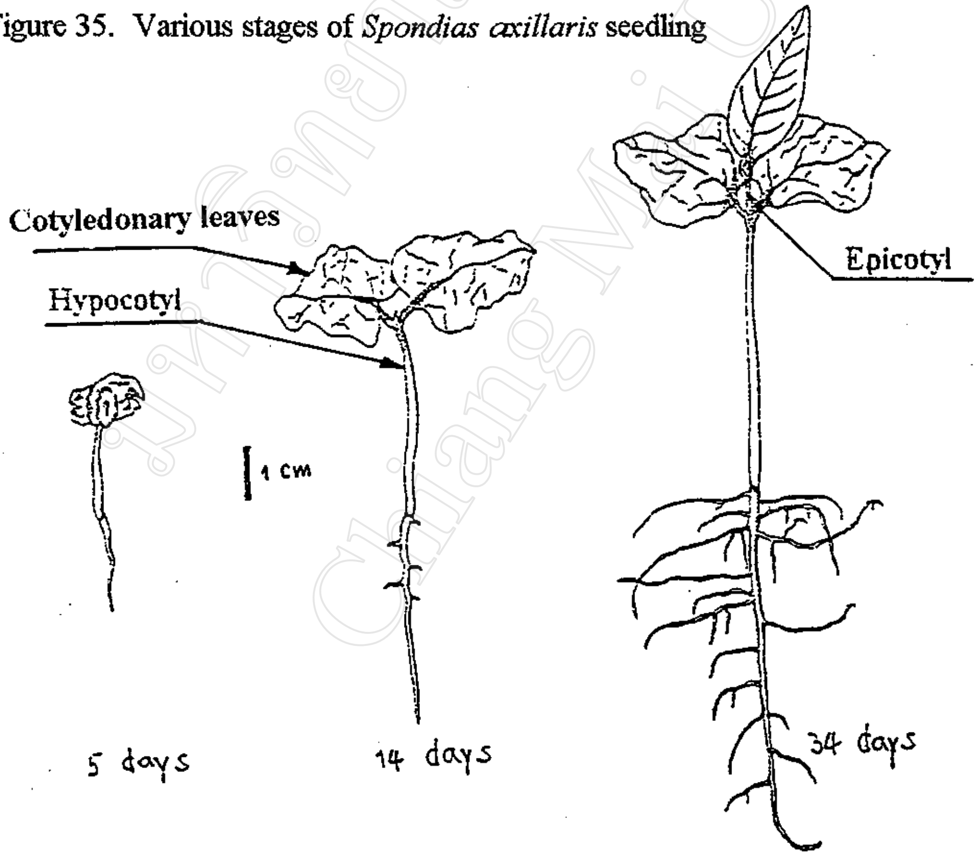


Figure 36. Various stages of *Micromelum hirsutum* seedling

Archidendron cleipearia (Jack) Niels.**spp. clypearia var. clypearia** (Mimosoideae)

This description is based on 50 seedlings examined on 14 January 1998 (about 8 months old,12.5-30.0 cm tall), grown at the FORRU nursery, all seeds collected from the same parent tree, in Doi Suthep-Pui National Park Headquarters, c. 1,050 m above sea level, at 27 May 1997(CMU Herberium, voucher Zangkum s112b2). The seedlings originated from seed sown on 30 May 1997 and germinated on 7 June-9 July 1997, in sunny conditions. Various stages of development are illustrated in Figure 37.

Seedlings: hypogeal, hidden within a black silky testa **(cryptocotylar).**

Roots: Primary root at the cotyledon stage, white, about 1.0 mm in diameter, becoming cream coloured, fibrous, sinuous or straight in older seedlings, with white nitrogen fixing nodules; 0.5-2.0mm in diameter. **Secondary roots**: fibrous, slender, densely branching, white when young becoming cream with age.

Stems: 3.0-5.0 cm long, green with minute hairs (at first leaf pair stage) by the 5-6 node stage becoming dark green with raised round lenticels which become more prominent in older seedlings . **Internodes:** first internode about 3.0 cm long, circular in cross-section. After 6th node ; 3.0-5.0 cm long; slightly fluted in cross-section, similar to the epicotyl; youngest part green, becoming lenticilate and brown with age. Stems of larger seedlings erect, slender. **Axillary buds** ovate to conical, green with brownish apex, hairy, about 1.0 mm long by about 1.0 mm across.

Cotyledons two, opposite, thick and fleshy, oval-spherical convex shaped with black testa.

Leaves opposite at first node, spiral at later nodes, petiolate. **Blades** decussate-doubly compound leaflet, dark green above, green underneath, imparipinnate, elliptic-obovate with apex mucronulate, margin entire, attenuate-truncate at the base. **Venation** pinnate, midnerve sunken on the upper surface and raised on the lower surface. **Stipules** absent. **Petioles** green, hairy, 0.5-5.0 cm long, **Rachis** about 4.0 cm long, **Petiolules** green with hairs, 3.0-5.0 mm long.

Branches not yet formed

Odour and sap with a strong tannin smell, sap white.

Eugenia fructicosa (DC.) Roxb. (Myrtaceae)

This description is based on 40 seedlings examined on 2 December 1997 (about 6 months old, 13.5-28.5 cm tall), grown at the FORRU nursery, all seeds collected from the same parent tree, in Doi Suthep-Pui National Park Headquarters, c. 1,050 m above sea level, at 27 May 1997 (CMU Herbarium, Voucher Zangkum s112b2). The seedlings originated from seed sown on 2 June 1997 and germinated on 9 June-25 July 1997, in sunny conditions. Various stages of development are illustrated in Figure 38.

Seedlings: hypogeal, enclosed within a brown fibrous testa **(cryptocotylar).**

Roots: Primary root at the cotyledon stage, cream, about 1 mm in diameter, becoming light brown, fibrous, turning into a straight, tough, tap root in older seedlings; after the 6 node stage, becoming lignified; 3.0-4.0 cm in diameter and about 20.0 cm long, tip white. **Secondary roots**: fibrous, very fine, densely branching, light brown becoming brown with age.

Stems: Hypocotyl: not elongating, yellow. **Epicotyl** 3.0-5.0 cm long, red to maroon, hairless (at first leaf pair stage) by the 5-6 node stage becoming light brown with well-developed lenticels which become more prominent in older seedlings . Younger seedlings have red younger nodes whereas older seedlings have green younger nodes. **Internodes**: first internode about 3.0 cm long, green, circular in cross-section. After 5thnode ; 3.0-5.0 cm long; slightly fluted in cross-section, red, similar to the epicotyl; becoming lignified and less distinct as the node ages. Stems of larger seedlings erect, slender. **Axillary buds** conical, minute, brown, 3 lobed, about 1.0 mm long at the base.

Cotyledons two, opposite, yellow, hemispherical inside, dorsal surface smooth, inner surface convoluted, about 9.0 mm long, 6.0 mm wide, with brown, fibrous seedcoat. **Cotyledonary petiole** not developed. **Venation** indistinct.

Leaves simple spiral up to the 5th node, opposite at higher nodes, petiolate. Blades at 1-5 nodes lanceolate, dark green above, green underneath, acuminate-apiculate apex, margin entire, base attenuate. Blades at higher nodes lanceolate with cirrhose apex, dark green above, green underneath, margin entire, base attenuate. **Venation** pinnate, midnerve sunken on the upper surface and raised on the lower surface. **Stipules** absent. **Petioles** light green, hairless, 1.5 mm diameter, 3.0-6.0 cm long.

Branches not yet formed.

Odour and sap not distinctive.

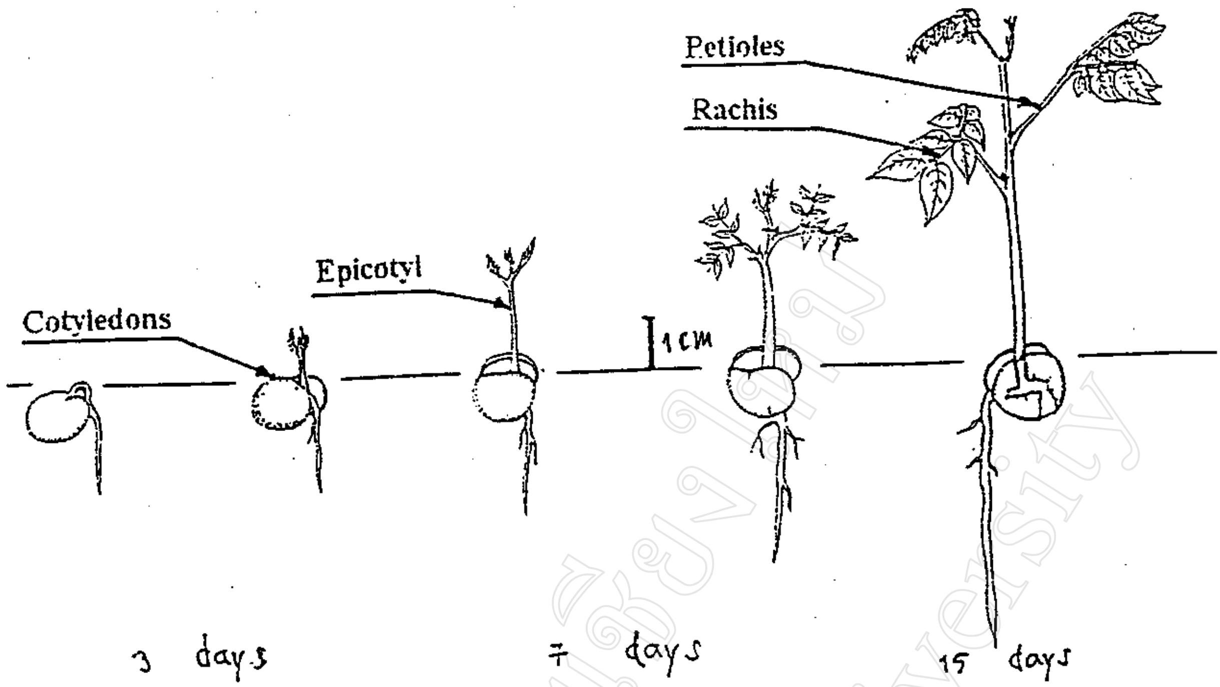


Figure 37. Various stages of *Archidendron clypearia* seedling

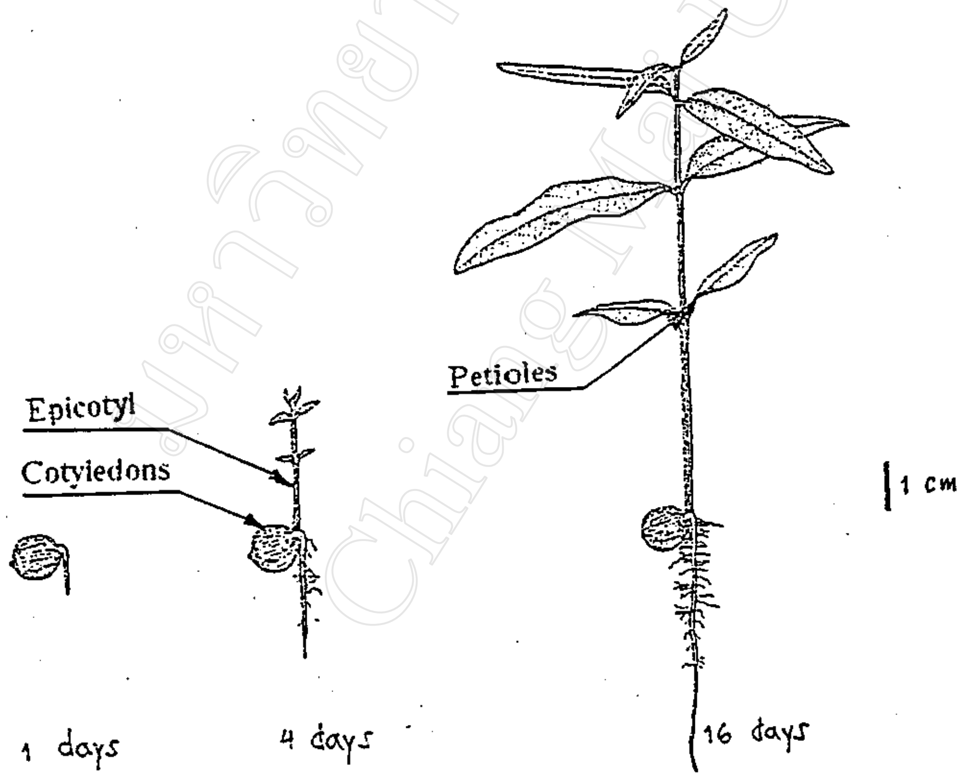


Figure 38. Various stages of *Eugenia fruticosa* seedling

APPENDIX IV: Analysis of Variance

Analysis of Variance on Germination and % Mortality

Table 1. *Spondias axillaris* : Number of germinated seedlings after 3 months

	Block					
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	4	14	23	41	**13.66667**	9.504385
Rex tray + Media	12	21	20	53	**17.66667**	4.932883
Tubecell + Forest soil	18	24	20	62	**20.66667**	3.05505
Tubecell + Media	22	12	23	57	**19**	6.082763
Square + Forest soil	19	18	0	37	**12.33333**	10.69268
Square cell + Media	10	8	21	39	**13**	7
Block Total	85	97	107	289	**96.33333**	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	184.2778	5	36.85556	**0.605955**	4.502674
Block	40.44444	2	20.22222	**0.332481**	
Residual	608.2222	10	60.82222		
Total	832.9444	17	48.99673		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 2. *Micromelum hirsutum* : Number of germinated seedlings after 3 months

	Block					
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	32	26	23	81	**27 AB**	4.582576
Rex tray + Media	24	35	23	82	**27.33333 AB**	6.658328
Tubecell + Forest soil	38	32	30	100	**33.33333 B**	4.163332
Tubecell + Media	28	31	27	86	**28.66667 B**	2.081666
Square + Forest soil	25	11	19	55	**18.33333 A**	7.023769
Square cell + Media	36	39	28	103	**34.33333 B**	5.686241
Block Total	183	174	150	507	**169**	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	491.1667	5	98.23333	**4.087379**	2.830391
Block	97	2	48.5	**2.018031**	
Residual	240.3333	10	24.03333		
Total	828.5	17	48.73529		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 3. *Archidendron clypearia* : Number of germinated seedlings after3 months

	Block					
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	18	20	21	59	**19.66667**	1.527525
Rex tray + Media	23	21	24	68	**22.66667**	1.527525
Tubecell + Forest soil	17	19	10	46	**15.33333**	4.725816
Tubecell + Media	23	15	17	55	**18.33333**	4.163332
Square + Forest soil	20	19	15	54	**18**	2.645751
Square cell + Media	21	27	23	71	**23.66667**	3.05505
Block Total	122	121	110	353	**117.6667**	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	144.9444	5	28.98889	**2.720542**	1.884636
Block	14.77778	2	7.388889	**0.693431**	
Residual	106.5556	10	10.65556		
Total	266.2778	17	15.6634		
			5%	1%	
Critical Value of F Distribution for Treatments			3.33	5.64	
Critical Value of F Distribution for Blocks			4.1	7.56	

Table 4. Eugenia fruticosa : Number of germinated seedlings after3 months

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**		Standard Deviation
Rex tray + Forest soil	21	20	20	61	**20.33333**		0.57735
Rex tray + Media	19	21	27	67	**22.33333**		4.163332
Tubecell + Forest soil	24	15	22	61	**20.33333**		4.725816
Tubecell + Media	25	21	23	69	**23**		2
Square + Forest soil	19	24	18	61	**20.33333**		3.21455
Square cell + Media	26	22	27	75	**25**		2.645751
Block Total	134	123	137	394	**131.3333**		
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error		
Treatment	55.11111	5	11.02222	**1.054198**	1.866865		
Block	18.11111	2	9.055556	**0.8661**			
Residual	104.5556	10	10.45556				
Total	177.7778	17	10.45752				
			5%	1%			
Critical Value of F Distribution for Treatments			3.33	5.64			
Critical Value of F Distribution for Blocks			4.1	7.56			

Table 5. *Spondias axillaris* : % mortality after 3 months

	Block					
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	0	21.43	17.39	38.82	**12.94**	11.38697
Rex tray + Media	16.67	38.09	10	64.76	**21.58667**	14.67625
Tubecell + Forest soil	16.67	8.33	5	30	**10**	6.011564
Tubecell + Media	4.55	58.33	0	62.88	**20.96**	32.44323
Square + Forest soil	5.26	27.78	0	33.04	**11.01333**	14.75662
Square cell + Media	10	5.556	19.05	34.606	**11.53533**	6.876769
Block Total	53.15	159.516	51.44	264.106	**88.03533**	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error	
Treatment	406.2105	5	81.24209	**0.383218**	8.406338	
Block	1277.615	2	638.8076	**3.01325**		
Residual	2119.995	10	211.9995			
Total	3803.821	17	223.7542			
			5%	1%		
Critical Value of F Distribution for Treatments			3.33	5.64		
Critical Value of F Distribution for Blocks			4.1	7.56		

Table 6. *Micromelum hirsutum* : % Mortality after 3 months

	Block					
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	3.125	0	26.09	29.215	**9.738333**	14.2469
Rex tray + Media	12.5	2.86	4.35	19.71	**6.57**	5.189287
Tubecell + Forest soil	15.79	21.88	20	57.67	**19.22333**	3.118402
Tubecell + Media	14.29	16.13	7.41	37.83	**12.61**	4.596346
Square + Forest soil	12	0	5.26	17.26	**5.753333**	6.015192
Square cell + Media	13.89	15.38	28.57	57.84	**19.28**	8.079796
Block Total	71.595	56.25	91.68	219.525	**73.175**	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	536.8135	5	107.3627	**1.733873**	4.543154
Block	105.2312	2	52.61559	**0.849725**	
Residual	619.2075	10	61.92075		
Total	1261.252	17	74.1913		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 7. *Archidendron clypearia* : % Mortality after 3 months

	Block					
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	5.556	20	52.38	77.936	**25.97867**	23.9777
Rex tray + Media	13.04	33.33	41.67	88.04	**29.34667**	14.72479
Tubecell + Forest soil	0	5.26	0	5.26	**1.753333**	3.036862
Tubecell + Media	13.04	13.33	17.65	44.02	**14.67333**	2.581944
Square + Forest soil	25	26.32	20	71.32	**23.77333**	3.333787
Square cell + Media	14.29	14.29	21.74	50.32	**16.77333**	4.30126
Block Total	70.926	112.53	153.44	336.896	**112.2987**	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error	
Treatment	1497.55	5	299.5099	**2.705323**	6.074848	
Block	567.3934	2	283.6967	**2.56249**		
Residual	1107.114	10	110.7114			
Total	3172.056	17	186.5916			
			5%	1%		
Critical Value of F Distribution for Treatments			3.33	5.64		
Critical Value of F Distribution for Blocks			4.1	7.56		

Table 8. *Eugenia fruticosa* : % Mortality after 3 months

	Block					
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standard Deviation
Rex tray + Forest soil	0	0	0	0	**0**	0
Rex tray + Media	5.26	0	0	5.26	**1.753333 A**	3.036862
Tubecell + Forest soil	0	0	0	0	**0**	0
Tubecell + Media	0	0	4.35	4.35	**1.45 A**	2.511474
Square + Forest soil	0	0	0	0	**0**	0
Square cell + Media	11.54	9.09	18.52	39.15	**13.05 B**	4.892985
Block Total	16.8	9.09	22.87	48.76	**16.25333**	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	394.3521	5	78.87042	**12.51039**	1.449643
Block	15.89874	2	7.949372	**1.260926**	
Residual	63.04392	10	6.304392		
Total	473.2948	17	27.84087		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Analysis of Variance on the target seedling characteristics

Table 9. *Micromelum hirsutum* : Height at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	180	145	157.5	482.5	**160.83 AB**	**0.800428**	17.7365
Rex tray + Media	185	200	217.8	602.8	**200.93 C**	1	16.41991
Tubecell + Forest soil	145	143.8	135	423.8	**141.27 A**	**0.703081**	5.460159
Tubecell + Media	167.5	197.5	159.8	524.8	**174.93 BC**	**0.870602**	19.91892
Square + Forest soil	165	165	160	490	**163.33 AB**	**0.81287**	2.886751
Square cell + Media	175	178.8	205	558.8	**186.27 BC**	**0.927039**	16.33442
Block Total	1017.5	1030.1	1035.1	3082.7			

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	6571.043	5	1314.209	**5.165057**	9.209456
Block	27.41778	2	13.70889	**0.053878**	
Residual	2544.422	10	254.4422		
Total	9142.883	17	537.8166		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 10. *Archidendron clypearia* : Height at 6 months old

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	200	185	190	575	**191.6667**	**0.871343**	7.637626
Rex tray + Media	232.5	188.8	185	606.3	**202.1**	**0.918774**	26.39564
Tubecell + Forest soil	152.5	160	165	477.5	**159.1667**	**0.723593**	6.291529
Tubecell + Media	173.75	180	197.5	551.25	**183.75**	**0.835353**	12.31107
Square + Forest soil	212.5	200	162.5	575	**191.6667**	**0.871343**	26.02082
Square cell + Media	246.2	231.2	182.5	659.9	**219.9667**	**0.999998**	33.3026
Block Total	1217.45	1145	1082.5	3444.95	**1148.317**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	6084.587	5	1216.917	**3.085227**	11.46638
Block	1520.375	2	760.1876	**1.927289**	
Residual	3944.336	10	394.4336		
Total	11549.3	17	679.3705		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 11. *Eugenia fruticosa* : Height at 6 months old

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standardiz -ed Value	Standard Deviation
Rex tray + Forest soil	166.25	177.5	175	518.75	**172.9167 A**	**0.757851**	5.90727
Rex tray + Media	222.5	230.8	231.2	684.5	**228.1667 D**	**0.999999**	4.911551
Tubecell + Forest soil	177.5	157.5	181.2	516.2	**172.0667 A**	**0.754126**	12.75003
Tubecell + Media	197.8	203.8	196.2	597.8	**199.2667 BC**	**0.873337**	4.006661
Square + Forest soil	177.5	195	187.5	560	**186.6667 AB**	**0.818114**	8.779711
Square cell + Media	195	210	212.5	617.5	**205.8333 C**	**0.902117**	9.464847
Block Total	1136.55	1174.6	1183.6	3494.75	**1164.917**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	6943.027	5	1388.605	**23.11692**	4.474699
Block	207.9169	2	103.9585	**1.730657**	
Residual	600.6881	10	60.06881		
Total	7751.632	17	455.9784		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 12. *Micromelum hirsutum* : Root Collar Diameter at 6 months old

	Block							
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**		Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	3.2	2.98	3.3	9.48	**3.16**		**0.782178**	0.163707
Rex tray + Media	3.4	3.4	3.38	10.18	**3.393333**		**0.839934**	0.011547
Tubecell + Forest soil	2.95	2.98	3.1	9.03	**3.01**		**0.74505**	0.079373
Tubecell + Media	3.08	3.1	3.28	9.46	**3.153333**		**0.780528**	0.110151
Square + Forest soil	3.25	3.35	3.05	9.65	**3.216667**		**0.796205**	0.152753
Square cell + Media	3.58	5.29	3.25	12.12	**4.04**		**1**	1.095034
Block Total	19.46	21.1	19.36	59.92	**19.97333**			
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error			
Treatment	2.050378	5	0.410076	**1.849335**	0.271871			
Block	0.318178	2	0.159089	**0.71745**				
Residual	2.217422	10	0.221742					
Total	4.585978	17	0.269763					
			5%	1%				
Critical Value of F Distribution for Treatments			3.33	5.64				
Critical Value of F Distribution for Blocks			4.1	7.56				

Table 13. *Archidendron clypearia* : Root Collar Diameter at 6 months old

TREATMENT	Block 1	Block 2	Block 3	Treatment Total	Treatment Mean	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	3.82	4.45	4	12.27	**4.09 ABC**	**0.824597**	0.3245
Rex tray + Media	4.8	5.08	4.6	14.48	**4.826667 BC**	**0.973118**	0.241109
Tubecell + Forest soil	2.7	3.7	3.75	10.15	**3.383333 A**	**0.682124**	0.592312
Tubecell + Media	3.65	3.75	3.75	11.15	**3.716667 A**	**0.749328**	0.057735
Square + Forest soil	3.65	4.7	3.7	12.05	**4.016667 AB**	**0.809812**	0.592312
Square cell + Media	4.85	5.78	4.25	14.88	**4.96 C**	**1**	0.770909
Block Total	23.47	27.46	24.05	74.98	**24.99333**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	5.728378	5	1.145676	**8.324181**	0.21419
Block	1.549144	2	0.774572	**5.627841**	
Residual	1.376322	10	0.137632		
Total	8.653844	17	0.50905		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 14. *Eugenia fruticosa* : Root Collar Diameter at 6 months old

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	1.85	1.85	2.12	5.82	**1.94 AB**	**0.718519**	0.155885
Rex tray + Media	2.28	2.5	2.62	7.4	**2.466667 C**	**0.91358**	0.172434
Tubecell + Forest soil	1.75	1.6	1.8	5.15	**1.716667 A**	**0.635802**	0.104083
Tubecell + Media	1.9	2.08	2.02	6	**2 AB**	**0.740741**	0.091652
Square + Forest soil	2.18	2.4	2.4	6.98	**2.326667 BC**	**0.861728**	0.127017
Square cell + Media	2.45	3.3	2.35	8.1	**2.7 C**	**1**	0.522015
Block Total	12.41	13.73	13.31	39.45	**13.15**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	2.03385	5	0.40677	**7.108878**	0.138106
Block	0.1516	2	0.0758	**1.324712**	
Residual	0.5722	10	0.05722		
Total	2.75765	17	0.162215		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 15. *Micromelum hirsutum* : Root dry weight at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standardiz -ed Value	Standard Deviation
Rex tray + Forest soil	0.142	0.114	0.127	0.383	**0.127667 A**	**0.350415**	0.014012
Rex tray + Media	0.169	0.51	0.414	1.093	**0.364333 B**	1	0.175842
Tubecell + Forest soil	0.104	0.208	0.177	0.489	**0.163 A**	**0.447397**	0.053395
Tubecell + Media	0.1	0.337	0.285	0.722	**0.240667 AB**	**0.660573**	0.124565
Square + Forest soil	0.195	0.196	0.127	0.518	**0.172667 A**	**0.473929**	0.039552
Square cell + Media	0.249	0.272	0.3	0.821	**0.273667 AB**	**0.751151**	0.025541
Block Total	0.959	1.637	1.43	4.026	**1.342**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.114221	5	0.022844	**3.616963**	0.045883
Block	0.040243	2	0.020122	**3.185882**	
Residual	0.063158	10	0.006316		
Total	0.217622	17	0.012801		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 16. *Archidendron clypearia* : Root dry weight at 6 months old

TREATMENT	Block 1	Block 2	Block 3	Treatment Total	Treatment Mean	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.708	0.74	0.533	1.981	**0.660333 ABC**	**0.713103**	0.111429
Rex tray + Media	0.702	0.768	0.551	2.021	**0.673667 BC**	**0.727502**	0.11124
Tubecell + Forest soil	0.261	0.412	0.326	0.999	**0.333 A**	**0.359611**	0.075743
Tubecell + Media	0.505	0.478	0.758	1.741	**0.580333 AB**	**0.62671**	0.154455
Square + Forest soil	0.738	1.01	1.03	2.778	**0.926 C**	1	0.16312
Square cell + Media	1.18	0.89	0.473	2.543	**0.847667 BC**	**0.915407**	0.355396
Block Total	4.094	4.298	3.671	12.063	**4.021**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.656452	5	0.13129	**3.450436**	0.112621
Block	0.034093	2	0.017046	**0.447998**	
Residual	0.380504	10	0.03805		
Total	1.071049	17	0.063003		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 17. *Eugenia fruticosa* : Root dry weight at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.284	0.32	0.38	0.984	**0.328 A**	**0.539181**	0.048497
Rex tray + Media	0.302	0.488	0.486	1.276	**0.425333 A**	**0.699182**	0.106814
Tubecell + Forest soil	0.258	0.239	0.377	0.874	**0.291333 A**	**0.478907**	0.074795
Tubecell + Media	0.17	0.445	0.359	0.974	**0.324667 A**	**0.533702**	0.140678
Square + Forest soil	0.499	0.307	0.381	1.187	**0.395667 A**	**0.650415**	0.096837
Square cell + Media	0.627	0.634	0.564	1.825	**0.608333 B**	**1.000001**	0.038553
Block Total	2.14	2.433	2.547	7.12	**2.373333**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.199837	5	0.039967	**4.684128**	0.053331
Block	0.014694	2	0.007347	**0.861065**	
Residual	0.085325	10	0.008533		
Total	0.299856	17	0.017639		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 18. *Micromelum hirsutum* : Root - Shoot Ratio in weight at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.56	0.34	0.34	1.24	**0.413333 A**	**0.596157**	0.127017
Rex tray + Media	0.27	0.36	0.32	0.95	**0.316667 A**	**0.456733**	0.045092
Tubecell + Forest soil	1.02	0.47	0.59	2.08	**0.693333 AB**	**1.000005**	0.289194
Tubecell + Media	0.59	0.35	0.44	1.38	**0.46 AB**	**0.663465**	0.121244
Square + Forest soil	0.37	0.33	0.43	1.13	**0.376667 A**	**0.543272**	0.050332
Square cell + Media	0.37	0.32	0.17	0.86	**0.286667 A**	**0.413464**	0.104083
Block Total	3.18	2.17	2.29	7.64	**2.546667**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.319711	5	0.063942	**4.040441**	0.07263
Block	0.101478	2	0.050739	**3.206136**	
Residual	0.158256	10	0.015826		
Total	0.579444	17	0.034085		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 19. *Archidendron clypearia* : Root - Shoot Ratio in weight at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.52	0.63	0.57	1.72	**0.573333**	**0.955556**	0.055076
Rex tray + Media	0.41	0.38	0.4	1.19	**0.396667**	**0.661111**	0.015275
Tubecell + Forest soil	0.55	0.56	0.54	1.65	**0.55**	**0.916667**	0.01
Tubecell + Media	0.41	0.47	0.92	1.8	**0.6**	1	0.278747
Square + Forest soil	0.41	0.46	0.53	1.4	**0.466667**	**0.777778**	0.060277
Square cell + Media	0.41	0.36	0.31	1.08	**0.36**	**0.6**	0.05
Block Total	2.71	2.86	3.27	8.84	**2.946667**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.146378	5	0.029276	**1.999848**	0.069854
Block	0.028011	2	0.014006	**0.956736**	
Residual	0.146389	10	0.014639		
Total	0.320778	17	0.018869		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 20. *Eugenia fruticosa* : Root - Shoot Ratio in weight at 6 months old

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.53	0.76	0.85	2.14	**0.713333 AB**	**0.745642**	0.165025
Rex tray + Media	0.44	0.45	0.48	1.37	**0.456667 A**	**0.47735**	0.020817
Tubecell + Forest soil	0.63	0.75	0.72	2.1	**0.7 AB**	**0.731705**	0.06245
Tubecell + Media	0.25	0.49	0.65	1.39	**0.463333 A**	**0.484319**	0.201329
Square + Forest soil	0.73	0.53	0.62	1.88	**0.626667 A**	**0.65505**	0.100167
Square cell + Media	1.2	0.9	0.77	2.87	**0.956667 B**	**0.999997**	0.22053
Block Total	3.78	3.88	4.09	11.75	**3.916667**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	0.519828	5	0.103966	**4.106245**	0.091867
Block	0.008344	2	0.004172	**0.164787**	
Residual	0.253189	10	0.025319		
Total	0.781361	17	0.045962		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 21. *Micromelum hirsutum* : Degree of root spiral'ng at 6 months old

	Block						
TREATMENT	1	2	3	Treatment Total	Treatment Mean	Standardiz -ed Value	Standard Deviation
Rex tray + Forest soil	0.25	0	0.25	0.5	**0.166667 AB**	**0.125**	0.144338
Rex tray + Media	1.4	0.25	0.62	2.27	**0.756667 BC**	**0.567501**	0.587055
Tubecell + Forest soil	0	0	0.25	0.25	**0.083333 A**	**0.0625**	0.144338
Tubecell + Media	0	0.88	0.62	1.5	**0.5 AB**	**0.375001**	0.452106
Square + Forest soil	1.5	1.4	0.75	3.65	**1.216667 C**	**0.912502**	0.407226
Square cell + Media	1.2	1.4	1.4	4	**1.333333 C**	**1.000003**	0.11547
Block Total	4.35	3.93	3.89	12.17	**4.056667**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	4.117694	5	0.823539	**5.42484**	0.224951
Block	0.021644	2	0.010822	**0.071288**	
Residual	1.518089	10	0.151809		
Total	5.657428	17	0.33279		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 22. *Archidendron clypearia* : Degree of root spiraling at 6 months old

TREATMENT	Block 1	Block 2	Block 3	Treatment Total	Treatment Mean	Standardiz-ed Value	Standard Deviation
Rex tray + Forest soil	0.12	0	0.25	0.37	**0.123333 A**	**0.056061**	0.125033
Rex tray + Media	1.2	0.25	0.12	1.57	**0.523333 A**	**0.237879**	0.589604
Tubecell + Forest soil	0	0	1.5	1.5	**0.5 A**	**0.227273**	0.866025
Tubecell + Media	0.62	0.62	1.2	2.44	**0.813333 A**	**0.369697**	0.334863
Square + Forest soil	1.4	2.1	2.1	5.6	**1.866667 B**	**0.848485**	0.404145
Square cell + Media	1.8	2.4	2.4	6.6	**2.2 B**	**1**	0.34641
Block Total	5.14	5.37	7.57	18.08	**6.026667**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	10.41478	5	2.082956	**8.615839**	0.283877
Block	0.599878	2	0.299939	**1.240653**	
Residual	2.417589	10	0.241759		
Total	13.43224	17	0.790132		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

Table 23. *Eugenia fruticosa* : Degree of root spiraling at 6 months old

	Block						
TREATMENT	**1**	**2**	**3**	Treatment Total	**Treatment Mean**	Standardiz -ed Value	Standard Deviation
Rex tray + Forest soil	0.12	0.12	0.38	0.62	**0.206667 A**	**0.070455**	0.150111
Rex tray + Media	1.2	1.1	0.25	2.55	**0.85 B**	**0.289776**	0.522015
Tubecell + Forest soil	0	0	0.38	0.38	**0.126667 A**	**0.043182**	0.219393
Tubecell + Media	1.4	1	1	3.4	**1.133333 B**	**0.386368**	0.23094
Square + Forest soil	2.2	1.62	2.6	6.42	**2.14 C**	**0.729554**	0.492747
Square cell + Media	2.8	3	3	8.8	**2.933333 D**	1	0.11547
Block Total	7.72	6.84	7.61	22.17	**7.39**		

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio	Standard Error
Treatment	18.44318	5	3.688637	**30.02227**	0.202372
Block	0.076633	2	0.038317	**0.311864**	
Residual	1.228633	10	0.122863		
Total	19.74845	17	1.161674		

	5%	1%
Critical Value of F Distribution for Treatments	3.33	5.64
Critical Value of F Distribution for Blocks	4.1	7.56

APPENDIX V: Cost-Benefit Analyses

Cost

1. Containers

REX Tray

Cost	50	Baht/tray
Transportation (Khon Kean-Chiang mai)	2,000	Baht/100 trays
Transportation	20	Baht/tray
Total cost (50 + 20)	70	Baht/tray
One tray has 24 cells : 1 cell	(70/24)	
	2.92	**Baht/seedling**

Tubecell (Conversion Rate : $1 = 40 Baht)

Cost of the tube	105.5	$/2,000 tubes
Cost of the tube	0.053	$/tube
Cost of the stack	127	$/20 trays
Cost of the stack	6.35	$/tray
One tray can carry 98 tubes	(0.053*98)	
	5.19	$/tray
Cost of the stack + tubecells	5.19+6.35	$/98 seedlings
Cost of the stack + tubecell	0.018	$/ seedling
Transportation (USA-Bkk)	328.46	$/2,000tubecells
Transportation (Bkk-Chiang mai)	560	$/2,000tubecells
Total transportation cost	888.5	$/2,000tubecells
One tubecell	(888.5/2000)	
	0.444	$/seedling
Total cost	(0.018 + 0.444)	
	0.462	$/seedling
Convert to Thai currency	**18.48**	**Baht/seedling**

Squarecell

Cost	30	Baht/tray
One tray has 72 cells : 1 cell	(30/72)	
	0.42	**Baht/seedling**

Plastic bag

Cost	28	Baht/Kg
One bag	0.004089	Kg
One plastic bag	**0.135**	**Baht/seedling**

Reusable time

REX Tray	12	seasons
Tubecell	6	seasons
Squarecell	4	seasons
Plastic bag	1	seasons

Container cost/seedlings/season

REX Tray	**0.243**	Baht/seedling/season
Tubecell	**3.08**	Baht/seedling/season
Squarecell	**0.105**	Baht/seedling/season
Plastic bag	**0.135**	Baht/seedling/season

2.Potting Media

Forest soil

Gasolene	500	Baht
Labour 4 people in 2 days : 150 * 8	1200	Baht
	1700	Baht

Volume of soil (1.5*1.5*1.5)/2			1.6875	cubic metres
			1,687,500	cubic centimetres
Forest soil	**1 cm3**	**=**	**0.001**	**Baht**

Media

Coconut husk	(98,400 cm3)	=	70	Baht
Peanut valve	(98,400 cm3)	=	60	Baht
Forest soil	(98,400 cm3)	=	99.12	Baht
Total	(295200 cm3)	=	229.12	Baht
Media	**1 cm3**	**=**	**0.0008**	**Baht**

Volume used

REX Tray	300	cm3
Tubecell	200	cm3
Squarecell	50	cm3
Plastic bag	500	cm3

Potting media cost/seedling/season

REX Tray

Forest soil	0.30	Baht/seedling/season
Media	0.24	Baht/seedling/season

Tubecell

Forest soil	0.20	Baht/seedling/season
Media	0.16	Baht/seedling/season

Squarecell

Forest soil	0.05	Baht/seedling/season
Media	0.04	Baht/seedling/season

Plastic bag

Forest soil	0.50	Baht/seedling/season
Media	0.40	Baht/seedling/season

3. Time Consuming

REX Tray	30	second/unit
Tubecell	10	second/unit
Squarecell	30	second/unit
Plastic bag	20	second/unit

Time consuming/cell

Rex Tray	(1 unit = 24 cells)	1.25	s/ seedling
Tubecell	(1unit = 1 cell)	10	s/ seedling
Squarecell	(1unit = 72 cells)	0.42	s/ seedling
Plastic bag	(1 unit = 1 cell)	20	s/ seedling

4. Labor cost

Labor wages 1 day = 150 Baht,works in 8 hrs. 1hr. = 18.75 Baht

Labor cost for filling containers/seedling

REX Tray	0.0065	Baht/seedling
Tubecell	0.0521	Baht/seedling
Squarecell	0.0022	Baht/seedling

Plastic bag	0.1048	Baht/seedling

Seed collection = 150 /1500 seeds	=	0.1	Baht/Seedling
Pruning time (4second/bag)	=	0.021	Baht/Seedling

Labor cost/seedling/season

REX Tray (0.0065 + 0.1)	0.1065	Baht/seedling/season
Tubecell (0.0521 + 0.1)	0.1521	Baht/seedling/season
Squarecell (0.0022 + 0.1)	0.1022	Baht/seedling/season
Plastic bag (0.1048 + 0.1 + 0.021)	0.2268	Baht/seedling/season

Total cost/seedling/season

Total cost/seedling/season = container cost + potting media cost + labor cost

Treatments	Cost			Total
	Container	Media	Labor	(Cost/seedling/season)
Rex Tray + Forest Soil	0.243	0.30	0.107	**0.65**
Rex Tray + Media	0.243	0.24	0.107	**0.59**
Tubecell + Forest Soil	3.08	0.20	0.152	**3.43**
Tubecell + Media	3.08	0.16	0.152	**3.39**
Squarecell + Forest Soil	0.105	0.05	0.102	**0.26**
Squarecell + Media	0.105	0.04	0.102	**0.25**
Plastic Bag + Forest Soil	0.135	0.5	0.227	**0.86**
Plastic Bag + Media	0.135	0.4	0.227	**0.76**
Total Old Method (S+P) FS	0.24	0.55	0.329	**1.12**
Total Old Method (S+P) M	0.24	0.44	0.329	**1.01**

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