PROPAGATION AND GROWTH OF POTENTIAL FRAMEWORK TREE SPECIES FOR FOREST RESTORATION

SUWAREE SINGPETCH

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

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9 May 2001

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Thesis Title Propagation and Growth of Potential Framework Tree Species for Forest Restoration

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ABSTRACT

One of the current major problems in Thailand is deforestation. Deforestation causes depletion of soil, land, water and biological resources (especially loss of biodiversity). Restoring forests by planting native species can help promote biodiversity. Successful restoration programs largely depend on the availability of good planting stock. Producing high quality planting stock can be achieved by seed germination or by vegetative propagation. However, some species cannot germinate under normal conditions and their seedlings are not high quality for planting stock. So it is necessary to determine optimal seed pre-treatment for germination of framework tree species and determined optimal fertilizer treatments to prepare seedlings grown in nurseries for planting out on deforested sites. This research was conducted at the

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Forest Restoration Research Unit Nursery (FORRU), Doi Sutep-Pui National Park Chiangmai Province. Seeds were collected from 9 species which have previously proved difficult to propagate in the nursery: *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoidae), *Terminalia alata* Hey. ex Roth (Combretaceae), *Bauhinia variegata* L. (Leguminosae, Caesalpinoideae), *Aporusa villosa* (Lindl.) Baill. (Euphorbiaceae), *Macaranga denticulata* (Bl.) M.-A. (Euphorbiaceae), *Rhus chinensis* Mill. (Anacardiaceae), *Ficus abelii* Miq., *Ficus glaberrima* Bl. var. *galberrima* and *Ficus hirta* Vahl var. *roxburghii* (Miq.) King. (Moraceae), Six different pre-sowing treatments were applied to the seeds to increase and accelerate germination (4 levels of temperature and two methods of scarification by hand and concentrated H_2SO_4). For the first 6 species and 5 treatments for all 3 taxa of *Ficus.*, seeds were sown in baskets in a medium of 50% sand and 50 % rice husk. The treatments were replicated in 3 randomized completed blocks. After the seeds had germinated, seedlings were transferred into REX trays with a medium of forest soil and organic matter. Two fertilizer treatments Osmocote (slow release granules) and soluble NPK: 15:15:15 were applied. These treatments were replicated in 2 randomized complete blocks. Morphological characteristics of seedlings such as height, diameter and mortality were measured to monitor performance

Scarification by hand was the best treatment for *Albizia chinensis* and *Bauhinia variegata* seeds increasing percent germination to a maximum of 78% and 62% respectively. Treating the seeds with concentrated sulfuric acid was the best treatment for *Rhus chinensis* raising the percent germination of 68. Soaking seeds in water at 27^{o} C (control) increased germination of *Aporusa villosa* and *Ficus abelii* to 49% and 34%

respectively. Almost all seeds were killed when treated with hot water 80-100 °C and boiling. The optimal fertilizer for *Albizia chinennsis* and *Terminalia alata* was NPK, and the best fertilizer for *Bauhinia variegata, Aporusa villosa,* and *Rhus chinensis* was Osmocote. Height and diameter were monitored every 45 days for species: *Albizia chinensis, Aporusa villosa, Bauhinia variegata* and *Terminalia alata.* RGRs (Relative growth rate) of height and diameter of seedlings were high in the first three months after transfer into REX trays and declined after 6 months.

ชื่อเรื่องวิทยานิพนธ์	การขยายพันธุ์และการเจริญเติบโตของพรรณไม้โครงสร้างที่มีศักยภาพในการฟื้นฟูป่า
ชื่อผู้เขียน	นางสาว สุวารี สิงห์เพ็ชร
วิทยาศาสตรมหาบัณฑิต	สาขาวิชาวิทยาศาสตร์สิ่งแวดล้อม
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บทคัดย่อ

ปัญหาที่สำคัญอย่างหนึ่งของประเทศไทยในปัจจุบันนี้ก็คือปัญหาการตัดไม้ทำลายป่า การตัดไม้ทำลายป่าเป็นสาเหตุทำให้เกิดความเสื่อมโทรมของทรัพยากรดิน น้ำ และ ทรัพยากรชีวภาพ โดยเฉพาะอย่างยิ่งการสูญเสียความหลากหลายทางชีวภาพ การฟื้นฟูป่าโดยการปลูกต้นไม้ที่พบอยู่ในป่า หรือพันธุ์ไม้ท้องถิ่นจะสามารถช่วยส่งเสริมความหลากหลายทางชีวภาพได้ การปลูกป่าจะประสพความสำเร็จได้หากมีการจัดเตรียมต้นกล้า หรือผลิตต้นกล้าให้มีคุณภาพ ซึ่งสามารถเตรียมได้จากการเพาะเมล็ด และการขยายพันธุ์โดยวิธีอื่นเช่นปักชำ อย่างไรก็ตามบางชนิดไม่สามารถงอกภายใต้สภาวะปกติได้ ดังนั้นต้นกล้าจึงไม่มีคุณภาพดีที่จะนำไปปลูก งานวิจัยนี้ได้ทำการศึกษาที่หน่วยวิจัยการฟื้นฟูป่า อุทยานแห่งชาติดอยสุเทพ-ปุย จังหวัดเชียงใหม่ โดยทำการเก็บเมล็ดพันธุ์บนอุทยานแห่งชาติดอยสุเทพ-ปุย 9 ชนิดคือ กางหลวง (*Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoidae), รกฟ้า (*Terminalia alata* Hey. ex Roth) (Combretaceae), เสี้ยวดอกขาว (*Bauhinia variegata* L.), เหมือดโลด (*Aporusa* *villosa* (Lindl.) Baill.) (Euphorbiaceae), ตองแตบ (*Macaranga denticulata* (Bl.) M.-A.), มะเหลี่ยมหิน (*Rhus chinensis* Mill.) (Anacardiaceae), เดื่อ (*Ficus abelii* Miq.), เดื่อไทร (*Ficus glaberrima* Bl. var. *glaberrima*) และ เดื่อขน (*Ficus hirta* Vahl var. *roxburghii* (Miq.) King. (Moraceae). ทำการทดลองด้วยวิธีทดสอบ 6 วิธี เพื่อเร่งการงอกของเมล็ด (ที่ระดับอุณหภูมิต่าง ๆ 4 ระดับ และวิธีทำลายเปลือกเมล็ดด้วยการตัดและกรดกำมะถันเข้มข้น) สำหรับ 6 ชนิดแรก และทำการทดสอบด้วยวิธีทดสอบ 5 วิธี สำหรับเมล็ดพันธุ์ของเดื่อ 3 ชนิด เมล็ดที่ผ่านการทดสอบจะนำไปเพาะในตะกร้าที่ประกอบด้วยขี้เถ้าแกลบ 50% และ ทราย 50% ทำการทดลอง 3 ซ้ำ โดยการสุ่มในบล็อค หลังจากเมล็ดงอก ย้ายต้นกล้าไปปลูกในกระบะเร็กซ์ (REX tray) ซึ่งประกอบด้วยดินป่าและอินทรียสาร การทดลองเกี่ยวกับปุ๋ย ใช้ปุ๋ย 2 ชนิดดังนี้คือ ปุ๋ยละลายช้า (Osmocote) และปุ๋ย ธรรมดา NPK: 15 : 15: 15 ทำการทดสอบสองซ้ำแบบสุ่มในบล็อค ทำการวัดและจดบันทึก ลักษณะทางสัณฐานวิทยาของต้นกล้า

ผลการศึกษาพบว่าการตัดเมล็ดเป็นวิธีที่ดีที่สุดสำหรับ กางหลวง และเสี้ยวดอกขาว จะเพิ่มการงอกของเมล็ดเป็นร้อยละ 78 และ 62 ตามลำดับ การแช่เมล็ดในกรดกำมะถันเข้มข้นดีที่สุดสำหรับเมล็ดของมะเหลี่ยมหิน โดยเพิ่มการงอกของเมล็ดเป็นร้อยละ 68 การแช่เมล็ดในน้ำที่อุณหภูมิ 27 องศาเซียลเซียส เพิ่มการงอกของเหมือดโลด และเดื่อ เป็นร้อยละ 49 และ 34 ตามลำดับ เมล็ดส่วนใหญ่จะตายเมื่อแช่ในน้ำร้อนอุณหภูมิ 80 และ 100 องศาเซียลเซียส การทดสอบเกี่ยวกับปุ๋ย NPK พบว่าเหมาะสมกับการเจริญเติบโตของ กางหลวง รกฟ้า และ Osmocote เหมาะสมกับเหมือดโลด มะเหลี่ยมหิน และ เสี้ยวดอกขาว การศึกษาการเจริญเติบโต วัดทุกๆ 45 วัน พบว่าอัตราการเจริญเติบโตสัมพัทธ์ของ ความสูง และเส้นผ่านศูนย์กลางโคนต้นของต้นกล้าหลังจากที่มีการย้ายมาปลูกในกระบะเร็กซ์ จะสูงในช่วง 3 เดือนแรก แล้วจะลดลงในช่วง 6 เดือนหลัง .

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ABBREVIATION

cm	:	centimeter
m	:	meter
ml	:	milliliter
mm	:	millimeter
T 1	:	Treatment 1 (control 27°C)
T 2	:	Treatment 2 (55 °C)
T 3	:	Treatment 3 (80 °C)
T 4	:	Treatment 4 (100°C)
T 5	:	Treatment 5 (scarification by hand)
T 6	:	Treatment 6 (scarification by H_2SO_4)

มหาวิทยาลัยเชียงใหม่
Chiang Mai University

INTRODUCTION

Forest is most important for the conservation of terrestrial biodiversity. If forests are destroyed, we will loose of huge treasure of biodiversity, which is important for national development. In Thailand, one of the most important causes of biodiversity loss currently is deforestation. The country's forest area has been reduced from 53.3 % in 1961 to 27.9 % in 1986 (Klankamsorn, 1990). This year, forest cover is estimated to be about 15% (Maxwell, 1999). Between 1961-1993, Thailand's forest cover area decreased by an average of 2.73 million rai (0.44 million hectare) per year (OEPP, 1997). In 1994, the rate of deforestation in Thailand remained at 1 million rai (0.16 million hectare) per year (Green World Foundation, 1995). At the present time, official estimates put the forest area at 22.8% or 111,010 km^2 (FAO, 1999).

In Thailand, most of the remaining forest is located in the northern region, especially in Chiang Mai Province. Forest cover in the northern region has been reduced from 60.32% in 1981 to 45.47% in 1991 (Green World Foundation, 1995). In Chiang Mai Province, satellite images (LANDSAT 1& 2) revealed that the forest area was reduced from 86.87% or 17,467 km^2 in 1978 to 15,203 km^2 or 75.61% in 1988 (Pooma, 1991) with a further reduction from 60.32% in 1981 to 45.47% in 1991 (Green World Foundation, 1995). In 1998, forest covered about 14,060 km^2 or 69.93% of Chiang Mai Province. At that time, the rate of forest loss averaged of 35,937 rai (5,796.2 hectares) or 0.28% per year (RFD, 1998).

The main cause of the forest loss, degradation and encroachment are logging, shifting cultivation, tourism promotion, farming, establishment of large scale cash crop monoculture plantations and conflicts between forest policy and national land policy (OEPP, 1997).

Over-logging, both legal and illegal have caused immense forest destruction especially in the North region. The history of legal logging in this region began in 1864, when the Monarchy allowed teak logging concessions to be controlled by the central government. Conflicts between local regimes in the North and the central government increased. For political as well as economic reasons, the central government decided to invest in infrastructure, such as roads, in this region during 1863-1957 (TDRI, 2000). The development of roads led to over-exploitation of forest resources. Illegal logging in this region has also caused the forest destruction. The loggers cut down timber and transported it out of the deep forest by elephant or ox-drawn carts (Tuntiwitttayapitunk, 1992). Illegal logging has been a problem for decades and continues until now. The government could not solve these problems, because the real problem is not the equipment and the loggers, but the system and the corrupt local authorities (Tuntiwitttayapitunk, 1992).

Shifting cultivation is carried out in this region by hilltribes. In the past, hilltribes cleared land for opium cultivation. At present, however, attitudes are changing. They have established large-scale monocultures of cash crops such as cabbage and fruit tree orchards. These are all reasons causing the continual loss of forest. Moreover, during 1987-1995, the bubble economy period led to land speculation in the hills. This caused degradation and encroachment of forest areas. In addition, tourist promotion in the northern region led to the construction of a lot of the tourist facilities such as roads, resorts and hotels. For example, the Mae Rim-Samoeng road was constructed through the northern part of Doi Suthep-Pui National Park (Elliott, 1994). Many buildings and tourist spots were constructed along the roadsides such as Mae Sa Elephant camp (km 10), Mae Sa valley (km 16), and Erawan Resort (km 15). Furthermore, in some areas such as Doi Mae Ookor in Mae Hong Son Province, ecologically harmful exotic plant (*Titonia diversifolia* (Hemsl.) A. Gray (Compositae), Mexican sunflower) is promoted as a main tourist attraction. Consequently, more forest was lost.

Forests provide fundamental ecological resources for life, such as water resources, clean air and soil. Moreover, forests provide products which are important for human beings, such as fuel-wood, medicinal plants, food, chemical substance, fiber, recreation, educational values, genetic resources, etc. Indirect benefits of forests include watershed protection and prevention of soil erosion and flood damage. So forests are essential for human life and other living things.

Deforestation, therefore, reduces the quality of life. Since forest destruction causes depletion of topsoil, especially on steep slopes, which are without vegetation. Consequently, carbon, nitrogen and phosphorus cycles are changed (Vitousek, 1983). Furthermore, converting forested areas to agriculture or orchards also results in soil degradation due to over-use of chemical fertilizers and pesticides. During 1945-1991, the soil erosion caused by deforestation in Asia affected about 298 million hectares

(Green World Foundation, 1994). Also the climate has been changed due to forest loss. Global warming, the so-called "green house effect", is a common concern for every country including Thailand. The data from Meteorological Department showed that annual average temperature in Thailand increased by 0.64°C from 1986 to 1995 (OEPP, 1996), and that total average annual rainfall decreased from 1,541.9 mm in 1986 to 1,427.6 mm in 1993. However, the total average annual rainfall increased to 1,692.2 and 1,686.5 mm in 1994 and 1995 respectively (OEPP, 1996).

Watershed Class I and biosphere reserves have been destroyed by deforestation. Consequently drought, water shortages and flooding have occurred in some areas. Normally, watersheds provide water resources to support the urban areas and watershed areas. Kasem and Permsuk (1978) reported that the Huay Kok Ma watershed yielded about 1.3 million m^3 km^{-2} per year, or 65% of total rainfall (Boonyawatt, 1997). In the dry season, water shortages now occur in some areas of the Mae Sa watershed. Moreover, water quality in Mae Sa stream has deteriorated due to pollution. Chemical fertilizers and pesticides have contaminated the water.

Forests are an important habitat for wildlife. Fragmentation by construction of infrastructure in forest areas causes habitat destruction. Consequently, shortages of habitat and food for wild animals increases competition among species. Therefore, several species are unable to maintain their populations by reproduction and have become locally extirpated. This also causes loss of ecological balance. The overall effect is a loss of biodiversity (Maxwell, 1999).

In order to mitigate the loss of forest area, Thailand has initiated reforestation to increase forest area. In 1985, the national forest policy of Thailand was that 40 % of country should be under forest (Klankamsorn, 1990). The Policy and Prospective Plan for Enhancement and Conservation of National Environmental Quality for the 20 year period from 1997-to 2016 proposed that 50% of the country should be forested. At least 30% is to be designated as conservation forest and 20 % as economic forest (OEPP, 1997). However, most forest restoration project in Thailand were undertaken by establishing plantations of single species such as pine and eucalyptus. So reforestation does not compensate for deforestation, because plantations are low of value for wildlife conservation and watershed protection. In 1993, to celebrate His Majesty King Bhumibol Adulyade's Golden Jubilee a large forest restoration program was launched. The objective of this project was to plant 8,000 km^2 (5 million rai) of deforested land (OEPP, 1995). His Majesty recommended that these projects should plant native tree species (Green World Foundation, 1995). This encouraged a change of the reforestation policy. Native forest trees were recommended in the belief that they can promote biodiversity (Wightman, 1997). Unfortunately the policy could not be implement effectively, since there was a 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 projects between Chiang Mai University and Doi Suthep- Pui National Park, was established in November 1994 to address such gaps in knowledge. FORRU initiated a research program to develop appropriate methods to propagate and plant a wide range of native forest tree species and assess which ones might be useful for forest restoration programs. The approach being developed by FORRU is the "framework species" method of forest restoration, whereby trees species are selected because of their ability to shade out competing weeds and attract wildlife into planted areas. The unit carried out germination tests under different shade levels to determine which species would be able to grow well in the hot, dry, sunny conditions found in deforested gaps. Growth rates of seedlings in a nursery were measured. However, some species could not be easily germinated and their seedlings could not be produced in sufficient quantities for field trials.

Hypothesis

This research was designed to test the hypothesis that different seed pre-treatments can be used to increase seed germination rates and percentages and lead to recommendations for optimum seed pre-treatments. Moreover, different fertilizer can be used to increase growth rates.

Objective

The objective of this research was to determine optimal seed pre-treatments for germination of some framework tree species and to determine optimal fertilizer treatments to prepare seedlings grown in the nursery for planting out on deforested sites.

Educational Advantages

This research will provide knowledge of nursery techniques for propagation of native trees species for forest restoration, especially how to break dormancy and how to choose suitable treatments to increase seed germination of 8 species of forest native tree. This knowledge will help other nurseries produce these and other seedlings of this species.

Site Description

This study was conducted at the Forest Restoration Research Unit Nursery (FORRU) at the headquarters of Doi Sutep -Pui National Park, Thailand (18° 50' N, 98°C 50' E) at about 1050 m elevation in primary evergreen, seasonal, hardwood forest on granite bedrock. The annual rainfall during 1999 and 2000 was about 1,729.3 and 1,498 mm respectively, at the Chang Kian Research Station (about 7 kilometer from the FORRU). The averaged temperature during the dry season (November to April) was 18.5- 21.7 °C . The average temperature for both all years was 15.4°C.

LITERATURE REVIEW

Plantation projects such as timber plantations and industrial forests have been established in Thailand for many years. However, few plantation projects emphasize conservation of biological resources and restoration of forest ecosystems. In 1993, many forest restoration projects were initiated to celebrate the 50th anniversary of His Majesty the King. The private sector, NGO's and the government became involved in forest restoration projects by planting native tree species to restore forest ecosystems and to increase biodiversity and species richness.

Restoring forest by planting native tree species can help promote biodiversity (Wightman, 1997). Successful reforestation programs largely depend on the availability of good seed and planting stock (Josiah and Jones, 1992) and other factors such as the diversity of native tree species. There are two methods to prepare good quality seedlings for planting. The first is by sowing seeds. The second is vegetative propagation *e.g.* cuttings or tissue culture. Most planting programs involve the use of seed for producing planting material (Suangtho, 1983). This method is very popular because of low costs and high availability. Seedling quality is determined by two main factors: *i.e.* the genetic make-up of the parent stock and the seedling's immediate environment (*i.e.* nursery conditions and practices) (World Bank, 1993). To prepare good quality seedlings, it is necessary to know about techniques such as how to increase germination and survival rates.

Boonyasririkul (1964) studied the effects of different treatments on germination and rates of teak seeds. Seven different treatments were used such as soaking seeds in water, in 7.5% and 2.5% citric acid (CH_3COOH), 7.5% and 2.5% sulfuric acid (H_2SO_4) and 7.5% and 2.5% hydrochloric acid (HCl) for 60 minutes. The results showed no significant differences in seed germination among the treatments. Germination percentages were still low: for example in water about 1.33%, in 2.5% sulfuric acid about 2.33% and in 7.5% hydrochloric acid about 5.66%.

Kuntikul (1967) studied the effects of different treatments on germination of *Spondias pinata* (L. f.) Kurz (Anacardiaceae), seeds by soaking them in cold water for different periods. Five different treatments were used such as soaking in cold water for 24, 46, 96 and 168 hours and control. The results show that with 24 hours soaking the percent germination is 10.0%, for 46 hours 12.4%, for 96 hours 3.0%, 108 hours 9.2% and for the control 12.6 % . Soaking, therefore, failed to increase germination.

Puaeleang and Liengsriri (1987) studied the effects of different pre-treatments on *Dalbergia cochinchinensis* Pierre (Leguminosae, Papilionoideae) seed. They tested twelve treatments, such as scarification by sandpaper, scarification by H_2SO_4 for 1, 3, 5, 10, 20 minutes, soaking seeds in water 100 ml for 24 hours, soaking seeds in hot water 50 and 100 ml, soaking seeds and boiling 1, 3, and 5 minutes, and control. Scarification by sandpaper was the most effective treatment, increasing percent germination to about 82-86%. Seeds were killed when treated with hot boiling water.

Hardwick and Elliott (1992) studied the factors affecting germination of tree seeds from seasonal tropical forests in northern Thailand. They experimented with methods to break seed dormancy *e.g.* cleaning, scarification, fire, storage and ripeness and found that the time of germination is strongly influenced by season, but the relative importance of various environmental factors (moisture, temperature, light, *etc.*) in breaking dormancy is unclear. They recommended more detailed research, including a study of germination under natural forest conditions.

Korpachon (1995) studied the effects of heat treatment (60-70°C) on seed germination of some native trees on Doi Sutep. Nine species such as *Acrocarpus franinifolius* Wight ex Arn.(Leguminosae, Caesalpinioideae), *Aphanamixis polystachya* (Wall.) R. Parker (Meliaceae), *Cassia fistula* L. (Leguminosae, Caesalpinioideae), *Craibiodendron stellatum* (Pierre) W.W. Sm., *Dalbergia cultrata* Grah. ex Bth. (Leguminosae, Papilionoideae), *Dalbergia discolor* Grah. ex Bth. (Leguminosae, Papilionoideae), *Delonix regia* (Boj. ex Hk) Rafin. (Leguminosae, Caesalpinioideae), *Peltophorum dasyrhachis* (Miq.) Kurz var. *dasyrharchis* (Leguminosae, Papilionoideae), and *Pterocarpus macrocarpus* Kurz (Leguminosae, Papilionoideae), responded positively to wet heat treatments (in water 60-70°C for 20 minutes). Percent germination increased after treatment. Thirteen species such as *Albizia odoratissima* (L.f.) Bth. (Leguminosae, Mimosoideae), *Amoora SP.* (Meliaceae), *Anneslea fragrans* Wall. (Theaceae), *Baccaurea ramiflora* Lour. (Euphorbiaceae), *Bridelia glauca* Bl. (Euphorbiaceae), *Buchanania latifolia* Roxb. (Anacardiaceae), *Cratoxylum cochinchinensis* (Lour.) Bl. (Guttiferae), *Cephalotaxus griffithii* Hk. f. (Cephalotaxaceae), *Garcinia xanthochymus* Hk. f. ex T. And.

(Guttiferee), *Helicia nilagirica* Bedd. (Proteaceae), *Schima wallichii* (DC.) Korth. (Theaceae), *Streblus asper* Lour. var. *asper* (Moraceae), and *Symplocos hookeri* Cl. (Symplocaceae), responded negatively to dry heat treatments (hot sand 60-70°C for 20 minutes). The percent of germination decreased after treatment.

Boonnarutee *et al.* (1999) studied the effects of different treatments on germination of forest tree seeds after 1 year of storage . Five different treatments were used such as scarification by hand, scarification by conc. H_2SO_4 for 15 minutes, soaking in 98°C water and leaving them to cool for 24 hours and soaking in 30°C water for 24 hours. Scarification by hand was the most suitable treatment, increasing seed germination of 8 species such as *Acacia catechu* (L.f.) Willd. (Leguminosae, Mimosoideae), *Cassia bicapsulerris*, *Cassia fistula* L., *Cassia garrettiana* Craib, *Senna siamea* (Lamk.) Irwin & Barneby, *Senna surattensis* (Burn. f.) Irwin & Barnby (all Leguminosae, Caesalpinioideae), *Dalbergia cocinchinensis* Pierre and *Dalbergia oliveri* Pierre (Leguminosae, Papilionoideae). Scarification by conc. H_2SO_4 was the most suitable treatment for increasing seed germination of *Cassia garrettiana* Craib, *Senna siamea* (both Leguminosae, Caesalpinioideae), and *Dalbergia cultrata* Grah. ex Bth. (Leguminosae, Papilionoideae). Soaking seeds in 98°C water and leaving them cool for 24 hours increased germination of *Delonix regia.*

A viable seed is one capable of germination under suitable conditions (Bradbeer, 1992).

To produce good quality seedlings, the target seedling program should be implemented. The target seedling concept is achievement of specific physiological and morphological seedling characteristics that can be qualitatively linked with reforestation success (Rose *et al.,* 1995). Ritchie (1984) divides seedling quality parameters into two major categories: material attributes (morphological and physiological characteristics) and performance attributes (growth potential) (Wightman, 1997). Morphological characteristics consist of height, stem diameter, root volume, leaf number and area and root weight. Physiological characteristics involve plant water potential, nutrients and cold hardiness.

Nutrients on soil particles or from fertilizer particles must continually replenish nutrients in soil water. Recent results with fertilizer "tagged" with radioactive phosphorus show that plants receiving phosphorus fertilizers also take up more soil phosphorus than plants not receiving fertilizer phosphorus. The explanation lies in the development of more extensive root systems as a result of fertilizer use (Ignatioff and Page, 1958).

Normally seedlings require fertilizer for growth, so fertilizer should be added. Elliott *et al.* (1998) recommended adding about 10 granules (approximately 0.3 g) of slow-release Osmocote fertilizer to the surface of the potting mix in each container every 3 months. Although slow release fertilizers like Osmocote, are more expensive than ordinary fertilizers, they are used in very small quantities and labor costs are reduced because they are applied infrequently.

Seeds and seed structure

The seed is the product of the fertilized ovules. In the gymnosperms is naked and borne on the surface of scales that comprise the cone, whereas in the angiosperms the seed is formed within an ovary. (Bradbeer, 1992). A seed is a reproductive unit which develops from an ovule, usually after fertilization (FAO, 1985). Normally seeds consist of 1) a seed coat, developed from the integument. Sometimes seed the coat divided into two parts such as outer seed coat (testa), and inner seed coat (tegmen); 2) an embryo consisting of a plumule, radical and cotyledons and 3) endosperm food reserve substance used by the seed during germination.

Type of seed

Seeds can be classified into two types recalcitrant seed and orthodox.

1) Recalcitrant seeds have high water content and are intolerant of dehydration (Smith and Berjak, 1995). In order to remain viable seeds must be maintained at high moisture content. There is a problem about how to store recalcitrant seeds especially in tropical regions because most seeds in tropical regions are recalcitrant.

2) Orthodox seeds are desiccation tolerant (Smith and Berjak, 1995) and easily stored dried.

The function of seeds

The seed's function is as a unit of propagation, a means of dispersal and source of genetic variation.

Seed germination

The germination process commences with a sequence of events at the molecular and cellular levels preceding visible growth of the embryo (Bradbeer, 1992). Germination consists of three overlapping processes. Absorption of water, mainly by imbibition, causes swelling of the seed and eventual splitting coat. Enzymatic activity and increased respiration and assimilation rates signal the use of stored food and translocation to growing regions. Finally, cell enlargement and division results in the emergence of the radicle and plumule.

Structure of seedlings

A seedling is a plant which is born from the seed, not from propagation of other parts of the plant. Normally seedlings were consist of a radical, cotyledons, shoot and true leaves (with age).

MATERIALS and EQUIPMENT

Species studied

The following nine potential framework tree species were selected from Doi Sutep-Pui National Park:

Albizia chinensis (Obs.) Merr. (Leguminosae, Mimosoideae)

Aporusa villosa (Lindl.) Baill. (Euphorbiaceae)

Bauhinia variegata L. (Leguminosae, Caesalpinioideae)

Ficus abelii Miq. (Moraceae)

Ficus glaberrima Bl. var. *glaberrima* (Moraceae)

Ficus hirta Vahl var. *roxburghii* (Miq.) King (Moraceae)

Macaranga denticulata (Bl.) M.-A. (Euphorbiaceae)

Rhus chinensis Mill. (Anacardiaceae)

Terminalia alata Hey. ex Roth (Combretaceae)

Albizia chinensis (Obs.) Merr. (Leguminosae, Mimosoideae)

General characteristics

Albizia chinensis (Obs.) Merr. is a medium-sized deciduous forest tree belonging to Leguminosae, Mimosoideae. The tree is distributed throughout tropical and subtropical Asia (Nielsen, 1985). This tree is indigenous to Thailand and is scattered throughout the northern region in the Provinces of Chiang Mai, Phrae, Nan, Lumpang, Phitsanulok; in the northeast in Loei and in the southwest in Kanchanaburi. Its vernacular name in the north is *kang luang*, *san kham* or *san ngoen* and in the northeast it is known as *khang hung* (Nielsen, 1985).

Albizia chinensis (Obs.) Merr. is a pioneer species. It can be found in open, disturbed areas and secondary growth in mixed evergreen + deciduous forest, degraded areas in evergreen and evergreen + pine forest at an elevation between 350-1,450 m (FORRU, 2000).

Mature trees are up to 23 m high with a girth at breast high of up to 52 cm. The bark is light brown when young and becomes dark grey-black and thick and roughly cracked. Branchlets are finely lenticellate. The leaves are compound, spirally arranged, and doubly pinnate. The 9-13 pairs of leaflets are arranged oppositely. The secondary leaflets are arranged oppositely with 17-33 pairs. The leaflet apex is obtuse and the base is truncate to acute. The leaflet segments are green above and light green underneath. The flowers are arranged in spreading panicles of glomerules and are fragrant and cream in color. The central flower of each group is slightly larger than the other ones. Flowering has been observed from April to May. Fruits are flattened pods, dehiscent along 1 valve; mid-green when young becoming light brown when ripe. Pods are 135 mm in length and 21 mm in width. Each pod contains of 9-13 flattened, ovoid and dark brown seeds. Seeds are about 5 mm wide and are dispersed by the wind (FORRU, 2000).

Aporusa villosa (Lindl.) Baill. (Euphorbiaceae)

Aporusa villosa or *mueat lod* in the vernacular, is a medium-size deciduous forest tree distributed across India, Southeast Asia. In Thailand it can be found in Chiang Mai and Mae Hong Son Provinces. Growing in open areas in deciduous dipterocarp-oak and fireprone forest at elevations of not more than 1,200 m (Airy Shaw, 1972). The mature trees are up to 8-10 m high. The bark is brown with deep longitudinal fissures. The leaves are simple with entire margins, 9-18 cm long and 5-8 cm wide, arranged spirally. The leaf blade is green above and light green-yellow underneath (Herbarium database, 1995). The flower is imperfect or unisexual. The inflorescence is umbellate. The staminate inflorescence is longer than the pistillate inflorescence. The flowers boom in January to March. The fruit is a simple, and fleshy oval capsule, yellow-orange in color, 5-7 mm in diameter. The fruits are dispersed by birds, gibbons, *etc.*

Bauhinia variegata L. (Leguminosae, Caesalpinioideae)

Bauhinia variegata is a shrub or medium-size deciduous forest tree native to Malaysia and Southern China (Larsen *et al.* 1984). In Thailand, it has been found in the north in Chiang Mai and Mae Hong Son Provinces and in the southwest in Kanchanaburi (Si Sawat). This species grows in deciduous forest at elevations of 500 to 1,300 m. (Larsen and Vidal, 1984).

The mature trees are up to 15 m high. The bark is grey to black-grey, slightly cracked but mostly smooth. The leaves are simple, two lobed and heart-shape, margin entire. The leaf blade is light green above and lighter green underneath. The leaves are arranged alternately . The trees are leafless during the cold and dry seasons (December to March). The inflorescence is a short white raceme. Flowers bloom in January to February. Fruits are dehiscent pods up to 15 cm long. The unripe pod is green and ripens to black. Seeds are flat, about 10-15 mm in diameter and dispersed by wind.

Ficus abelli Miq. (Moraceae)

Ficus abelli Miq. is a medium-size to large evergreen tree. It can be found in Assam, East Bengal, Mayamar, Indonesia and South China (Corner, 1965). The mature trees are up to 20 m high, with large canopies. The bark is rough and grey in color. The leaves are simple with entire margins. The flowers and fruits are in figs. Figs are about 16 x 14 mm, red purple in color and white hairs. Birds disperse the fruits.

Ficus glberima Bl. var. *glaberrima*. (Moraceae)

Ficus glberrima is a medium-sized to large evergreen forest tree, distributed in north and east India, Mayamar, South China (Yunnan, Kweichou), Hainan, Indochina, Thailand, Sumatra and Java (Corner, 1965). In Thailand it grows mostly in shaded areas in primary evergreen, seasonal and hardwood forest at elevations of 450 to 2,000 m (Herbarium database, 1998).

The mature trees are up to 23 m high with large canopies. The bark is thick and slightly horizontally cracked, the color is grey. The leaves are simple with entire margins and spirally arranged. Each leaf is 12 to 20 cm long and 4 to 8 cm wide. The leaf blade is dark green above and light green underneath. The flowers and fruits are in figs which are about 10 x 8 mm, marron in color. Birds disperse the figs.

Ficus hirta Valh var. *roxburghii* (Miq.) King (Moraceae)

Ficus hirta var. *roxburghii* is a medium-sized evergreen forest tree belonging to the Moraceae, distributed in Mayamar, Indochina, Thailand, Sumatra and Java (Corner, 1965). In Thailand it occurs in open degraded areas, in primary evergreen, seasonal, hardwood forest at elevations of between 1,050 to 1,300 m (Herbarium database, 1997). The mature trees are about 8 m high with a girth breast at high of about 38 cm. The bark is peeling and brown. The leaves are simple and spirally arranged. The leaf shape is narrow obvate, often lobed with a round or cordate base. Leaf size is 15 to 22.5 cm long with long rough hairs. The leaf blade is green above and light green underneath. The flowers and fruits are in figs which are about 7 x 7 mm. The unripe fig is green turning, ripening to yellow -green. Birds disperse the fruits.

Macaranga denticulata (Bl.) M.-A. (Euphorbiaceae)

Macaranga denticulata is a very common and fast-growing species. It is small to medium-size deciduous forest tree, indigenous to the North, South-west and peninsular Thailand, eastern Himalayas to Indo-china, Southern China, peninsular Malaysia, Hainan, Sumatra, and Java (Airy, 1972). The bark is thin and finely roughened, slightly cracked with age. The species grows in open, disturbed areas and secondary growth in bamboo + deciduous, mixed evergreen + deciduous, and evergreen forest at elevations of 525 to 1,370 m. The mature trees are up to 19 m high. The bark is thin, finely roughened and slightly cracked with age. The leaves are simple and spirally arranged. The inflorescence is unisexual. Flowers numerous and yellowish color. The fruits are septicidal, depressed globose 3-lobed capsules. The unripe fruit is green and the ripening is light green-brown. The mean dimensions are 4.4 x 3.5 x 3.1 mm, containing 1 seed per lobe. The mean dimensions of the seed are 2.4 x 2.3 x 2.2 mm. The fruit is dispersed by wind (FORRU, 2000).

Rhus chinensis Mill. (Anacardiaceae)

Rhus chinensis is a medium-size deciduous forest tree belonging to the Anacardiaceae, widely distributed in temperate and subtropical Asia, India, Mayamar, Laos, Cambodia, Vietnam, China, Taiwan, Japan, and Ryukyu Island, Malaise (Sumatra). It is native to Thailand and can be found in the northern region in Chiang Mai, Chiang Rai and Mae Hong Son Provinces; and in the northeastern region in Loei Province (Chayamarit, 1994). It grows in secondary growth, deciduous and evergreen forest at elevations of 900 to 1,000 m. The mature trees are up to 8-10 m in height. The bark is brown and cracked. The leaves are compound and arranged oppositely with of 3-6 pairs leaflets. The leaflet blade is green above and light green underneath. The inflorescence is a large panicle raceme, pale yellow in color. The floret are small about 0.2-0.4 cm. The fruit is a drupe with a diameter of about 0.5 cm. The unripe fruit is white ripening to pink. Birds disperse the fruits.

Terminalia alata Hey. ex Roth (Combretaceae)

Terminalia alata is a large deciduous forest tree belonging to the family Combretaceae. It is distributed in India, Mayanmar and Indo-china (Nanakorn, 1985). In Thailand it can be found in the northern region in Chiang Mai and Chiang Rai Provinces; in the northeastern region in Loei and Khan Kaen Provinces; in the southeastern region in Prachin Buri Province; South-western such as Kanchanaburi; Central such as Bangkok (cultivated). Its vernacular name is *rok faa*.

Terminalia alata grows in deciduous dipterocarp-oak forest, in open disturbed and fire prone areas at elevations between 100 and 1,000 m. The mature trees average 30 m in height with a girth at breast height of about 1 m. The bark is thick rough, greyish-black, deeply crecaked and the inner bark is reddish. The leaves are simple and arranged oppositely. The leaf shape is oblong to ovate–oblong. Leaves are 10-15 cm in length and 5-10 cm in width. The leaf apex is acute or subacute and the base of leaf is obtuse. The surface of leaf is tomentose to glabrous. The leaf blade is green above and light green underneath. These trees loose their leaves during January to April. The young leaves appear with flower buds in June. Flowers are minute in spikes. Fruits are five winged nuts. The unripe fruits are green and the ripe fruits are brown. Fruiting occurs from August to March. Some animals such as squirrels disperse the fruits. They can also be dispersed by wind.

The criteria used to select these species for this project were:

1. Seven of the framework species have selected had very low germination rates or high seedling mortality in previous germination trials at FORRU's research nursery (Table 1.)

Table 1: List of some species which have a problem in FORRU's nursery

Name	Problem in Nursery	Seeds collection date	% germination (sun)	% germination (shade)
Albizia chinensis	% germination low	24 January 1997	3	0
Aporusa villosa	% germination low	May 1995	4	1
Ficus abelii	damping off	13 March 1998	93	36
Ficus glaberrima var. *glaberrima*	damping off	31 January 1998	76	60
Rhus chinensis	% germination low	13 January 1995	3	0
Macranga denticulata	% germination low	18 May 1995	0	0
Terminalia alata	% germination low	10 March 1995	13	13

Source: FORRU 2000

2. Some species have been suggested for plantations such as *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae) because it is very fast-growing (Nguyen *et al.* 1996). Moreover some species such as *Bauhinia variegata* L. (Leguminosae,

Caesalpinioideae) is tolerant of poor soils and percentage of survival in plantations is high. Jackson, (1987) reported that about forty eight percent after planting survived.

3. Some species are suitable for reforestation because they attract birds such as *Aporusa villosa* (Lindl.) Baill. (Euphorbiaceae) and *Ficus*.

4. FORRU has poor data about these particular species, especially on seedling morphology.

Therefore we must study more and collect for the database.

Equipment

REX trays

basket

vernire caliper (mm)

ruler (cm)

hot plate

thermometer

beaker 1000 ml, 500 ml and 100 ml

Erlenmeyer flask

clamp

glass string rod

glass string rod

aluminum pot

Materials

forest soil from Doi Pui

fine sand

peanut valve

coconut husk

rice husk

fertilizer

concentrated sulfuric acid

70% alcohol

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Chiang Mai University

Figure1 . Pre-treatment equipment

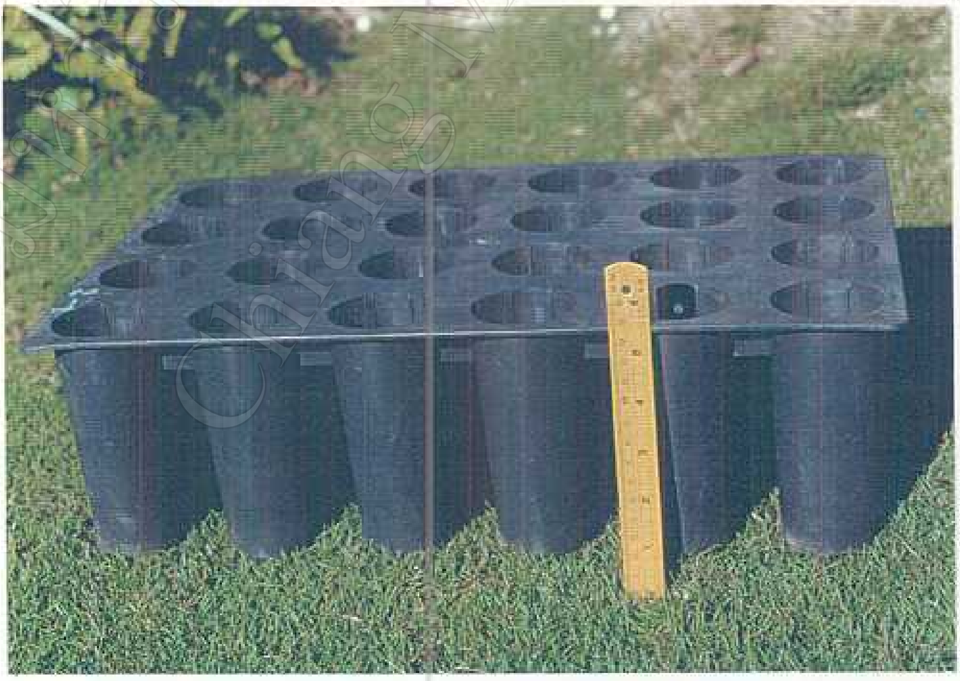

Figure 2. REX tray root-trainer

Figure 3. Organic planting media consisting of peanut valves & coconut husk

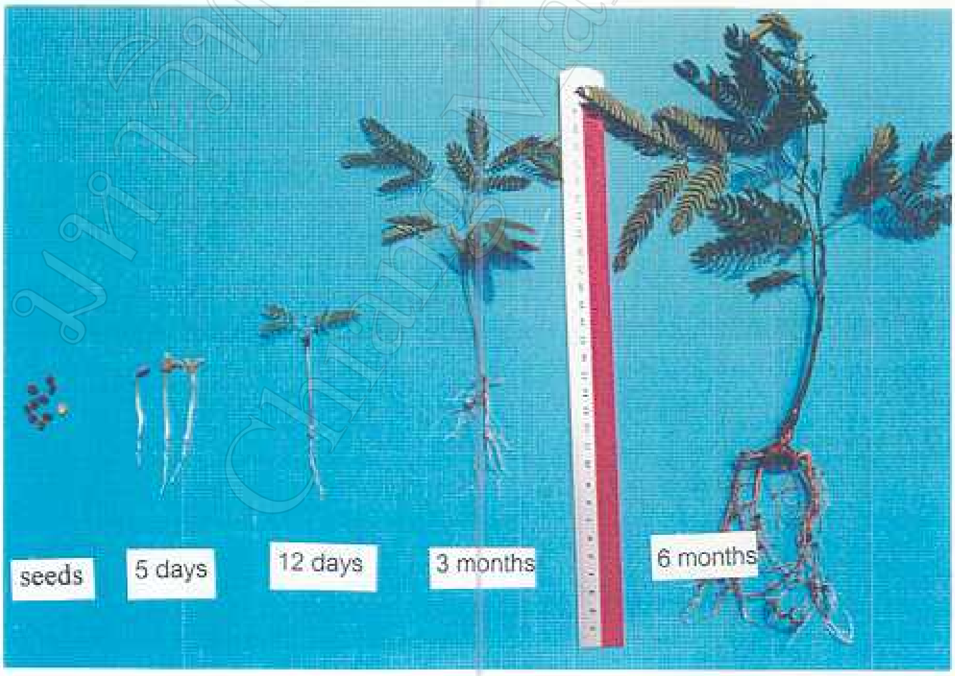

Figure 4. Seeds, germinated seeds, and seedling of *Albizia chinensis*

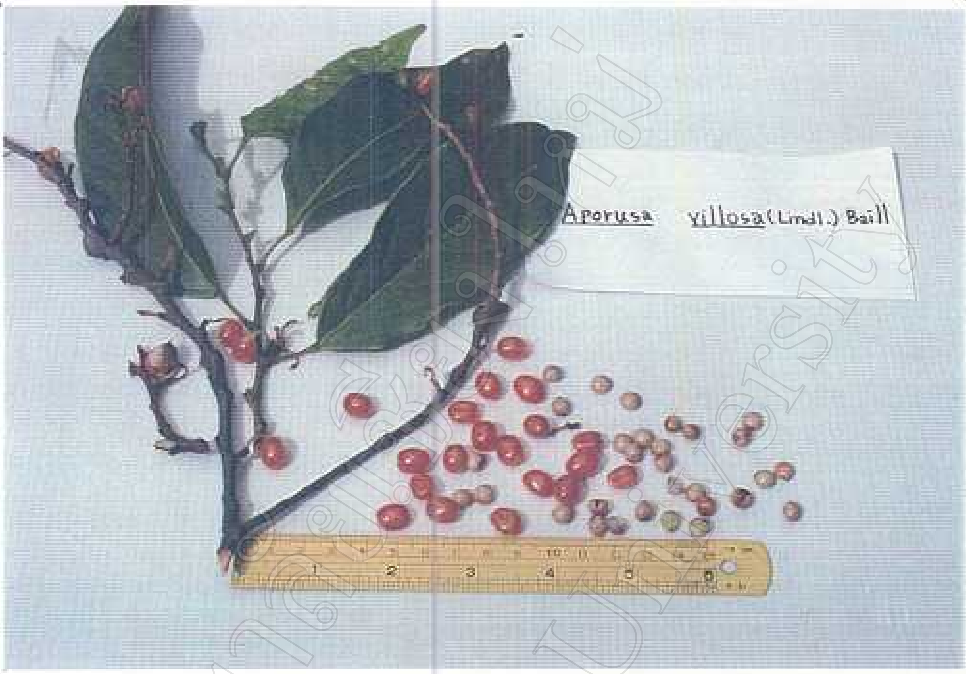

Figure 5. Branch with fruits & seeds of *Aporusa villosa*

Figure 6. Seedlings of *Aporusa villosa* 7 day after germination

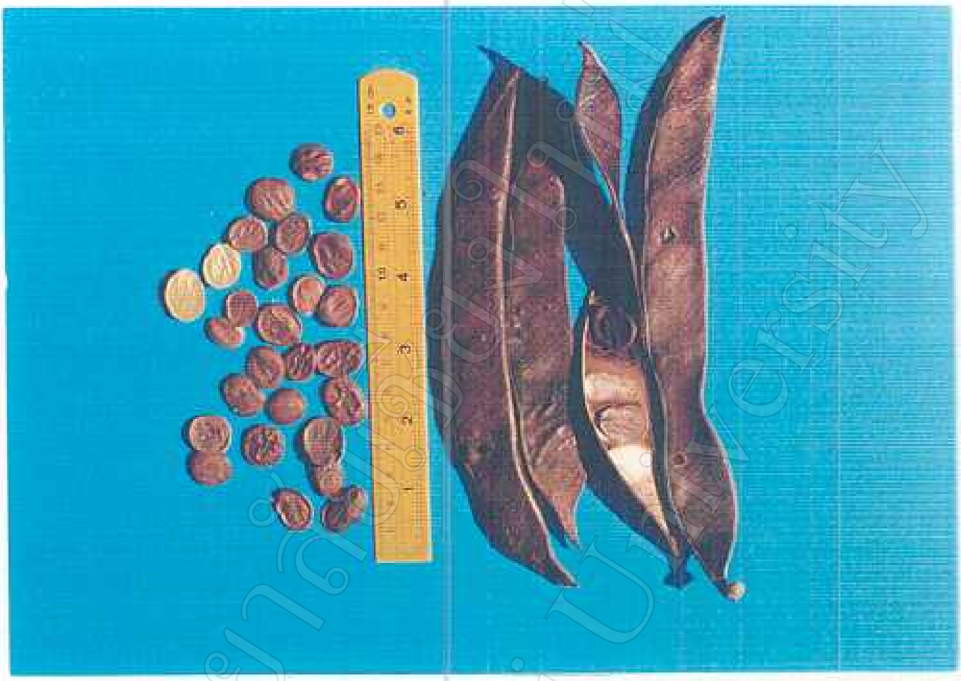

Figure 7. Seeds (left) and pods (right) of *Bauhinia variegata*

Figure 8. Seeds, germinated seeds and seedlings of *Bauhinia variegata*

Chiang Mai University

Figure 9. Branch with figs, cut figs a achenes of *Ficus abelii*

Figure 10. Seedlings of *Ficus abelii* 6 months after germination

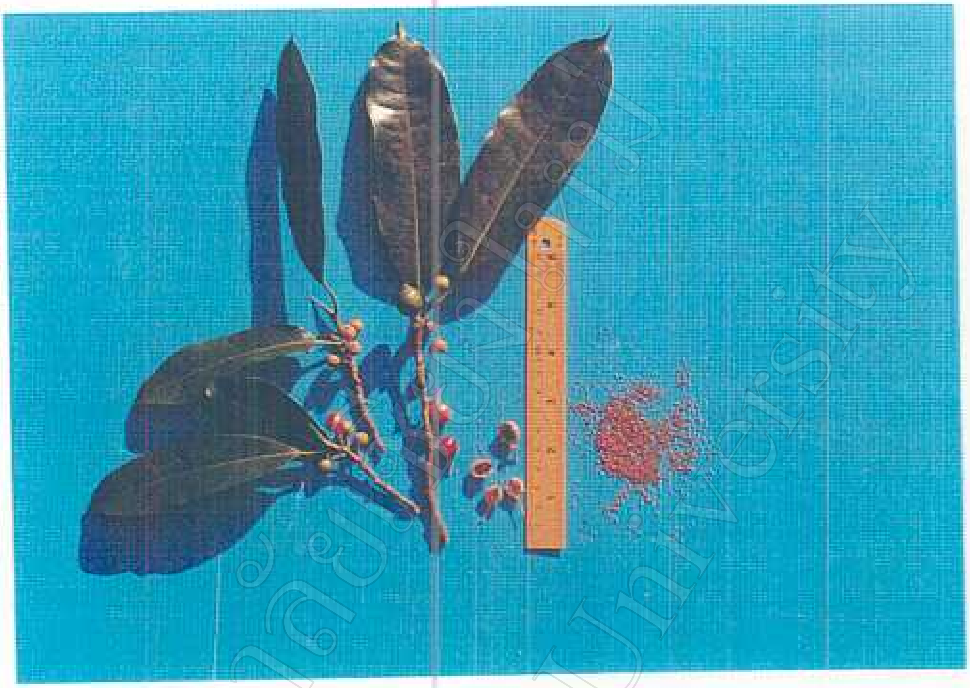

Figure 11. Branch with figs, cut figs and achenes of *Ficus glaberrima*

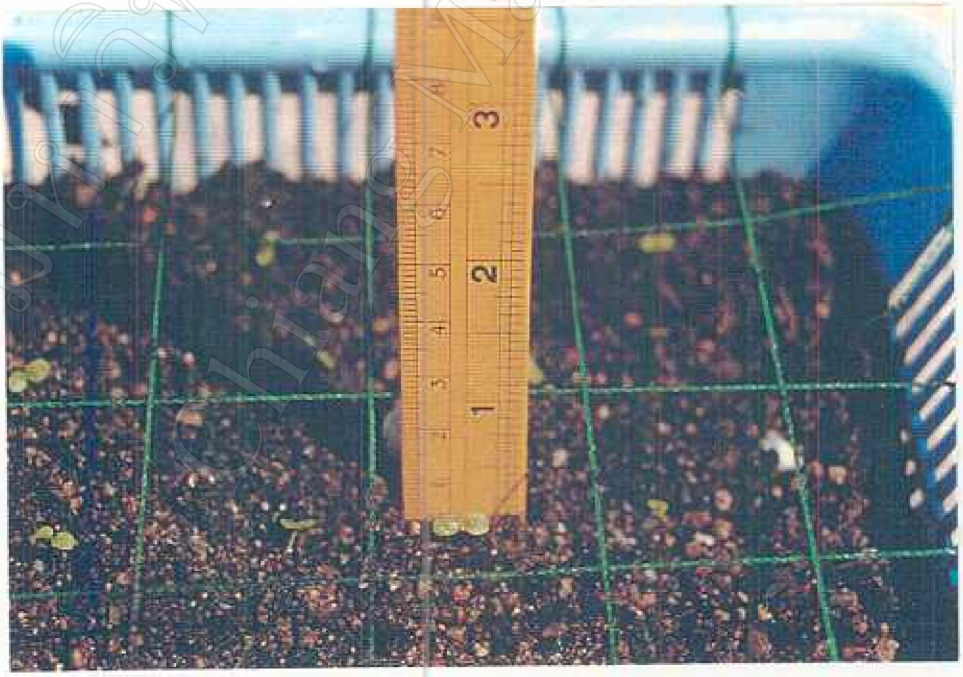

Figure 12. Seedlings of *Ficus glaberrima* 7 days after germination

Figure 13. Synconia of *Ficus hirta* Vahl var. *roxburghii* (Miq.) King

Figure 14. Capsules of *Macaranga denticulata*

Figure 15. Seedlings of *Macaranga denticulata* 5 months after germination

Figure 16. Inflorescence and seeds of *Rhus chinensis*

Figure 17. Seedlings of *Rhus chinensis* 1 month after germination

Figure 18. Nuts of *Terminalia alata*

Figure 19. Seeds, germinated seeds and seedlings *Terminalia alata*

Figure 20. Seedlings of *Bauhinia variegata* (left) and *Terminalia alata* (right) 6 months after germination

METHODS

Experimental Design

For germination, the experimental design was a completely randomized design with six pre-sowing treatments and three replications. The pre-treatments applied to the seeds were a control - room temperature (27°C), for 30 minutes; 55°C for 30 minutes, 80°C for 30 minutes and 100°C for 30 minutes; scarification with scissors hand and scarification by concentrated H_2SO_4 for 5-10 minutes.

For the fertilizer treatments applied to the young seedlings, the experimental design was a completely randomized block design with two treatments and two replications. The two treatments were osmocote fertilizer 0.3 gm/seedling, applied every 3 months, and normal, fertilizer 15:15:15; 1.5 tablespoon of soluble fertilizer in a 3 gallon watering can applied every 15 days.

Seed collection

Seeds of the chosen framework tree species were collected from March to November 2000 in Doi Sutep-Pui National Park, at elevations ranging from 410 to 1,300 m. This elevation range included the main forest types in the national park *i.e.* deciduous dipterocarp-oak forest, mixed deciduous forest, primary evergreen forest and secondary growth along roadsides and disturbed areas (nomenclature according to J. F. Maxwell, 1988). Collection methods differed among the nine framework species selected (Table 2). Some ripe fruits were collected from tall trees using a cutter mounted on a long pole. If parent trees were small enough, they were shaken to dislodge the fruits. Seeds of some species were collected from the ground. Good quality seeds were selected by putting seeds in a can of water for not more than 5 minutes. Damaged seeds floated and good seed sank. Good quality seed was removed from the water and spread out on the paper.

Table 2: List of species studied

Species Studied	Parent tree	Elevation (m)	G B H (cm)	Height (m)	Method of collection	Date of collection	Note
Albizia chinensis	1 2	840 1,050	146 200	10 12	cut branch and from the ground	7 January 2000	
Aporusa villosa	1 2 3	720 740 740	33 52 50	5 7 6	cut branch	16 May 2000	
Bauhinia variegata	1 2	1,300 1,300	110 120	12 13	cut branch and from the ground	4 April 2000	

Table 2: List of species studied (continue)

Species Studied	Parent tree	Elevation (m)	G B H (cm)	Height (m)	Method of collection	Date of collection	Note
Ficus abelii	1	890	49.5	7	cut branch	11 April 2000	
Ficus glaberrima	1	860	306	15	cut branch	29 November 2000	
Ficus hirta var. *roxburghii*	1	1,050	120	8	cut branch	18 September 2000	
Macranga denticulata	1 2	1,050 1,130	60 52	6 10	cut branch	5 August 2000	
Rhus chinensis	1 2 3	1,260 1,260 1,140	26 27 70	5 6 10	cut branch	4 May 1 November 2000	collected twice
Terminalia alata	1 2 3	850 870 410	54 72 135	8 10 12	cut branch and from the ground	4 April 2000	

Pre-sowing seed treatments

Control (ambient temperature). About 300 seed per species were divided into three groups (100 seeds per group). The seeds were maintained for 30 minutes at ambient temperature by putting them in a beaker with water at a temperature of 27°C. After this the seeds were stirred with a glass stirring rod and the temperature was maintained for 30 minutes. Then the seeds were poured on to tissue paper and spread out.

Heat pre-treatments: seeds were treated in the same way as for the control, except that they were maintained in a beaker of water at temperatures of 55°C, 80°C and 100°C for 30 minutes. Scarification by hand: 300 seeds of each species were divided into 3 groups, of 100 seeds per group. Small holes, about 1-2 mm wide, were cut in the seed coats using scissors, on the opposite site from the hilum.

Scarification with acid: seeds were placed in a 500 ml or 1,000 ml flask (depending on seed size) and concentrated H_2SO_4 was poured into the flask. The level of conc. H_2SO_4 covered all the seeds by at least 1-2 mm. Large seeds like *Terminalia alata* were soaked in acid for about 10 minute; but for small seeds, like *Ficus abelii* Miq. 3 minutes was used. Medium-sized seeds like *Macaranga denticulata* were soaked in acid for 5 minutes. After acid treatment, seeds were spread on a sieve and washed with water to remove all traces of acid. The seeds were spread out on paper.

Sowing the Seeds

After the seeds were treated, they were sown in baskets in a medium of 50 % sand and 50% rice husk. Different seeds were sown at different depths according to their sizes. *Albizia chinensis* and *Rhus chinensis* seeds were sown at about 0.5-1 cm depth and *Bauhinia variegata* at about 2.5 cm. For large seeds like *Terminalia alata* seeds were sown at about 2.5 to 3 cm. For small seeds such as *Ficus abelii* and *Ficus hirta*, seeds were sown at about 0.5 cm. Germination baskets were placed in the germination room protected from seed predators on benches in filtered sunlight under a plastic roof. Basket were watered everyday, but if moisture was high, especially in rainy season, watering frequency was reduced.

When the first 1-2 pairs of leaves had expanded, seedlings were transferred into REX trays with a medium of forest soil and organic matter. The ratio of forest soil, rice husk, and peanut valve was 2:1:1. The trays were divided into two fertilizer treatments groups and placed on tables 1.5 meters above ground level. For the Osmocote treatment, about 10 granules of Osmocote were placed on the surface of the potting medium every 3 months.

For the soluble fertilizer treatment, 1.5 tablespoon of soluble fertilizer was dissolved in a gallon watering can and applied to seedlings every 15 days.

Data collection

The pH of the germination medium was measured using litmus paper.

The number of germinated seeds was recorded every week from the sowing date for 4 months and the percent germination and seedling mortality were calculated by these formulae

$$\text{Percent of germination} = \frac{\text{total number of seed germinated}}{\text{number of seed sowing}} \times 100$$

$$\text{Percent mortality} = \frac{\text{number of dead seedlings}}{\text{total number of all seedling}} \times 100$$

The height and root collar diameter of every seedlings were measured every 45 days using vernier calipers. Relative growth rates (RGR) were calculate using the formula:-

$$RGR = \frac{\ln(H_t) - \ln(H_o)}{T_t - T_o} \times 365 \text{ days}$$

Whereas H_t = height or diameter at time t (at the beginning of measurement)

H_o = height or diameter at time o (at the end of measurement)

$T_t - T_o$ = Number of days between the beginning(T_o) and the end(T_t) time of measurement

Data Analysis

Data were analyzed by ANOVA using the SPSS computer program. One-way analysis of variance was used to detect significant differences among treatments because the experimental design was a Randomize Complete Block design. The treatments are allocated at random within blocks. In this experiment the main comparison was among the six treatments.

Figure 21. The germination room at the FORRU nursery

Figure 22. Experiment design was randomized block

RESULTS

Seed Germination

Germination Type

The germination type of 7 species: *Albizia chinensis, Aporusa villosa, Ficus abelii, Ficus glaberrima, Macaranga denticulata, Rhus chinensis and Terminalia alata* was epigeal, because their cotyledons were lifted above the soil surface (Figures 52-53, 55-58). The germination type of *Bauhinia variegata*, was hypogeal where the cotyledons were not lifted above the soil surface (Figure 54).

Albizia chinensis seeds began to germinate between the 1st and 5th weeks after sowing (Figure 23). Seeds germinated rapidly when treated with conc. H_2SO_4 and scarified by hand. The median length of dormancy (MLD) was 7 days. In contrast the MLD of seeds treated with hot water (at 55°C) was 19 days. The germination class was rapid (MLD < 22 days) (Table 3). ANOVA showed significant differences among treatments ($F=0.000$, df 5, $p<0.05$). The percentage germination was highest (81%) when seeds were treated with conc. H_2SO_4. Scarification by hand resulted in germination of 78%, not significantly lower statistically compared with conc. H_2SO_4 ($F=0.000$, df =5, $p < 0.05$). Treating seeds with hot water at 55°C, resulted in a low germination percent (63%). Almost all seeds were killed when treated with hot water at 80 and 100°C.

Moreover, no germination occurred with the control treatment (27°C), although seeds were observed in the germination room for a long time (Appendix II, Table 24).

Aporusa villosa seeds began to germinate from the 1st to the 9th week after sowing (Figure 24). MLD for the 55 °C treatment was 16 days. Scarification by hand and control treatments resulted in a MLD of 32 days. The germination class was intermediate (MLD 22-48 days) for the control and scarification by conc. H_2SO_4 and by hand. For the 55°C treatment, germination was classified as rapid (Table 3). ANOVA showed significant differences among the treatments (F=0.000, df =5, $p < 0.05$). The percent germination for seeds treated with scarification by hand and by conc. H_2SO_4 was 61% and 61.66% respectively. For the control treatment, percent germination was about 49%. The lowest percentage germination was 3.6% with seeds treated with hot water at 55°C. Almost all seeds were killed when treated with hot water at 80°C and boiling (Appendix II, Table 25).

Bauhinia variegata germinated rapidly. Seeds germinated from 2 to 4 weeks after sowing (Figure 25). The MLD was 12 days for the control treatment and 10 days for scarification by hand and the 55°C treatment. Germination was classified as rapid (Table 3). ANOVA showed significant differences among treatments (F=0.000, df =5, $p<0.05$). The percentage germination was lowest with the 55°C treatment (5%). The control treatment had a percent germination of about 67%, but there was no significance difference between the two treatments. Almost all seeds were killed when treated with

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hot water at 80°C, boiling water, and scarification by conc. H_2SO_4. (Appendix II, Table 26).

Ficus abelii, seeds began to germinate 3 to 11 weeks after sowing (Figure 27). The MLD was 32 days for the control treatment and scarification by conc. H_2SO_4 and 40 days for seeds treated with hot water at 55°C. The germination class was intermediate (Table 3). ANOVA showed significant differences among treatments ($F=0.000$, $df=4$, $p<0.05$). Germination was highest (34 %) with the control treatment, whereas treating seeds with hot water at 55°C resulted in the lowest percent germinate (4%). Scarification with conc. H_2SO_4 also resulted in quite low germination (10%). Almost all seeds were killed after treatment with hot or boiling water (80, 100°C) (Appendix II, Table 27).

Ficus glaberrima, seeds began to germinate 5 to 7 weeks after sowing (Figure 28). The MLD was 48 and 34 days for the control and scarification by conc. H_2SO_4 respectively. The germination class was intermediate (Table 3). ANOVA showed significant differences among treatments ($F=0.000$, $df=4$, $p<0.05$). Germination was highest (10 %), when seeds were treated by conc. H_2SO_4. Almost all seeds were killed when treated with hot or boiling water (Appendix II, Table 28).

Macaranga denticulata seeds began to germinate 3 to 7 weeks after sowing (Figure 26). The MLD of seeds treated with scarification by conc. H_2SO_4 was 17 days, less than that of the control seeds control (34 days). The MLD of seeds treated with hot water

(55°C) was 41 days. The germination class was variable according to treatment. The MLD of 17 days was classified as rapid, whilst the MLD's of 34 and 41 days were classified as intermediate (Table 3). ANOVA showed significant differences among treatments (F=0.000, df =5, $p<0.05$). For almost all treatments, percent germination was low. For the control, percent germination was about 5%. Treating seeds with hot water (55°C) resulted in the lowest percent germination 2%. Scarification by hand increased germination to about 13%. Almost all seeds were killed by treatment with hot or boiling water (80, 100°C) and scarification by conc. H_2SO_4 (Appendix II, Table 29).

For *Rhus chinensis* the experiments were carried out twice. In the first experiment, seeds began to germinate 2 to 9 weeks after sowing (Figure 29). Seeds germinated after treatment with 55°C and 80°C water, scarification by hand and conc. H_2SO_4. The MLD's varied among the treatments: 55, 14, 18, and 11 days respectively. The germination class was intermediate for the 55°C treatment. MLD's of 11, 14, 18 days were classified as rapid (Table 3). ANOVA showed significant differences in percent germination among treatments (F=0.000, df =5, $p<0.05$). Scarification by conc. H_2SO_4 increased germination to about 67%, the highest value. Percent germination was lowest (2%) when seeds were treated with hot water 55°C. (Appendix II, Table 30)

In the second experiment, seeds began to germinate in 1 to 6 weeks after sowing (Figure 30). Scarification by hand and conc. H_2SO_4 resulted in MLD' s of about 13 days. Treating seed with 80°C water resulted in a MLD of about 21 days. The longest

MLD was 28 days with 55°C treatment. The germination class was rapid (Table 3). For germination, ANOVA showed significant differences among the treatments (F=0.000, df =5, $p < 0.05$). Percent germination was highest when seeds were treated with conc. H_2SO_4 (68%). Treating seeds with hot water at 55°C resulted in a percent germination about 34%. Percent germination was lowest (3%) when seeds were treated with hot water at 88°C. Scarification by hand resulted in a percent germination of about 14% (Appendix II, Table 31).

Percent germination was highest when seeds were treated with conc. sulfuric acid in both experiments, percent germination were 67% and 63% respectively. Also, when seeds were treated with hot water at 55°C, percent germination was similar in both experiments (36% and 33%) when seeds were treated by scarification by hand, percent germinated was low (13% and 14%) in first and second experiments. Moreover, MLD of both experiments were similar, especially when seeds were treated by conc. sulfuric acid. The MLD of first experiment was 11 days and of the second was 13 days.

The experiment with *Terminalia alata* was carried out twice. In the first experiment, seeds began to germinate 1 to 7 weeks after sowing (Figure 31). The MLD's were very similar among treatments: 31, 24, 28 and 28 days respectively. The germination class was intermediate (Table 3). For germination, ANOVA showed significant differences among treatments (F=0.000, df =5, $p<0.05$). Percent germination was similar, when compared between the control and scarification by conc. H_2SO_4: 32% and 33% respectively. For the 55°C treatment, percent germination was about 27%. Percent germination was lowest with scarification by hand (Appendix II, Table 32).

In the second experiment, seeds germinated more rapidly 1 to 3 weeks after sowing (Figure 32). MLD among treatments was different. The MLD of control treatment was shortest and the MLD of the 55°C treatment and scarification by hand was the same (21 days). MLD was about 10 days when seeds were treated by using conc. H_2SO_4. The germination class was rapid (Table 3). ANOVA showed significant differences among treatments (F=0.000, df =5, $p<0.05$). Percent germination of control was highest (48%). Scarification by hand resulted in lowest germination (22%). Treatment with hot water at 55°C resulted in a percent germination of about 28%. Scarification by conc. H_2SO_4, increased percent germination to about 32% (Appendix II, Table 33).

In both experiments, percent germination of each treatment was similar such as control treatment about 32% and 48% respectively. For the 55°C treatment, percent germination was 16.7% and 28%. Scarification by conc. sulfuric acid resulted in the same percent germination in both experiments. When the MLD of both experiments was compared, especially when seeds were treated by conc. sulfuric acid, MLD was different; 24 and 10 days. Similarly in control treatment, MLD was different between the first experiment and the second experiment, MLD was 28 and 5 days respectively.

Table 3. Median length of dormancy (MLD)

Treatment	*Albizia chinensis*	*Aporusa villosa*	*Bauhinia variegata*	*Ficus abelii*	*Ficus glaberrima*	*Macaranga denticulata*	*Rhus chinensis*	*Rhus chinensis*	*Terminalia alata*	*Terminalia alata*
	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)	MLD (days)
27°C	none	32	12	32	48	34	none	none	28	5
55°C	19	16	10	32	none	41	55	28	28	21
80°C	none	none	none	none	none	none	14	21	none	none
100°C	none	none	none	none	none	none	none	none	none	none
scarification by hand	7	32	10	none	none	17	18	13	31	21
scarification by H_2SO_4	7	25	none	40	34	none	11	13	24	10

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Table 4. Percent germination of *Albizia chinensis* and *Aporusa villosa*

Treatment	*Albizia chinensis*		*Aporusa villrosa*	
	Mean	SD	Mean	SD
27 °C	0.0 A	0.0	49.0 B	28.0
55 °C	63.0 B	4.0	3.7 A	4.6
80 °C	0.0 A	0.0	0.0 A	0.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	78.3 C	3.5	61.7 B	7.0
scarification by H_2SO_4	81.3 C	1.5	61.0 B	12.2

Table 5. Percent germination of *Bauhinia variegata* and *Macaranga denticulata*

Treatment	*Bauhinia variegata*		*Macaranga denticulata*	
	Mean	SD	Mean	SD
27 °C	67.7 B	10.1	5.0 AB	2.0
55 °C	5 A	5	2.0 AB	1.0
80 °C	0.0 A	0.0	0.0 A	0.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	62.0 B	11.0	13.0 C	4.0
scarification by H_2SO_4	0.0 A	0.0	0.0 A	0.0

Table 6. Percent germination of *Rhus chinensis*

Treatment	*Rhus chinensis* (1)		*Rhus chinensis* (2)	
	Mean	SD	Mean	SD
27 °C	0.0 A	0.0	0.0 A	0.0
55 °C	36.7 C	6.1	33.7 C	2.4
80 °C	5.3 AB	2.5	3.3 AB	0.7
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	13.0 B	8.0	14.0 B	2.9
scarification by H_2SO_4	67.0 D	3.6	68.3 D	2.0

Table 7. Percent germination of *Terminalia alata*

Treatment	*Terminalia alata* (1)		*Terminalia alata* (2)	
	Mean	SD	Mean	SD
27 °C	32.7 A	11.4	48.0 C	10.4
55 °C	26.7 C	9.5	28.0 B	11.1
80 °C	0.0 A	0.0	0.0 A	0.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	15.3 B	5.7	22.0 B	6.2
scarification by H_2SO_4	32.0 D	1.0	32.0 BC	1.0

Table 8. Percent germination of *Ficus abelii* and *Ficus glaberrima* var. *glaberrima*

Treatment	*Ficus abelii*		*Ficus glaberrima* var. *glaberrima*	
	Mean	SD	Mean	SD
27 °C	34.3 B	2.1	5.7 B	2.3
55 °C	4.0 A	2.0	0.0 A	0.0
80 °C	0.0 A	0.0	0.0 B	0.0
100 °C	0.0 A	0.0	0.0 B	0.0
scarification by H_2SO_4	10.3 A	1.5	9.7 A	5.7

Table 9. Percent germination of *Ficus hirta* var. *roxburghii*

Treatment	Mean	SD
27 °C	0.0	0.0
55 °C	0.0	0.0
80° C	0.0	0.0
100 °C	0.0	0.0
scarification by H_2SO_4	10.3	1.5

Figure 23. Germination of *Albizia chinensis* (Obs.) Merr.

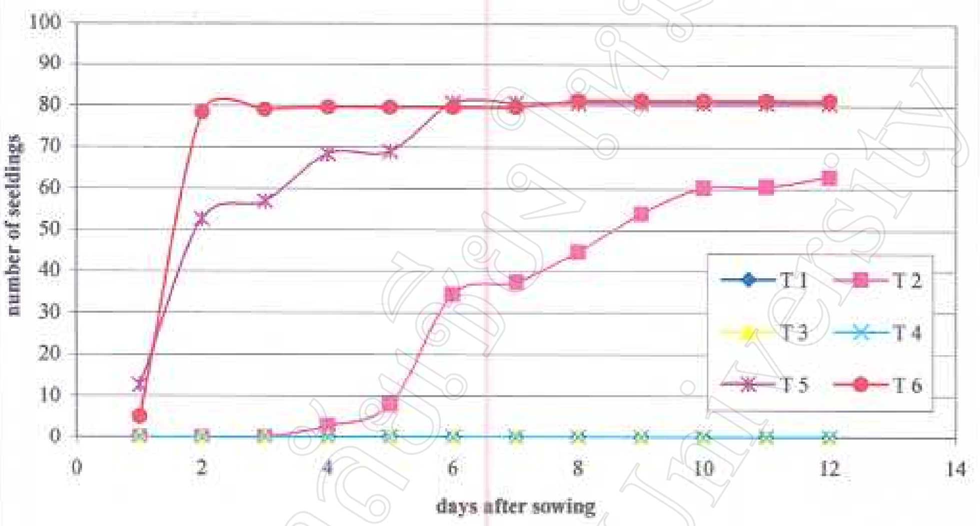
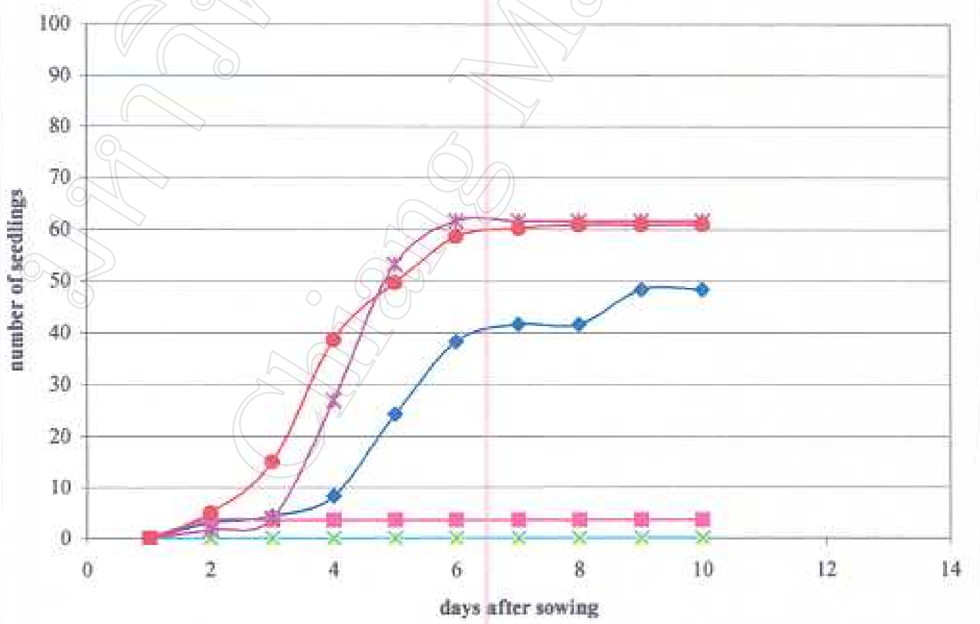
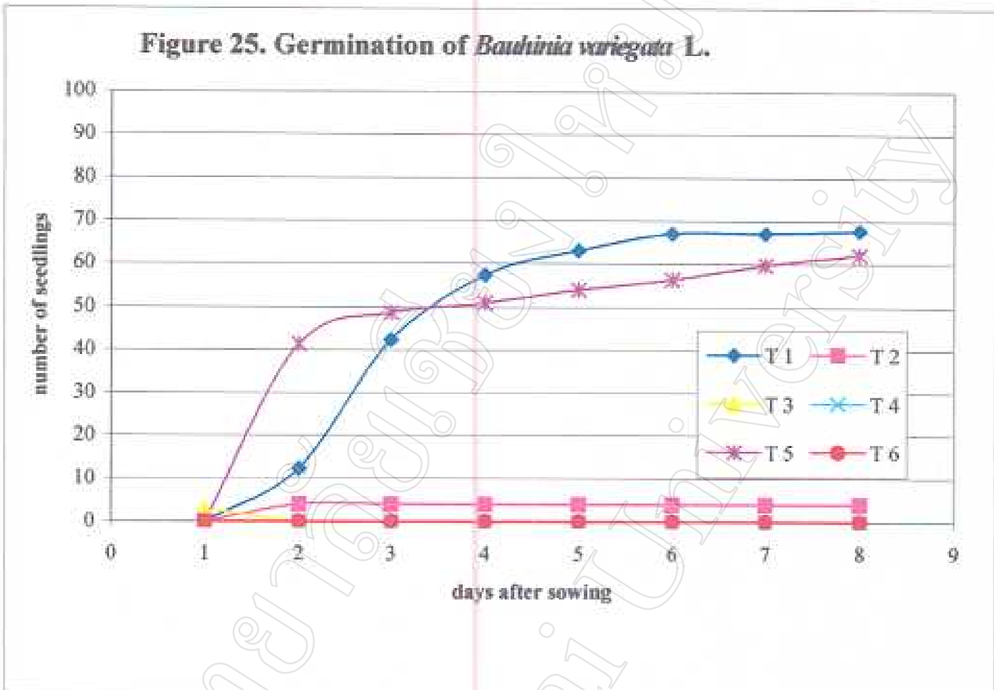
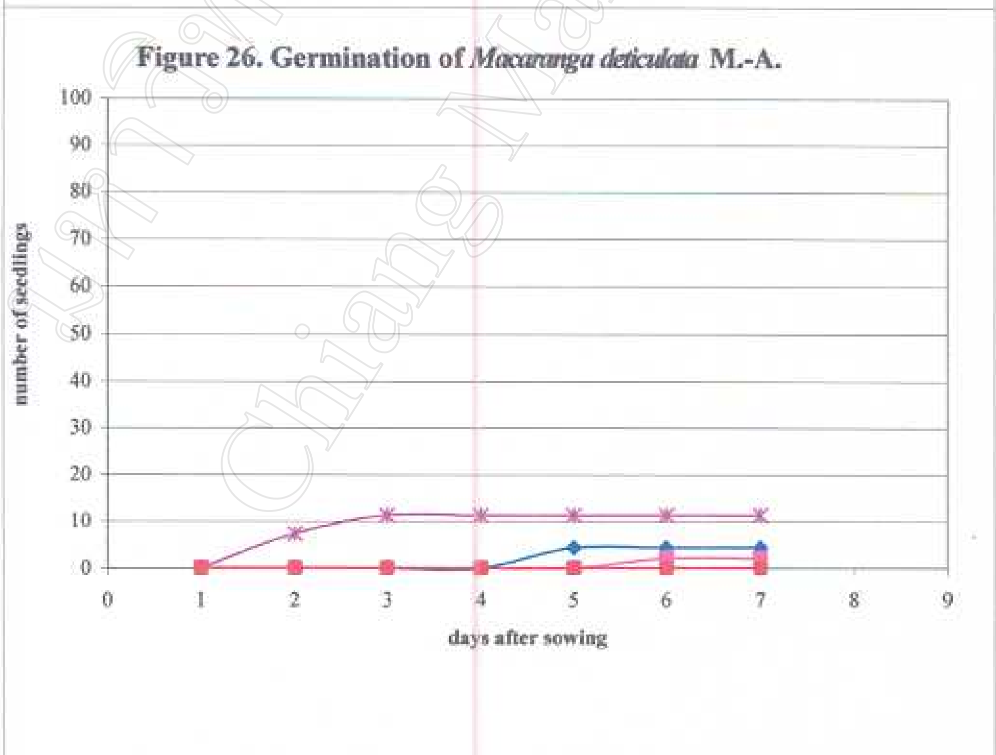


Figure 24. Germination of *Aporusa villosa* (Lindl.) Baill.



T 1 = control treatment, T 2 = 55°C, T 3 = 80°C, T 4 = 100°C, T 5 = scarification by hand, T6 = H_2SO_4





T 1= control treatment, T 2 = 55°C, T 3 = 80°C, T 4 = 100°C, T 5 = scarification by hand, T 6 = H_2SO_4

Figure 27. Germination of *Ficus abelii* Miq.

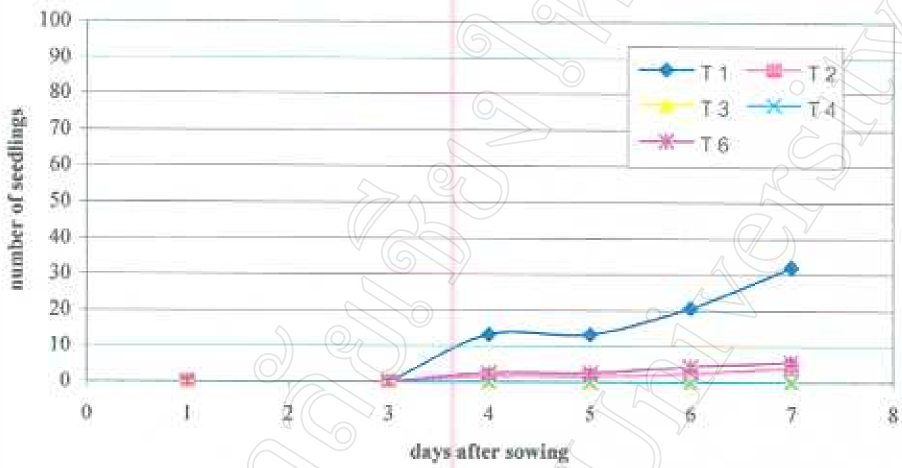
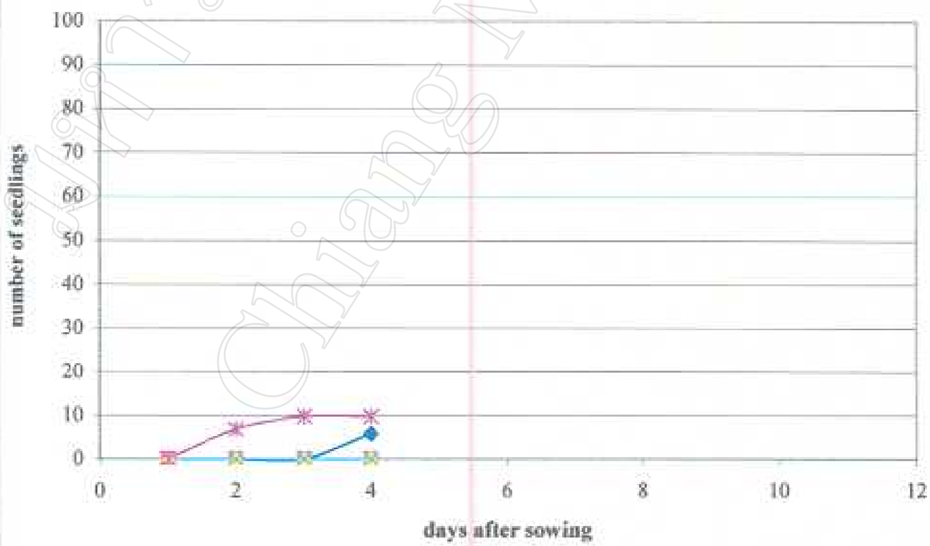


Figure 28.Germination of *Ficus glaberrima* Bl. var.*glaberrima*



T 1 = control treatment, T 2 = 55°C, T 3 = 80°C, T 4 = 100°C, T 5 = scarification by hand, T 6 = H_2SO_4

Figure 29. Germination of *Rhus chinensis* Mill. (1)

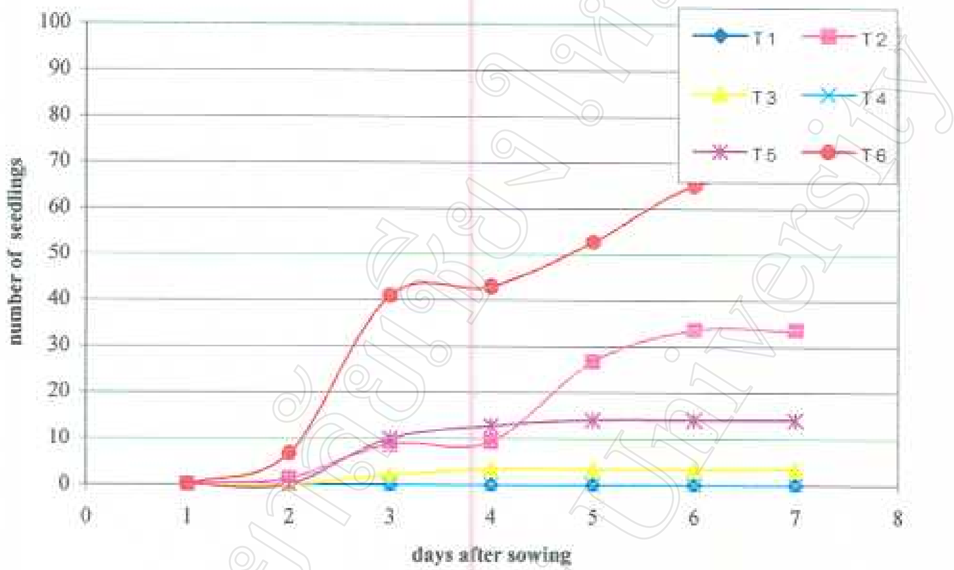
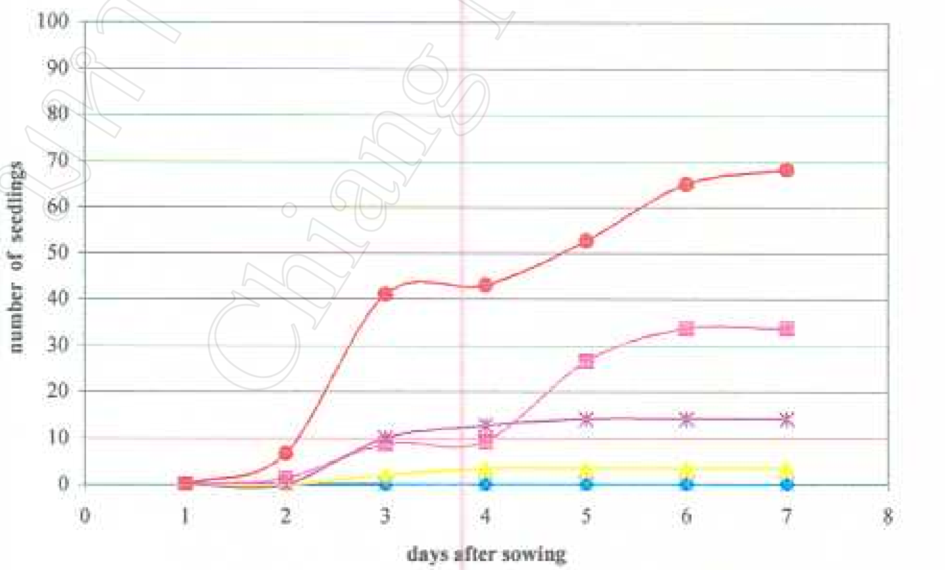


Figure 30. Germination of *Rhus chinensis* Mill. (2)



T 1= control treatment, T 2 = 55°C, T 3 = 80°C, T 4 =100°C, T 5 = scarification by hand, T 6 = H_2SO_4

Figure 31. Germination of *Terminalia alata* Hey. ex Roth (1)

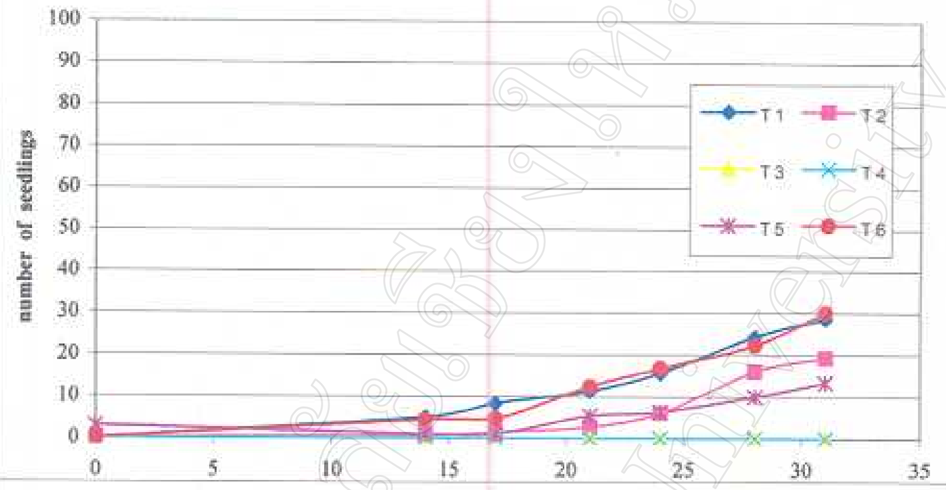
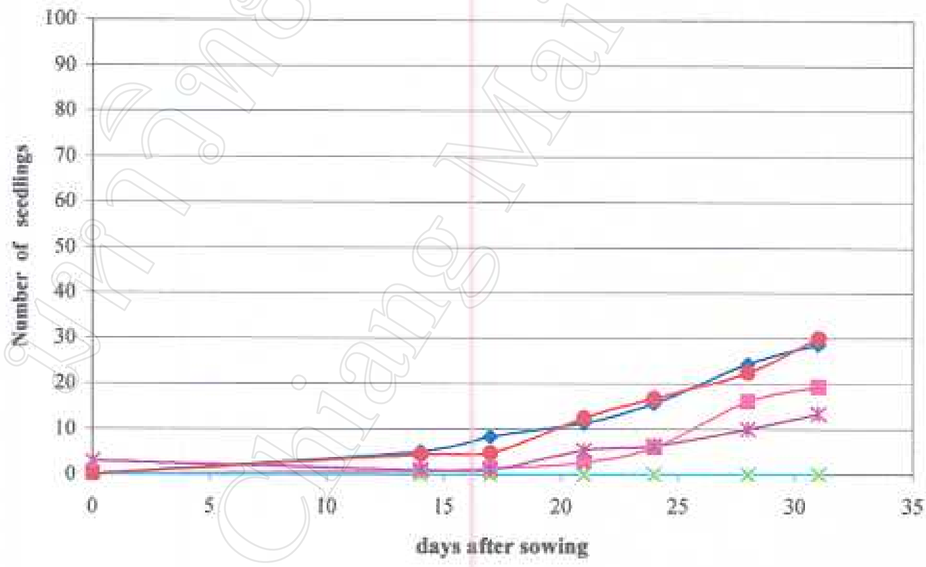


Figure 32. Germination of *Terminalia alata* Hey. ex Roth (2)



T 1 = control treatment, T 2 = 55°C, T 3 = 80°C, T 4 = 100°C, T 5 = scarification by hand, T 6 = H_2SO_4

Mortality in seed germination basket

Percent mortality was compared among treatments by ANOVA during the seed germination period over 3 months. Percent mortality of *Albizia chinensis* varied from 4.4 to 8.6% (Appendix II, Table 34) whereas for *Aporusa villosa* mortality varied from 10.1 to 96.3% (Appendix II, Table 35). Percent mortality was highest when seeds were treated with hot water at 55°C. Similarly for *Bauhinia variegata* (Appendix II, Table 36), percent mortality was highest when seeds were treated with hot water at 55°C. There was no mortality in two species *Ficus glaberrima* and *Macaranga denticulata* (Appendix II, Table 38 and 39). *For Rhus chinensis*, in the first experiments, percent mortality varied from 2.5 to 48.1 (Appendix II, Table 40), and in the second experiment from 0.8 to 16.21 (Appendix II, Table 41). For *Terminalia alata* percent mortalities during both first and second experiments were very similar and not high (Appendix II, Table 42 and 43). For *Ficus abelii*, percent mortality was high when seeds were treated with hot water at 55°C (Appendix II, Table 37).

Table 10. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Albizia chinensis*		*Aporusa villosa*	
	Mean	SD	Mean	SD
27 °C	0.0 A	0.0	15.4 B	13.7
55 °C	8.6 B	5.7	96.3 C	6.4
80 °C	0.0 A	0.0	0.0 A	0.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	4.4 AB	3.3	10.1 AB	9.2
scarification by H_2SO_4	8.2 B	6.9	7.0 AB	5.8

Table 11. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Bauhinia variegata*		*Macaranga denticulata*	
	Mean	SD	Mean	SD
27 °C	7.5 AB	6.4	0.0	0.0
55 °C	20.0 B	20.0	0.0	0.0
80 °C	0.0 A	0.0	0.0	0.0
100 °C	0.0 A	0.0	0.0	0.0
scarification by hand	7.2 AB	5.5	0.0	0.0
scarification by H_2SO_4	0.0 A	0.0	0.0	0.0

Table 12. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Rhus chinensis*(1)		*Rhus chinensis*(2)	
	Mean	SD	Mean	SD
27 °C	0.0 A	0.0	0.0 A	0.0
55 °C	7.1 A	2.2	16.3 AB	7.8
80 °C	48.1 B	16.2	25.0 B	25.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	11.8 A	10.5	7.8 AB	3.0
scarification by H_2SO_4	2.5 A	0.8	3.3 A	3.1

Table 13. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Terminalia alata*(1)		*Terminalia alata*(2)	
	Mean	SD	Mean	Mean
27 °C	6.3 A	9.0	4.0 AB	1.4
55 °C	9.2 B	5.1	7.2 BC	4.6
80 °C	0.0 A	0.0	0.0 A	0.0
100 °C	0.0 A	0.0	0.0 A	0.0
scarification by hand	5.7 A	3.2	13.2 C	5.6
scarification by H_2SO_4	7.2 A	4.5	5.2 AB	3.6

Table 14. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Ficus abelii*		*Ficus glaberrima* var. *glaberrima*	
	Mean	SD	Mean	SD
27 °C	8.8 AB	5.8	0.0	0.0
55 °C	25.0 C	25.0	0.0	0.0
80 °C	0.0 A	0.0	0.0	0.0
100 °C	0.0 A	0.0	0.0	0.0
scarification by H_2SO_4	13.1 B	6.1	0.0	0.0

Table 15. Percent mortality of seedlings in seed germination baskets from germination to age 3 months

Treatment	*Ficus hirta* var. *roxburghii*	
	Mean	SD
27 °C	0.0	0.0
55 °C	0.0	0.0
80 °C	0.0	0.0
100 °C	0.0	0.0
scarification by H_2SO_4	0.0	0.0

Relative Growth Rate (RGR)

RGR's were calculated for height and root collar diameter of seedlings, which survived for six months of 5 species: *Albizia chinensis, Aporusa villosa, Bauhinia variegata, Rhus chinensis* and *Terminalia alata.* RGR's of *Albizia chinensis* (Figures 33-38) both for height and diameter were similar among treatments. RGR were highest in 6 weeks (August). For *Aporusa villosa* (Figures 39-41) and *Bauhinia variegata* (Figures 42-45) the pattern of RGR was the same as *Albizia chinensis.* RGR was high in 6 weeks (August). For *Terminalia alata* (Figures 46-51) height and diameter were high in the first 3 months (August-October).

The effects of the different fertilizer treatments

The effects of the different fertilizer treatments were determined by ANOVA over 6 months. For *Albizia chinensis,* ANOVA showed no significant differences among fertilizer treatments with seedling grown from the $55^{\circ}C$ treatment, scarification by hand, and scarification by conc. sulfuric acid ($F = 0.689, 0.69, 0.149$, $df = 1$, $p < 0.05$) but significant differences among blocks ($F = 0.038, 0.015, 0.046$, $df = 1$, $p < 0.05$) (Appendix II, Table 44-46). Average heights seedlings from both fertilizer treatments were similar, for seedlings grown from seeds treated at $55^{\circ}C$: 8.5 cm for seedlings treated with Osmocote and 9.3 cm for seedling treated with NPK. For scarification by hand, average heights were 9.3 cm (Osmocote) and 10.3 cm (NPK). Seedlings grown from seeds were treated by conc. sulfuric acid had average heights of 9.7 cm (Osmocote) and 11 cm (NPK) (Table 16).

For *Aporusa villosa,* ANOVA showed no significant differences among fertilizer treatments ($F = 0.557, 0.188, df = 1, p< 0.05$) and no significant differences between blocks ($F = 0.427, 0.527, df = 1, p< 0.05$) (Appendix II, Table 47-48). Average heights after 6 months were sufficient for planting. Moreover, average height did not different significantly seedling grown from different seed treatments. For example average height of seedlings derived from seeds treated with osmocote was 4.6 cm and with NPK about 5.1 cm (Table 16).

For *Bauhinia variegata,* the fastest growing species, ANOVA showed no significant differences among fertilizer treatments, in seedlings grown from the control and scarification by hand ($F = 0.846, 0.259, df = 1, p< 0.05$), but significant differences among blocks in seedlings grown the control ($F = 0.03, df = 1, p< 0.05$) (Appendix II, Table 49-50). Average height at 6 months was 31.3 cm (Osmocote) and 35.1 cm with seedlings were treated by NPK. Similarly seedlings grown from seeds scarified by hand, average 32.5 cm tall (Osmocote) and 34.4 cm (NPK). Averaged heights at 10 months were 41.3 cm (Osmocote) and 40.9 (NPK) (Table 16).

For *Rhus chinensis,* ANOVA showed no significant differences among fertilizer treatments and among blocks for seedlings grown from the 55°C treatments and scarification by conc. sulfuric acid ($F = 0.281, 0.641, df = 1, p< 0.05$) and ($F = 0.186, 0.241, df = 1, p< 0.05$) respectively (Appendix II, Table 51-52). Average height at 6 weeks was 7.2 cm (Osmocote) and 4.6 cm (NPK) with seedling grown form 55 °C and 5.6 cm (Osmocote) and 5.2 cm (NPK) for seedlings with grown form scarification by conc. sulfuric acid (Table 16).

For *Terminalia alata,* ANOVA showed no significant differences among fertilizer treatments and among blocks for seedlings grown from the control, 55°C treatment, scarification by hand and by conc. sulfuric acid ($F = 0.14, 0.767, df = 1, p< 0.05$) and ($F = 0.14, 0.099, df = 1, p< 0.05$) respectively (Appendix II, Table 53-56). Moreover, ANOVA showed no significant differences among blocks but significant differences among fertilizer treatments ($F = 0.808, df = 1, p< 0.05$) and ($F = 0.018$ $df = 1, p< 0.05$) (Appendix II, Table 54). respectively. Average heights at 6 months were not significantly different among seedlings grown from different seeds treatments. Most of them were between 6.2 cm to 13.1 cm (Table 16).

Mortality of seedlings during the fertilizer treatments

Percent mortality was determined after transfer of seedlings into REX trays for 6 months. Percent mortality of seedlings of *Albizia chinensis* varied from 8.3 to 45.8%. Percent mortality was high (45.8%) in seedlings grown from seed scarified by hand, especially under sunny conditions, but percent mortality was low under shaded conditions (8.3%). Percent mortalities of other treatments of this species were similar, indicating that this species grows well under shaded conditions. For *Aporusa villosa,* mortality varied from 4.16 to 33.33%. *Bauhinia variegata* grew well under both sunny and shaded conditions, percent mortality was zero. For *Terminalia alata*, percent mortality varied from 41.66 to 75%. Also for *Rhus chinensis,* percent mortality varied from 12.5 to 33 percent. The factors causing seedlings mortality were not clear, because seedlings died at different times.

Table 16. Average height of *Albizia chinensis, Aporusa villosa, Bauhinia variegata, Rhus chinensis, Terminalia alata*

Treatment		*Albizia chinensis* (at 6 months)	*Aporusa villosa* (at 6 months)	*Bauhinia variegata* (at 6 months)	*Bauhinia variegata* (at 10 months)	*Rhus chinensis* (at 6 weeks)	*Terminalia alata* (at 6 months)
27 °C	Osmocote	none	3.9	31.3	none	none	none
	NPK	none	4.1	35.1	none	none	none
55 °C	Osmocote	8.5	none	none	none	7.2	12.8
	NPK	9.3	none	none	none	4.6	13.1
scarification by hand	Osmocote	9.3	4.6	32.5	41.3	none	6.2
	NPK	10.3	5.1	34.4	40.9	none	10.3
scarification by H_2SO_4	Osmocote	9.7	5.1	none	none	5.6	9.7
	NPK	11	4.9	none	none	5.2	11

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Table17. Percent mortality of seedlings in fertilizer treatment during 6 months

Treatment	*Albizia chinensis*		*Aporusa villosa*	
	Osmocote (%)	NPK (%)	Osmocote (%)	NPK (%)
27 °C	none	none	20.8	33.3
55 °C	37.5	12.5	none	none
80 °C	none	none	none	none
100 °C	none	none	none	none
scarification by hand	48.5	8.3	20.8	16.7
scarification by H_2SO_4	25.0	12.5	20.8	4.1

Table 18. Percent mortality of seedling in fetilizer treatment during 6 months

Treatment	*Bauhinia variegata*		*Rhus chinensis*	
	Osmocote (%)	NPK (%)	Osmocote (%)	NPK (%)
27 °C	0	0	none	none
55 °C	none	none	none	none
80 °C	none	none	none	none
100 °C	none	none	none	none
scarification by hand	0	0	none	none
scarification by H_2SO_4	none	none	33	12.5

Table 19. Percent mortality of seedling in fertilizer treatment during 6 months

Treatment	*Terminalia alata*	
	Osmocote (%)	NPK (%)
27 °C	41.7	66.7
55 °C	58.3	62.4
80 °C	none	none
100 °C	none	none
scarification by hand	73.7	57.9
scarification by H_2SO_4	75.0	58.3

RGR for height

Figure 33. ***Albizia chinensis*** **treatment at 55°C**

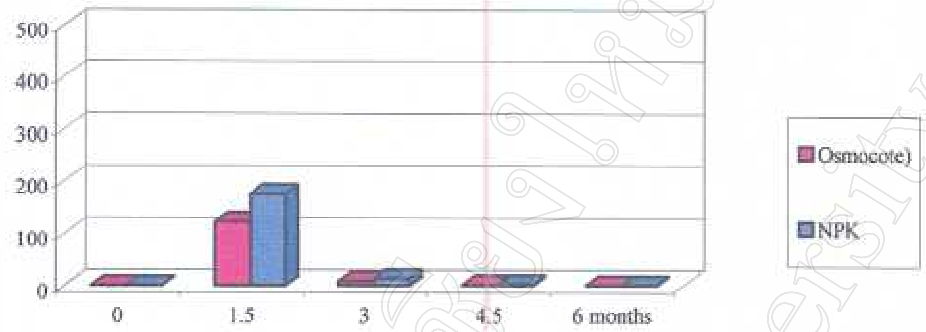


Figure 34. ***Albizia chinensis*** **scarification by hand**

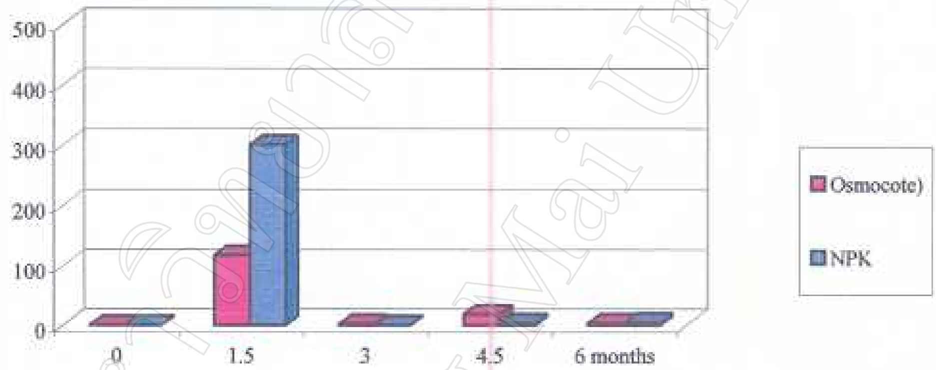
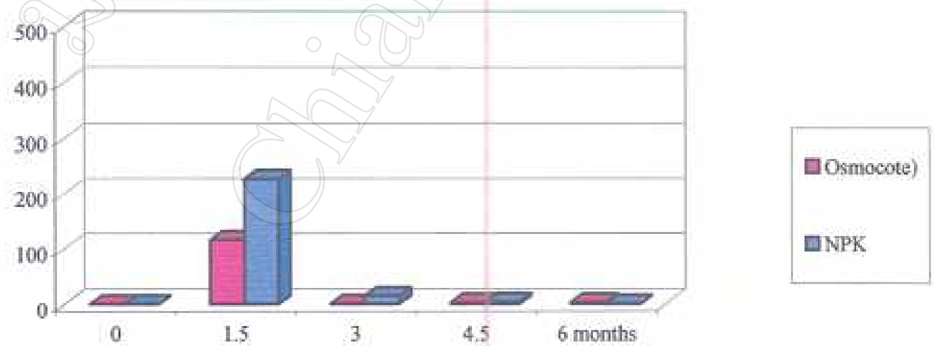


Figure 35. ***Albizia chinensis*** **scarification by H_2SO_4**



RGR for diameter

Figure 36. ***Albizia chinensis*** **treatment at 55°C**

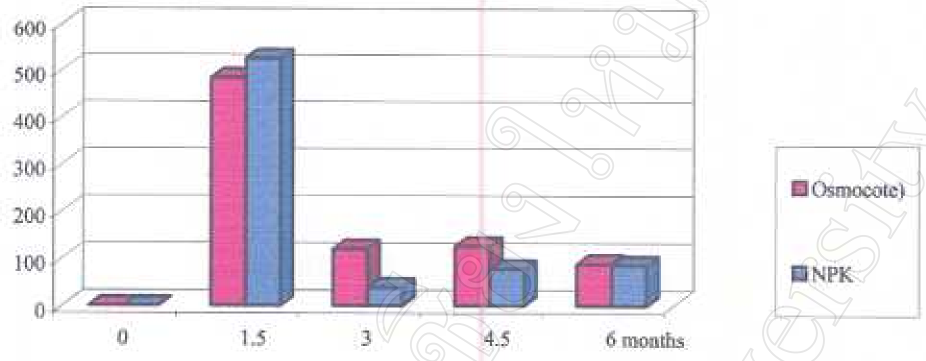


Figure 37. ***Albizia chinensis*** **scarification by hand**

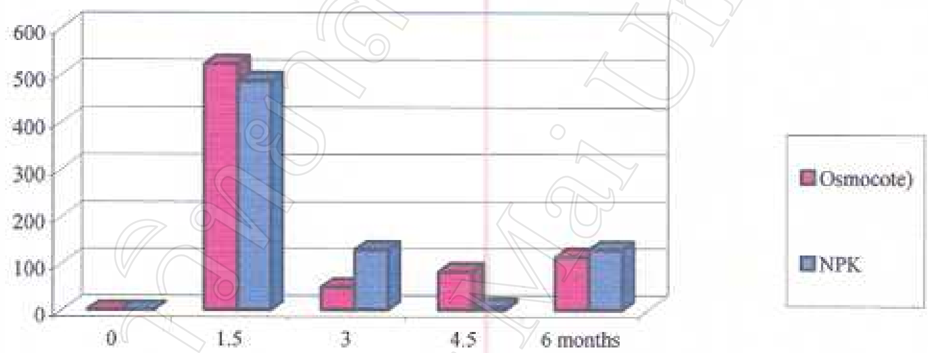
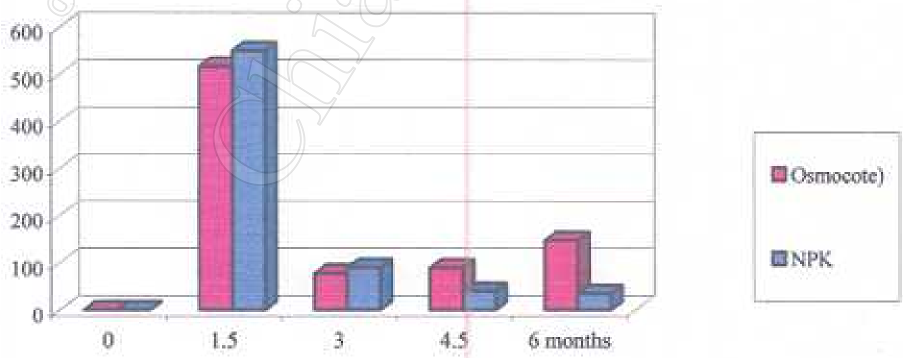


Figure 38. ***Albizia chinensis*** **scarification by H_2SO_4**



RGR for height

Figure 39. ***Aporusa villosa*** **control (27°C)**

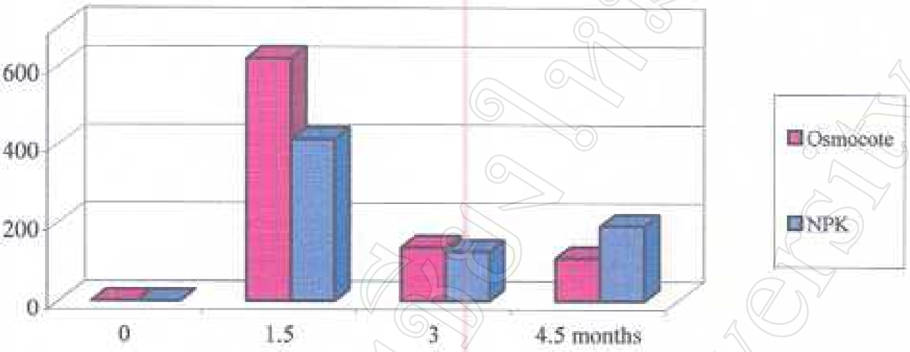


Figure 40. ***Aporusa villosa*** **scarification by hand**

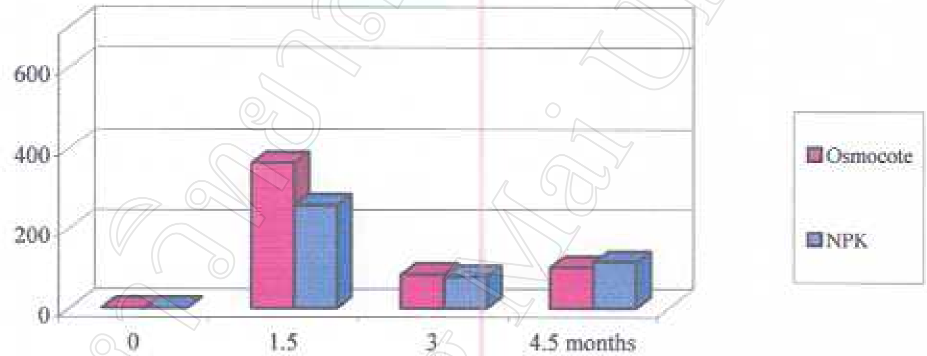
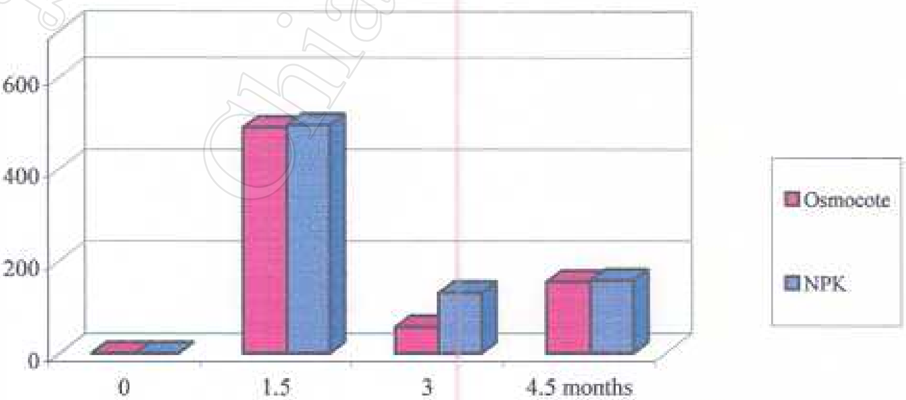


Figure 41. ***Aporusa villosa*** **scarification by H_2SO_4**



RGR for height

Figure 42. ***Bauhinia vareigata*** **control (27°C)**

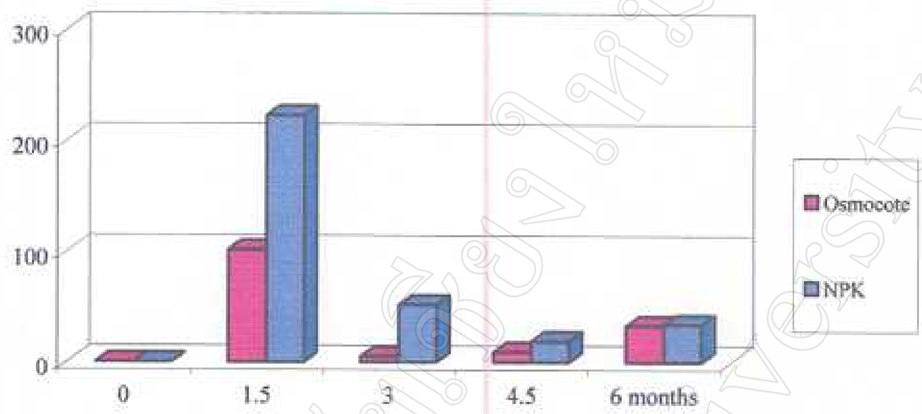
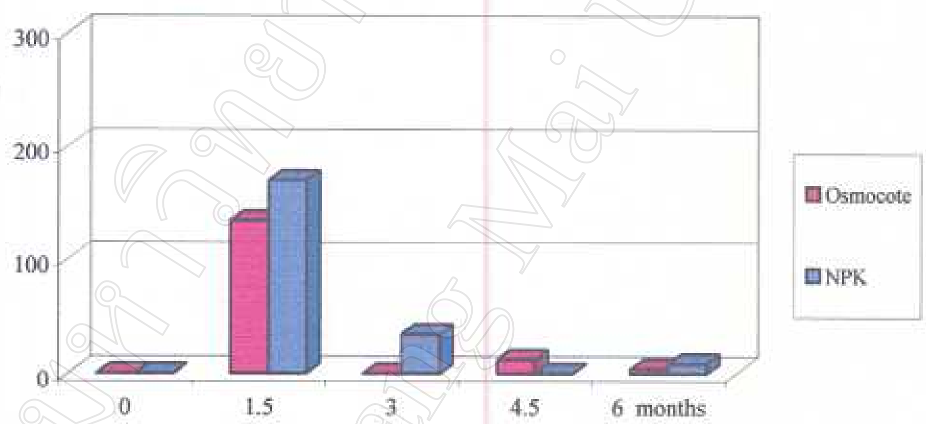


Figure 43. ***Bauhinia variegata*** **scarification by hand**



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RGR for diameter

Figure 44. ***Bauhinia variegata*** **control (27°C)**

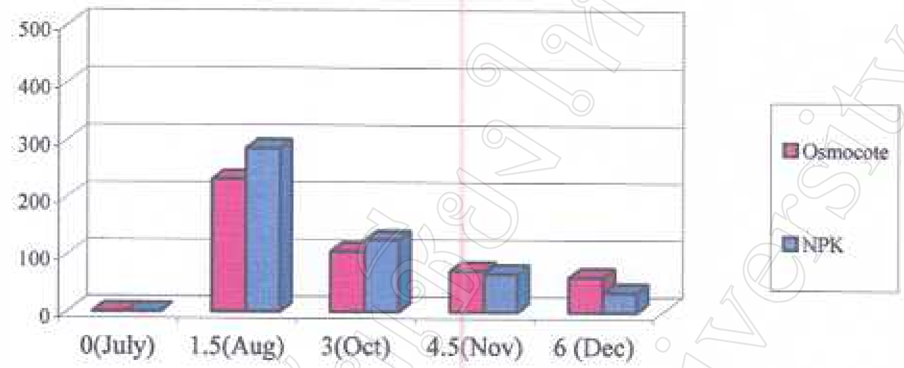
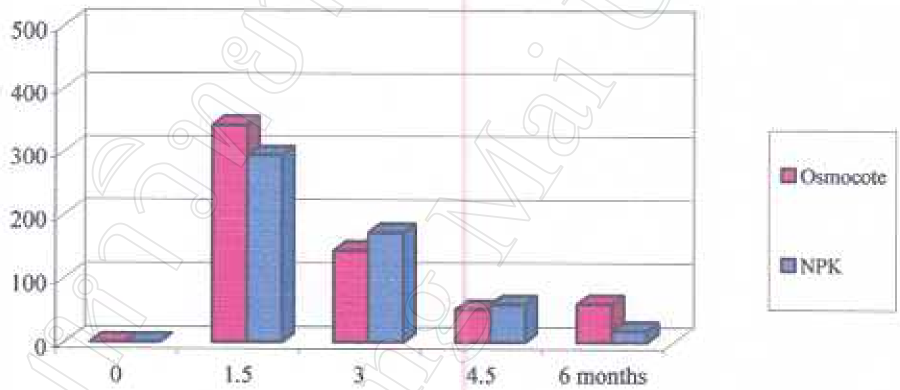


Figure 45. ***Bauhinia variegata*** **scarification by hand**



RGR for height

Figure 46. ***Terminalia alata*** **control (27°C)**

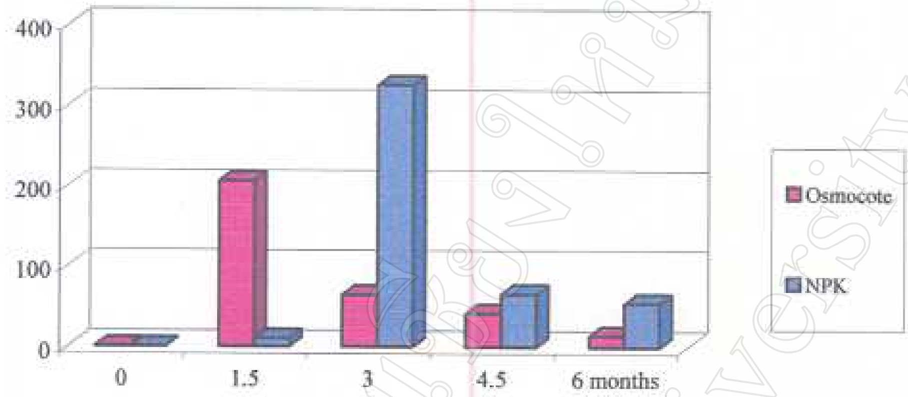


Figure 47. ***Tarminalia alata*** **scarification by hand**

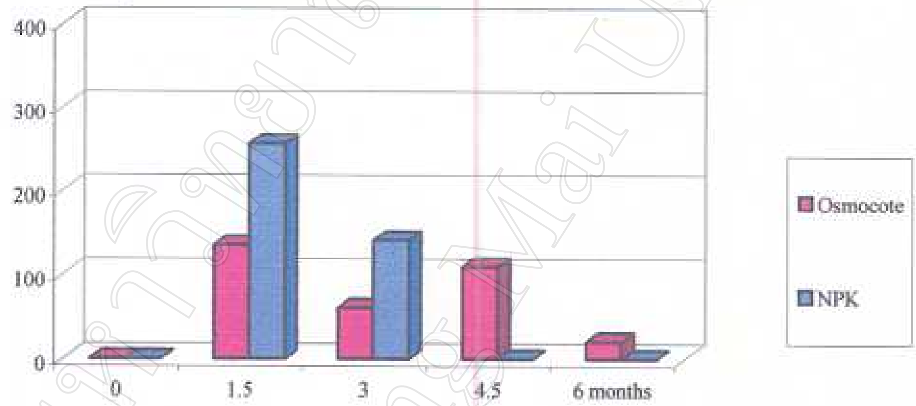
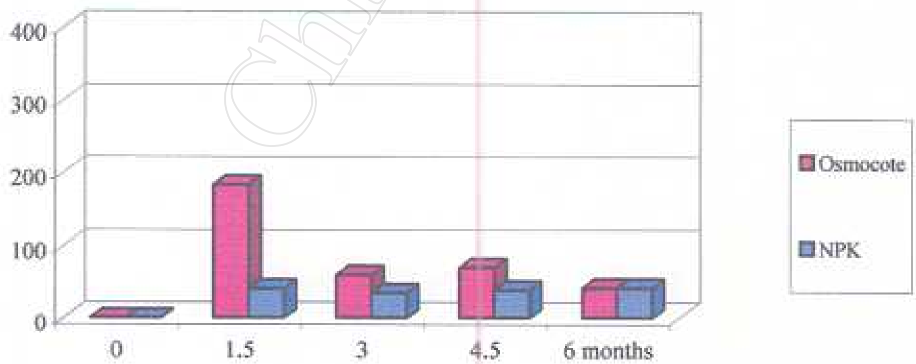


Figure 48. ***Terminalia alata*** **scarification by H_2SO_4**



RGR for diameter

Figure 49. ***Terminalia alata*** **control (27°C)**

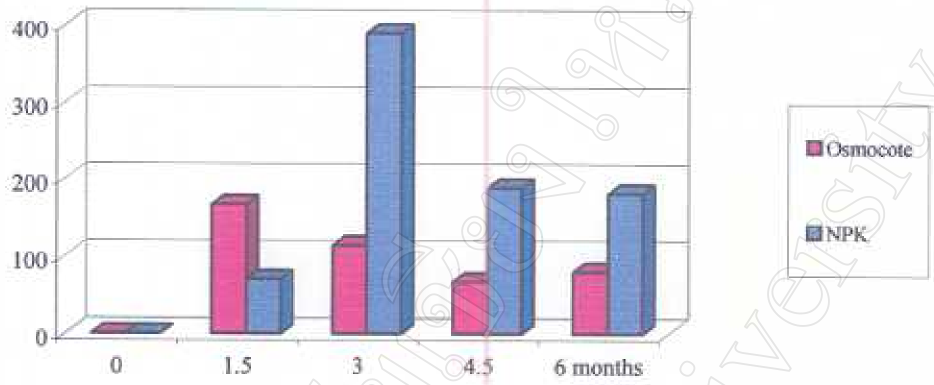


Figure 50. ***Terminalia alata*** **scarification by hand**

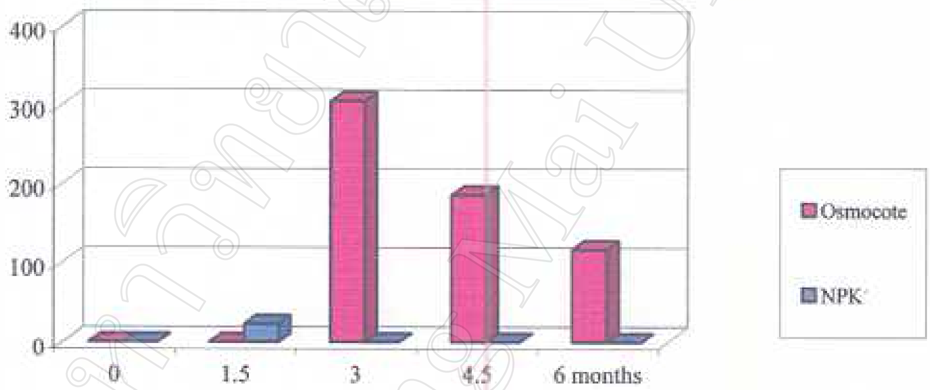
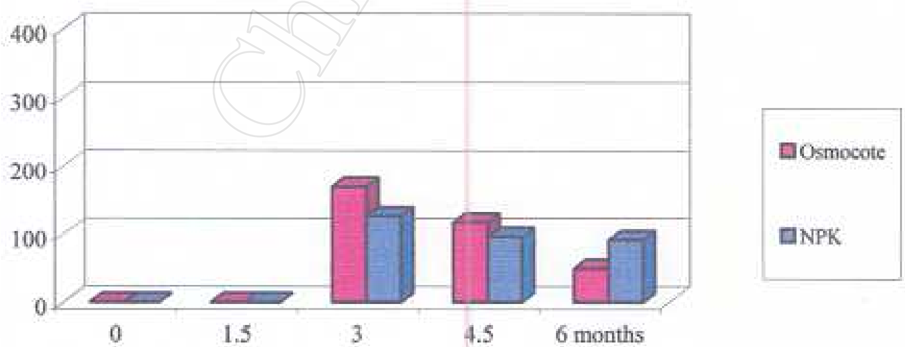


Figure 51. ***Terminalia alata*** **scarification by H_2SO_4**



Total cost per seedling per season (see APPEND IX III)

1. Container	
REX Tray	0.2604 baht/seedling/season
Basket	.02534 baht/seedling/season
2. Media	
For germinate(Basket)	
Media	0.0481baht/seedling/season
For growing seedling(REX Tray)	
Media	0.157 baht/seedling/season
3.Chemical Regent	0.7 baht/seedling/season
4. Fertilizer	
Osmocote	0.18 baht/seedling/season
NPK	0.15 baht/seedling/season
5. Aluminum Table	0.735 bath/seedling/season
6. Labor	
Labor cost for seed collection	0.1 baht/seedling/season
Labor cost for sowing	.00052baht/seedling/season
Labor cost for cutting	.00020baht/seedling/season
Labor cost for filling container	.00651baht/seedling/season

Total cost/seedling/ Season

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

Table 20. Total cost per seedling per season for germination

Treatment	Cost				
	Container	Media	Chemical Reagent	Labor	Total
27 °C	0.2534	0.0481	none	0.10052	0.402
55 °C	0.2534	0.0481	none	0.10052	0.402
80 °C	0.2534	0.0481	none	0.10052	0.402
100 °C	0.2534	0.0481	none	0.10052	0.402
scarification by hand	0.2534	0.0481	none	0.10072	0.4022
scarification by H_2SO_4	0.2534	0.0481	0.7	0.10052	1.102

Table 21. Total cost per seedling per season for growing seedling

Treatment	Cost					
	Container	Media	Aluminum Table	Labor	Fertilizer	Total
27 °C	0.2604	0.157	0.735	0.0065	0.18 0.15	1.3389 1.3089
55 °C	0.2604	0.157	0.735	0.0065	0.18 0.15	1.3389 1.3089
80 °C	none	none	none	none	none	none
100 °C	none	none	none	none	none	none
scarification by hand	0.2604	0.157	0.735	0.0065	0.18 0.15	1.3389 1.3089
scarification by H_2SO_4	0.2604	0.157	0.735	0.0065	0.18 0.15	1.3389 1.3089

Note: Fertilizer Osmocote= .18, NPK=.15

Benefit Value

It was very difficult to determine what was the optimal seed pre-treatment for germination of the 8 species and what was the optimal fertilizer treatment to prepare seedlings grown in nurseries. In some species germination among treatments was very similar. In order to determine which is the best treatment for each species. benefit values were calculated. The benefit value was calculated from the germination index(percent germination/time of germination) and RGR, divided by the total cost per seedling per season.

For *Albizia chienesis*

treatment	benefit value	
	Osmocote	NPK
55°C	0.753	0.549
scarification by hand	1.091	1.145
scarification by H_2SO_4	0.7497	0.746

Aporusa villosa

27°C	0.930	0.905
scarification by hand	0.827	0.775
scarification by H_2SO_4	0.7374	0.829

Bauhinia variegata

27°c	1.091	1.110
scarification by hand	1.148	0.9584

Rhus chinensis

55° C	0.635	0.689
scarification by hand	0.819	0 .489

Terminalia alata

27°c	0.945	1.023
55°c	0.984	0.938
scarification by hand	0.819	0.489
scarification by H_2SO_4	0.753	0.829

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DISCUSSION

All species showed no statistically significant differences in germination among blocks, but did have significant differences among treatments. Therefore, a single block might be sufficient in future experiments.

Optimal treatments

Albizia chinensis (Obs.) Merr. (Leguminosae, Mimosoideae)

The fruit of this species is a flat, dehiscent pod, bearing 8-10 seeds. The seeds are flat, oval in shape, with a glossy surface, about 4.6 x 6 mm. The seeds are classified as orthodox (mature desiccation-tolerant). Seeds in family Leguminosae, Mimosoideae usually have a hard seed coat (Smith *et al,* 1995). *Albizia chinensis* seeds are light brown with a hard seed coat. Smith *et al*, (1995) reported that a hard seed coat can cause seed dormancy in three ways. Firstly a hard seed coat may be impermeable to water. Secondly it is impermeable to gases and the thirdly it may mechanically constrain the embryo. So dormancy of this species is due to the seed coat. In this experiment, three treatments increased percent germination. Considering the benefit value, scarification by hand was the best treatment for this species, because benefit value was about 1.145. Scarification by hand stimulated germination by permitting penetration of water (at cutting site) to the embryo and gaseous exchange. The results from this experiment agreed with those of Boonnarutee *et al,* (1997). Scarification by hand was the most suitable pretreatment to increase seed germination in some species in the Family Leguminosae, with hard seed coats. The alternative treatment was scarification by conc. sulfuric acid, because conc. sulfuric acid could remove inhibitors and the impermeable layer of the hard seed coat. In nature, inhibitors or an impermeable layer such as waxy layer, pectin, suberrins, and mucilage are barriers for exchange of O_2 and CO_2 between the embryo and external air (Smith *et al,* 1995). Seed barriers can be removed by conc. sulfuric acid, allowing water and gases to penetrate the seed. The third treatment for this species was hot water at 55°C. Percentage germination was about 63%. Hot water might remove the inhibitors by washing them away. Furthermore, Smith *et al*., (1995) reported that heating seeds caused loss of the plug by eruption and allowed the entry of water.

Aporusa villosa (Lindl.) Baill. (Euphorbiaceae)

The fruit is a capsule with soft aril which covers the seeds. The seeds are oval, about 5 x 7 mm and are recalcitrant (intolerant of dehydration). For this species, three treatments resulted in 49, 61.7 and 61% germination. The control treatment was the best treatment for this species followed by scarification by conc. sulfuric acid and scarification by hand. As for *Albizia chinensis,* scarification by hand permitted increased water uptake and gaseous exchanged, whereas conc. sulfuric increased permeability of the seed coat. Inhibitor substances sometimes come from fleshy fruits. So before treating the seeds, the aril was removed. The control treatment indicated that seeds could germinate after soaking in water, perhaps the water washed out inhibitory substances. In this experiment, seeds were soaked in water for about half an hour. Soaking seeds in water for more than 30 minutes might further increase percentage germination .

Bauhinia variegata L. (Leguminosae, Caesalpinoideae)

This species belongs to Leguminosae, Caesalpinoideae but seeds do not have a hard seed coat. The seeds are flattened, about 14 x 15 mm, in a dehiscent pod. The seeds are recalcitrant. The benefit value of control and scarification by hand were very similar. The best treatment was scarification by hand, because it permitted penetration of water to embryo. Since seeds did not have hard seed coats, when seed were treated with conc. sulfuric acid, the acid damaged the seeds.

Ficus abelii Miq., *Ficus glaberrima* Bl. var. *glaberrima* and *Ficus hirta* Vahl var. *roxburghii* (Miq.) King (Moraceae)

The seeds of these species are very small and two species germinated easily in the nursery (Herbarium database, 1998), but seedlings died after germination due to damping off. In this experiment, only seed germination was studied but seedling growth was not because the seedlings were too young and some species did not germinate, especially *Ficus hirta*. So benefit value could not be used to determine the best treatment for these species. So the further work needs to be done especially a growth rate. The control resulted in the highest percent germination. This result was in agreement with data from FORRU. For *Ficus abelii,* percent germination was not more than 35 and for *Ficus glaberrima* percent germination was not more than 10.

This contrasts with FORRU 's result from 1998, which showed a percent germination under sunny conditions of 93 % for *Ficus abelii*, and 76 % for *Ficus glaberrima*. For *Ficus abelii*, a delay in sowing the seeds of 53 days might have caused low germination. In addition, the seeds might have been sown too deep (about 0.5 cm) when compared with FORRU's nursery methods. FORRU scattered seeds on the surface of forest soil. The media consisted of sand and rice husk, which had more rapid drainage than forest soil used in this experiment. FORRU sowed a lot of seeds in one container, but in this experiment, one seed was sown in one cell (one container =100 cell). For *Ficus hirta*, percent germination was zero. This might have been due to selection of figs with only male flower or unfertilized female flowers.

Macaranga denticulata (Bl.) M.-A. (Euphorbiaceae)

Seeds of this species had a very hard seed coat, and a size about 3.2 mm in diameter. In this experiment, percent germination was very low. The best treatment for this species was scarification by hand. Although percent germination was not high, the results indicated that water removed inhibitory substances. This result is in agreement with FORRU's data. (Kerby. *et al.*, 2000). FORRU recommended soaking seeds in water for 12-24 hours resulting in a germination percent of about 90%. Seeds were killed when scarified by conc. sulfuric acid.

Rhus chinensis Mill. (Anacadiaceae)

Seeds of this species have a hard seed coat, glossy surface, irregular shape and are light brown to dark brown in color. The seeds are classified as orthodox. Because of this, in both the first and second experiments, the benefit values were high, when seeds were treated with conc. sulfuric acid. Scarification by conc. sulfuric acid was the best treatment. The MLD was 11-13 days. Furthermore, this treatment resulted in highly syncronous germination. The other treatment was scarification by hand. Although the MLD was longer than with conc. sulfuric, this treatment could be used if the nurseries lack conc. sulfuric acid. Treatment with hot water at 55°C is an alternative but percentage germination was poor. Seeds treated with hot water at 80°C had low percent germination. Perhaps hot water removed inhibitory substances. Percent mortality was very high in the first experiment, 48.1% and in the second experiment it was 25%, indicating that this treatment was not good for this species. Hot water at temperature 80°C might cause embryo damage. So seedlings were not vigorous after germination. In comparing between the two experiments, percent germination was very similar, indicating that the collection time did not influence germination, because seeds of this species was collected at different times. Seeds were first collected in May. The second seeds were collected in 1 November 2000. MLD 's of the first and second experiments were different The MLD of seeds in the first experiment (18 and 55 days respectively). When seeds were treated with scarification by hand, and treated with hot water at 55°C, was longer than in the second experiment (28 and 13 days respectively). For scarification by conc. sulfuric acid the MLD's were very similar 11 days for the first experiment and 13 days for the second. This indicated that dormancy increased with increased storage time.

Terminalia alata Hey. ex Roth (Combretaceae)

This species belong to Combretaceae. The fruit is an indehiscent drupe (Kumar, 1992) 3.5 to 5 by 1.3 to 2.5 cm. in size with 5 coriaceous wings. Kumar recommended pretreating the seed of this species by soaking them in cold water for 48 hours. That recommendation is agreement with the results from this experiment describe here. The benefit values of the two experiments showed that the control treatment (soaking in the water for 30 minutes) was the best. The second best treatment was water 55°C. This indicates that both cool water and hot water might dissolve inhibitory substances. Percent germination was very similar for both experiments although MLD's were reduced in the second experiment, indicating that dormancy decreased after storage seed. These means that this species requires a period of after-ripening.

Effects of fertilizer

For the fertilizer treatments, *Albizia chinensis*, *Aporusa villosa*, *Bauhinia variegata* and *Rhus chinensis* showed no significant differences in growth between of two fertilizers. For *Terminalia alata,* there was a significant difference between two fertilizers in seedlings grown from seeds treated at 55°C. However, seedlings from treatment such as control treatment, scarification by hand and conc. sulfuric acid showed no significant difference between the two fertilizers. For *Aporusa villosa, Rhus chinensis,* and *Terminalia alata* there were no significant differences between the two blocks, indicating that environmental factors such as light intensity, temperature, quantity of rainfall *etc.* had less influence than fertilizer on growth. For

Albizia chinensis and *Bauhinia variegata* there were significant differences between the two blocks, indicating that environmental factors influenced growth more than fertilizer The number of replicates should be increased to more than two blocks because two block were not enough for this experimental design. Moreover, the fertilizer treatment should be varied especially the dose of fertilizer. However, considering the benefit value, the best fertilizer treatment for *Albizia chinensis* and *Terminalia alata* was soluble NPK and for *Bauhinia variegata, Aporusa villosa* and *Rhus chinensis* it was Osmocote.

RELATIVE GROWTH RATE (RGR)

For *Albizia chinensis,* RGR of height and diameter of three treatments (scarification by hand, conc. sulfuric acid and 55°C), was high 6 weeks after potting but there was significant difference between the two blocks. This means that environmental factors affected growth more than fertilizer. Height growth in block 2 (under shade condition) was higher than block 1 (under sunny conditions).

For *Aporusa villosa,* the pattern was the same as for *Albizia chinensis*. RGR was high in the first month and was reduced after 41/2 months. RGR of diameter was zero after 41/2 months.

For *Bauhinia variegata,* seedlings came from two treatments control and scarification by hand. RGR in terms of height and diameter of both treatments was similar Growth was rapid in first 6 weeks and reduced after 6 months.

For *Rhus chinensis* , *Aporusa villosa* and *Terminalia alata* RGR showed a similar pattern as for *Albizia chinensis* and *Bauhinia variegata.*

For all species RGRs at the beginning were high, because plants had high photosynthesis due to the many leaves in this season (rainy season). The optimal water, nutrient and other environmental factors such as light might promoted growth of seedlings. Moreover, roots could find and absorbed water and nutrient very well because the soil structure did not compact due to the high moisture. In contrast, RGR was reduced at 6 months (December) because in this season (winter) the seedlings began to shed their leaves. Although, the seedlings grown in FORRU's nursery and the soil moisture are still high because watering, but the air humidity was lower than in rainy season. The Chang Khian station reported that an average air humidity in November and December 2000 are 52.1 and 50.4, respectively, but in the rainy season are 68.0 to 70.2 in May and June, respectively. So the soil moisture was reduced because of evaporation. Furthermore, the species in this study were deciduous trees losing their leaves when the soil moisture are low. So the photosynthesis of the seedling is reduced. Therefore, the RGR reduced in this season

CONCLUSIONS

The media for germination sand and rice husk was suitable for the nine frameworks tree species because it had more rapid drainage than forest soil, especially for *Ficus spp,* where the percent mortality was low.

REX trays supported good seedling development, especially root morphology of *Albizia chinensis, Aporusa villosa, Bauhinia variegata, Rhus chinensis* and *Terminalia alata.*

For all species studied, the best pre-treatments for each species were different due to the seed coat. For *Albizia chinensis*, the best treatment was scarification by hand, and an alternative treatment was scarification by conc. sulfuric acid. Seeds germinated rapidly and grew well under shaded conditions. Good quality seedlings could be produced in the first year and planted in June in the second year. For *Aporusa villosa*, the best treatment was soaking seeds in water at 27°C for 30 minutes; the alternative treatment was scarification by hand and conc. sulfuric acid. Because seeds of this species are recalcitrant they cannot be kept for along time. Seeds should be sown as soon as possible after collected. Growth rate of seedlings was low. Seedlings could be produced in two years. For *Bauhinia variegata*, seeds germinated very rapidly and seedlings were fast-growing. Seeds are recalcitrant. The best treatment was scarification by hand and seedlings grew well under shade conditions. For *Ficus abelii* and *Ficus glaberrima* var *glaberrima,* the best treatment was soaking seeds in water at 27°C for 30 minutes; seedlings could be ready for planting in the third years after seed collection. For *Macaranga denticulata,* The best treatment was scarification by hand. For *Rhus chinensis,* the best treatment was scarification by conc. sulfuric acid because the seeds had a hard coat. Seedlings grew under both shaded and sunny conditions. For *Terminalia alata,* the best treatment was soaking in water at 27° C for 30 minutes; and seedling grew well in both sunny and shaded conditions. Good quality seedlings could be produced in the first year and planted in the second year. The production schedule shown in Table 23.

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Table 22: Optimal pre-treatment and optimal fertilizer for each species

Species studied	Friut/ seed type/ Dispersed	Germination type	Type of seed	Optimal germination pre-treatment	Optimal fertilizer
Albizia chinensis	pods, dehisent, by wind	epigeal	orthodox	scarification by hand	NPK
Aporusa villosa	Capsule, by animals	epigeal	recalcitrant	control (soaking in water 27°C, 30 min)	Osmocote
Bauhinia variegata	pods, deshisent by wind	hypogeal	recalcitrant	scarification by hand	Osmocote
Ficus abelii	fruit in figs by animals	epigeal	recalcitrant	control (soaking in water 27°C, 30 min)	none
Ficus glaberrima var. *glaberrima*	fruit in figs by animal	epigeal	recalcitrant	control (soaking in water 27°C, 30 min)	none
Macaranga denticulata	Capsule by wind	epigeal	orthodox	scarification by hand	none
Rhus chinensis	drupe, by animal and wind	epigeal	orthodox	scarification by conc H_2SO_4	Osmocote
Terminalia alata	fruit with five wing nut, by wind	epigeal	orthodox	control (soaking in water 27°C, 30 min)	NPK

Table 32. Production schedule for nine fraemwork tree species

Species	Family	This year												Next year												Harden and plant in
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Albizia chinensis (Obs.) Merr.	Leguminosae, Mimosoideae	X	X	*	*	+	+	+	+	+	+	+	+	+	+	+	+	☺	P							May & Jun of 3 rd year
Aporusa villosa (Lindl.) Baill.	Euphorbiaceae					X	X	*	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	☺ P
Bauhinia vareigata L.	Leguminosae, Caesalpinoideae			X	X	*	*	+	+	+	+	+	+	+	+	+	+	☺	P							
Ficus abelii Miq.	Moraceae	X	X	*	*	*	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	☺ P
Ficus glaberrima Bl. var. *glaberrima*	Moraceae	X	X	*	*	*	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	☺ P
Macaranga denticulata (Bl.) M.-A	Euphorbiaceae								X	X	*	*	*	+	+	+	+	+	+	+	+	+	+	+	+	☺ P
Rhus chinensis Mill.	Anacardiaceae					X	X	*	*	*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	☺ P
Terminalia alata Hey.ex. Roth	Combretaceae				X	X	*	*	+	+	+	+	+	+	+	+	+	☺	P							

X = Collecting and sowing seeds
* Pricking out and potting seedlings

+ Growth in nursery
☺ Hardening off seedlings

P = Transplantation into deforested sites

RECOMMENDATIONS

1. The seedlings of five species from these experiments should be planted in a deforestation area and monitored after planting, to see the long- term effectiveness of the treatments.
2. Experiments should be repeated in some species especially *Ficus abelii, Ficus glaberrima* ver. *glaberrima, Ficus hirta* var. *roxburghii* and *Macaranga deticulata,* to determined optimal treatments.
3. Experiments should be carried to determine optimal fertilizer treatments for all species.
4. The factor causing seedling mortality should be determined for all species.

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APPENDIX I: Seedlings Descriptions

Albizia chinensis (Obs.) Merr.(Leguminosae, Mimosoidae)

48 seeds, which germinated at the FORRU nursery, in sunny conditions. All seeds were collected from two different parent trees. The first parent tree is located at 840 m and the second at 1050 m in Doi Sutep- Pui National Park, both collected on 7 January 2000. The description is based on 48 seedlings examined on 29 December 2000.The various stage of development are shown in Figure 52.

planting: date 6 April 2000.

germination date: 12 April 2000

Germination: orthodox epigeal (the cotyledons are exposed and lifted above soil surface taking 7 days to germinate.

Cotyledons cryptocotyledonary, thick and fleshy, oblong, apex and base obtuse, glabrous; outside light green to pink, inside light green to green, averaging 8 mm long and 6 mm wide, falling after 3-4 nodes have developed.

Cotyledonary leaves: opposite compound, the first leaf is once pinnate with 5 pairs of opposite leaflets; the next leaf is bifoliate with a leaflets similar to the pinnate leaf and

and with 5 pairs of secondary leaflets. The leaflets are oblong, apex and base rounded, entire, mid-green above and light green underneath, 4.6 x 6 mm.

Epicotyl leaves: bifoliate, one leaf pinnate, next bifoliate, alternate at later nodes, leaflets similar to cotyledonary leaves. The first three leaves have leaflet. Venation: mid-rip eccentric, secondary nerve indistinct. Petiole: light green 5-15 mm long. Stipules: erect, light green, 2 mm long.

Hypocotyl: about 4-6 cm long when cotyledons are fully expanded; in younger seedling green to light green, glabrous. Epicotyl initially light green, turning dark green with age at about the 5th node or older, hairless. Internodes about 0.5-1 cm long and elongating with age; In older seedlings there are fine cream striations and pale lenticels.

Roots: primary root white, slender or slightly sinuous remaining white in older seedlings, 1-2 cm long, diameter about 0.5 mm. Secondary roots, fibrous, sinuous, and densely branching. In older seedlings some fibrous roots have whitish nitrogen fixing nodules 1-2 mm in diameter.

Voucher: Singpetch S301b1.

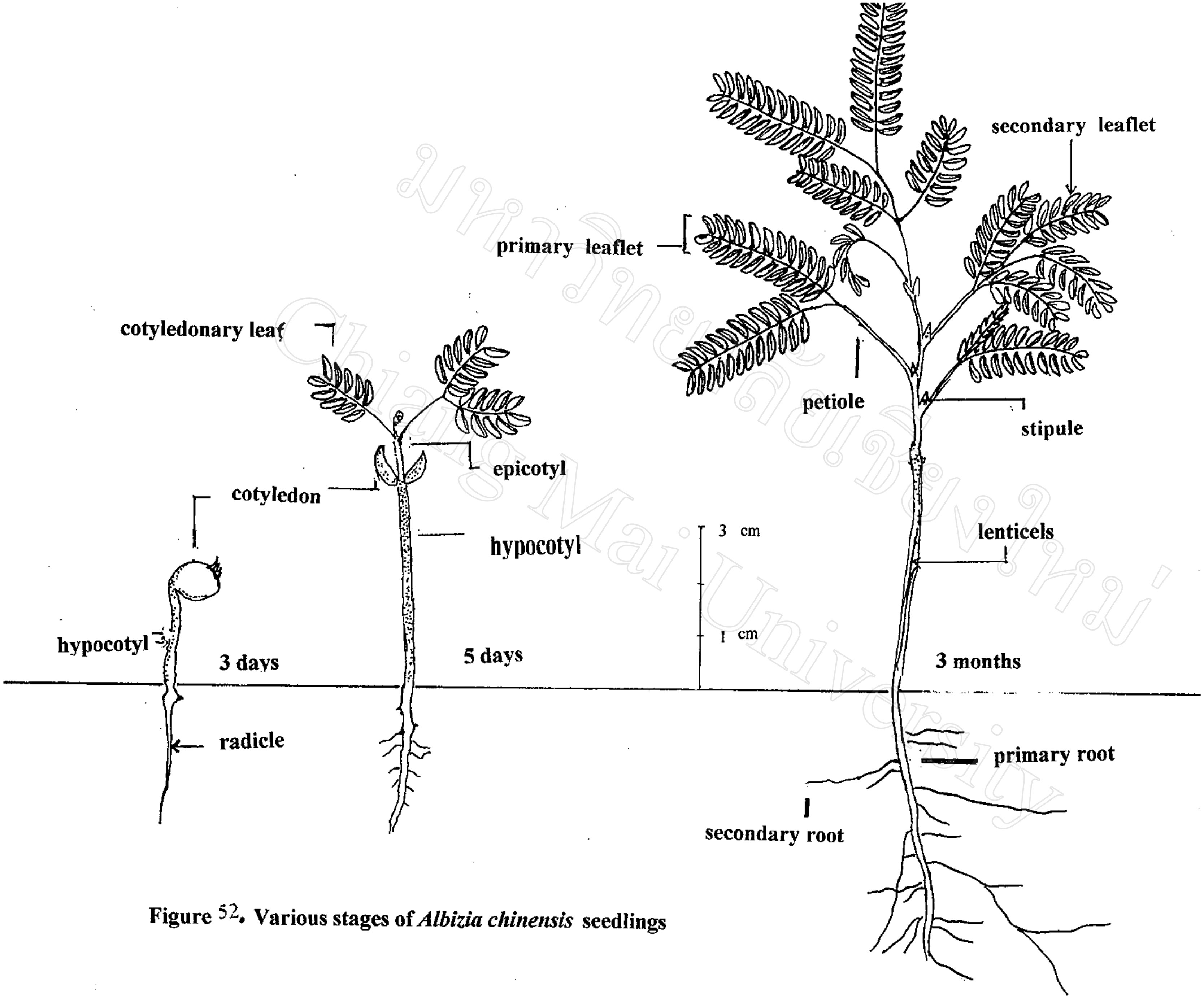

Figure 52. Various stages of *Albizia chinensis* seedlings

Aporusa villosa (Lindl.) Baill. (Euphorbiaceae)

48 seeds germinated at FORRU nursery, in sunny conditions. All seeds were collected from 3 different trees. Mature fruits were collected on 16 May 2000 at 720 to 740 m in Doi Sutep-Pui National Park. This description is based on 48 seedlings collected on 30 January 2001, (about 8 months after planted). The various stage of development are shown in Figure 53.

planting date: 21 May 2000

germinate date: 6 June 2000

Germination: recalcitrant, epigeal, taking about 16-32 days to germinate

Cotyledons phanerocotyledonary, thin, obovate, tip nearly truncate, base acute, entire, youngest one pale yellow to mid-green above and light green underneath, glabrous, averaging 5-10 mm long, 5-15 wide, and becoming larger with age (at 3 months about 2.5 x 2 .5 cm). Main venation distinct, midnerve with two primary nerves from the base, secondary nerves pinnate.

Cotyledonary leaves simple, spiral, lanceolate tip, entire, glabrous on both surfaces, mid-green above, light green underneath, Main venation, midnerve sunken above, secondary nerve pinnate, 4-6 pairs, finer vein reticulate, arching and joining the other

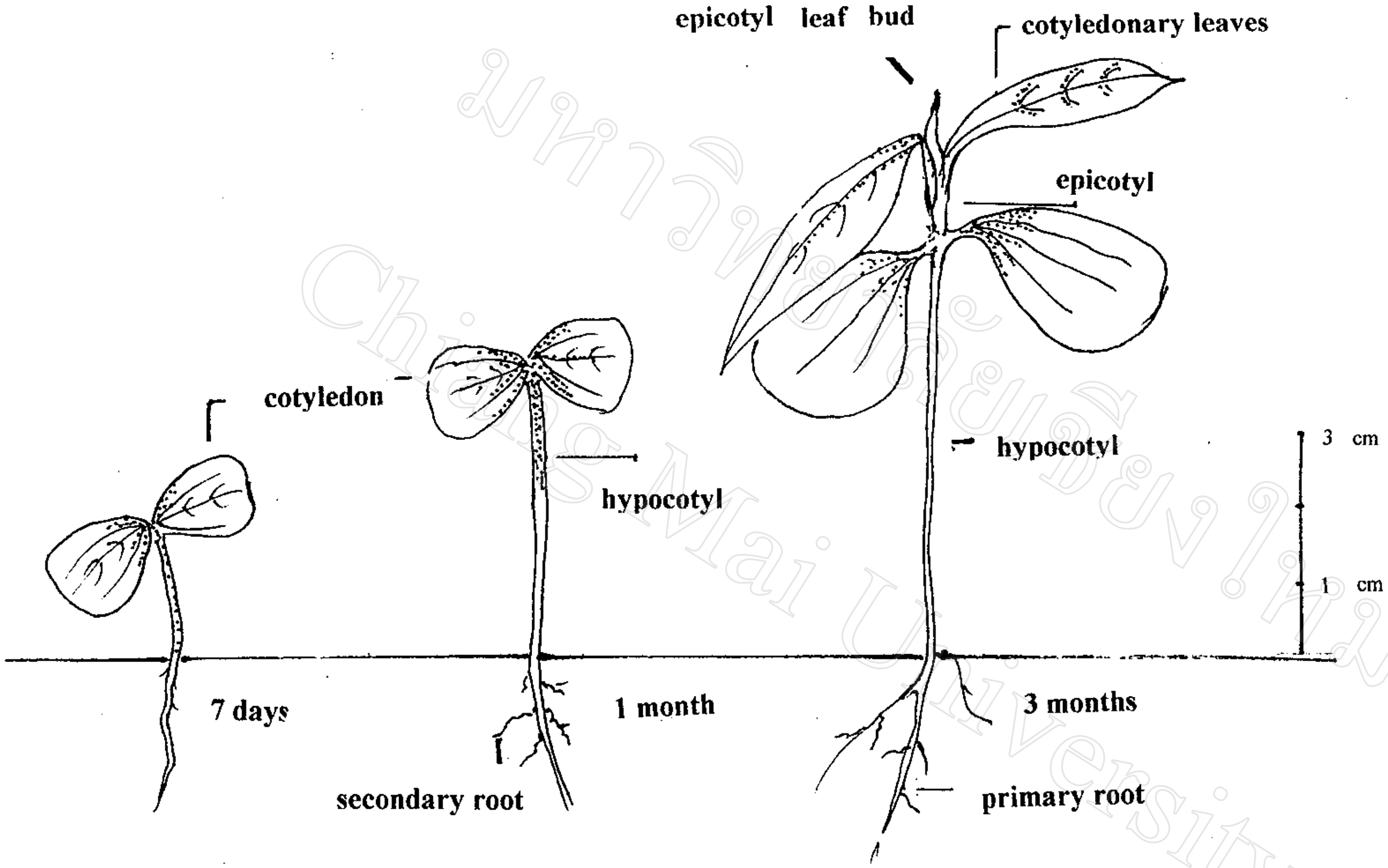

Figure 53. Various stages of *Aporusa villosa* seedlings

veins at the margin; light green above, light green underneath, petiole light green, 3-4 long, cover with scattered hair, stipule absent

Upper part of hypocotyl dull green, in younger seedlings 1-3 cm long when cotyledons are fully expanded, glabrous, becoming dark brown and rigid with age, outside dark brown, inside white; internodes: first internode about 0.5 cm long, pale yellow to light green, densely dark grey hairy; epicotyl dark grey hairy

Roots: primary root at the cotyledon stage, cream or whitish, becoming light brown and later brown with age, hard and slender or slightly sinuous, about 1 mm diameter, secondary roots slender, sinuous, and sparsely branched

Voucher: Singpetch S113b1

Bauhinia variegata L. (Leguminosae, Caesalpiniodeae)

48 seedlings, germinated at FORRU nursery in sunny conditions. The seeds were collected from two parent trees 2000 in Doi Sutep- Pui National Park on 4 April 2000. Both trees are located at 1,300 m elevation. The description is based on 48 seedlings collected on 29 December 2000, (about 8 months) after sowing. The height averaged of 33.2 cm, the various stage of development are shown in Figure 54.

planting date: 20 April 2000

germinate date: 30 April 2000

Germination recalcitrant: hypogeal (the cotyledons are not exposed and lifted above soil surface)

Seedling development: initially fast growing especially during the first 2-3 weeks and becoming slower later.

Cotyledons cryptocotyledonary, elliptic, plano-convex, rounded at both ends, entire, glabrous; pale yellow about 2.5 x 1.5 cm.

Embryo leaf: solitary, elliptic, apex deeply ands broadly bifid, base cordate, entire. Main venation distinct, each lobe with three primary nerves from the base, secondary venation, thin scalarifrom, finer venation, thin, reticulate; glabrous, dark green above and light green underneath. c. 12 x 16 mm. Petiole glabrous, green 10 mm after 7 days. Other node spiral with leaves similarly to the other ones. All petioles slightly pulvinate at the base.

Epicotyl: glabrous, first node with a leaf similarly to the embryo leaf but larger, petiole glabrous, green, other node spiral with leaves similarly to the other one, all petioles slightly pulvinate at the base.

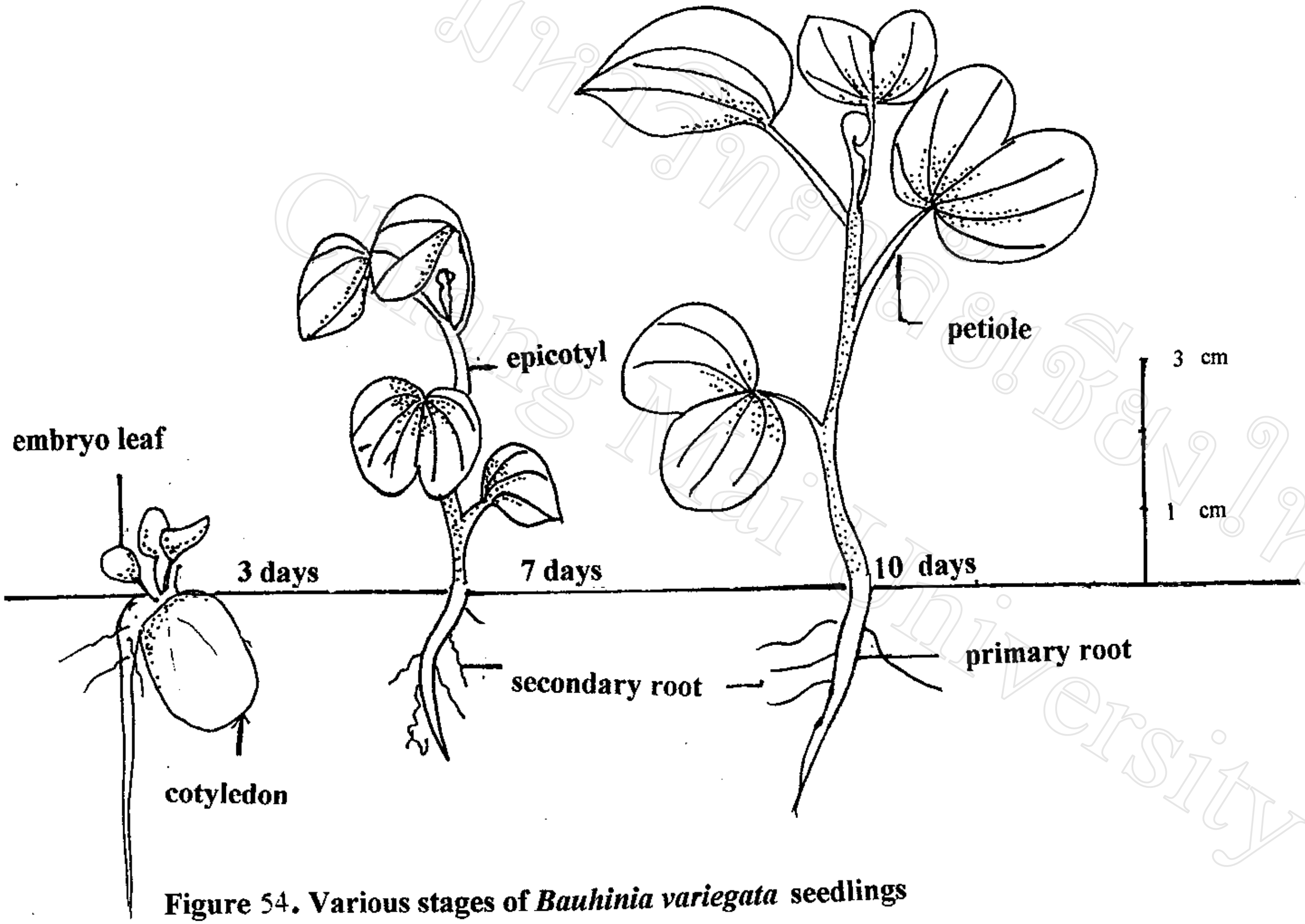

Figure 54. Various stages of *Bauhinia variegata* seedlings

Roots: primary root whitish, becoming light brown with age, slightly sinuate, secondary roots numerous.

Voucher: Singpetch S339b1

Ficus abelii Miq. (Moraceae)

20 seeds germinating at FORRU nursery in sunny conditions. All seeds were collected from one parent trees at an elevation of 890 m in Doi Sutep- Pui National Park on 11 April 2000. For seedling development the description is based on 20 seedlings collected on 29 December 2000 (about 8 months) after sowing. The height averaged 6.4 cm. The various stages of development are shown in Figure 55.

planting date: 4 June 2000

germination date: 22 June 2000

Germination recalcitrant, epigeal, taking 18-81 days to germinate

Cotyledonary leaves sub-orbicular, pale yellow to mid-green and light green underneath, glabrous, venation, pinnate, secondary veins 4 pairs

Hypocotyl leaves simple, spirally arranged; earliest blades 8 x 6 mm, increasing in size at subsegnent nodes blades, lancelolate, apex acute, base narrowed and shallowly cordate, entire to undulate; mid-rib prominent, secondary nerves pinnate 8-14 pairs, arching and joining below the margin, glabrous and with minute scattered punctate glands on both surface; dark green above, glossy green underneath, petioles, glabrous, light green c. 4-6 mm long, stipules scarious, triangular, whitish to light green turning brown with age, glabrous.

Stem: hypocotyl very finely brown puberulous, green; earliest nodes only with stipules.

Roots: primary roots, whitish when young and becoming light brown with age.

Voucher: Singpetch S 370b1

Ficus glaberrima Bl. var. *glaberrima* (Moraceae)

20 seeds germinated at FORRU nursery in sunny conditions. All seeds were collected from one parent tree at 860 m in Doi Sutep -Pui National Park on 29 November 2000. The description is based on 20 seedlings collected on 25 February 2001 (about 50 days) after germination. The height averaged 0.5 cm.

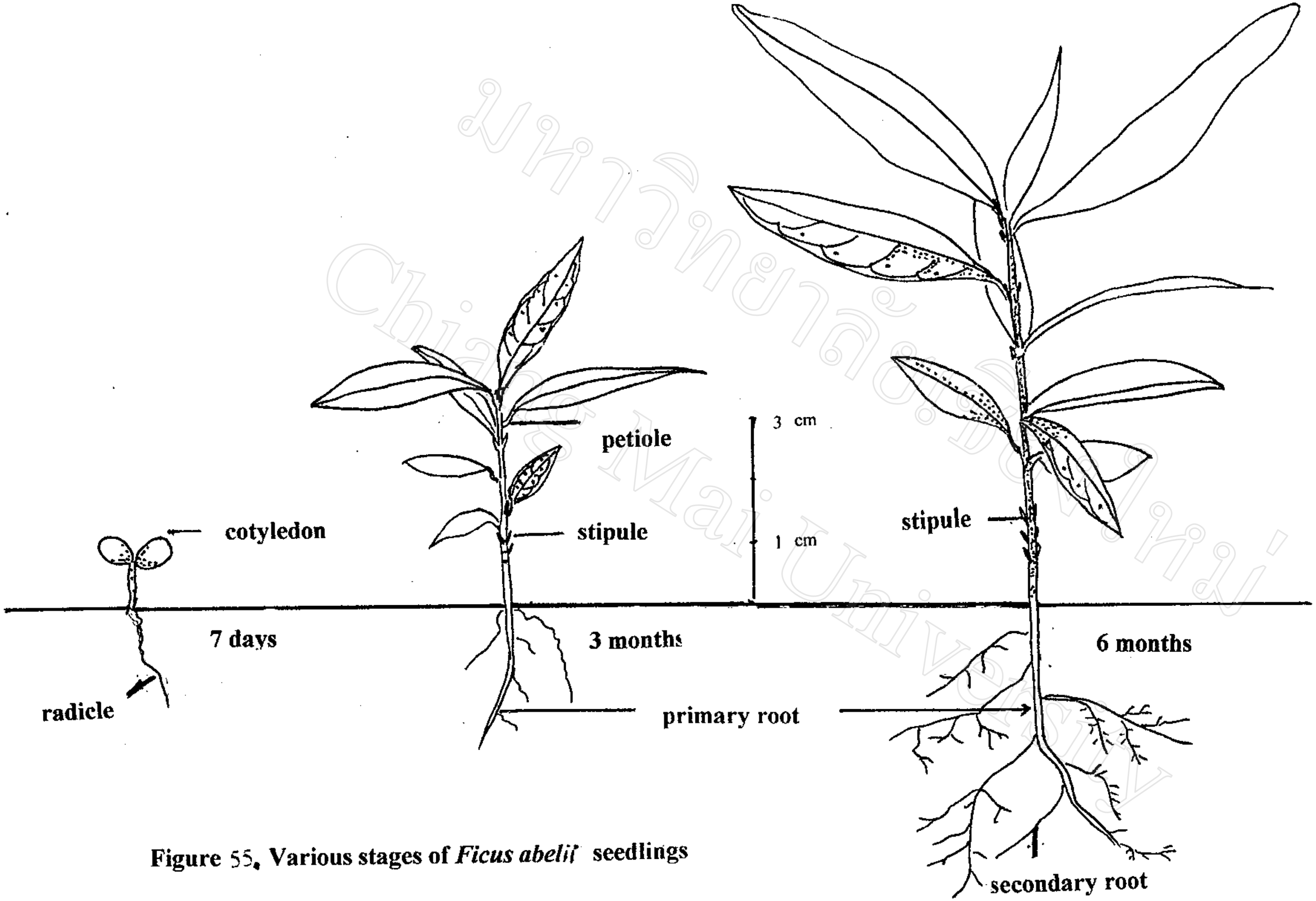

Figure 55. Various stages of *Ficus abelii* seedlings

planting date: 7 December 2000

germination date: 11 January 2000.

Germination recalcitrant, epigeal, taking 38-48 days to germinate.

Cotyledonary leaves: opposite, simple, elliptic, thin, entire, tip broadly rounded, base rounded and more acute at the petiole, pale yellow to mid-green and light green underneath, glabrous, with distinct minute, scattered punctate glands, most obvious dorsally, venation obscute, pinnate, secondary vein 4 pair; 3.25 x 2.7 mm: petiole c. 1 mm long.

Epicotyl: first epicotyl leaves similar to the cotyledonary leaves, but slightly larger

Roots: primary root whitish

Macaranga denticulata (Bl.) M.-A.(Euphorbiaceae)

20 seedlings germinated at FORRU nursery under sunny conditions. All of the seeds were collected from two parent trees located at 1,050 and 1130 m elevation on 5 August 2000 in Doi Suthep Pui National Park. For seedling development the description is based on 20 seedlings collected on 29 December 2000 (about 3 months) after germinated. The height averaged 4-5 cm. the various are stage of development are shown in Figure 56.

planting date: 17 August 2000

germination date: 3 September 2000

Germination orthodox, epigeal

Cotyledons: thin opposite, asymmetrically suborbicular, apex rounded, base broadly rounded to truncate; glabrous, entire , veins thin; midnerve with two primary nerves from the base, secondary nerves obscure; dark green above and light pink to light green underneath c. 8 x 7 mm. petiole c.1 mm long.

Seedling leaves: spirally arranged, ovate, apex acute, base shallowly cordate, and remotely denticulate, papillate. Venation distinct: mid-rib depressed above and raised underneath. Primary nerves 5-6 on each side, pinnate, secondary venation scalarifrom, tertiary venation reticulate. Petioles light maroon to green, finely puberculous, 8 mm long.

Stem: Hypocotyl finely glossy brown finely puberulous, epicotyl green maroon to pink at lower part and green upper part. Stipule: subulate, c. 1 mm long.

Radicle: primary root whitish, become light brown with age, slightly sinuous. Secondary roots: fibrous.

Voucher: Singpetch S124b1

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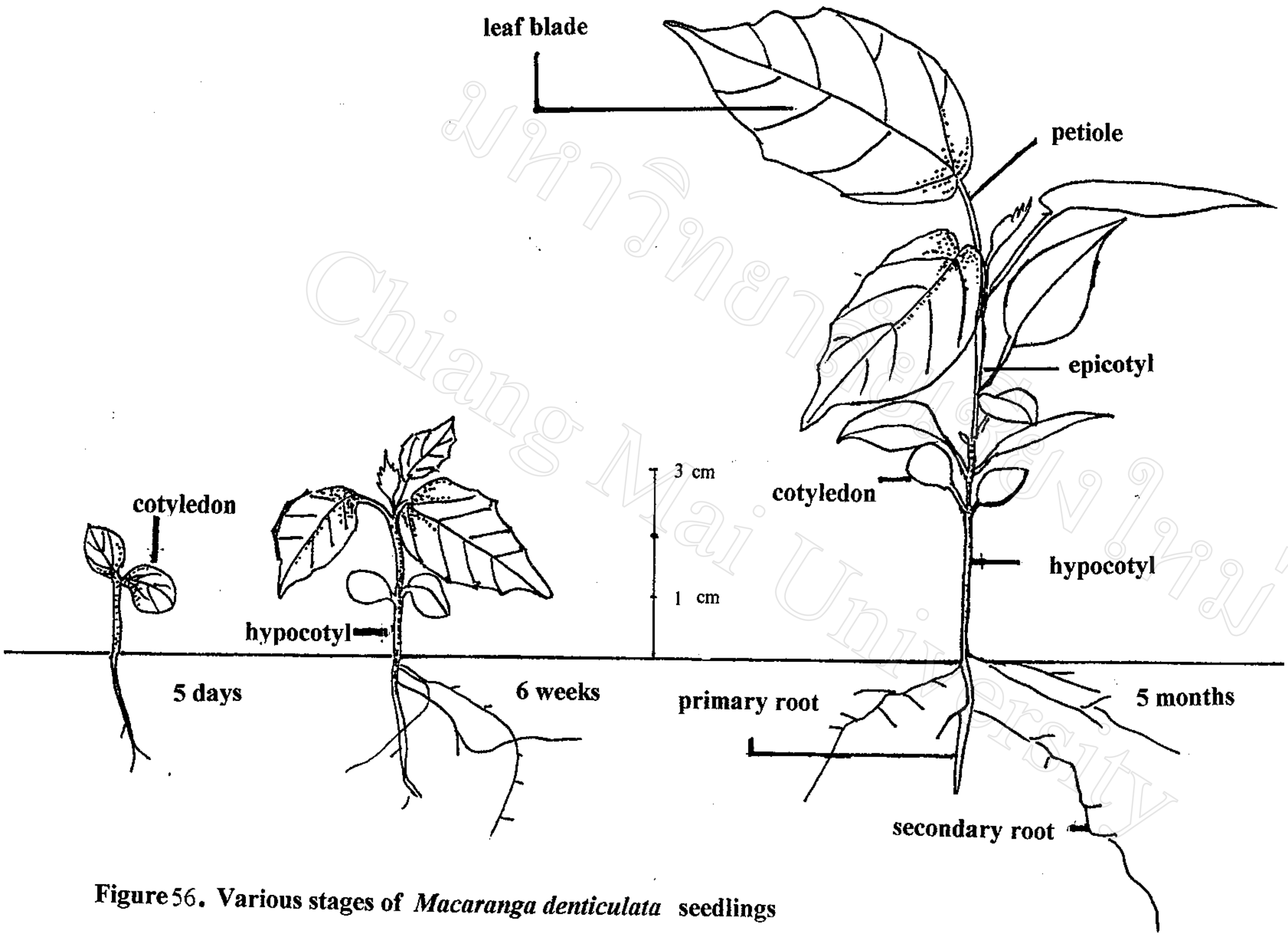

Figure 56. Various stages of *Macaranga denticulata* seedlings

มหาวิทยาลัยเชียงใหม่ Chiang Mai University

Rhus chinensis Mill. (Anacardiaceae)

48 seedlings germinated at FORRU nursery under sunny conditions. All seeds were collected from different three parent's tree located at the elevation 1,260 and 1140 m elevation in Doi Sutep- Pui National Park on 7 May 2000. The description is based on 48 seedlings collected on 40 seedlings on December 2000 (about 6 weeks) after germinated. The height averaged 5.9 cm. The various stage of development are shown in Figure 57.

planting date: 7 May 2000

germination date: 18 May 2000

Germination orthodox, epigeal.

Cotyledons: opposite, thin, elliptic; apex rounded, base obtuse, slightly, entire. Main veins obscure, midnerve with 2 nerves from just above the base, other nerves indistinct, glabrous; dark green above, light green underneath, c.12 x 6 mm.

Cotyledonery (seedling) leaves: paired, trifoliate, leaflet blades thin, ovate-lanceolate; apex and base acute deeply irregularly doubly, serrate in the upper 2/3, lower 1/3 entire; mid rip above, raised sunken underneath, very finely puberculous; primary nerves pinnate, 5-6 on each side, straight to the margin. secondary nerves reticulate dark

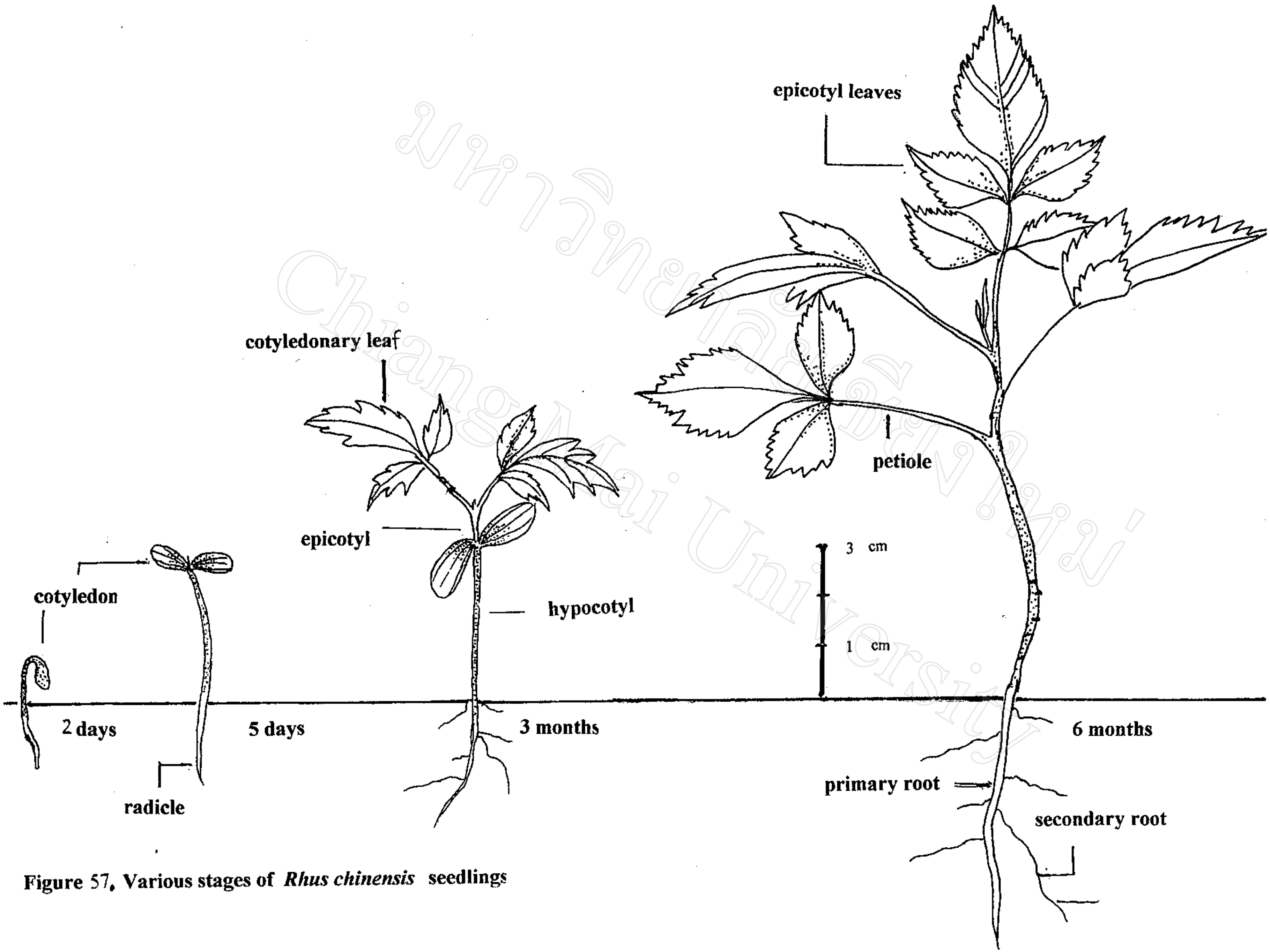

Figure 57. Various stages of *Rhus chinensis* seedlings

green above, light green underneath; petiole finely puberlous, c.17 mm after 14 days; terminal leaflets c. 22x7 mm, about twice as larger the lateral pair.

Stem: hypocotyl greenish to brown, hairless; epicotyl slightly greenish to brown, hairy; internodes about 1-2 mm long.

Roots: primary root white, slender or slightly sinuous, the diameter about 0.5 - 0.8 mm: the secondary roots fibrous, sinuous and sparsely branching, become light brown with age.

Voucher: Singpetch S038b1.

Terminalia alata Hey. ex Roth (Combretaceae)

Seeds germinated at FORRU nursery under sunny conditions. All seeds were collected from different three parent's tree located at the elevation 410 , 850 and 870 m in Doi Sutep Pui National Park on 4 April 2000. The description is based on 48 seedlings collected on 29 December 2000 (about 6 months) after germination. The height an averaged 11.4 cm. The various stage of development are showed in Figure 58.

planting date: 19 May 2000

germination date: 18 May 2000

Germination orthodox, epigeal

Cotyledons 7 days after germination: coriaceous, opposite obovate, apex truncate, base acute, entire, glabrous. Main venation sunken above, raised below; midnerve with two primary nerves from above the base, secondary nerves obscure, dark green above light green underneath, hairy , 38 x 34 mm; petiole 15 mm long.

First seedling leaves: opposite, elliptic, apex acute, base obtuse, entire: midrib depressed above, raised underneath; primary nerves pinnate, 4-5 on each site of the midrib; margin obscurely serrulate; secondary nerve obscure, reticulate; dark green above, light green underneath, sparsely pilose, especially along the margins above, nearly glabrous below: 36 x 18 mm: petioles finely pilose, green 2-3 mm long.

Stipules absent

Stem: hypocotyl pale cream, c 1.5 mm long, epicotyl finely pilose, green

Radicle: primary root whitish when young and becoming dark brown with age, thicker than the hypocotyl; secondary roots whitish when young and becoming light brown with age.

Voucher: Singpetch S063b1

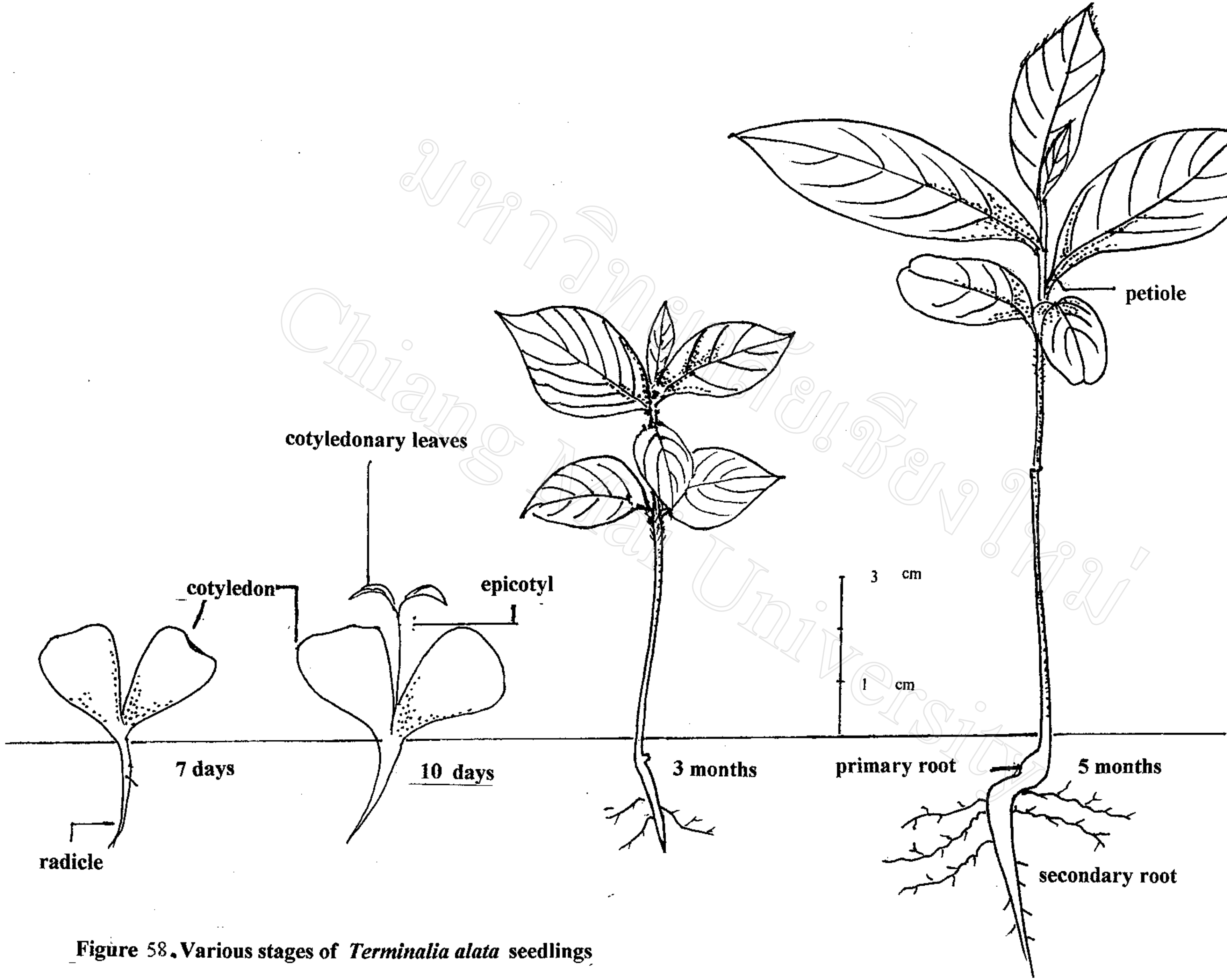

Figure 58. Various stages of *Terminalia alata* seedlings

APPENDIX II : Analysis of Variance

Table 24. *Albizia chinensis*: Number of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.000
55°C	63	67	59	189	63.000 B	4.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	78	82	75	235	78.333 C	3.512
scarification by H_2SO_4	83	81	80	244	81.333 C	1.528
Block Total	224	230	214	668	222.33	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	25370.44	5	5074.089	1282.775		
Block	21.778	2	10.889	2.753		
Residual	39.556	10	3.956			
Total	25431.78	17	1495.987			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 25. *Aporusa villosa*: Number of germinated seedlings after 3 months

Treatment	Block 1	Block 2	Block 3	Treatment Total	Treatment Mean	Standard Deviation
27°C	49	21	77	147	49.000 B	28.000
55°C	1	1	9	11	3.667 A	4.619
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	55	61	69	185	61.667 B	7.024
scarification by H_2SO_4	47	67	69	183	61.000 B	12.166
Block Total	152	150	224	526	175.333	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio
Treatment	14443.78	5	2888.756	20.446
Block	592.444	2	296.222	2.097
Residual	1412.889	10	141.289	
Total	16449.11	17	967.595	

	5%	1%
Critical Value of Distribution for Treatment	3.10	5.06
Critical Value of Distribution for Blocks	3.68	6.35

Table 26. *Bauhinia variegata*: Number of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	77	69	57	203	67.667 B	10.066
55°C	0	5	10	15	5.000 A	5.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	62	73	51	186	62.000 B	11.000
scarification by H_2SO_4	0	0	0	0	0.000 A	0.000
Block Total	139	147	118	404	135	
Sourec of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	16275.78	5	3255.156	77.524		
Block	74.778	2	37.389	0.89		
Residual	419.889	10	41.989			
Total	16770.44	17	986.497			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 27. *Ficus abelii*: Number of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	36	35	32	103	34.333 B	2.082
55°C	2	4	6	12	4.000 A	2.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by H_2SO_4	10	12	9	31	10.333 A	1.528
Block Total	48	51	47	146	49	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	2483.600	4	620.900	253.429		
Block	1.733	2	0.867	0.354		
Residual	19.600	8	2.450			
Total	2504.933	14	178.924			
Critical Value of Distribution for Treatment			5%	1%		
			3.47	5.99		
Critical Value of Distribution for Blocks			3.88	6.92		

Table 28. *Ficus glaberrima*: Number of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	7	7	3	17	5.667 B	2.309
55°C	0	0	0	0	0.000 A	0.000
80°C	0	0	0	0	0.000 B	0.000
100°C	0	0	0	0	0.000 B	0.000
scarification by H_2SO_4	16	5	8	29	9.667 A	5.686
Block Total	23	12	11	46	15	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	235.600	4	58.900	8.181		
Block	17.733	2	8.867	1.231		
Residual	57.600	8	22.21			
Total	310.933	14				
Critical Value of Distribution for Treatment			5%	1%		
			3.47	5.99		
Critical Value of Distribution for Blocks			3.88	6.92		

Table 29. *Macaranga denticulata*: Number of germinated seedlings after 3 months

Treatment	Block 1	Block 2	Block 3	Treatment Total	Treatment Mean	Standard Deviation
27°C	3	5	7	15	5.000 AB	2.000
55°C	1	3	2	6	2.000 AB	1.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	13	9	17	39	13.000 C	4.000
scarification by H_2SO_4	0	0	0	0	0.000 A	0.000
Block Total	17	17	26	60	20	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio
Treatment	394.000	5	78.800	20.446
Block	9.000	2	4.500	2.097
Residual	33.000	10	3.300	
Total	436	17	25.647	

	5%	1%
Critical Value of Distribution for Treatment	3.10	5.06
Critical Value of Distribution for Blocks	3.68	6.35

Table 30. *Rhus chinensis*: Number of germinated seedlings after 3 months (1)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.000
55°C	38	30	42	110	36.667 C	6.110
80°C	5	3	8	16	5.333 AB	2.517
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	13	5	21	39	13.000 B	8.000
scarification by H_2SO_4	68	70	63	201	67.000 D	3.606
Block Total	124	108	134	366	122	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	10650.67	5	2130.33	115.768		
Block	57.333	2	28.667	1.558		
Residual	184.000	10	18.400			
Total	10892.00	17	640.706			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 31. *Rhus chinensis*: Number of germinated seedlings after 3 months (2)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.000
55°C	35	37	29	101	33.667 C	2.404
80°C	2	4	4	10	3.333 AB	0.667
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	14	19	9	42	14.000 B	2.887
scarification by H_2SO_4	68	72	65	205	68.333 D	2.028
Block Total	119	132	107	358	119.3300	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	10909.78	5	2181.956	364.334		
Block	52.111	2	26.056	4.351		
Residual	59.889	10	5.989			
Total	11021.78	17	648.34			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 32. *Terminalia alata*: Number of germinated seedlings after 3 months (1)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	42	20	36	98	32.667 A	11.373
55°C	30	16	34	80	26.667 C	9.452
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	20	17	9	46	15.333 B	5.662
scarification by H_2SO_4	33	31	32	96	32.000 D	1.0000
Block Total	125	84	111	320	106.667	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	3423.111	5	684.662	19.058		
Block	144.778	2	72.389	2.015		
Residual	359.222	10	35.992			
Total	3927.111	17	231.007			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 33. *Terminalia alata*: Number of germinated seedlings after 3 months (2)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	42	60	42	144	48.000 C	10.392
55°C	30	38	16	84	28.000 B	11.136
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	20	17	29	66	22.000 B	6.245
scarification by H_2SO_4	33	31	32	96	32.000 BC	1.000
Block Total	125	146	119	390	130.000	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	5338.000	5	1067.600	22.382		
Block	67.000	2	33.500	0.702		
Residual	477.000	10	47.700			
Total	5882.000	17	346.00			
Critical Value of Distribution for Treatment			5%	1%		
			3.10	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 34. *Albizia chinensis*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.000
55°C	14.28	2.98	8.47	25.73	8.577 B	5.651
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	1.28	7.86	4	13.14	4.380 AB	3.306
scarification by H_2SO_4	8.43	1.23	15	24.66	8.220 B	6.887
Block Total	23.99	12.07	27.47	63.53	21.1767	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	256.71	5	51.342	3.232		
Block	21.742	2	10.871	0.684		
Residual	158.857	10	15.886			
Total	437.310	17	25.724			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 35. *Aporusa villosa*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	16.32	28.57	1.29	46.18	15.393 B	13.664
55°C	100	100	88.88	288.88	96.293 C	6.420
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	9.09	19.67	1.44	30.2	10.067 AB	9.154
scarification by H_2SO_4	6.38	1.49	13.04	20.91	6.970 AB	5.798
Block Total	131.79	149.73	104.65	386.17	128.7233	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	20692.99	5	4138.598	79.751		
Block	171.702	2	85.851	1.654		
Residual	518.943	10	51.894			
Total	21383.63	17	1257.861			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 36. *Bauhinia vareigata*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	1.29	7.24	14.03	22.56	7.520 AB	6.375
55°C	0	40	20	60	20.000 B	20.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	12.9	6.84	1.96	21.7	7.233 AB	5.481
scarification by H_2SO_4	0	0	0	0	0.000 A	0.000
Block Total	14.19	54.08	35.99	104.26	35	

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio
Treatment	922.717	5	184.543	2.283
Block	132.983	2	66.492	0.823
Residual	808.362	10	80.836	
Total	1864.063	17	109.651	

	5%	1%
Critical Value of Distribution for Treatment	3.1	5.06
Critical Value of Distribution for Blocks	3.68	6.35

Table 37. *Ficus abelii*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	2.77	14.28	9.37	26.42	8.807 AB	5.776
55°C	50	25	0	75	25.000 C	25.000
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by H_2SO_4	20	8.33	11.11	39.44	13.147 B	6.096
Block Total	72.77	47.61	20.48	140.86	47	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	1303.407	4	325.852	2.333		
Block	273.554	2	136.777	0.979		
Residual	1117.479	8	139.685			
Total	2694.440	14	192.46			
Critical Value of Distribution for Treatment			5%	1%		
			3.47	5.99		
Critical Value of Distribution for Blocks			3.88	6.92		

Table 38. *Ficus glaberrima*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	none	none	none
55°C	0	0	0	none	none	none
80°C	0	0	0	none	none	none
100°C	0	0	0	none	none	none
Scarification by H_2SO_4	0	0	0	none	none	none
Block Total		none	none	none	none	none

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio
Treatment	none	none	none	none
Block	none	none	none	
Residual	none	none	none	
Total	none	none	none	
Critical Value of Distribution for Treatment			5%	1%
			3.47	5.99
Critical Value of Distribution for Blocks			3.88	6.92

Table 39. *Macaranga denticulata*: Percent mortality of germinated seedlings after 3 months

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	none	none	none
55°C	0	0	0	none	none	none
80°C	0	0	0	none	none	none
100°C	0	0	0	none	none	none
Scarification by hand	0	0	0	none	none	none
Scarification by H_2SO_4	0	0	0	none	none	none
Block Total	none	none	none	none	none	none

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio
Treatment	none	none	none	none
Block	none	none	none	
Residual	none	none	none	
Total	none	none	none	
Critical Value of Distribution for Treatment			5%	1%
			3.1	5.06
Critical Value of Distribution for Blocks			3.68	6.35

Table 40. *Rhus chinensis*: Percent mortality of germinated seedlings after 3 months (1)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.0000
55°C	5.26	6.66	9.52	21.44	7.146 A	2.1713
80°C	40	66.66	37.5	144.16	48.053 B	16.1623
100°C	0	0	0	0	0.000 A	0.0000
scarification by hand	15.38	0	20	35.38	11.7933 A	10.4713
scarification by H_2SO_4	2.94	2.85	1.58	7.37	2.4567 A	0.7605
Block Total	63.58	76.17	68.6	208.35	69.45	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	5104.296	5	1020.859	13.815		
Block	13.39	2	6.695	0.091		
Residual	738.930	10	73.893			
Total	5856.615	17	344.507			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 41. *Rhus chinensis*: Percent mortality of germinated seedlings after 3 months (2)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	0	0	0	0	0.000 A	0.0000
55°C	8.57	16.21	24.13	48.91	16.303 AB	7.7804
80°C	0	50	25	75	25.000 B	25.0000
100°C	0	0	0	0	0.000 A	0.0000
scarification by hand	7.14	5.26	11.11	23.51	7.836 A	2.9866
scarification by H_2SO_4	1.47	6.9	1.53	9.9	3.300 A	3.1178
Block Total	17.18	78.37	61.77	157.32	52.4400	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	1514.329	5	302.866	2.818		
Block	333.78	2	166.890	1.553		
Residual	1074.571	10	107.457			
Total	29922.68	17	171.92			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 42. *Terminalia alata*: Percent mortality of germinated seedlings after 3 months (1)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	2.38	0	16.6	18.98	6.327 A	8.976
55°C	3.33	12.5	11.76	27.59	9.197 B	5.094
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	0	5.88	11.11	16.99	5.663 A	3.209
scarification by H_2SO_4	6.06	0	15.62	21.68	7.227 A	4.547
Block Total	11.77	18.38	55.09	85.24	28.4134	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	223.052	5	44.61	2.053		
Block	181.552	2	90.776	4.177		
Residual	217.313	10	21.731			
Total	621.917	17	36.583			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Table 43. *Terminalia alata*: Percent mortality of germinated seedlings after 3 months (2)

Treatment	Block			Treatment Total	Treatment Mean	Standard Deviation
	1	2	3			
27°C	2.38	5	4.76	12.14	4.047 AB	1.448
55°C	3.88	5.26	12.5	21.64	7.213 BC	4.630
80°C	0	0	0	0	0.000 A	0.000
100°C	0	0	0	0	0.000 A	0.000
scarification by hand	15	17.64	6.89	39.53	13.177 C	5.602
scarification by H_2SO_4	3.08	3.22	9.37	15.67	5.223 AB	3.5918
Block Total	24.34	31.12	33.52	88.98	29.6600	
Source of Variation	Sum of Square	Degree of Freedom	Mean Square	Variance Ratio		
Treatment	368.089	5	73.618	5.748		
Block	7.556	2	3.778	0.295		
Residual	128.085	10	12.809			
Total	503.730	17	29.631			
Critical Value of Distribution for Treatment			5%	1%		
			3.1	5.06		
Critical Value of Distribution for Blocks			3.68	6.35		

Analysis of Variance on Growth of seedlings

Table 44. *Albizia chinensis*: Height at 6 months (55°C)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	102.708	2	51.354	2.371	0.105
TREAT	3.521	1	3.521	0.163	0.689
BLOCK	99.188	1	99.188	4.579	0.038
Explained	102.708	2	51.354	2.371	0.105
Residual	974.771	45	21.662		
Total	1077.479	47	22.925		

Table 45. *Albizia chinensis*: Height at 6 months (scarification by hand)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	192.708	2	96.354	3.309	0.046
TREAT	4.688	1	4.688	0.161	0.69
BLOCK	188.021	1	188.021	6.457	0.015
Explained	192.708	2	96.354	3.309	0.046
Residual	1310.271	45	29.117		
Total	1502.979	47	31.978		

Table 46. *Albizia chinensis*: Height at 6 months (scarification by H_2SO_4)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	108.375	2	54.188	2.161	0.127
TREAT	54.188	1	54.188	2.161	0.149
BLOCK	54.188	1	54.188	2.161	0.046
Explained	108.375	2	54.188	2.161	0.127
Residual	1128.604	45	25.08		
Total	1236.979	47	26.319		

Table 47. *Aporusa villosa*: Height at 6 months (control)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	4.26	2	2.13	0.497	0.612
TREAT	1.505	1	1.505	0.351	0.557
BLOCK	2.755	1	2.755	0.642	0.427
Explained	4.26	2	2.13	0.497	0.612
Residual	192.984	45	4.289		
Total	197.245	47	4.197		

Table 48. *Aporusa villosa*: Height at 6 months (scarification by hand)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	11.271	2	5.635	1.098	0.342
TREAT	9.188	1	9.188	1.791	0.188
BLOCK	2.083	1	2.083	0.406	0.527
Explained	11.271	2	5.635	1.098	0.342
Residual	230.896	45	5.131		
Total	242.167	47	5.152		

Table 49. *Bauhinia variegata*: Height at 6 months (control)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	177.667	2	88.833	2.541	0.09
TREAT	1.33	1	1.333	0.038	0.846
BLOCK	176.33	1	176.333	5.04	0.03
Explained	177.667	2	88.833	2.541	0.09
Residual	1573	45	34.956		
Total	1750.667	47	37.248		

Table 50. *Bauhinia variegata*: Height at 6 months (scarification by hand)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	114.708	2	57.354	1.032	0.365
TREAT	72.521	1	72.521	1.305	0.259
BLOCK	42.188	1	42.188	0.759	0.388
Explained	114.708	2	57.354	1.032	0.365
Residual	2501.104	45	55.58		
Total	2615.813	47	55.656		

Table 51. *Rhus chinensis*: Height at 6 months (55 °C)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	35.417	2	17.708	1.496	0.235
TREAT	14.083	1	14.083	1.19	0.281
BLOCK	21.333	1	21.333	1.803	0.186
Explained	35.333	2	17.708	1.496	0.235
Residual	532.5	45	11.833		
Total	567.917	47	12.083		

Table 52. *Rhus chinensis*: Height at 6 months (scarification by H_2SO_4)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	11.135	2	5.568	0.816	0.449
TREAT	1.505	1	1.505	0.221	0.641
BLOCK	9.63	1	9.63	1.411	0.241
Explained	11.135	2	5.568	0.816	0.449
Residual	307.109	45	6.825		
Total	318.245	47	6.771		

Table 53. *Terminalia alata*: Height at 6 months (control)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	181.5	2	90.75	2.254	0.177
TREAT	90.75	1	90.75	2.254	0.14
BLOCK	90.75	1	90.75	2.254	0.14
Explained	181.5	2	90.75	2.254	0.177
Residual	1811.75	45	40.261		
Total	1993.25	47	42.41		

Table 54. *Terminalia alata*: Height at 6 months (55 °C)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	259.208	2	129.604	3.068	0.056
TREAT	256.688	1	256.668	6.077	0.018
BLOCK	2.521	1	2.521	0.06	0.808
Explained	259.208	2	129.604	3.068	0.056
Residual	1900.771	45	42.239		
Total	2159.979	47	45.957		

Table 55. *Terminalia alata*: Height at 6 months (scarification by hand)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	55.875	2	27.938	1.467	0.241
TREAT	1.688	1	1.688	0.089	0.767
BLOCK	54.188	1	54.188	2.845	0.099
Explained	55.875	2	27.938	1.467	0.241
Residual	857.104	45	19.047		
Total	912.979	47	19.425		

Table 56. *Terminalia alata*: Height at 6 months (scarification by H_2SO_4)

Source of Variation	Sum of Squares	DF	Mean Squares	F	Sig of F
Main Effects	56.417	2	28.208	0.983	0.382
TREAT	0.083	1	0.083	0.003	0.957
BLOCK	56.333	1	56.333	1.963	0.168
Explained	56.417	2	28.208	0.983	0.382
Residual	1291.583	45	28.702		
Total	1348	47	28.681		

APPENDIX III : Cost-benefit Analyses

Note: the cost based on FORRU Nursery's expense

1. Container

1.1 REX Tray

Cost	50 baht/tray
Transportation(Khon Kaen-Chiang Mai)	2,500 baht/100 tray
Transportation	25 baht/tray
Total cost(50+25)	75 baht/tray
One tray has 24 cells: 1 cell	(75/24)
	3.125 baht/ seedling
Reusable time 12 season	
Container cost/seedling/season	0.2604 baht/seedling/season

1.2 Basket

Cost	30 baht/basket
Transportation(urban area to DSNP)	5 baht/12 basket
Transportation	0.41 baht/basket
Total cost (30+0.41)	30.41 baht/basket
One basket has 100 cell : 1 cell	30.41/100
	0.3041basket/seedling
Reusable time 12 season	
Container cost/seedling/season	0.02534 baht/seedling/season

2. Potting Media

Media for germination

Sand (1 m^3)	300 baht
Transportation(urban area to DSNP and labor)	500 baht
Sand 1 cm^3	0.0008 baht
Rice husk(45,000cm^3)	20 baht

Rice husk 1 cm^3	0.00044 baht
Media 1 cm^3	0.00062 baht/seedling
Volume use 77.7 cm^3/seedling	
Potting media cost/ seedling/season	0.0481 baht/seedling/season
Media for growing seedling	
Forest soil volume of soil(150*150*150 cm)/2	1,687,500 cm^3
Forest soil 1 cm^3	0.00059 baht
Media	
Coconut husk(98,400 cm^3)	50 baht
Penut value(98,400 cm^3)	40 baht
Forest soil (196,800 cm^3)	116.112 baht
Total(393,600cm^3) 1 cm^3	0.0005 baht
Volume use REX Tray	300 cm^3
Potting media cost/ seedling/season	0.157 baht

3. Chemical Reagent

Conc.H_2SO_4 1000 ml	700 baht
(1 container=2.5 l)	1,750 baht
Volume used/seed	1 ml/seed 0.7 baht/seedling/season

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4. Fertilizer

Osmocote (1,000 gm)	150 baht
1 gm	0.150 baht
Volume use 0.3 gm/seedling/time	0.045 baht
use every 3 months (4 time)	0.18 baht/seedling/season
NPK(1000 gm)	15 baht
1 gm	0.015 baht
Volume use 20 gm/ 48 seedling/time	0.00625 baht
use every 15 days (24 time)	0.15 baht/seedling/season

5. Aluminium Table

Cost	1,500 baht/table
Transportation(urban area-FORRU)	200 baht/table
Total cost(1500 +200)	1,700 baht/table
One table contain 8 Rex trey	1,700/192
	8.82 baht/seedling
Reusable time 12 season	
Table cost/seedling/season	0.735 bath/seedling/season

6.Time consuming

Basket	10 second/unit
Time consuming/cell	
Basket(1 unit=100 cell)	0.1 second/seedling
REX Tray	30 second/unit
Time consuming/cell	
REX Tray(1 unit=24 cells)	1.25 second/seedling
Cutting	25 seeds/second
Time consuming/cell	0.04 second/seed

7. Labor Cost

Labor wage 1 day,150 Baht, work in 8 hrs. 1 hr 18.75 baht

Seed collection 150/1500 seeds	0.1 baht/seedling/season
Labor cost for sowing seed	0.00052 baht/seedling/season
Labor cost for cutting seed	0.00020 baht/seedling/season
Labor cost for filling container	0.00651 baht/seedling/season
Labor cost for germination/seedling /season	0.1+0.00052 0.10052 baht/seedling

Labor cost for growing seedling/seedling /season depended on treatment

CURRICULUM VITAE

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December 1984	Bachelor's Degree of Science in Biology, Khon Kaen University, Khon Kaen

Work Experience

1984-1994	Union Drug Laboratories
1994-1996	Pollution Control Department Ministry of Science Technology and Environment
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