PROPAGATION OF NATIVE FOREST TREE SPECIES FOR FOREST RESTORATION IN DOI SUTHEP-PUI NATIONAL PARK

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIRMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN BIOLOGY

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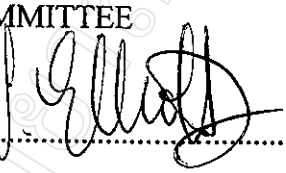
EXAMINING COMMITTEE



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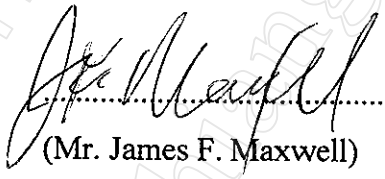

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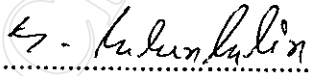

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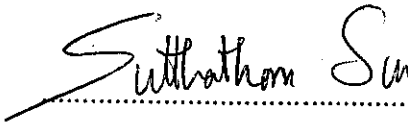

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Thesis Title Propagation of Native Forest Tree Species for Forest Restoration in Doi Suthep-Pui National Park.

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ABSTRACT

Restoring forest ecosystems by tree planting requires production of a planting stock, on a large scale, of a very wide range of indigenous forest tree species. Many of these species have proved difficult to propagate from seed, due to long dormancy periods or seed production too late for seedlings to grow large enough by planting time. The aim of this study was, therefore, to investigate how to improve propagation of native trees for forest restoration, based on an understanding of their reproductive ecology. The study included development of new techniques to germinate the seeds of 30 indigenous tree species, of potential value to forest restoration, but which had not previously been grown in nurseries. Seed germination in the nursery was compared with that of seeds sown in a forest gap, where the effects of seed predation were also investigated. For 10 species, with limited seed germination, vegetative propagation of was investigated using a novel non-mist system to propagate leafy stem cuttings, testing various chemical treatments to induce rooting. In addition, the seasonality of production of seeds and material for cuttings was investigated. The

aim was to examine whether knowledge of the reproductive ecology of native tree species could be used to predict which horticultural practices are likely to result in successful propagation.

The phenology of 32 forest tree species was recorded monthly over 12 months. Leaf fall occurred in the dry season, in response to declining soil moisture, whilst flushing occurred in the dry to early wet seasons. Most species (60%) flowered in April (hottest, driest time of year), when leafless or flushing with young leaves. Fruiting peaked in September (75% of species), whilst seed dispersal occurred over the late wet season to early dry season (August-January) (more than 50% of studied species). Consequently, most species required lengthy dormancy periods, to survive the dry season and germinate in the rainy season. Therefore, in order to accelerate seedling production in the nursery, treatments to break dormancy had to be developed.

Consequently, experiments to increase and accelerate seed germination were carried out on 30 indigenous forest tree species. Seven pre-treatments were tested to promote seed germination. Scarification increased seed germination for *Acrocarpus fraxinifolius*, scarification + soaking for *Afzelia xylocarpa*, scarification alone and scarification + soaking for three species (*Albizia chinensis*, *Elaeocarpus lanceifolius* and *Sindora siamensis*), and scarification and/or acid treatment for 3 minutes for *Cassia fistula*. Accelerated and more synchronous germination was achieved for three species (*Acrocarpus fraxinifolius*, *Albizia chinensis* and *Cassia fistula*) because of the treatments. Despite low germination percentages (38-47%) ten tree other species might still qualify as potentially useful for forest restoration, due to other attributes, such as high growth rate in containers or good field performance. On the other hand, germination of *Betula alnoides*, *Ficus hirta* and *Schleichera oleosa*, were unacceptably low for all treatments (≤ 20%). Therefore, other seed pre-treatments or alternative propagation systems must, therefore, be considered for these species. The

remaining three species had intermediate germination (*Afzelia xylocarpa*, *Elaeocarpus lanceifolius* and *Sindora siamensis*).

Shade dependence for germination and early seedling development would make a tree species unsuitable for forest restoration in open, degraded sites. Therefore, germination experiments were replicated in deep shade. Shade-dependence was found only for one species, *Elaeocarpus lanceifolius*. Shade-tolerance was demonstrated for eighteen species. Only seven species were shade-inhibited. However, four species produced mixed results. This indicates that very few tree species will be unable to grow in open degraded sites due to strong sunlight. It raises the possibility of planting pioneer and most climax tree species together in a single step for restoring forest to degraded sites.

To determine the influence of nursery conditions on germination and to investigate the possibility of direct seedling as an alternative to planting seedlings, seed experiments were also replicated in a forest gap. Fourteen species (47%) germinated better in the nursery than in the gap, five species germinated better in the gap than in the nursery and eleven species showed no difference in germination between nursery and gap. This indicates that nursery conditions generally enhance germination above natural levels.

The impact of seed predation on seed germination in the forest gap varied among species, with seed size and seed coat. The mean number of seeds removed was highest for *Eleaocarpus prunifolius*, *Irvingia malayana*, *Reevesia pubescens* and *Terminalia chebula*. Seven native tree species with high and rapid germination in the gap and no seed predation were identified as suitable for direct seeding. Except for the small seeds, burial did not seem to protect seeds from predators.

Some associations were found between ecological parameters and best treatments to break seed dormancy. Pre-treatments brought about significant

improvement in germination of seeds with thick integuments ($p=0.001$), large and medium seed size ($p=0.028$) and seed dormancy ($p=0.017$). Prolonged dormancy was significantly associated with better seed germination under gap conditions ($p=0.004$) and with thick integuments ($p=0.024$). Better seed germination under nursery conditions (compared with the gap) was significantly associated with the small seed size group ($p=0.0024$) and thin integuments ($p=0.016$). Heavy seed predation was strongly associated with large seed size group ($p=0.004$) and thick integuments (endocarp) ($p=0.040$).

The effects of various hormone treatments on leafy stem cuttings varied among the species tested. Only five of ten tree species achieved a maximum of 60% or more cuttings developing roots. Seradix #3 produced the best results with *Debregeasia longifolia* (68%) and *Saurauia roxburghii* (65%). IBA 3000 ppm produced the best results with *Ficus superba* (72%) and IBA 8000 ppm produced the best results with *Colona flagrocarpa* (63%). Also, *Morus macroura* cuttings (90%) grew roots most efficiently without any hormone treatment, with the non-treated control cuttings producing the highest success ranking scores. Unlike pre-treatments to promote seed germination, the chemical treatments to improve vegetative propagation showed no significant associations with ecological variables.

Relationships among ecological variables and best horticultural practices are clearly complex and will require further research, if useful, predictive models are to be developed.

ชื่อเรื่องวิทยานิพนธ์	การขยายพันธุ์ไม้ยืนต้นท้องถิ่นเพื่อการฟื้นฟูป่าในเขตอุทยานแห่งชาติดอยสุเทพ-ปุย
ชื่อผู้เขียน	นางสาวสุภาวรรณ วงค์คำจันทร์
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	นายสมเกียรติ กลั่นกลิ่น กรรมการ
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บทคัดย่อ

การฟื้นฟูระบบนิเวศของป่าโดยการปลูกต้นไม้ จำเป็นจะต้องมีการเตรียมต้นกล้า ซึ่งมักจะให้ครอบคลุมชนิดของพรรณไม้ท้องถิ่นมากหลายชนิด แต่พบว่าส่วนใหญ่ของพรรณไม้เหล่านี้ยากที่จะเพาะกล้าจากเมล็ด เนื่องจากเมล็ดมีช่วงพักตัวนาน หรือผลิตเมล็ดช้าเกินไป ทำให้กล้าไม้โตไม่ทันต่อฤดูการปลูก ดังนั้น วัตถุประสงค์ของการศึกษานี้ เพื่อหาวิธีที่จะปรับปรุงวิธีการขยายพันธุ์ไม้ท้องถิ่นที่จะใช้ในการฟื้นฟูป่า โดยอาศัยความเข้าใจถึงนิเวศวิทยาของการสืบพันธุ์ของพรรณไม้เหล่านี้ การศึกษารวมถึงการพัฒนาเทคนิคใหม่ๆ ในการเพาะเมล็ดของชนิดไม้ท้องถิ่น 30 ชนิด ที่มีศักยภาพในการฟื้นฟูป่า ที่ยังไม่เคยได้เพาะในเรือนเพาะชำมาก่อน ทำการเปรียบเทียบการเพาะเมล็ดในเรือนเพาะชำกับที่เพาะในพื้นที่โล่งในป่า ซึ่งจะดูผลกระทบจากสัตว์ที่มากินเมล็ดด้วย สำหรับไม้ยืนต้น 10 ชนิด ที่มีปัญหาในการขยายพันธุ์ด้วยเมล็ด ได้ทำการทดลองโดยการปักชำกิ่ง เพื่อทดสอบการชักนำให้เกิดราก โดยอาศัยฮอร์โมนเร่งราก ที่ระดับความเข้มข้นต่างๆ กัน โดยไม่ใช้ระบบพ่นไอหมอก นอกจากนี้ ยังทำการตรวจสอบช่วงเวลาที่เหมาะสมกับการผลิตเมล็ดและกิ่งชำ จุดประสงค์เพื่อตรวจสอบว่า จะใช้ความรู้ทางนิเวศวิทยาของการสืบพันธุ์ของพรรณไม้ท้องถิ่น ในการที่จะทำนายว่าวิธีการปฏิบัติอย่างไร ที่มีแนวโน้มว่าจะประสบความสำเร็จในการขยายพันธุ์ดังกล่าว

การศึกษาชีพลักษณ์ของไม้ป่ายืนต้น จำนวน 32 ชนิด โดยการจดบันทึกทุกๆ เดือน ในเวลา 1 ปี พบว่า การร่วงของใบเกิดขึ้นในฤดูแล้ง ซึ่งเป็นการตอบสนองต่อความชื้นในดินที่ลดลง ขณะที่การแตกใบอ่อน เกิดขึ้นในช่วงฤดูแล้งไปจนถึงช่วงต้นฤดูฝน ส่วนใหญ่แล้วประมาณร้อยละ 60 ของจำนวนชนิดที่ทดลองทั้งหมด ออกดอกในเดือนเมษายน (ช่วงที่ร้อนจัดและแห้งแล้งที่สุดของปี) และเป็นเวลาที่ไม่มีใบหรือกำลังแตกใบอ่อน มีการออกผลสูงสุดในเดือนกันยายน (75% ของจำนวนชนิดทั้งหมด) ขณะที่การกระจายเมล็ดเกิดขึ้นมากในช่วงปลายฤดูฝน ถึงต้นฤดูแล้ง (สิงหาคม-มกราคม) (มากกว่า 50% ของชนิดที่ทำการศึกษา) สิ่งที่เกิดขึ้นตามมาก็คือ ส่วนใหญ่ต้องการระยะเวลายาวนานในการพักตัวของเมล็ด เพื่อการอยู่รอดในฤดูแล้ง และงอกในฤดูฝน ดังนั้นในการเร่งผลิตต้นกล้าในเรือนเพาะชำ การเตรียมเมล็ดก่อนเพาะเพื่อทำลายการพักตัว จึงต้องมีการพัฒนาวิธีขึ้น

เพราะฉะนั้น เพื่อเพิ่มและเร่งการงอกของเมล็ดไม้ยืนต้นท้องถิ่น ได้ทำการทดลองจำนวน 30 ชนิด โดยการเตรียมเมล็ดก่อนทำการเพาะ 7 วิธี เพื่อการกระตุ้นการงอกของเมล็ด การตัดบางส่วนของเมล็ด เพิ่มการงอกของเมล็ดสะเดาช้าง (*Acrocarpus fraxinifolius*), การตัดเมล็ดบางส่วน แล้วนำไปแช่น้ำเพิ่มการงอกของเมล็ดของมะค่าโมง (*Afzelia xylocarpa*), การตัดเมล็ดบางส่วนอย่างเดียว และ การตัดเมล็ดบางส่วนแล้วนำไปแช่น้ำ ช่วยเพิ่มการงอกของ เมล็ด 3 ชนิด [กางหลวง (*Albizia chinensis*), มุ่น (*Elaeocarpus lanceifolius*) และ มะค่าแต้ (*Sindora siamensis*)] และ การตัดเมล็ดบางส่วน และ/หรือ แช่น้ำกรด นาน 3 นาที สำหรับเมล็ดของคูณ (*Cassia fistula*) ปรากฏว่าเมล็ดถูกกระตุ้นให้งอกอย่างรวดเร็ว และสม่ำเสมอจำนวน 3 ชนิด [สะเดาช้าง (*Acrocarpus fraxinifolius*), กางหลวง (*Albizia chinensis*) และ คูณ (*Cassia fistula*)] แม้ว่าร้อยละของการงอกจะต่ำ (38-47%) ในจำนวน 7 ชนิด แต่ยังคงมีคุณสมบัติที่มีศักยภาพเป็นไม้โครงสร้าง เพราะว่าคุณสมบัติที่ดีข้ออื่นๆ เช่น มีอัตราการเจริญเติบโตสูงในภาชนะปลูก และง่ายต่อการดูแลรักษาในแปลงปลูก ในทางตรงกันข้าม การงอกของกำลังเสือโคร่ง (*Betula alnoides*), มะเดื่อขน-ทอง (*Ficus hirta*) และมะโจ๊ก (*Schleichera oleosa*) ได้ผลไม่เป็นที่พอใจในการทดลอง ($\leq$ 20%) เพราะฉะนั้น ควรจะเตรียมเมล็ดโดยวิธีอื่น หรือใช้วิธีอื่นในการขยายพันธุ์ต่อไป ส่วนที่เหลืออีกจำนวน 3 ชนิด งอกได้เร็วและสม่ำเสมอในระดับปานกลาง [มะค่าโมง (*Afzelia xylocarpa*), มุ่น (*Elaeocarpus lanceifolius*) และ มะค่าแต้ (*Sindora siamensis*)]

พรรณไม้ที่มีเมล็ดซึ่งต้องการร่มเงาในการงอกและการพัฒนาของต้นกล้าในระยะเริ่มแรกนั้น ทำให้ไม้เหล่านี้ไม่เหมาะสมในการใช้ฟื้นฟูป่าที่เสื่อมโทรมโล่งแจ้ง ดังนั้น จึงได้ทำการเพาะ

เมล็ดในที่มีร่มเงา จากการทดลองเพาะเมล็ดพบว่า ชนิดที่ต้องอาศัยร่มเงาในการงอก มีเพียงหนึ่งชนิด คือ มุ่น *(Elaeocarpus lanceifolius)* ชนิดทนร่มเงามีจำนวน 18 ชนิด เพียง 7 ชนิดเท่านั้นที่ชอบแสง อย่างไรก็ตาม มี 4 ชนิดเป็นชนิดผสม สิ่งเหล่านี้ชี้บ่งได้ว่ามีไม้จำนวนน้อยที่ไม่สามารถจะปลูกในป่าเสื่อมโทรมซึ่งมีแสงแดดจัด จึงมีความน่าจะเป็นไปได้ว่าในการฟื้นฟูพื้นที่เสื่อมโทรมสามารถจะปลูกไม้ชนิดเบิกนำ และชนิดเสถียรสูง พร้อมๆ กันในคราวเดียวได้

ในการตรวจสอบว่า สภาพภายในเรือนเพาะชำมีอิทธิพลต่อการงอก และความเป็นไปได้ในการหว่านเมล็ดโดยตรงแทนการปลูกด้วยต้นกล้า ได้ทำการทดสอบเมล็ดในช่องว่างในป่า พบว่า 14 ชนิด (47%) งอกในเรือนเพาะชำได้ดีกว่าในช่องว่างในป่า และ 5 ชนิด งอกในช่องว่างในป่าได้ดีกว่า และ 11 ชนิด ไม่มีความแตกต่างของการงอกในเรือนเพาะชำและในช่องว่างในป่า สิ่งเหล่านี้บ่งบอกถึง การงอกของเมล็ดภายใต้สภาวะของเรือนเพาะชำเพิ่มการงอกได้มากกว่าในสภาพธรรมชาติ

ผลกระทบต่อการงอกของเมล็ดจากสัตว์ที่มากินเมล็ด ในสภาพป่าธรรมชาติ มีความแปรผันระหว่างชนิด, ขนาดของเมล็ด และ เปลือกหุ้มเมล็ด จำนวนเมล็ดเฉลี่ยที่ถูกเคลื่อนย้ายไปจากแปลงเพาะ พบว่า เมล็ดของปอหะแหย่ (*Elaeocarpus prunifolius*), กระบก (*Irvingia malayana*), โมลี (*Reevesia pubescens*) และสมอไทย (*Terminalia chebula*) ถูกเคลื่อนย้ายไปมากที่สุด พบว่าไม้ป่า 7 ชนิดที่มีการงอกสูง และรวดเร็ว ในช่องว่างของป่า และไม่มีสัตว์มากินเมล็ด มีความเหมาะสมในการหว่านเมล็ดโดยตรงในป่า การฝังเมล็ดดูเหมือนว่าจะไม่ได้ช่วยป้องกันสัตว์ที่มากินเมล็ด ยกเว้นเมล็ดขนาดเล็ก

การหาความสัมพันธ์ระหว่างตัวแปรทางระบบนิเวศและการเตรียมเมล็ด ต่อการทำลายระยะพักตัวของเมล็ด พบว่า การเตรียมเมล็ดก่อนเพาะมีผลมากที่สุด ต่อเมล็ดที่มีเปลือกหุ้มเมล็ดที่หนา ($p=0.001$), เมล็ดขนาดใหญ่และขนาดกลาง ($p=0.028$) และเมล็ดที่มีระยะพักตัวนาน ($p=0.017$) เมล็ดที่มีระยะพักตัวนานมีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับเมล็ดที่งอกได้ดีในสภาวะการเพาะเมล็ดในช่องว่างในป่า ($p=0.004$) และมีเปลือกหุ้มเมล็ดที่หนา ($p=0.024$) สภาวะการงอกของเมล็ดในเรือนเพาะชำ มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติ กับกลุ่มของเมล็ดที่มีขนาดเล็ก ($p=0.006$), และมีเปลือกหุ้มเมล็ดที่บาง ($p=0.016$) และพบว่ามีความสัมพันธ์อย่างมาก ($p=0.004$) ระหว่างสัตว์ที่มากินเมล็ดกับเมล็ดที่มีขนาดใหญ่ และมีเปลือกหุ้มเมล็ดที่หนา (endocarp) ($p=0.040$)

อิทธิพลของฮอร์โมนที่ใช้ในระดับความเข้มข้นที่แตกต่างกัน ต่อการทดลองปักชำกิ่ง มีความผันแปรไปตามชนิดของพรรณไม้ พบว่า จำนวน 5 ชนิด จากที่ใช้ทดลองทั้งหมดจำนวน 10 ชนิด มีการออกรากมากกว่าร้อยละ 60 ซึ่งได้แก่ ไข่ปลา *(Debregeasia longifolia)* และ ส้านเห็บ (*Saurauia roxburghii*) ออกรากและยอดได้ดีเมื่อใช้เซราดิกส์ เบอร์ 3 (68% และ 65% ตามลำดับ), ผักเฮือด (*Ficus superba*) ออกรากได้ดีเมื่อใช้ IBA 3000 ppm (72%) และ ยาบใบยาว *(Colona flagrocarpa)* เมื่อใช้ IBA 8000 ppm (63%) อย่างไรก็ตาม ม่อนหลวง (*Morus macroura*) สามารถออกรากและยอดได้สูงถึงร้อยละ 90 โดยปราศจากสารเร่งราก หรือมีระดับคะแนนสูงที่สุดในกลุ่มควบคุมซึ่งไม่ได้ใช้ฮอร์โมน การใช้สารเคมีเพื่อปรับปรุงการขยายพันธุ์ ไม่มีความสัมพันธ์กับตัวแปรอื่นๆ ในเชิงระบบนิเวศ

ความสัมพันธ์ระหว่างตัวแปรทางระบบนิเวศและวิธีการปฏิบัติในการขยายพันธุ์ที่ดีที่สุดนั้น มีความซับซ้อน และต้องอาศัยการทำวิจัยเพิ่มเติมในอนาคตเพื่อกำหนดรูปแบบที่จะเป็นประโยชน์ต่อไป

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ABBREVIATIONS

cm	centimeter
g	gram
g/L	grams/litre
GA	gibberellic acid
GP	germinaion period
IAA	indoleacetic acid
IBA	indolebutyric acid
km	kilometer
m	meter
mins	minutes
MLD	median length of dormancy
mm	millimeter
ppm	part per million
NAA	alpha-naphthaleneacetic acid
v/v	volume/volume

CHAPTER 1

Introduction and Literature Review

1.1 Deforestation in Thailand

Forests, especially tropical forests, play a very important role in many countries' economic development and also in global environmental protection. Tropical forests contain a substantial portion of the world's biological resources, richness and diversity. Hence, they are often called a treasury of biological resources. Although tropical forests contain many important natural resources, they have been widely degraded throughout the world. Deforestation means the clearing of forest from large tracts of land, which consequently remain unforested, either as barren land or as agricultural cropland (Bruenig, 1996). Deforestation has accelerated considerably in recent years. Vast areas of tropical forests have been lost in the last 40 years, mainly due to the activities of the developed countries (Miyamaki, 1993). Deforestation has been caused by many factors, including increased human population density, infrastructure development, the establishment of settlements, illegal encroachment and logging, shifting cultivation, the migration of poor people, *etc*. Deforestation causes climatic change, global warming (or the green-house effect), soil erosion, degradation of watersheds, losses of biodiversity, *etc*. (Bhumibhamon, 1986; Miyawaki, 1991; Godt and Hadley, 1991; Elliott, *et al*., 1996; Hau, 1999).

Like many rapidly developing tropical countries, Thailand has experienced extensive deforestation, despite a ban on commercial logging since 1989 (FORRU, 2000). Illegal logging has been a problem for decades and still continues. However, the ban on commercial logging has helped to slow the rate of destruction (FORRU, 2000). The main causes of deforestation in Thailand, include; illegal logging, agricultural expansion and various development projects (Bhumibhamon, 1986), such as construction of infrastructure (roads, dams, resorts, *etc*.) (Elliott, 2001).

The productive forest area in Thailand was 58% of the total land area in 1959 (Bhumibhamon, 1986), but has now declined to 22.8% (FAO, 1999).

Thailand is divided into 4 geographical regions, comprising the central region, western region, southern region and northern region. The trend of forest depletion has differed among the regions (Bhumibhamon, 1986). In 1995 the remaining forest area in Thailand was officially 131,485 km^2 or 26 % of the total land area, although even in 1992 it was considered to be closer to 18% in reality (Leungaramsri and Rajesh, 1992). The country now has only about 18% forest cover, compared with 53% in 1961 (Elliott *et al.*, 1996; Kamyorng, 2000), while Maxwell estimated forest cover to be about 15% (Maxwell, 1999). The lowest estimation was approximately 13% of the country (Blakesley *et al.*, 2000). The impacts of deforestation on the human population and environment of northern Thailand include; ecological effects (climate changes, soil condition, soil erosion, siltation and water balance) as well as economic, social and political effects (Bhumibhamon, 1986).

Although most remaining forest is located in the northern region of Thailand, the forest area has been reduced from 68.5% or 116,275 km^2 of the region in 1961 to 43.6% or 73,886 km^2 in 1995 (FORRU, 2000). In particular, destruction of upper watershed forests is caused by unsuitable land practices (Svasti, 2000). The regional rate of deforestation is approximately 0.9% per year (FORRU, 2000). The consequences of deforestation are particularly serious in the north (Svasti, 2000), as streams dry up in the dry season and rivers become choked with silt, especially in March and April. In 2002, most provinces in northeastern and northern Thailand lacked water for agriculture and drinking. In August 2001, flash floods and mudslides occurred in the rainy season, in Lom Sak district, Phetchabun province and there were unprecedented flash floods and mudslides in northern Thailand. Seventy-eight people were killed and 70 went missing. Seventy houses were totally destroyed and about 200 others were partly damaged. A total of 6,880

people were affected and more than 12,000 rai of residential land and 11,000 rai of plantations were damaged. Hundreds of million baht were spent in helping the flood victims, as well as those in Chiang Rai and Chiang Mai (The Nation, August 12, 2001).

A similar event happened in southern Thailand in November 1988 in Nakhon Si Thammarat province. Two hundred people were killed, 300 houses were buried under sand, and hundreds of fruit trees were knocked down by mudslides from the surrounding hills (Rao, 1988). Furthermore, there was extensive damage to watersheds, loss of biodiversity and impoverishment of rural communities (Elliott *et al.*, 1995 in Blakesley *et al.*, 2000). The Thai government and private organizations have undertaken many ways to solve this problem by designating forest reserves, reforestation, forest restoration, protecting forests against fire and providing artificial rainfall dams, *etc.* (Phonesavanh, 1994).

In Chiang Mai, the forest area has been reduced from 93.3% or 16,750 km^2 of the total land area in 1961 to 70.8% or 14,233 km^2 in 1995 (Kamyorng, 2000). Satellite images revealed that the area deforested more than doubled in just ten years from 3,235 km^2 in 1975 to 6,513 km^2 in 1985 (GRID, 1988). Forest covered about 14,060 km^2 or 69.96% in 1998 and the rate of forest loss averaged of 0.28% per year (RFD, 1998). The main cause of deforestation is shifting cultivation or swidden agriculture of tribal people, home land for the accelerated growth of human populations rates, and development projects (Bhumibhamon, 1986; Svasti, 2000; Elliott *et al.*, 2000).

To help protect remaining forests, the government has established an extensive system of national parks. For example, Doi Suthep-Pui National Park plays a vital role in protecting the economic and natural resources of the Chiang Mai province, although nearly 60% of the park has been deforested (Elliott, 1994). In 10 years, between 1975 and 1985, forest cover in the park fell from 225.34 km^2 or 86% to

148.98 km^2 or 56.7% (Elliott, 2001). The causes of deforestation, include; logging in the lowlands, clearance of land for agriculture, urban sprawl, various tourism development projects, establishment of government offices and construction of infrastructure (roads, resorts, *etc.*) (Elliott, 2001). Although Doi Suthep-Pui has lost several species, it still retains a diverse flora and fauna of great scientific and educational value (Maxwell and Elliott, 2001). Its biodiversity includes at least 2,247 vascular plants species (Maxwell and Elliott, 2001), of which 1,116 are trees (CMU Herbarium Database, 2002), 150 mammal species, 383 birds, (Lekagul & Mc Neely, 1988; Round, 1988; in FORRU, 2000), 500 butterflies, 300 moths, 28 amphibians and 50 reptiles (Pinratana, 1977-85; Banziger, 1988; Nabhitabhata, 1987 in Elliott, 2001). Doi Suthep-Pui National Park must now serve many functions. It is a refuge for wildlife, a religious and cultural centre, a watershed protection area [that feeds the Chao Phraya River and irrigates rice fields of the central plains and supplies water to the nation's capital (Elliott, 2001; FORRU, 2000)], a tourist attraction and a site for recreation, education and research (Elliott, 2001).

1.2 Reforestation in Thailand

In consequence, many areas of degraded forestland now require forest restoration. Forest restoration refers to the planting of a wide range of native forest tree species to restore degraded areas, to recover original levels of species diversity, ecosystem structure and ecosystem function that have been partially or totally destroyed. Forest restoration is one specific form of reforestation. The term reforestation refers to planting any tree species, and includes plantations, social forestry and agro-forestry (Elliott, 2000). In 1906, the first plantations in Thailand were established by Governmental organizations. At first only teak was planted in association with upland rice or so-called agro forestry (Bhumibhamon, 1986). Since then the Royal Forest Department has successfully established plantations with a total area in 1984 of 4,918,332 rai. The RFD also promotes tree planting

campaigns for specific occasions *i.e.* the King's birthday, Queen's birthday, *etc.* In 1961, the Army Mapping Department made the first forest map, used for planning the establishment of conserved forests and for logging operations and reforestation programs (Bhumibhamon, 1986). For instance, since 1968 up to 1982, The Forest Industry Organization has been actively engaged in tree planting programs totaling 50,176.60 ha (Bhumibhamon, 1986), The Thai Plywood Company has planted about 2,700 ha, *etc.* However, most reforestation projects used single tree species for instance teak, pine and eucalyptus for the production of timber. They are not so useful for the conservation of biodiversity (Karimuna, 1995; Elliott *et al*, 1997). In 1994, for the first time, a wide range of native forest tree species began to be planted for forest restoration for conservation by both the government and private organizations, to celebrate the Golden Jubilee of His Majesty King Bhumibol Adulyadej (Hardwick, 1999). Karimuna (1995) suggested that a pine plantation can be used for the early stages of regeneration, but after that, the pines should be selectively thinned to allow other tree seedlings and saplings to grow naturally. Various forest restoration methods have been developed, for instance, the accelerated natural regeneration (ANR) (Jensen and Pfeifer, 1989), the framework species method (Tucker, 2000), and the accelerated pioneer-climax series method (APCS) (Sôû, 2000).

Sometimes, it is not necessary to plant trees to restore forests. Accelerated natural regeneration (ANR) is a technologically simple and cost-effective approach to forest restoration (Jensen and Pfeifer, 1989). ANR is practiced on a small scale by non-governmental and community organizations in Thailand (Bangkok Post, 1994b in Hardwick, 1999) and the Phillipines (Dungan, 2000). ANR can be used for watershed protection and conservation, agro forestry or timber production (Hardwick, 1999). Hardwick studied tree colonization of abandoned agricultural clearings in a seasonal tropical montane forest on Doi Suthep. Success at each stage of the colonization process was strongly influenced by seed size. Colonization was largely restricted to species with medium sized seeds of between

2 and 14 mm. Tree species were divided into three seed-sized-based functional groups, characterized by different critical stages (where colonization was likely to be blocked) and inhibiting stages (where the probability of colonization was much reduced). The critical stage for small-seeded species was recruitment. Seeds were dispersed prolifically to the clearings but failed to develop into seedlings. Medium-seeded species had no consistent critical stage. The critical stage for large-seeded species was seed dispersal. This group was also limited at the fruit production stage as many large-seeded species fruited supra-annually, so in some years no seed was available to start the colonization process. For the few large seeds dispersed into gaps by animals, levels of recruitment and first year establishment were high. However ANR can only work with the trees that are already established in deforested areas (Elliott, 2000). Hardwick *et al.* (2000) suggested that there were 4 groups of potential limiting factors that must be overcome by ANR techniques namely: i) disturbance, ii) site resources, iii) weed competition and iv) plant and propagule availability. One of the main problems with ANR is that only fast-growing pioneer trees with small or medium sized seeds, that are easily dispersed, colonize degraded areas. To restore the full tree community, some tree planting is inevitable, since the complete forest tree community includes large-seeded tree species too (Elliott, 2000).

1.3 Forest Restoration in Northern Thailand

The Thai government has recently embarked on a nation-wide project to restore forests to degraded areas (Elliott *et al.*, 1995). Traditional methods of intensive plantation forestry are employed, but now mixtures of native species are used instead of the previous practice of planting monocultures of pine, teak or eucalyptus (Elliott *et al.*, 2000). Tree seedlings are raised in nurseries, then planted out in degraded areas (Elliott *et al.*, 2000). These days, native forest trees are recommended for reforestation projects. Restoring forests by planting a wide length

of native forest trees species can help promote biodiversity (FORRU, 2000; Svasti, 2000; Elliott and Anusarnsunthorn, 2001).

1.3.1 Conservation of Biological Diversity

Biodiversity is the property of groups of living things to be varied from each other. It includes diversity of the biotic components of ecosystems at all levels of organization, such as genes, species, populations and communities, (Palmberg-Lerche, 1993; Bruenig, 1996). Biodiversity has several different types of values, which are often difficult to quantify in standard economic terms, including products, ecological services, esthetics and tourism and cultural values (Palmberg-Lerche, 1993; Bruenig, 1996). High biodiversity and complexity hinder attempts to recreate natural forest ecosystems in the tropics. Any individual forest type contains not only several hundred tree species and wild animals but also a wealth of other species, each of which may have evolved intricate relationships with hundreds of other organisms (Palmberg-Lerche, 1993; Blakesley *et al.*, 2000). The concept of conservation, outlined in the original World Conservation Strategy, "The management of human use of genetic resources so that they may yield the greatest sustainable benefit to present generations, while maintaining their potential to meet the needs and aspirations of future generations" (Palmberg-Lerche, 1993; Bruenig, 1996). Therefore, conservation deals with biological interactions among plants, animals and micro-organisms and physical elements of the environment (Palmberg-Lerche, 1993; Bruenig, 1996; Rashid, 2000; Blakesley *et al.*, 2000; Elliott and Anusarnsunthorn, 2001).

1.3.2 Rationale and Approach

Forest restoration is mostly aimed at rehabilitating degraded areas for the conservation of biodiversity (Elliott *et al.*, 2000). These natural assets are permanently renewable if wisely conserved. Improvements in economic status and

human welfare cannot be sustained unless the conservation of these living resources is specifically drawn into the process of development (Bruenig, 1996). Forest restoration and wildlife conservation can contribute to sustainable rural and national development (Bruenig, 1996). One way to achieve this might be to complement natural regeneration by planting native tree species that grow rapidly and attract seed-dispersing animals into planted areas (FORRU, 2000; Svasti, 2000). Seed dispersal is one of the most important ecological services carried out by wildlife in restored areas (Elliott, 2000a). Seed dispersal by wildlife, especially birds and bats, attracted by the planted trees, would disperse the seeds of other, non-planted tree species into replanted sites and thus accelerate the recovery of biodiversity (Elliott *et al.*, 2000). Furthermore, wildlife carries out many other ecological functions that help the process of forest restoration. Birds and bats pollinate flowers, soil invertebrates improve soil texture and help recycle nutrients, and a diverse range of wildlife species are involved in biological control of pests (Elliott, 2000a; Elliott and Anusarnsunthorn, 2001).

1.4 Restoration in Doi Suthep-Pui National Park

The Forest Restoration Research Unit (FORRU) was established in 1994, to carry out research to reforest degraded areas. It is a joint initiative between Chiang Mai University and Doi Suthep-Pui National Park (under the Royal Thai Forest Department) which adjoins the university campus (FORRU, 2000). The aim of the unit is to develop effective methods to complement and accelerate natural forest regeneration on deforested sites within conservation areas, to increase biodiversity and protect watersheds (FORRU, 1998). With more than 1,100 tree species growing naturally in northern Thailand, it would be impossible to grow and plant them all. Forest restoration projects cannot replant all the tree species that might once have grown on any particular site, but it can aim to achieve similar levels of biodiversity and ecosystem structure and function that was present in the original forest ecosystem (FORRU, 2000). Since 1997, FORRU has been developing and

adapting the framework species method of forest restoration. This technique involves planting mixtures of 20-30 native forest tree species that rapidly shade out weeds and attract wildlife (Elliott, *et al.*, 1997) or using "native trees in the native land" (Miyawaki, 1993). However, the success of such tree-planting projects is often limited by a lack of skills and knowledge about how to grow, plant and take care of native forest trees, which have never before been planted on a large scale in Thailand (FORRU, 1998). FORRU's initial priority was to gather basic ecological data about the very large number of tree species, which grow in northern Thailand, to determine which ones might be useful for restoring damaged forest ecosystems. With more than 600 tree species growing on Doi Suthep (Elliott and Maxwell, 1995 in FORRU, 2000), there were plenty to choose from. Apart from a few commercially valuable tree species, very little was known about seed production, germination and seedling growth of the vast majority of wild forest trees. Without such information, it was impossible to make sensible choices as to which tree species to use in forest restoration projects. Therefore, FORRU collected and germinated the seeds of many species as possible and developed criteria to assess their potential to restore damaged forest ecosystem (Elliott *et al.*, 1997a in FORRU, 2000). FORRU's previous work includes: i) seed production (Elliott *et al.*, 1994; FORRU, 1998; CMU Herbarium Database, 2000) and collection (Pakkad, 1997; FORRU, 1998; CMU Herbarium Database, 2000) ii) germination (Hardwick and Elliott, 1992; Kopachon, 1995; Hardwick *et al.*, 1997; FORRU, 1998; CMU Herbarium Database, 2000; Singpetch, 2001) iii) seedling growth in the nursery (FORRU, 1998; CMU Herbarium Database, 2000; Singpetch, 2001) iv) tree-planting experiments (FORRU, 1998; CMU Herbarium Database, 2000) and v) working with a local community (FORRU, 2000).

1.5 The Importance of the Propagating Native Forest Tree Species for Forest Restoration, by Seed and Vegetative Mean.

Restoring complex natural forest ecosystems requires a completely different approach to that of conventional plantation forestry with pines, teak or eucalyptus, because, forest ecosystems contain a very wide diversity of tree species (FORRU, 1998). Therefore, this kind of forest restoration requires production of high quality planting stock of a wide range of native forest tree species. Although research on propagation of commercial species is well advanced, forest restoration involves planting lots of species which have never been grown before. Information is required on how to propagate native forest tree from seed and vegetative (FORRU, 2000). For seed propagation, many native tree species are difficult to germinate successfully under normal conditions (Hardwick and Elliott, 1992; Kopachon, 1995; Singpetch, 2001). Hence, cycles of flowering and fruiting (phenology) must be known. Phenology can play an important role in developing sound seed collection and nursery work programs for mass propagation of native trees (FORRU, 1998; FORRU, 2000; Mishra *et al.*, 2001). Seed dormancy is common in many tropical tree species. However, treatments can play an important role to break dormancy and improve seed coat permeability, including the use of acid, scarification, soaking in water and hot water treatments (Hardwick and Elliott, 1992; Kopachon, 1995; Singpetch, 2001). Even so, propagation of some tree species from seed can still be very difficult. Vegetative propagation is an alternative method.

Vegetative propagation, involves duplication of a whole plant from any living organ, such as a portion of stem, root, or leaf tissue, induced to form roots and shoots by rooting hormones, chemical, mechanical, and/or environmental manipulation (Rashid *et al.*, 1986; Hartmann *et al*, 1990; Avery and Beyl, 1991; Kantarli, 1993; Aminah *et al.*, 1995; Hidayat *et al.*, 1995; Khun and Dick, 1995; Priadjati, 1995; Ahmad *et al.*, 1998; Nghia and Tien, 2001). Vegetative

propagation of native forest tree species by stem cuttings is an important alternative for the production of high quality and uniform planting stocks for large-scale forest plantation programs. It offers several advantages over seeds, maintenance of genetic consistency, handing of relatively small numbers of many different species, saving of time and labor, and it is also inexpensive and easier to practice than other vegetative propagation methods (Kantarli, 1993; Ahmad *et al.*, 1998; Maoyuan *et al.*, 1998; Blakesley *et al.*, 2000). Furthermore, it is able to produce a continuous supply of planting stock throughout the year for forest restoration activities. However, almost all propagation of cuttings has focused on exotic and commercial plantation trees (Blakesley *et al.*, 2000), such as Eucalyptus species, *Hopea oderata*, Dipterocarp species, *Pinus merkusii etc.* (Kantarli, 1993; Aminah, 1995; Hidayat *et al.*, 1995; Priadjati, 1995; Khun *et al.*, 1995; Ahmad *et al.*, 1998; Maoyuan *et al.*, 1998; Klunklin, 1998; Nghia and Tien, 2001). Very little work has been carried out on the very large number of native forest tree species, which grow in northern Thailand (Blakesley *et al.*, 2000).

1.6 Factors Affecting Seed Germination and Vegetative Propagation Techniques

1.6.1 Factors Affecting Seed Germination

Seed Dormancy and Germination

Generally, orthodox seeds are those that can be dried to a moisture level of 1-8% (Roberts, 1973) or 2-5% (Baskin and Baskin, 1998) without losing viability over time and sometimes even down to 0.5% moisture content without a loss of viability and easily stored dried (Baskin and Baskin, 1998). They have a long period of dormancy until the next rainy season when they may germinate (Stubsgaard and Poulsen, 1995). In contrast, recalcitrant seeds are intolerant of dehydration and need to be used immediately after collection or they may die (Roberts, 1973). The

moisture content of seeds at the time of maturation is 30-70%, but it varies among species and even within the same species dried (Baskin and Baskin, 1998). They lose viability if the moisture content drops below a certain critical level before germination occurs. In addition, they are also vulnerable to chilling injuries at low temperatures.

The seed's function is to be a unit of propagation. Seed germination is the activation of the metabolic machinery of the embryo leading to the emergence of a new seedling. Seeds of some species do not germinate due to hard seed coats hindering intake of water (dormancy) (Poulsen and Stubsgaard, 1995; Baskin and Baskin, 1998). However, seed treatments can be applied to break dormancy and improve the seed coat permeability. The most convenient measure of dormancy is the mean of median length of dormancy (MLD). This is defined as the number of days between seed sowing and germination of the median seed (Blakesley *et al.*, 2002).

A seed is a ripened ovule. At the time of separation from the parent tree, it consists of an embryo and stored food supply, both of which are encased in a protective covering. Activation of the metabolic machinery of the embryo, leading to emergence of a new seedling, is known as germination (Hartmann *et al.*, 1990). For germination to be initiated, three conditions must be fulfilled: first, the seed must be viable; that is the embryo must be alive and capable of germination. Second, the seed must be subjected to appropriate environmental conditions, available water, proper temperature regimes, a supply of oxygen, and sometimes light and third, dormancy must be overcome (Bradbeer, 1988; Stubsgaard and Poulsen, 1995). Internal processes leading to removal of primary dormancy are collectively known as after-ripening and result from interactions of the environment with the specific primary dormancy condition. After-ripening requires a period of time and sometimes specific methods often seed handling. Even in the absence of primary dormancy and/or if the seeds are subjected to adverse environmental conditions, a

secondary dormancy can develop and further delay germination (Hartmann *et al.*, 1990; Poulsen, 1994; FORRU, 1998).

There are three stages of germination, 1) imbibition of water, synthesis of enzymes, cell elongation and emergence of the radicle; 2) digestion and translocation; fat, proteins, and carbohydrates, stored in the endosperm, cotyledons, perisperm, or female gametophyte, are digested to simpler chemical substances, which are translocated to the growing points of the embryo axis and 3) seedling growth; the growing point of the root (the radicle) emerges from the base of the embryo axis (Bradbeer,1988; Hartmann *et al.*, 1990). The growing point of the shoot (the plumule), is at the upper end of the embryo axis, above the cotyledons.

Mechanisms of Seed Dormancy

Although seeds of some species are capable of germinating soon after dispersal or harvesting, a large number of other species fail to germinate, even when placed under conditions, which are normally regarded as suitable for growth. Seeds from different species within the same genus or from different genera in the same family may react differently with regard to germination because of the absence or presence of a rest period (Hardwick and Elliott, 1992; Kopachon, 1995; Hardwick *et al.*, 1997; FORRU, 2000; Singpetch, 2001). Many tropical tree species are difficult to germinate successfully under normal conditions. Seed dormancy results from interactions between several environmental factors and the hereditary properties of the plants. It may last for only a few days under proper seed handling and storage, or may continue indefinitely until some special requirements are fulfilled. Seed dormancy can be broken if the causes are known and all the necessary conditions for germination and plant growth are fully satisfied. Seed dormancy is classified into several different types. Crocker (1916) described dormancy as resulting from: i) immaturity of the embryo; ii) impermeability of the seed coats to water; iii) mechanical resistance of the seed coats to embryo growth; iv) low permeability of

the seed coats to gases; v) a metabolic block within the embryo; vi) combinations of the foregoing and vii) secondary dormancy. Harper (1977) classified seed dormancy into 3 types: 1) innate dormancy, 2) induced dormancy and 3) enforced dormancy. Nikolaeva (1977) divided seed dormancy into 3 groups: 1) exogenous or seed-coat dormancy, 2) endogenous or embryo dormancy and 3) combined dormancy. Bewley and Black (1982) categorized dormancy into 3 groups: i) primary dormancy; ii) relative dormancy and iii) secondary dormancy. Kobmoo *et al.* (1990a) studied seed pretreatments of 19 leguminous tree species, and classified them into three groups: 1) those with seeds that required no pretreatment; 2) those with seeds which exhibited shallow dormancy and whose germination was improved by soaking in hot water; and 3) those with seeds which exhibited deep dormancy whose germination was substantially improved by scarification.

Seeds must be exposed to favorable environmental conditions before germinating, such as an adequate supply of water, adequate gas exchange and suitable temperatures and light. Temperature is one of the most important environmental factors affecting germination. It affects germination percentage, as well as rate of germination and its effects vary with different species (Piewluang and Liengsiri, 1989). The minimum temperatures required for seed germination of tropical species are normally higher than those required for temperate species. The seed of many tropical species germinate better under constant temperatures than under alternating temperatures. Gupta and Pattanath (1976) studied germination responses to temperatures of 20 tropical species. Fifteen species required constant temperatures, whereas only five required altermating temperatures. Various simple pretreatments are able to break dormancy and promote germination (Piewluang and Liengsiri, 1989; Kabmoo, 1990; Boonnarutee *et al.*, 1999; Reddy and Reddy, 1995; Palani *et al.*, 1995; Teketay, 1996a). For example, Kabmoo (1990) found that optimal seed germination of *Peltophorum dasyrachis* was achieved by either one of three pretreatments: 1) soaking in 75^0C distilled water for 1 minute, 2) manual scarification; a small part of the seed coat was cut to expose cotyledons at the end

opposite to the hilum or 3) soaking in concentrated sulfuric acid (95-97% concentration, specific gravity 1.84 for 15 minutes and washed for 5 minutes in tap water). Higher water temperatures of 85^0C or 95^0C reduced germination. Piewluang and Liengsiri (1989) showed that the seeds of *Dalbergia cochinchinensis,* collected from two sources and scarified on both flat sides of the seed coat individually by hand with medium-grain sandpaper, gave maximum germination. Soaking seeds in concentrated sulfuric acid for one minute and soaking them in cool water for 24 hours also resulted in a higher germination percentage than the controls. An advantage to soaking seeds in concentrated sulfuric acid was gaining more uniform germination than by soaking in water. However, prolonged soaking in concentrated sulfuric acid decreased germination. Boiling water killed the seeds in this species. Seeds from different sources respond to pretreatments differently, probably due to genetic differences, varying degrees of dormancy and/or maturity, or storage history (Piewluang and Liengsiri, 1989). Boonnarutee *et al.* (1999) reported that scarification by hand was the most suitable for *Acacia catechu, Cassia bicapsularis, Cassia fistula, Cassia garrettiana, Senna siamea, Senna surattensis, Dalbergia cocinchinensis* and *Dalbergia oliveri.* Soaking in conc. sulfuric acid was most suitable for *Cassia garrettiana, Senna siamea* and *Dalbergia cultrata.* Soaking seeds in 98 ^{0}C water and leaving them to cool for 24 hours was most suitable for *Delonix regia.*

Several projects have tested various simple treatments to break dormancy and germinate the seeds of trees from Doi Suthep-Pui National Park (Hardwick and Elliott, 1992; Kopachon, 1995; Singpetch, 2001). In native forest tree species, seed dormancy is mostly caused by impermeability of the seed coat. Seeds of such species were classified into two groups: hard and soft seeds. Hard seeds refer to those seeds, which reduce moisture content to low levels at maturation. Soft seeds are those which maintain a high level of moisture content, even after maturation. Hard seed coats caused dormancy in 3 different ways: 1) impermeability to water, 2) impermeability to oxygen or gases or 3) mechanical resistance to embryo

growth. However, seed treatments can be applied to break dormancy and improve seed coat permeability, such as scarification, soaking in water, boiling or hot water and hot sand (Hardwick and Elliott, 1992; Kopachon, 1995; Singpetch, 2001). Hardwick and Elliott (1992) studied the factors affecting germination of tree seeds from tropical forest in northern Thailand. They experimented with several methods to break seed dormancy *e.g.* cleaning, scarification, fire, storage and ripeness. Seed of 101 species of tree and liana were sown, of which 78 germinated. At least 50% germination occurred in 28 species. Dormancy for up to 37 weeks was common and was more predominant among species found in Thai seasonal forest than in Malaysian tropical rain-forest. Dormancy may be linked with the season of seed dispersal, tending to be longer for those dispersed at the end of the rainy season and during the cold season, and shorter for those dispersed during the hot season and the beginning of the rainy season (Blakesley *et al.*, 2000). This is not true for all species though. Kopachon (1995) reported on the effects of heat treatment on seed germination of 50 species of native trees on Doi Suthep. Twenty nine species germinated. Heat increased germination in some species but decreased the germination rate in some species. Singpetch (2001) reported the effects of six different pre-sowing treatments, (4 levels of temperature and 2 methods of scarification by hand and concentrated sulfuric acid (H_2SO_4) on seed germination of 9 species of native trees on Doi Suthep. The best treatments for each species were different due to the seed coat. Scarification by hand was the best for *Albizia chinensis* and *Bauhinia vaariegata*. Sulfuric acid was the best for *Rhus chinensis*. Soaking seeds in water was the best for *Aporusa villosa* and *Ficus abelii*. Almost all seeds were killed when treated with 80-100 ^{0}C hot water.

Seedling Structure

The seedling stem is divided into the section below the cotyledons (hypocotyl) and the section above the cotyledons (epicotyl). Initial growth of seedlings follows one of two patterns. In epigeal germination, the hypocotyl elongates and raises the

cotyledons above the ground. In hypogeal germination, the lengthening of the hypocotyls does not raise the cotyledons above the ground and only the epicotyls emerges (Hartmann *et al.*, 1990). The seedling structure or germination type of native tree species is useful for taxonomic classification (especially, for recognizing seedlings in the field) and for morphological and evolutionary considerations (Vogel, 1980; Teketay, 1996). Furthermore, seedling form can be used to predict the rate of germination and shade-tolerant species. Ng (1978) recognized that cotyledon position and exposure were independent traits and used these to divide seedlings into four types: epigeal (phanero-epigeal), hypogeal (cryptohypogeal), semi-hypogeal (phanero-hypogeal), and durian (crypto-epigeal). Garwood (1994), however, refers to five seedling types by short unambiguous codes: PEF, PER, PHR, CHR, and CER. These were produced by combining abbreviations for the dichotomous traits of exposure, position, and texture: phanerocotylar (P) or cryptocotylar (C); epigeal (E) or hypogeal (H); and foliaceous (F) or reserve storage or absorption (R) (Garwood, 1994). In the earliest stages of germination, speed of growth of the seedling is mainly determined by the food content of the seed and the genetic properties. Further development depends on food reserves in the seedling and/or assimilates produced by the (para) cotyledons and the leaves (Vogel, 1980).

1.6.2 Factors Affecting Vegetative Propagation Techniques.

1.6.2.1 Effects of Species

Sometimes, cuttings are difficult to root (Hartmann *et al.*, 1990), especially those from mature trees (Libby and Rauter, 1984; Kantarli, 1993; Klunklin, 1998) and some "difficult" species can be rooted only if various influencing factors are taken into consideration and maintained under optimum conditions (Hartmann *et al.*, 1990; Kantarli, 1993; Maoyuan *et al.*, 1998). For instance, age of the parent tree is most important. The younger the tree from which a cutting is taken, the easier it is

to root (Rashid, 1968; Kantarli, 1993; Klunklin, 1998). Rooting normally becomes progressively more difficult with increasing age of the parent tree (Rashid, 1968; Klunklin, 1998). Stem cuttings of Teak (*Tectona grandis*) and Gamar (*Gmelina arborea*) develop roots, when collected from parent trees less than 50 years old (Rashid, 1968). The size of cuttings (expressed as the number of nodes) is also an important factor in selecting material. Generally four to six nodes and 10.0 to 15.0 cm long cuttings provided good propagation material for all species (Kantarli, 1993). Extremely thin or woody cuttings should be avoided (Khun and Dick, 1995; Klunklin, 1998). Rashid (1986) experimented with juvenile cuttings of Teak (*Tectona grandis* Linn.f.), either leafy or non-leafy with 1-node, 2-nodes and 4-nodes. Cuttings were inserted in a rooting medium (sand), kept under shade and covered by a polyethylene tent for 45-50 days. After 7-10 days, buds appeared and after 45-50 days roots developed. Overall, leafy and 4-node cuttings of Teak rooted better than non-leafy and 1-node and 2-node cuttings. Adult leafy and non-leafy cuttings were tried. Leafy adult cuttings showed 10 percent success. *Gmelina arborea* Linn. in a juvenile stage; cuttings were 6-8 inches (15-20 cm) long. Treatments were divided into leafy and non-leafy. The medium was sand in an open mist bed and 5 cm of the bottom end was inserted into the sand medium. The non-leafy cuttings showed better success. The percentage success was 14.3.

1.6.2.2 Effects of Rooting Media

The rooting medium is the material or mixture of materials, in which unrooted cuttings are inserted to produce roots. The medium should be inexpensive, readily available, uniform and long lasting, inert, free from diseases and toxic substances and well drained with desirable air-water relations (Reisch, 1967; Maoyuan *et al.*, 1998; Klunklin, 1998). Materials for rooting media, include sand (Aminah, 1995; Ahmad *et al.*, 1998; Klunklin, 1998; Khun and Dick, 1995), husk rice charcoal (Klunklin, 1998), coconut husk (Kantarli, 1993, Soohuae and Limpiyaprapant, 1995; Aminah, 1995), sand mixed with coconut husk (Kantarli, 1993; Aminah,

1995) sand mixed with coffee compost (Hidayat *et al.*, 1995), coir dust, rice husk, virgin soil (Maoyuan, 1998), water (Priadjati, 1995), top soil, rice ash (Kantarli, 1993). Sand improves aeration, wetting and flow ability but it is also heavy and holds little water (Bodman and Sharman, 1993). Husk rice charcoal improves aeration, lightness and holds a minimal amount of water. The medium should be 0-15 cm deep and should give the necessary support to the cuttings. Both air and rooting media temperatures influence initiation and development of roots. Generally temperatures between 20-30 ^{0}C in the rooting medium are suitable for all species tried in cuttings experiments. It may be that high root-zone temperatures greatly enhance callus formation, root initiation and development in the cuttings (Bergh, 1957). High air temperatures (30-50 ^{0}C) initiate earlier shoot development by accelerating bud-break in cuttings. Misting inside polyethylene tents imparts a cooling effect on leaf surfaces and helps maintain high humidity at higher temperatures. If air temperature is not controlled or is too high, most of the stored food in cutting stems would be rapidly utilized for shoot development and thus root development would be hampered. A high relative humidity (more than 80%) must be maintained around cuttings, otherwise desiccation will inhibit root formation. Misting inside polyethylene tents under full sunlight helps to control all the above mentioned environmental conditions at a level suitable for rooting of cuttings to photosynthesizing food. Water used for misting should be free from iron, otherwise under warm polyethylene tent conditions, deposition of iron on the cutting leaves and rooting medium is severe. Deposition of iron disturbs aeration in the rooting medium and thus kills rooted cuttings (Hartmann and Kestes, 1983; Weaver, 1972; Rashid *et al.*, 1986; Hartmann *et al.*, 1990; Longman, 1993).

1.6.2.3 Effects of Rooting Hormone

Successful rooting depends on the presence in cuttings of several cofactors, which in combination with auxin, enable cuttings to root. Thimann and Delisle (1939) demonstrated that some unknown factor, other than auxin, is involved in root

initiation of coniferous evergreen cuttings. They believed that this factor was present in large amounts in young plants and was often present in lower amounts in older plants. The effect of hormone (auxin) on rooting cuttings varies with species. Indole acetic acid (IAA), indole butyric acid (IBA) and napthalene acetic acid (NAA) are the most commonly used rooting hormones. These rooting hormones are usually applied either in a powder form or by quickly dipping the rooting end of cuttings into a hormone solution. One of the best and most commonly used rooting stimulators is the auxin IBA. Another excellent auxin, frequently used for root promotion, is NAA. However, this compound is more toxic than IBA. IBA and NAA are more effective in induction of rooting than IAA. IAA is very unstable in plants. Equal parts of IBA and NAA induce a higher percentage of cuttings to root in some species than either material used alone (Hartmann and Ketes, 1983; Weaver, 1972). These roots have some characteristics of root systems treated with either IBA or NAA (Weaver, 1972). Fresh preparations of hormone should be used for better results. It has been observed that both IAA and IBA can increase rooting response in Teak (*Tectona grandis* Linn.f.), Gamar (*Gmelina arborea* Linn.), and Koroi (*Albizia procera* Benth.) but not in Kadam (*Anthocephalus chinensis* (lam.) Rich.) cuttings. The highest percentage rooting was obtained from cuttings treated with 100 ppm of both IAA and IBA (Rahman, 1977). Teak (*Tectona grandis* Linn.f.) and Gamar (*Gmelina arborea* Linn.) root better with IBA than IAA (Rashid, 1986). Pong-anant and Wongmanee (1990) studied rooting variation among selected mother trees of *Eucalyptus calaldulensis* at various concentrations of IBA. There was great variation in the percentage of rooting among selected mother trees (10-90%). Hormone application did not increase rooting percentage, however, at the highest concentration (500 ppm), the number of roots increased and stockings (rooted cuttings) had better developed root systems (Kantarli, 1993).

1.7 Research Objectives

The objectives of the present study were:

1) to develop the most appropriate propagation techniques for native forest tree species planted to restore forest in degraded areas.
2) to determine the variability in performance of native forest tree species seedlings propagated from seeds and cuttings.
3) to determine whether species traits (such as) seed size, dispersal time or germination type can be used to predict germination.
4) to determine what factors affect the performance of native forest tree species propagated from cuttings.

CHAPTER 2

Seasonal Cycles of Seed Production

Abstract

The phenology of flowering and fruiting of native forest tree species plays an important role in developing effective forest restoration strategies for the conservation of biodiversity and watershed protection. In particular, phenological data are used to plan seed collection programs and identify trees as sources of cuttings. In this chapter, the phenology of 32 native forest tree species, observed monthly over 12 months, is described (n=1-3 per species, 81 individuals trees) in Doi Suthep-Pui National Park. Leaf fall occurred in the dry season (27 species) and peaked sharply in January (20 species). This was probably a response to declining leaf water potentials and from the production of new shoots, during the early rainy season. Leaf flushing occurred in the dry to early wet season (18 species), with a sharp peak in April (28 species), at the hottest and driest period of the year. Generally, the time of bud break, varied with the time of leaf fall. Flowering occurred in every month, peaking sharply in April (19 species), at the hottest and driest period of the year, when trees are under severe water stress. One possible advantage of flowering during the dry season is that fruits ripen and seeds are dispersed in time for the following rainy season, when conditions for seed germination and seedling survival are optimal. Six species produced most of their flowers when leafless or nearly so, whilst ten species produced their flowers simultaneously while flushing with young leaves. These flowering strategies provide a highly visible display of flowers, ensuring maximum attraction to animal pollinators. Fruiting occurred in every month, peaking sharply in September (24 species), the wettest period of the year. Concerning seed dispersal mechanisms, wind and animals were the most important agents of dispersal. Under natural conditions, most fruits (>50% of all species) were dispersed in the late wet season to early dry season (August-January). Consequently, most species required lengthy dormancy periods, to survive the dry season and germinate in the rainy season. Therefore, in order to

accelerate seedling production in the nursery, treatments to break dormancy had to be developed.

2.1 Introduction

Phenology means the scientific study of seasonal cycles of plants or animals, particularly relationships between the periodicity of morphological and physiological changes and climatic or environmental variables (FORRU, 1998; Kreb, 1994; Le Floch, 1969). Phenological studies in Thailand have concentrated on seasonal cycles of leafing, flowering and fruit production, especially of forest trees (Sukwong *et al.*, 1975; Dhamanitayakul, 1979; Bhumibhamon *et al.*, 1993; Elliott *et al.* 1994; Phonesavanh, 1995; Maxwell and Elliott, 2001). The phenology of native tree species varies among species and among individuals of the same species (Murphy and Lugo, 1986; Mishra and Teki, 2001). Environmental factors known to affect flowering are light intensity, temperature (Owens, 1994; Maxwell, 2001a), moisture stress (Elliott, 1994), nutrient levels, photoperiod (Owens, 1994) and plant age (Murphy and Lugo, 1986). Furthermore, variations in phenology are dependent on elevation (Maxwell, 2001a). For instance, *Anneslea fragrans* Wall (Theaceae), which is found from 400 to 1,650 m elevation in Doi Suthep-Pui has different flowering and fruiting phenologies at different elevations. At 450 m, is species has been observed in full flower during March, whilst at the same time at 1,610 and 1,685 m the trees were in fruit (Maxwell, 2001a). Similarly, trees of this species change their leaves in February at 800 to 900 m, whilst remaining evergreen above 1,000 m (Maxwell, 2001a). In Doi Suthep-Pui National Park, there are 10 treelet or tree species, which are generally evergreen above *c.* 1,000 m elevation, but deciduous during the dry season at lower elevations (Maxwell, 2001a).

The phenology of native forest trees has an important role in developing forest restoration strategies to conserve biodiversity and for watershed protection. Phenological data can be used to plan seed collection, locate, stock trees as sources of cuttings, to develop nursery work programs for forest restoration projects and to

determine which treatments might be appropriate to break seed dormancy or stimulate rooting during cutting propagation (Kantarli, 1993; Elliott *et al.*, 1994; Ghazoul, 1997; FORRU, 1998; Ahmad *et al.*, 1998; Hardwick, 1999; FORRU, 2000; Blakesley *et al.*, 2000; Maxwell and Elliott, 2001). For example; The Forest Restoration Research Unit (FORRU, 1994) the studied phenology of nearly 100 native forest tree species to help identify framework tree species for forest restoration projects (Blakesley *et al.*, 2000; Maxwell and Elliott, 2001). Phenology has also been used to predict the yield and quality of seeds (Owens, 1994; Marzalina *et al.*, 1993; Ghazoul, 1997), for genetic selection (Owens, 1994; Bhumibhamon *et al.*, 1993; Valencia and Umali-Garcia, 1993; Moncur, 1993; Visuthiepkul and Moncur, 1993) and to improve techniques of accelerated natural regeneration (ANR) (Jensen and Pfeifer, 1989 and Hardwick, 1999).

Therefore, this chapter describes the phenology of flowering and fruiting of 32 species of native forest tree species and identifies the best time to collect seeds or collect leafy stems for cutting propagation.

2.2 Study Site

Doi Suthep-Pui was designated a national park on 14 April 1981, covering an area of about 261 km^2 (Maxwell and Elliott, 2001). It is situated directly west of Chiang Mai City in northern Thailand (18^0 50' north latitude and 99^0 0' east longitude). Doi Suthep rises to a height of 1,620 m above sea level, while the adjoining peak of Doi Pui is 1,685 m high. Base rocks are mostly granite, and soils are generally deep and highly weathered.

Average annual rainfall in Chiang Mai City, *i.e.* at the base of Doi Suthep-Pui (*c.* 350 m), is 1,067.8 mm. August and September have the most rain, with an average of 207.7 mm per month. The lowest amount of rainfall is during January-February with an average of 6.3 mm per month. Average rainfall at the national park headquarters (*c.* 1,050 m) is 1,670.1 mm per year, 2,095 mm at Puping village (*c.* 1,375 m) (Maxwell

and Elliott, 2001) and 2,094.9 mm at Kog-Ma Watershed Research Station (*c.* 1400 m) (Elliott *et al.*, 2000).

Temperatures of Kog-Ma Watershed Research Station (Figure 1) varied from a minimum of 4.5^{0}C in December to a maximum of 35.5^{0}C in March (Elliott and Anusarnsunthorn, 2001), while average lowland temperatures range from a low of 21.1 ^{0}C during December-January and a high of 29.0 ^{0}C during April-May (Maxwell and Elliott, 2001).

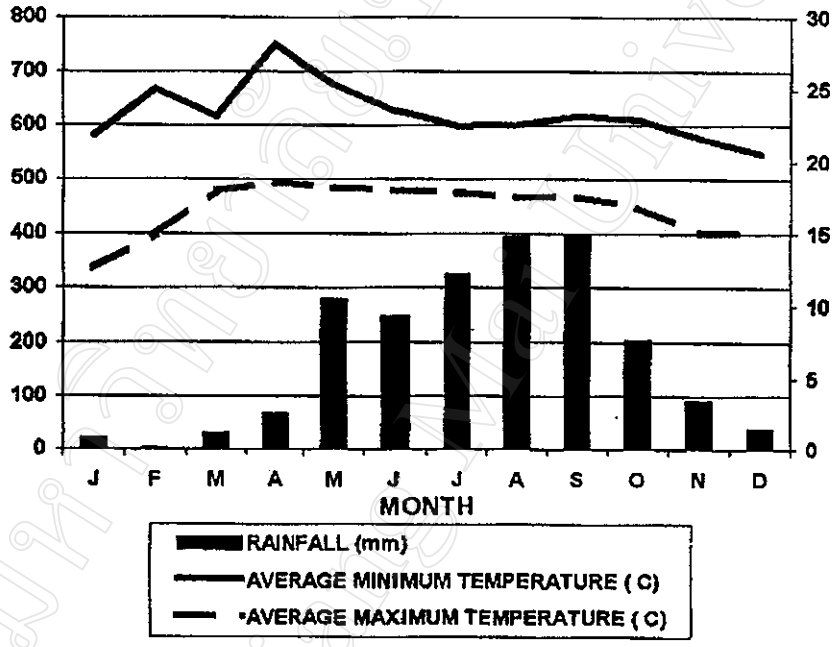


Figure 1. Average monthly rainfall, minimum and maximum temperature at Kog-ma Watershed Research Station (elevation 1,400 m) approximately 9 km from the study site (1966-1983) (from Elliott and Anusarnsunthorn, 2001).

The area has two main seasons: the wet season (May-October) and the dry season (mean monthly rainfall below 100 mm, November-April). The dry season is subdivided into the cool-dry season (November to January) and the hot-dry season (February to April) (Elliott *et al.*, 2000). Highest rainfall occurs in August and the dry season peaks in April (Elliott *et al.*, 1994).

This study of phenology was carried out in Doi Suthep-Pui National Park at elevations ranging from 640 to 1,560 m in all forest types represented on the mountain. There are two main types of forest in the park *viz.* deciduous forest (in the lowlands, 460 m up to 950 m above sea level) and evergreen forest (from about 950 m above sea level to the summit of Doi Pui). There are three deciduous vegetation associations, *viz.* deciduous dipterocarp + oak, bamboo + deciduous and mixed evergreen + deciduous, which tend to merge together without any clear boundaries because of disturbances (Maxwell, 2001).

2.3 Materials and Methods

2.3.1 Species Studied

A review of the information stored in the databases of the CMU Herbarium and FORRU was carried out to determine native forest tree species with limited seed germination success, but with high potential for forest restoration plantings. Thirty two native forest tree species were selected (Table 1).

2.3.2 Experimental Design

Phenological studies (Table 1) were carried out, primarily to determine the seasonal availability of seeds of a wide range of tree species, but in addition, the time of flowering, leaf flushing and leaf fall were also recorded. Thirty two tree species (81 individual trees, 1-3 replicates per species), including 10 species from deciduous forest, 16 from evergreen forest, 3 from mixed evergreen + deciduous forest and 3 from evergreen + pine forest were observed with binoculars monthly (from June, 2000 to May, 2001) and scored for the presence of flowers, fruits and foliage. A linear scale of 0-4 was used: 4 representing maximum intensity of reproductive activity or canopy cover. Values of 3, 2, and 1 represented three-quarters, half, and one-quarter of the maximum intensity, respectively. A value of 0.5 was used to indicate the presence of small amounts of flowers or fruits below one-quarter of the maximum intensity

(method from Elliott *et al.*, 1994). The data were entered into a computer spreadsheet program (Excel) and analyzed to produce graphs to show seasonal cycles of flowering, fruiting and leafing.

2.4 Results

Leaf Fall and Leaf Flushing

Data on leaf fall and leaf flushing for individual species are presented in Figures 2-33. Numbers of species in leaf flushing or leaf fall for each month are presented in Figure 34, Tables 2 and 5. Leaf fall occurred every month. Most tree species shed their leaves at the beginning of the dry season. This was probably in response to declining leaf water potentials. Leaf phenology data were divided into five groups (Table 4). Six species were evergreen, retaining at least some green leaves throughout the year. A few old leaves were shed and a few new ones were grown in nearly very month of the year. Fifteen species were completely deciduous, undergoing a period of total leaflessness at some time during the year. Two species (*Elaeocarpus lanceifolius*, and *Glochidion acuminatum*) were tropophillous. They showed obvious seasonal trends in leaf shedding and growth of new leaves, but were not bare of leaves for any considerable time. Three species were brevideciduous. They produced an entire canopy of new leaves at the same time as nearly all the old ones were being shed. Six species were leaf changing, loosing their leaves on one side of the canopy, whilst retaining them on the other. Leaf flushing occurred in every month. The highest number of species flushing new leaves occurred in April (28 species), the hottest, driest period of the year. The lowest of number occurred in September, November and December (5 species). In twelve species, leaf flushing occurred in the dry season (November-April) (*Afzelia xylocarpa*, *Betula alnoides*, *Diospyros undulata*, *Elaeocarpus lanceifolius*, *Elaeocarpus prunifolius*, *Eurya acuminata*, *Glochidion acuminatum*, *Irvingia malayana*, *Saurauia roxburghii*, *Shorea obtusa*, *Sindora siamensis* and *Terminalia mucronata*). Only one species flushed in the wet season (May-October) (*Acrocarpus fraxinifolius*). In eighteen species, leaf flushing occurred

in both the dry and wet seasons (*Albizia chinensis*, *Aporusa villosa*, *Cassia fistula*, *Colona fragrocarpa*, *Debregeasia longifolia*, *Ficus lamponga*, *Ficus superba*, *Ficus hirta*, *Lagerstroemia speciosa*, *Macropanax dispermus*, *Morus macroura*, *Reevesia pubescens*, *Schleichera oleosa*, *Terminalia bellirica*, *Terminalia chebula*, *Trema orientalis*, *Tetradium glabrifolium* and *Vaccinium sprengelii*).

Flowering

Data on flowering for individual species are presented in Figures 1-32. Six species produced most of their flowers when leafless or nearly so. This resulted in a brilliant display of flowers, unhindered by leaves that must have been clearly visible to pollinators. Five of these 6 species flowered in the dry season (November-April) (*Acrocarpus fraxinifolius*, *Aporusa villosa*, *Betula alnoides*, *Cassia fistula* and *Morus macroura*). The one species that flowered in the dry to wet season was *Ficus lamponga*. Ten species produced their flowers, simultaneously while flushing with young leaves. This flowering strategy also provided a highly visible display of flowers, not hidden by mature leaves to maximize attraction to animal pollinators. Again, this was primarily a dry season strategy, with 7 of the 10 species flowering in the dry season (November-April) (*Afzelia xylocarpa*, *Albizia chinensis*, *Eleaocarpus prunifolius*, *Lagerstroemia speciosa*, *Schleichera oleosa*, *Shorea obtusa* and *Vaccinium sprengelii*) and only 3 species in the wet season (May-October) (*Glochidion acuminatum*, *Irvingia malayana* and *Tetradium glabrifolium*). Ten species flowered after their leaves had matured; including 6 species flowering in the wet season (May-October) (*e.g. Colona fragrocarpa*, *Elaeocarpus lanceifolius*, *Macaranga kurzii*, *Macropanax dispermus*, *Sindora siamensis* and *Terminalia chebula*); 3 species flowering in the dry season (November-April) (*Reevesia pubescens*, *Terminalia bellirica* and *Terminalia mucronata*); and 1 species flowering in the wet to dry season (*Ficus superba*). Six species produced flowers when the tree crown was completely composed of mature leaves, including 3 species flowering in the wet season (May-October) (*Debregeasia longifolia*, *Eurya acuminata*, and *Ficus hirta*), 2 species flowering in the dry season (November-April) (*Diospyros undulata*

and *Trema orientalis*) and 1 species flowering in the wet to dry season (*Saurauia roxburghii*).

The numbers of species in flower each month are shown in Figure 34, Tables 3 and 5. Flowering occurred in every month. For flowers of figs were determined from the beginning of the reproductive organs occurred, before fruits ripen. The highest number of species in flower occurred in April (19 species). Seventeen species produced flowers during the dry season from November to April [November (3 species), December (5 species), January (8 species), February (10 species), March (14 species), and May (15 species)]. Three species flowered during both the dry and wet seasons and twelve species flowered during the wet season from May to October.

Fruiting

Data on fruiting for individual species are presented in Figures 2-33. Numbers of species in fruit each month are presented in Figure 34, Tables 3 and 5. Fruiting occurred in every month. For fruiting of figs were determined from the start to ripen of fruits. The highest number of species fruiting occurred in September (24 species). That is the rainy season, the wettest period of the year. Eight species fruited during the wet season from May to October, thirteen species during the wet and dry season, and eleven species during the dry season from November to April. The seasonality of ripe fruit production varied according to the seed dispersal mechanism.

Seed Dispersal Mechanism by Wind

Eight species were dispersed by wind. Almost all wind dispersed fruits/seeds (5 species) were dispersed during the dry season from November to April (*Acrocarpus fraxinifolius*, *Betula alnoides*, *Colona fragrocarpa*, *Terminalia mucronata* and *Reevesia pubescens*), two species was dispersed during both the dry and wet seasons (*Albizia chinensis* and *Lagerstroemia speciosa*) and 1 species at the beginning of the rainy season (*Shorea obtusa*). Two fruit types were wind dispersed pods (*Acrocarpus*

fraxinifolius, and *Albizia chinensis*), winged fruits (*Colona fragrocarpa* and *Shorea obtusa* (winged nuts), and two samara (*Betula alnoides* and *Terminalia mucronata*). Two fruit types were wind dispersed seeds from capsules *(Reevesia pubescens* and *Lagerstroemia speciosa*).

Seed Dispersal Mechanisms by Animals

Twenty-four species were dispersed by animals. They were divided into three groups; base on the season 8 species which fruited during the wet season from May to October (*Aporusa villosa*, *Diospyros undulata*, *Elaecarpus prunifolius*, *Irvingia malayana*, *Macaranga kurzii*, *Saurauia roxburghii*, *Terminalia chebula*, and *Vaccinium sprengelii*), 5 which fruited during the dry season (November-April) (*Cassia fistula*, *Debregeasia longifolia*, *Elaeocarpus lanceifolius*, *Macropanax dispermus*, and *Terminalia bellirica*) and 11 which fruited/figs during both the dry and wet seasons (*Afzelia xylocarpa*, *Eurya acuminata*, *Ficus lamponga*, *Ficus superba*, *Ficus hirta*, *Glochidion acuminatum*, *Morus macroura*, *Schleichera oleosa*, *Sindora siamensis*, *Tetradium glabrifolium*, and *Trema orientalis*). There were six fruit types of animal-dispersed species; including eight species with drupes (*Elaeocarpus lanceifolius*, *Eleaocarpus prunifolius*, *Irvingia malayana*, *Macropanax dispermus*, *Schleichera oleosa*, *Terminalia bellirica*, *Terminalia chebula*, and *Trema orientalis*), four with capsules (*Aporusa villosa*, *Glochidion acuminatum*, *Macaranga kurzii*, and *Tetradium glabifolium*), four with berries (*Diospyros undulata*, *Eurya acuminata*, *Saurauia roxburghii*, and *Vaccinium sprengelii*), three with achenes in figs (*Ficus lamponga*, *Ficus superba*, and *Ficus hirta*), three with pod (*Afzelia xylocarpa*, *Cassia fistula*, and *Sindora siamensis*) and two with achenes (*Debregeasia longifolia*, and *Morus macroura*).

2.5 Discussion

The phenology of native forest tree species in Doi Suthep-Pui National Park varied among species. Leaf phenology data were divided into five groups. The timing of leaf

fall is most often related to declining soil moisture (Jackson, 1978; Murphy and Lugo, 1986; Maxwell, 2001a). Leaf fall occurred every month. Most lowland tree species shed their leaves at the beginning of the dry season. This is a similar pattern to that observed by Frankie *et al.* (1974) and Sukwong *et al.* (1975). The deciduous forest species begin to loose their leaves in the dry season (Sukwong *et al.*, 1975). Frankie *et al.* (1974) found that dry forest species in the lowlands of Costa Rica leaf fall occurred in dry season and flushed predominantly during the beginning of the wet season. This was probably in response to declining leaf water potentials (Borchert *et al.* (in press); Maxwell 2001a). Leaf flushing in my study occurred in every month, but with a sharp peak in April (28 species), at the hottest and driest period of the year, when trees also peaked in flowering. This result agrees with Sukwong *et al.* (1975) who found that the most intense leaf flushing occurred in late March. Generally, the time of leaf bud break varies with the time of leaf fall. Borchert *et al.* (in press) postulated that trees enter the rainy season with a full complement of fully expanded, new leaves, and Murphy and Lugo (1986) found that leaf bud break correlates with flowering. Borchert *et al.* suggested that bud break and organ growth during the dry season require well-hydrated stem tissues, with stem water potentials near 0 Mega Pascals (MPa), and that bud break is induced by increasing photoperiod. Within a landscape, the time of bud break induced by leaf shedding varies with microsite water availability (Borchert, 1994 in Borchert *et al.* (in press)). On the other hand, Wright and Cornejo (1990) suggested that the timing of flowering and leaf fall are little affected and moisture availability is not the proximal cues for flowering and leaf fall for most species, in the tropical moist forests of Barro Colorado Island. In 1996, Wright found that seasonality affected the timing of leaf production and flowering, while the timing of fruit maturation and seed dispersal coincided with conditions that are optimal for seedling establishment (Garwood, 1983). Knowledge of leaf phenology enables the collector to select optimum timing and methods of leafy stem cutting harvesting most appropriate to the species. Murphy and Lugo (1986) suggested that in seasonal tropical forests, no single environmental factor is responsible for the type or timing of phenological events, while water stress or moisture deficit is most frequently cited as a primary factor (Murphy and Lugo, 1986; Lieberman, 1982).

It seems almost illogical that flowering of forest trees should peak at the hottest and driest period of the year when they are under severe water stress. One possible advantage to flowering during the dry season is that fruits ripen and seeds are dispersed in time for the following rainy season when conditions for seed germination and seedling survival are optimal. This agrees with Elliott *et al.* (1989), Elliott *et al.* (1994) and Hardwick (1999). Six species produced most of their flowers when leafless or nearly so, producing a brilliant display of showy flowers, unhindered by leaves, whilst ten species produced their flowers simultaneously while flushing with young leaves. These flowering strategies provide a highly visible display of flowers, not hidden by mature leaves, resulting in maximum attraction to animal pollinators as noted by Appanah (1990), Dayanandan *et al.* (1990) and Elliott *et al.* (1994). Flowering phenology has ecological significance to pollinators, which may be depend on flowers as resources, and to other plants in the community through competitive and mutualistic interaction for pollinators. The sequence of flowering among sympatric species is often closely related to pollinator or seed-predator population dynamics.

Fruit production of 32 species peaked slightly in the rainy season or in the wettest period of the year. This result was in agreement with Hardwick (1999), Elliott *et al.* (1994) and Newton (1988). One of the most essential processes in plant reproduction is the production and dispersal of seeds. As noted by Jackson (1981), dispersal agents are very important and they were related to fruit types. The 32 native tree species studied were divided to two types of fruits *viz.* dehiscent and indehiscent. Eight species were dispersed by wind and twenty-four species were dispersed by animals. Baskin and Baskin (1998), Ghazoul (1997) and Willan (1984) suggest that the main reasons for seed dispersal are for escaping competition from the parent tree and to escape seed predators. Wind dispersal occurs when the seeds are very light and small or when either the seed coat or the pericarp possesses wings or hairs which serve to assist flight. Fruits may also be winged by the subsequent enlargement of carpels after seed formation (Henry, 1930). In Doi Suthep-Pui National Park wind dispersal period coincides with the highest mean monthly wind speeds, as noted by Elliott *et al.* (1994). When such fruits or seeds are eaten by animals, the seeds, protected by the

hard testa or endocarp, often pass unharmed through the digestive tract and are often deposited in the feces at a considerable distance from the place where they were consumed (Traveset, 1998; Baskin and Baskin, 1998). In many cases the fruits were eaten and the seeds were carried some distance from the parent before they were released by birds and wildlife (White, 1994). For instance, cows and buffaloes in north-eastern Thailand and deer in Doi Suthep-Pui National Park were highly efficient dispersal agents for seeds of *Irvingia malayana*, birds and/or small animals for seeds of *Trema orientalis*, *Eurya acuminata*, *Debregeasia longifolia*, *Macropanax dispermus*, *Morus macroura*, *Tetradium glabrifolium*, *Vaccinium sprengelii*, and *etc.*). *Macaranga kurzii* was dispersed by animals. Soerianegara and Lemmens (1994) and Schmidt (2000) noted that the hard arils of the seeds of *Afzelia xylocarpa and Sindora siamensis* are attractive to rodents which disperse the seeds.

With regard to seasonal seed dispersal and seed dormancy, six species were dispersed in the early wet season (May-July). Willan (1984) noted that dormancy in nature serves to protect some seeds from conditions which are temporarily suitable for germination, but which quickly revert to conditions too harsh for survival of the tender young seedling. Thus, by evolution seed dispersal and germination occurs during the wet season. But eighteen species do not germinate until the beginning of the next rainy season (they were dispersed during the late wet and the early dry seasons). Five species, dispersed in the late dry season (February-April), germinate in the wet season. Three species were dispersed in both the wet and dry seasons (*Colona fragrocarpa*, *Ficus lamponga* and *Ficus superba*). A host of interacting factors determine the optimal time for native tree species to produce seeds, including the availability of dispersal agents; the absence of seed predators and the likely presence of conditions suitable for seed germination. For example, figs produce a very large numbers of seeds; they ensure that at least some of their seeds stand a good chance of being deposited in a suitable site. Also, with large numbers of small seeds contained within a soft fleshy tissue which requires very little chewing, most of the seeds pass undamaged through the digestive tracts of fig-eating animals. Figs are an extremely important source of food for forest animals. They are sometimes called "keystone"

species because they are available throughout the year and provide food when other more seasonal food supplies may be limited. Many different animals can be seen feeding together in a fig tree including birds, primates, squirrels and civets. On the forest floor, pigs, deer and rodents feed on the fallen figs.

Under natural conditions, most fruits (>50% of all species) are dispersed in the late wet to early dry season. If their seeds germinate at that time of year in the forest the seedlings might not grow big enough to survive the following dry season. Therefore, many lie dormant until the start of the following rainy season (Blakesley *et al.*, 2000). This seasonal pattern of fruit production has profound implications for nursery production of tree seedlings for forest restoration plantings. Because different species produce seeds at different times of the year. Seeds developing under different environmental conditions may not have the same dormancy-breaking and/or germination requirements (Baskin and Baskin, 1998). Also, all seedlings must reach a plantable size (40-60 cm tall) at the same time of the year (Kuarak *et al.*, 2000).

Therefore, in order for suitable seedlings to be planted, seed dormancy must be broken quickly to improve germination rate and seedling growth accelerated to produce seedlings big enough for planting, approximately 10 months after seed collection. Otherwise, seedlings would have to be stored in nurseries for 10 months to more than a year approximately, which is wasteful in terms of labour, space and costs. Experiments to break seed dormancy and accelerate germination by various pre-treatments (Chapter 3) and/or seed storage are therefore very important for forest restoration. Also, the many problems of seed germination and/or slow seedling growth encourage investigation of cutting propagation (Chapter 5).

Consequently, most species required lengthy dormancy periods, to survive the dry season and germinate in the rainy season. Therefore, in order to accelerate seedling production in the nursery, treatments to break dormancy had to be developed.

Further research is needed for more than one year and should concentrate on the relationships between flowering stage, breeding system, pollinator biology, fruiting stage, flower and fruit predators, genetic variation and it is opportune to ask what we can learn about them and how we can use the information so grained to propagate, utilize and conserve native forest tree species for forest restoration.

Table 1. Tree selected for phenological observations and collection of seeds and leafy stem cuttings for propagation.

Species	Family	Trees no.	Forest type[A]	Elevation	Seed dispersal mechanism	Phenology	Seed collection	Cutting
Acrocarpus fraxinifolius Wight *ex* Arn.	Leguminosae	1	evergreen	1,050	wind	*	*	
		2		1,050				
Afzelia xylocarpa (Kurz) Craib	Leguminosae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Albizia chinensis (Osb.) Merr.	Leguminosae	1	evergreen+	1,050	wind	*	*	
		2	pine forest					
Aporusa villosa (Lindl.) Baill.	Euphorbiaceae	1	mixed	740	animal	*	*	
		2	ever.+dec.	740				
Betula alnoides Ham. *ex* D. Don	Betulaceae	1	evergreen+	1,050	wind	*	*	
		2	pine forest	1,050				
		3		1,050				
Cassia fistula L.	Leguminosae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Colona fragrocarpa (Cl.) Craib	Tiliaceae	1	deciduous	685	wind	*		*
		2		685				
		3		685				
Debregeasia longifolia (Burm.f.) Wedd.	Urticaceae	1	evergreen	1,020	animal	*	*	
		2		1,020				
		3		1,020				
Diospyros undulata Wall. ex G. Don var. *cratericalyx* (Craib) Bakh.	Ebenaceae	1	mixed	720	animal	*	*	
		2	ever.+dec.	720				
		3		720				
Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae	1	evergreen	1,500	animal	*	*	
		2		1,500				
Elaeocarpus prunifolius Wall. *ex* C. Muell.	Elaeocarpaceae	1	evergreen	1,050	animal	*	*	
		2		1,050				

[A] Forest type sensu Maxwell and Elliott, 2001

Table 1. Tree selected for phenological observations and collection of seeds and leafy stem cuttings for propagation (continue).

Species	Family	Trees no.	Forest type[A]	Elevation	Seed dispersal mechanism	Phenology	Seed collection	Cutting
Eurya acuminata DC. var. *wallichiana* Dyer	Theaceae	1	evergreen	1,080	animal	*	*	*
		2		1,080				
		3		1,080				
Ficus lamponga Miq.	Moraceae	1	evergreen	1,050	animal	*	*	*
		2		1,050				
		3		1,050				
Ficus hirta Vahl var. *roxburghii* (Miq.) King	Moraceae	1	evergreen	1,420	animal	*	*	*
		2		1,420				
Ficus superba (Miq.) Miq. var. *superba*	Moraceae	1	evergreen	1,400	animal	*	*	*
		2		1,400				
Glochidion acuminatum M. -A. var. *siamense* A.S.	Euphorbiaceae	1	evergreen	1,425	animal	*	*	
		2		1,425				
		3		1,425				
Irvingia malayana Oliv. *ex* Benn.	Irvingiaceae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Lagerstroemia speciosa (L.) Pers. var. *speciosa*	Lythraceae	1	deciduous	460	wind	*	*	
		2		460				
		3		460				
Macaranga kurzii (O.K.) Pax & Hoffm.	Euphorbiaceae	1	evergreen	1,080	animal	*		*
		2		1,080				
		3		1,080				
Macropanax dispermus (Bl.) O.K.	Araliaceae	1	evergreen	1,275	animal	*	*	
Morus macroura Miq.	Moraceae	1	evergreen	1,020	animal	*	*	*
		2		1100				
Reevesia pubescens Mast. var. *siamensis* (Craib) Anth.	Sterculiaceae	1	evergreen	1,150	wind	*	*	
		2		1,150				
Saurauia roxbughii Wall.	Saurauiaceae	1	evergreen	1,180	animal	*	*	*
		2		1,180				
		3		1,180				

Table 1. Tree selected for phenological observations and collection of seeds and leafy stem cuttings for propagation (continue).

Species	Family	trees no.	Forest type[A]	Elevation	Seed dispersal mechanism	Phenology	Seed collection	Cutting
Schleichera oleosa (Lour.) Oken	Sapindaceeae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Shorea obtusa Wall. *ex* Bl.	Dipterocarpace	1	deciduous	460	wind	*	*	
		2		460				
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	Leguminosae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	1	deciduous	460	animal	*	*	
		2		460				
Terminalia chebula Retz. var. *chebula*	Combretaceae	1	deciduous	460	animal	*	*	
		2		460				
		3		460				
Terminalia mucronata Craib & Hutch.	Combretaceae	1	evergreen	1,050	wind	*	*	
		2		1,050				
Tetradium glabrifolium (Champ-*ex* Bth.) T. Hart.	Rutaceae	1	evergreen	1,080	animal	*	*	
		2		1,080				
		3		1,050				
Trema orientalis (L.) Bl.	Ulmaceae	1	mixed	840	animal	*	*	*
		2	evergreen+	840				
		3	deciduous	840				
Vaccinium sprengelii (D. Don) Sleum.	Ericaceae	1	evergreen+	1,560	animal	*	*	
		2	pine forest	1,560				

Table 2. Leaf flushing and leaf fall phenology of 32 native forest trees species.

Species	Ja	Fb	Mr	Ap	My	Jn	Jl	Ag	Sp	Oc	Nv	Dc
Acrocarpus fraxinifolius									""	"					
Afzelia xylocarpa							""	"								
Albizia chinensis		||	|||	""	"	"				|||	||
Aporusa villosa									""	""	"					
Betula alnoides	||""	""	"	"								|||
Cassia fistula				|||	""	""						
Colona fragrocarpa	||	|||	|||	""	"	"	"						
Debregeasia longifolia	"	"	"	"			"	"		"		"
Diospyros undulata			"									
Elaeocarpus lanceifolius		"	""	""	""									
Elaeocarpus prunifolius	||""	|""	"	"								
Eurya acuminata	"	"	"	"	"	"	"	"	"	"	"	"
Ficus lamponga	"				|||	|""				||	|||
Ficus superba	"	""	""	"	||""	|""	|""	"	|||	|"	"	
Ficus hirta	"	"	""			||	|||	|"	"	"	"	"
Glochidion acuminatum	"	"	|"	|""	"	"	"	"	"	"	"	"
Irvingia malayana								""							
Lagerstroemia speciosa	|||	|||	||""	|""	""	"	"						
Macaranga kurzii			||"	""	"	"	"	"	"	"		
Macropanax dispermus		""	""	"	"	"	"					
Morus macroura	|||||	|||"	|""	|""	""	"	"						
Reevesia pubescens			||	||"	|""	"	"	"						
Saurauia roxburghii				"	"		"	"	"		"	"	"
Schleichera oleosa				|""	"	"	"	"				
Shorea obtusa											""						
Sindora siamensis	||	""	"												
Terminalia bellirica									""	""	"	"					
Terminalia chebula	|||	|||	|||"	""	""	"	"					
Terminalia mucronata									""	"							
Tetradium glabrifolium			||	|||	|""	""	"	"					
Trema orientalis	"		"	"	"	"	"	"	"			
Vaccinium sprengelii		""	""	"	"	"	"									
no. of species leaf fall	20	18	16	11	3	3	2	1	1	2	6	11
no. of speciesleaf flushing	12	14	24	28	19	20	17	9	5	7	5	5

||| = leaf fall, "" = leaf flushing.

Table 3. Reproductive phenology of 32 native forest trees species.

Species	Ja	Fb	Mr	Ap	My	Jn	Jl	Ag	Sp	Oc	Nv	Dc
Acrocarpus fraxinifolius	,,"	""""	""‖	‖‖	‖‖d	dddd	d					
Afzelia xylocarpa	‖dd	,,,,	,,""	,""""	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖dd
Albizia chinensis	|ddd	|ddd		,,	""‖	‖‖	‖‖	‖‖d	‖‖d	‖‖d	‖‖d	‖dd
Aporusa villosa	,,,"	,"""	""‖	‖‖d	‖‖dd							
Betula alnoides	""‖	"‖‖d	‖‖dd									,,
Cassia fistula	‖d	,,"	,,""	,""""	""‖	‖	‖	‖	‖	‖	‖	‖d
Colona fragrocarpa	‖‖	‖‖d	dddd			,,""	,""|	""‖	‖‖	‖‖	‖‖	‖‖
Debregeasia longifolia									,,"	,""|	""‖	"‖‖d
Diospyros undulata				,,""	"‖‖	‖‖	‖‖d	‖dd				
Elaeocarpus lanceifolius						,,,,	,""|	""‖	‖‖	‖‖	‖‖d	dddd
Elaeocarpus prunifolius	,,	,,"	,,""	""‖	‖‖	‖‖	‖‖	‖‖d	‖‖d			
Eurya acuminata	‖‖	‖‖	‖dd	|ddd				,,	,""|	""‖	‖‖	‖‖
Ficus lamponga	""""	""""	‖‖d	‖‖dd		""""	""""	""""	‖‖d	|ddd		""""
Ficus superba	""""	""""	‖‖	‖‖dd		""	""""	‖‖	‖dd	""	""""	""""
Ficus hirta			"	""	""	""	‖‖	‖‖d	‖‖d	‖‖dd		
Glochidion acuminatum			,	,"	,""	"‖‖	‖‖	‖‖	‖‖d	‖‖dd		
Irvingia malayana				,,"	,""	"‖‖	‖‖	‖‖d	|ddd			
Lagerstroemia speciosa			,	,""	"‖‖	‖‖	‖‖	‖‖	‖‖d	‖dd	|ddd	|ddd
Macaranga kurzii					,"	,""	""‖	‖‖	‖‖	‖‖	‖‖d	‖dd
Macropanax dispermus	‖dd	|ddd			,,"	,""	,""|	""‖	‖‖	‖‖	‖‖	‖‖d
Morus macroura	,"	,""‖	""‖	"‖‖d	|ddd							
Reevesia pubescens	‖‖d	‖‖d	‖‖d	,,,	""‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖
Saurauia roxburghii				,,,	,""	,""‖	""‖	‖‖d	‖‖d			
Schleichera oleosa			,,"	"‖‖	‖‖	‖‖	‖‖	‖‖d	‖‖d	|ddd		
Shorea obtusa				"‖‖	‖‖d	‖dd						
Sindora siamensis				,,	,,"	"‖‖	‖‖	‖‖	‖‖	‖‖d	|ddd	
Terminalia bellirica	‖dd		,,"	,""	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖d
Terminalia chebula			,	,,	,""	""‖	‖‖	‖‖	‖dd			
Terminalia mucronata	|ddd			,""	"‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖‖	‖dd
Tetradium glabrifolium						,,,	,""	""‖	‖‖	‖‖d	‖‖d	‖‖dd
Trema orientalis			,"|	,""|	,""‖	""‖	"‖‖	"‖‖	‖‖d	‖‖d	‖‖d	‖d
Vaccinium sprengelii	"""|	""‖	"‖	‖‖	‖‖d	‖‖d				,,	,,,"	,""
no. of species flowers	8	10	14	19	15	14	9	7	2	4	3	5
no. of species fruits	11	8	10	11	16	18	21	23	24	20	16	14

,,,,= flower buds, """ = flowers, |||| = fruits, dd = dispersal

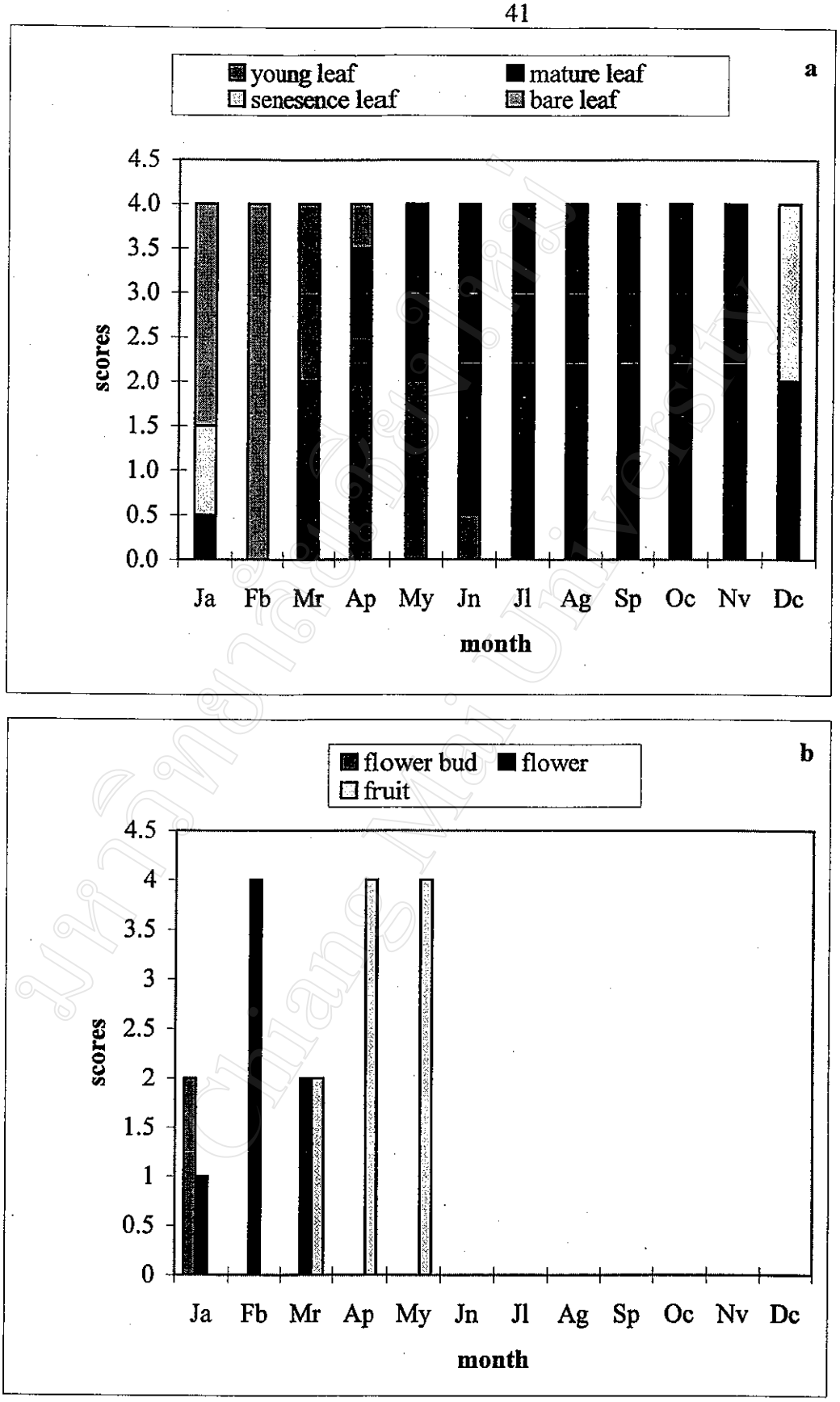


Figure 2. Phenology of *Acrocarpus fraxinifolius.*

a. Leafing phenology

b.Reproductive phenology

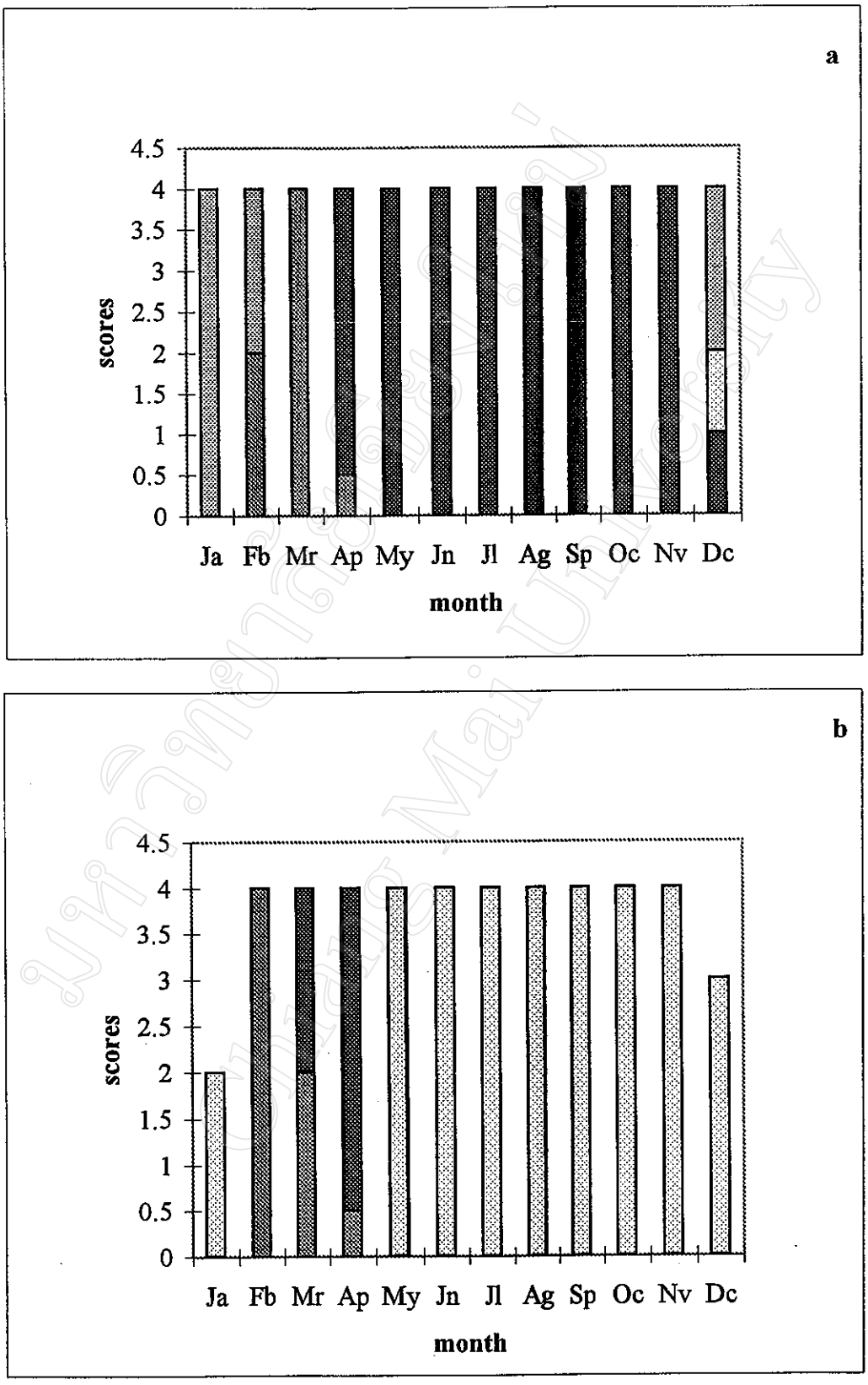


Figure 3. Phenology of *Afzelia xylocarpa.*

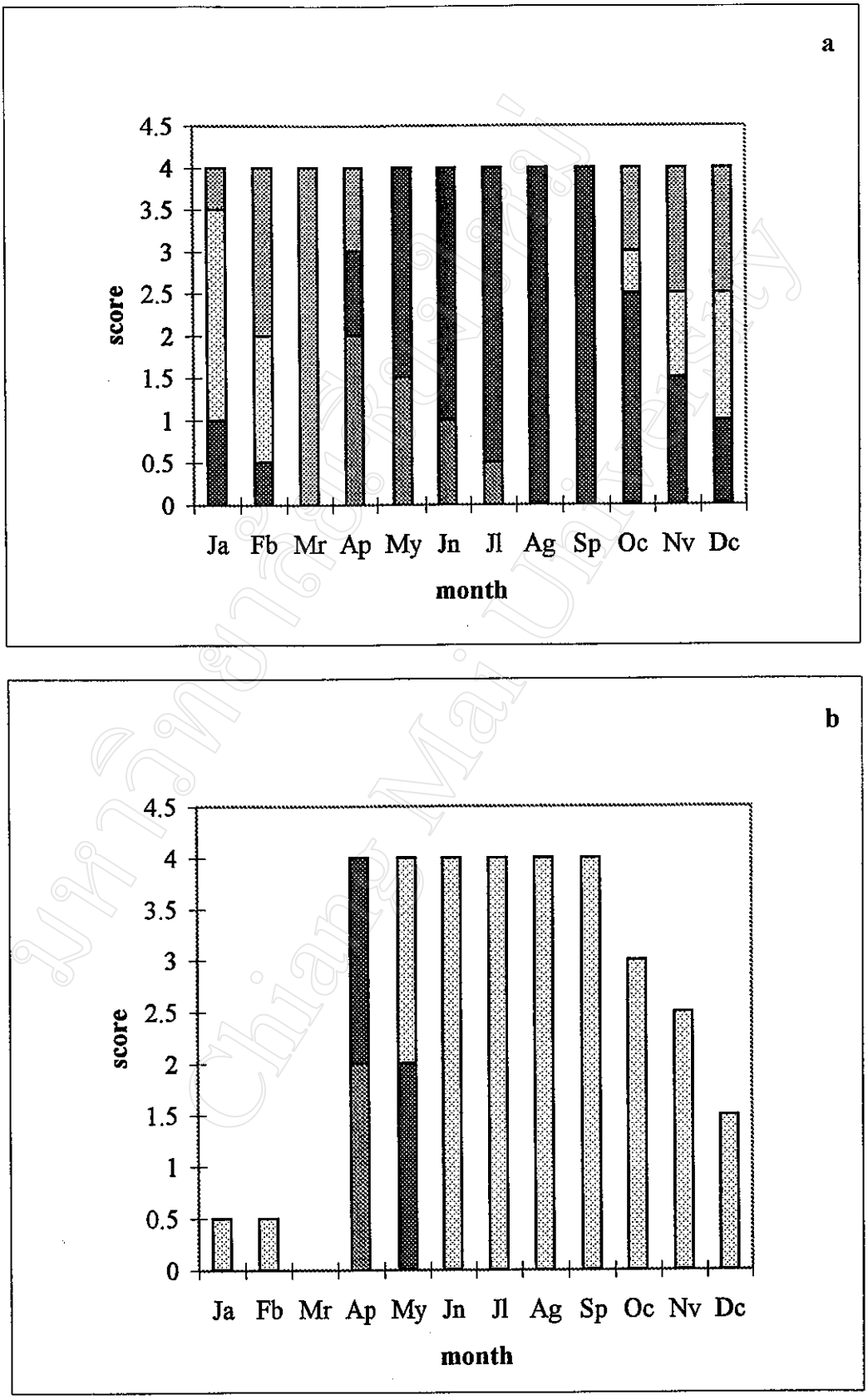


Figure 4. Phenology of *Albizia chinensis*.

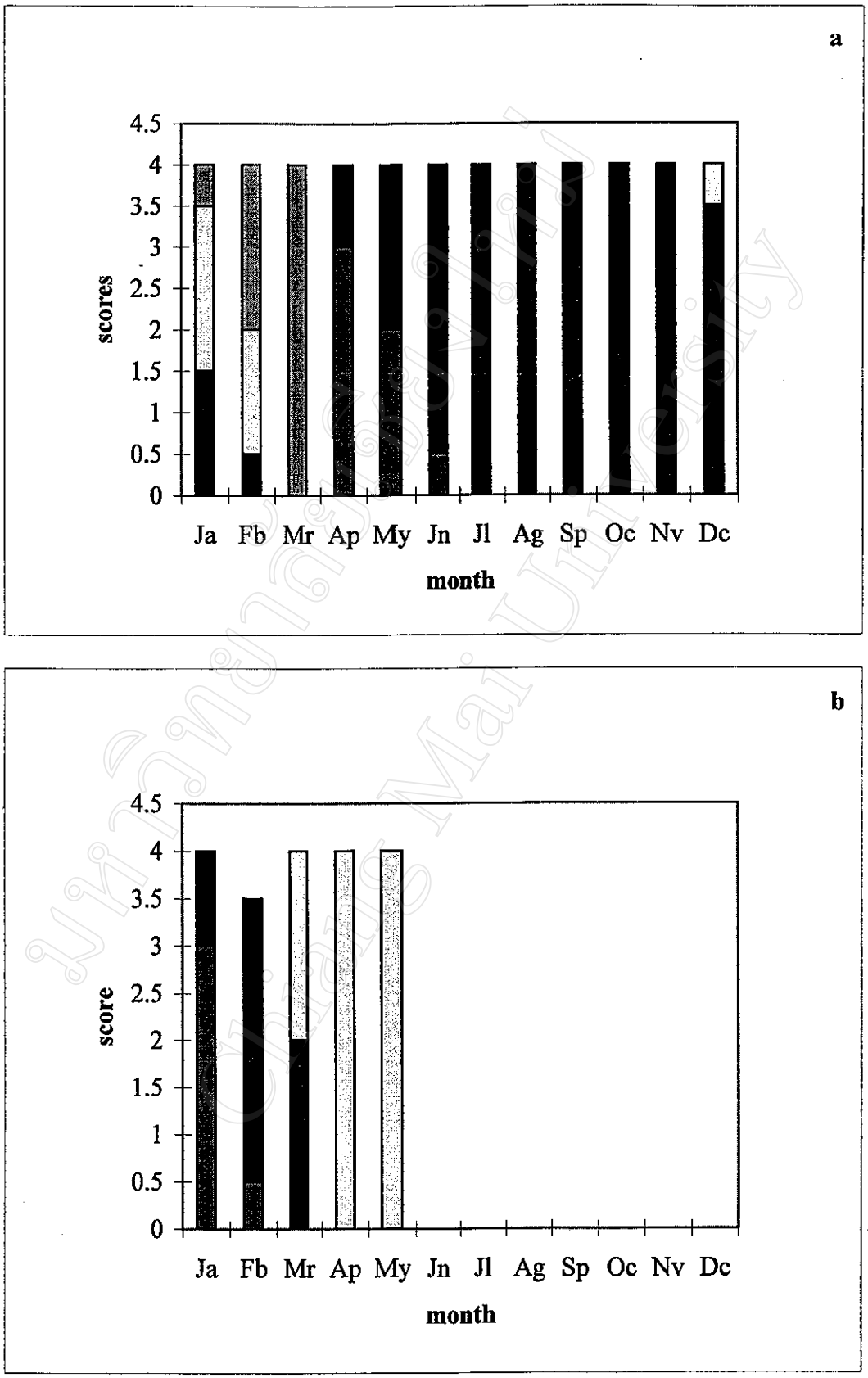


Figure 5. Phenology of *Aporusa villosa.*

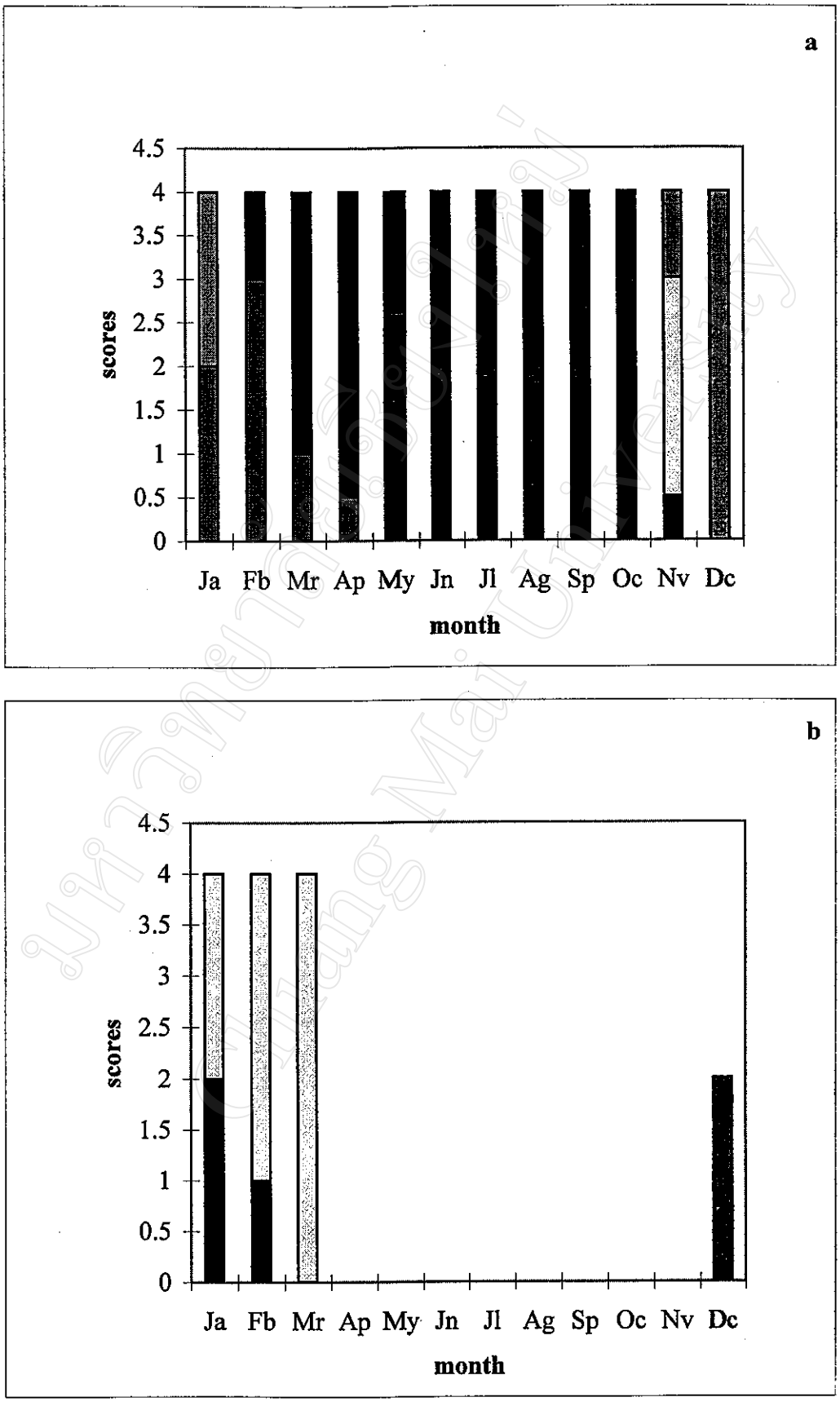


Figure 6. Phenology of *Betula alnoides*.

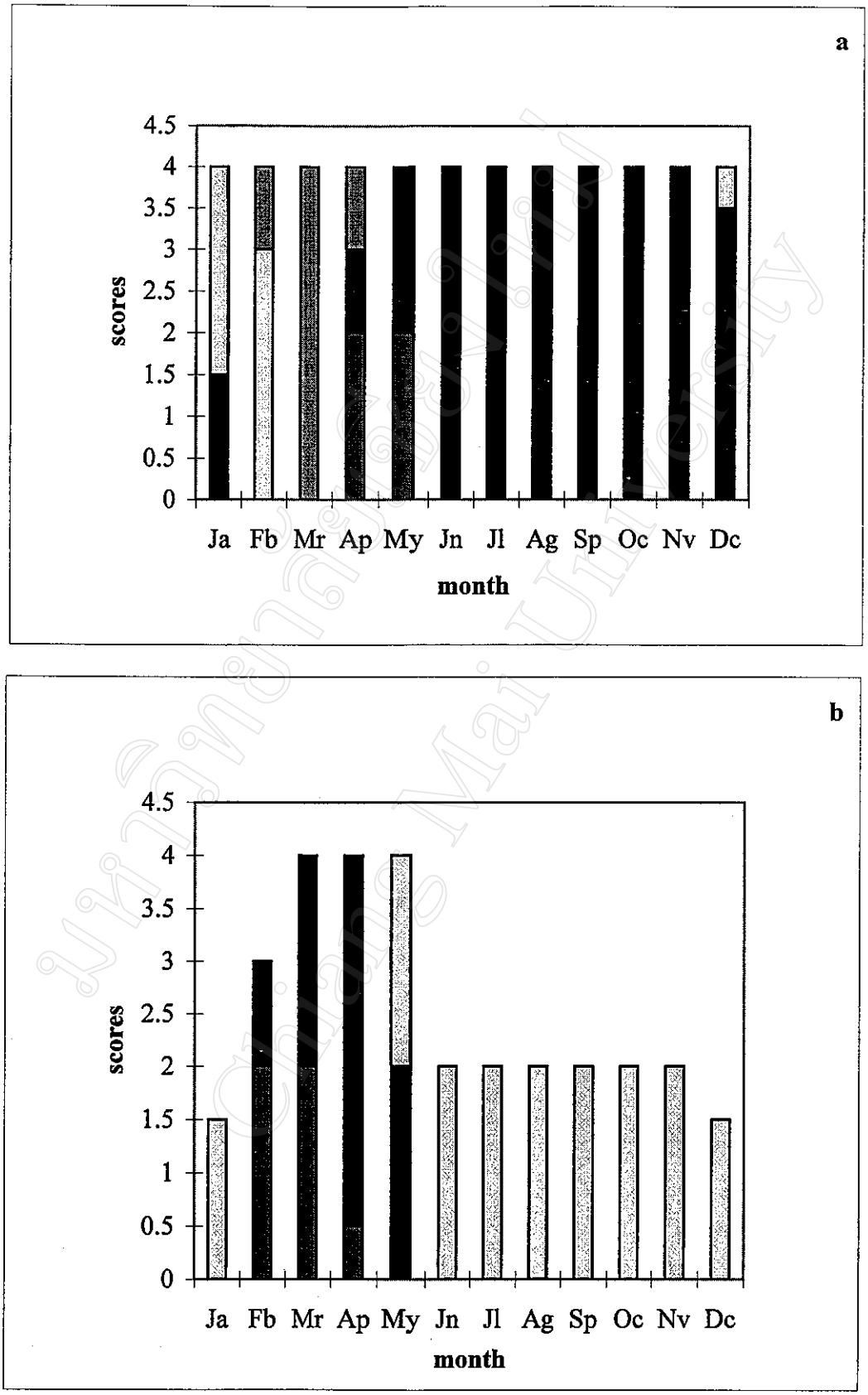


Figure 7. Phenology of *Cassia fistula.*

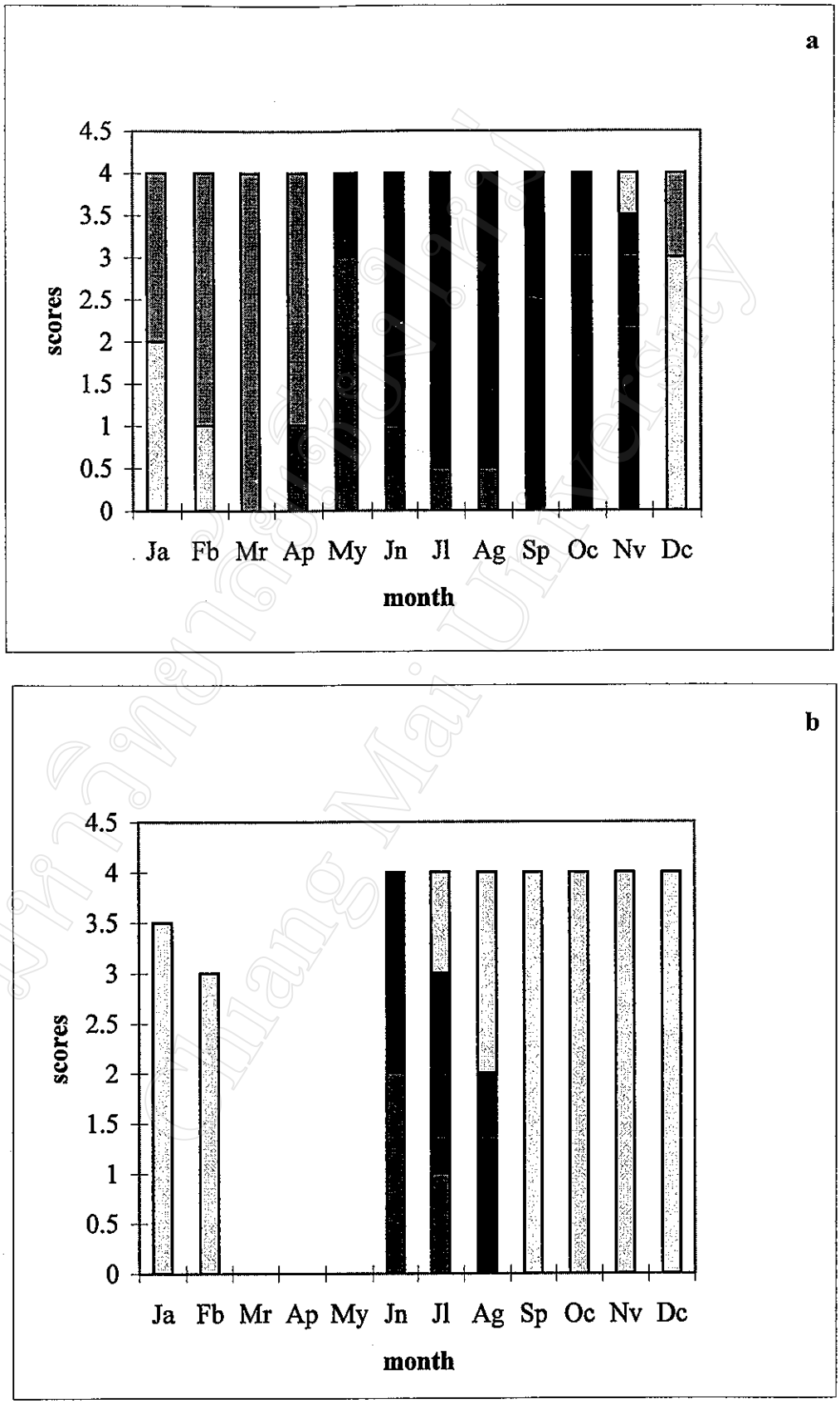


Figure 8. Phenology of *Colona fragrocarpa.*

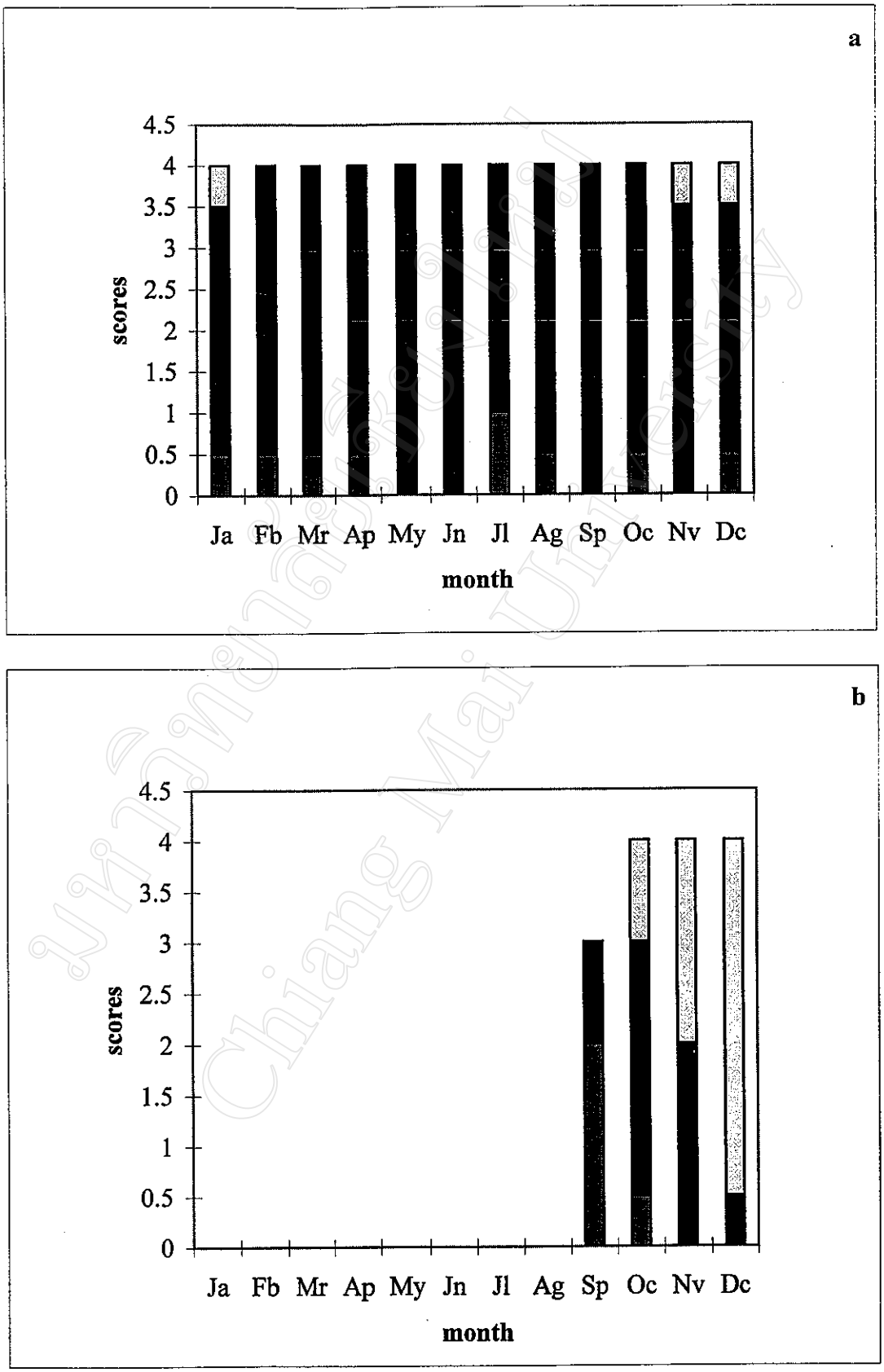


Figure 9. Phenology of *Debregeasia longifolia.*

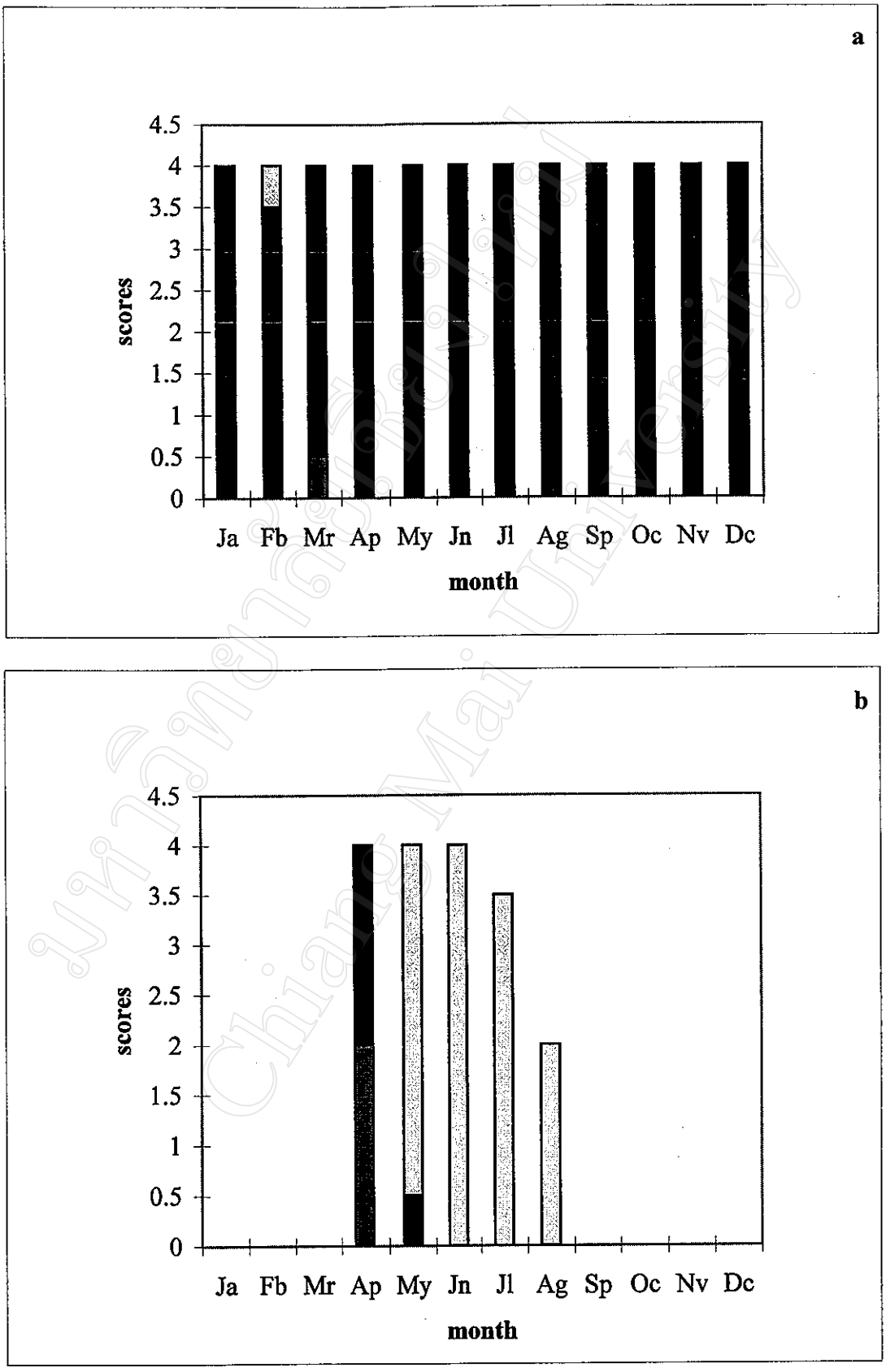


Figure 10. Phenology of *Diospyros undulata.*

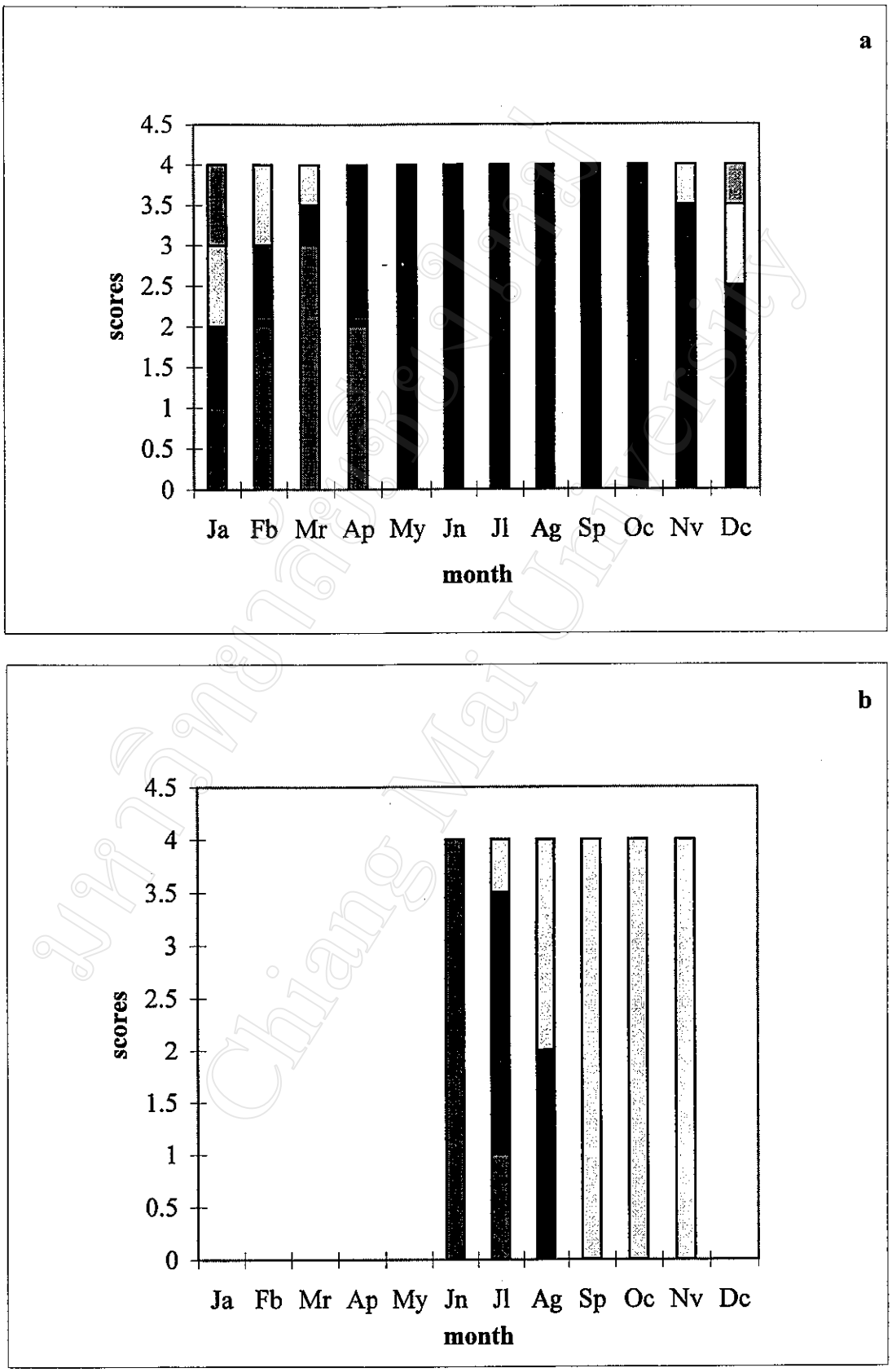


Figure 11. Phenology of *Elaeocarpus lanceifolius.*

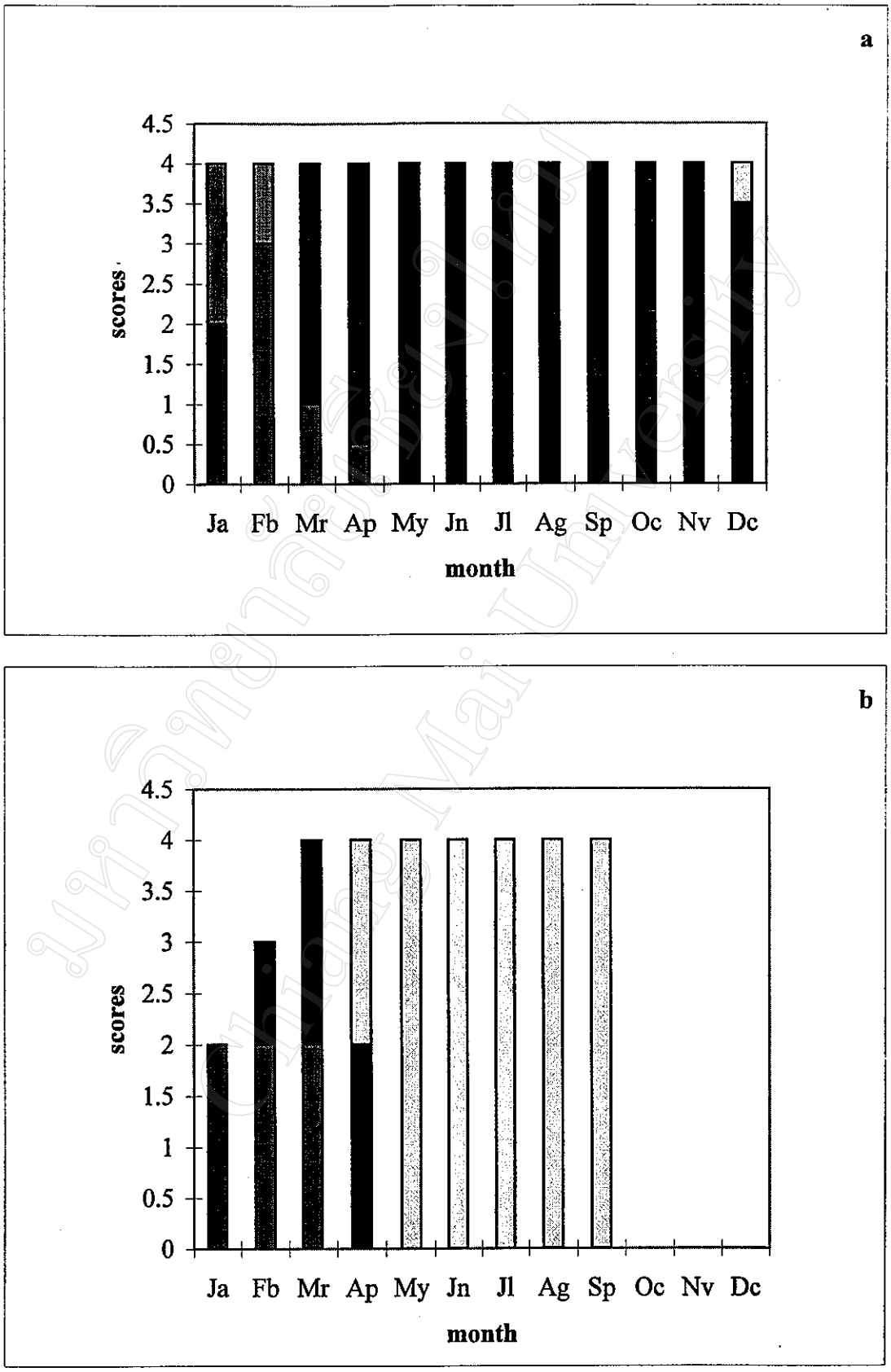


Figure 12. Phenology of *Elaeocarpus prunifolius.*

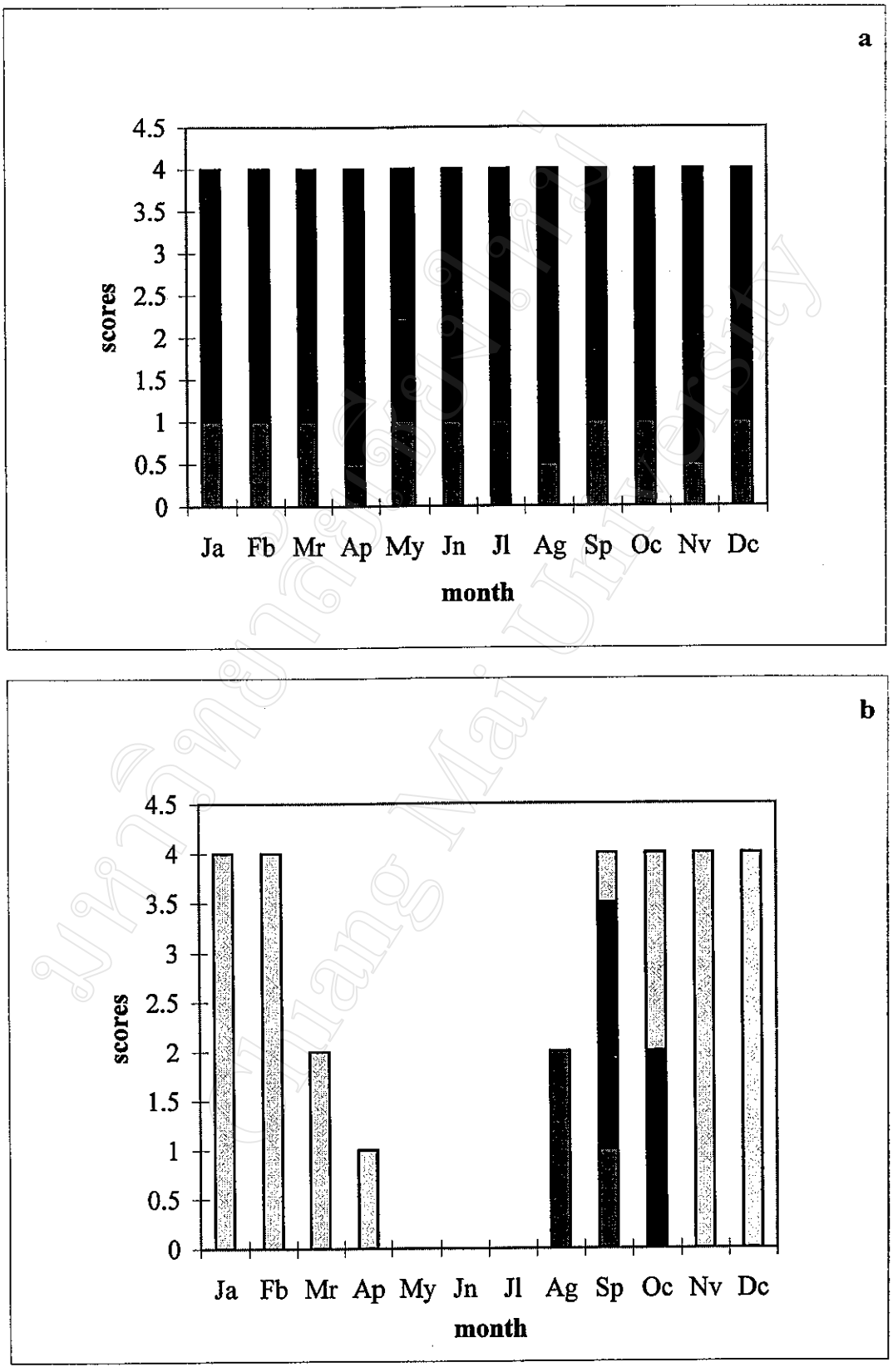


Figure 13. Phenology of *Eurya acuminata.*

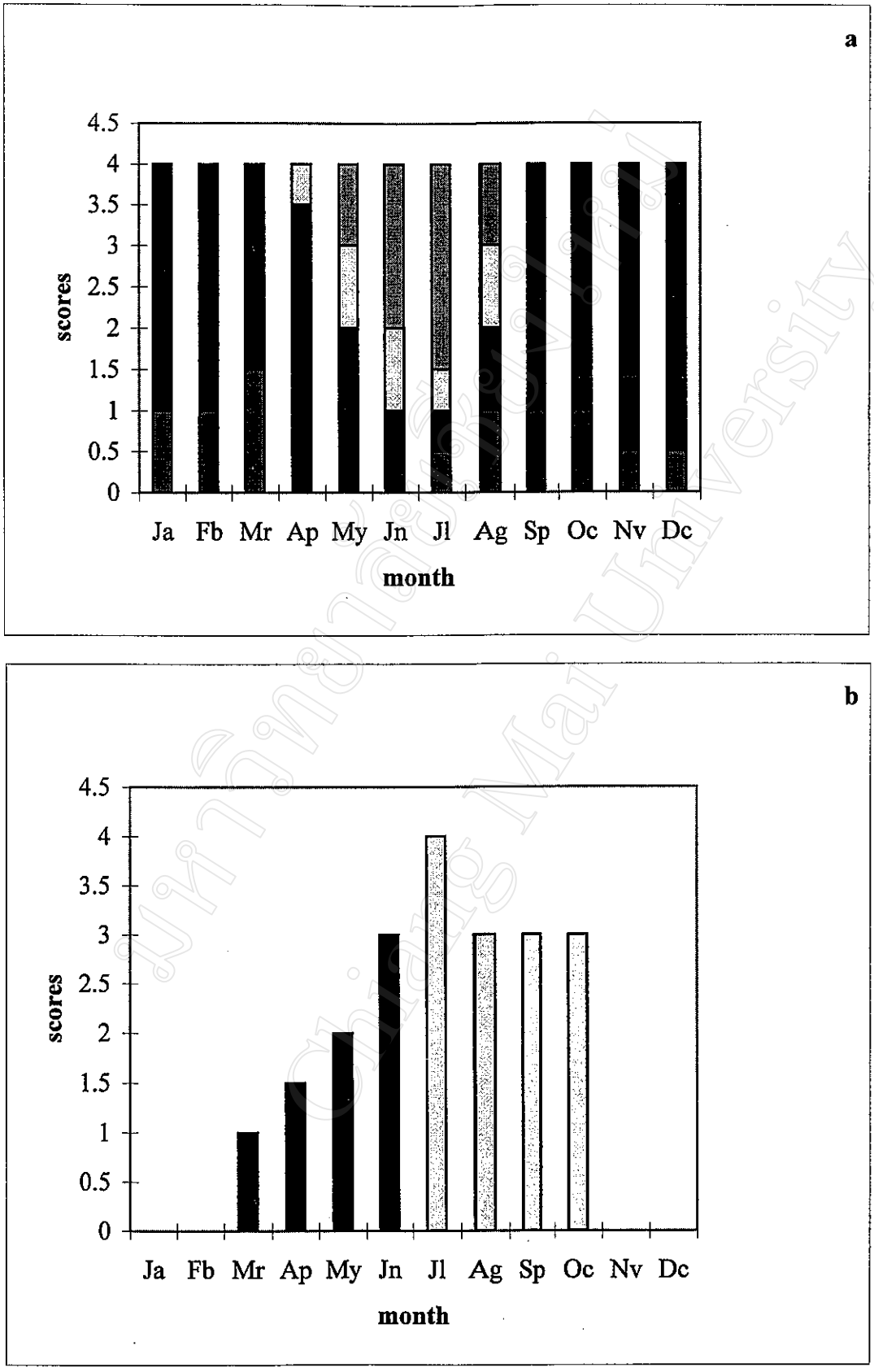


Figure 14. Phenology of *Ficus hirta.*

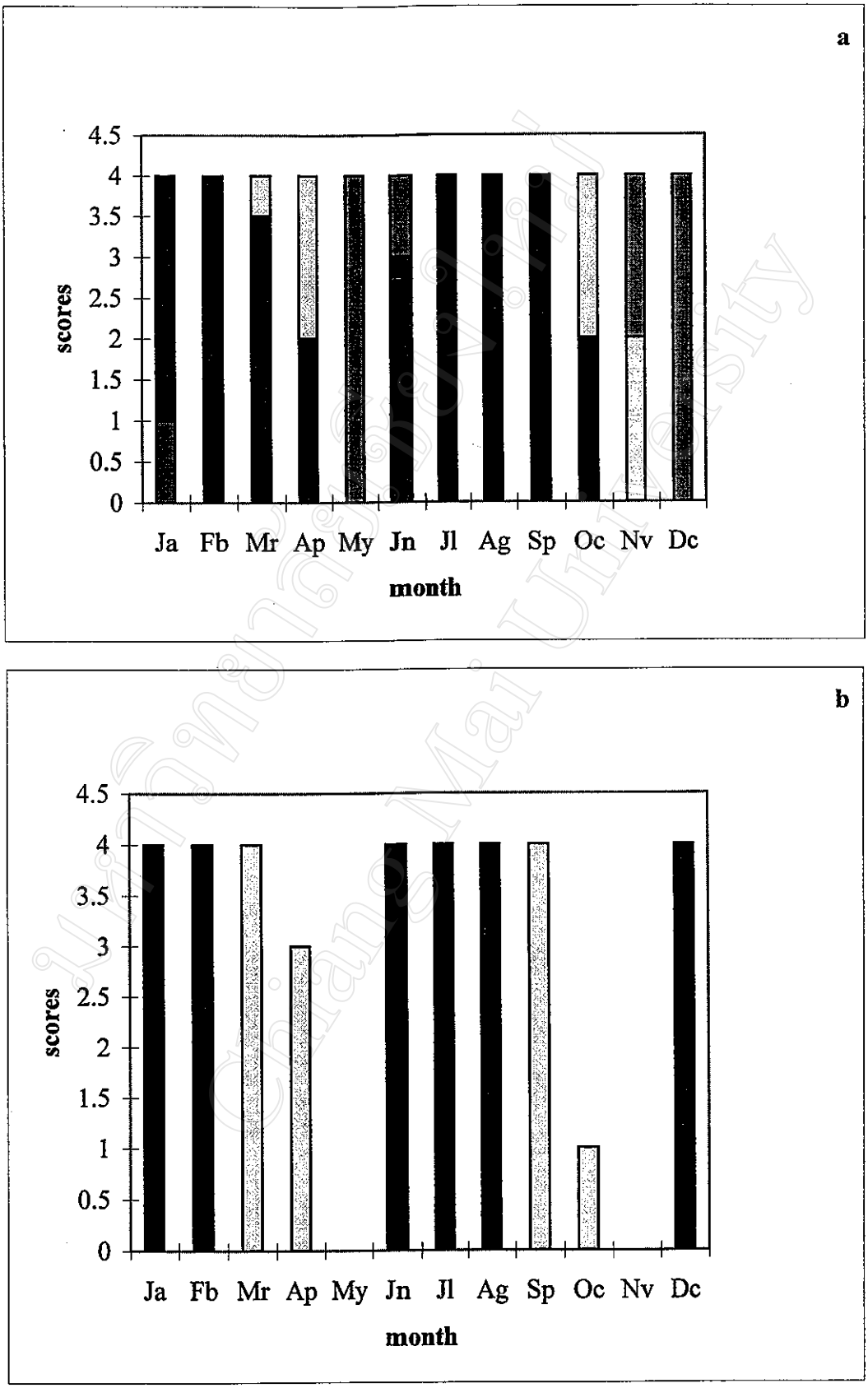


Figure 15. Phenology of *Ficus lamponga.*

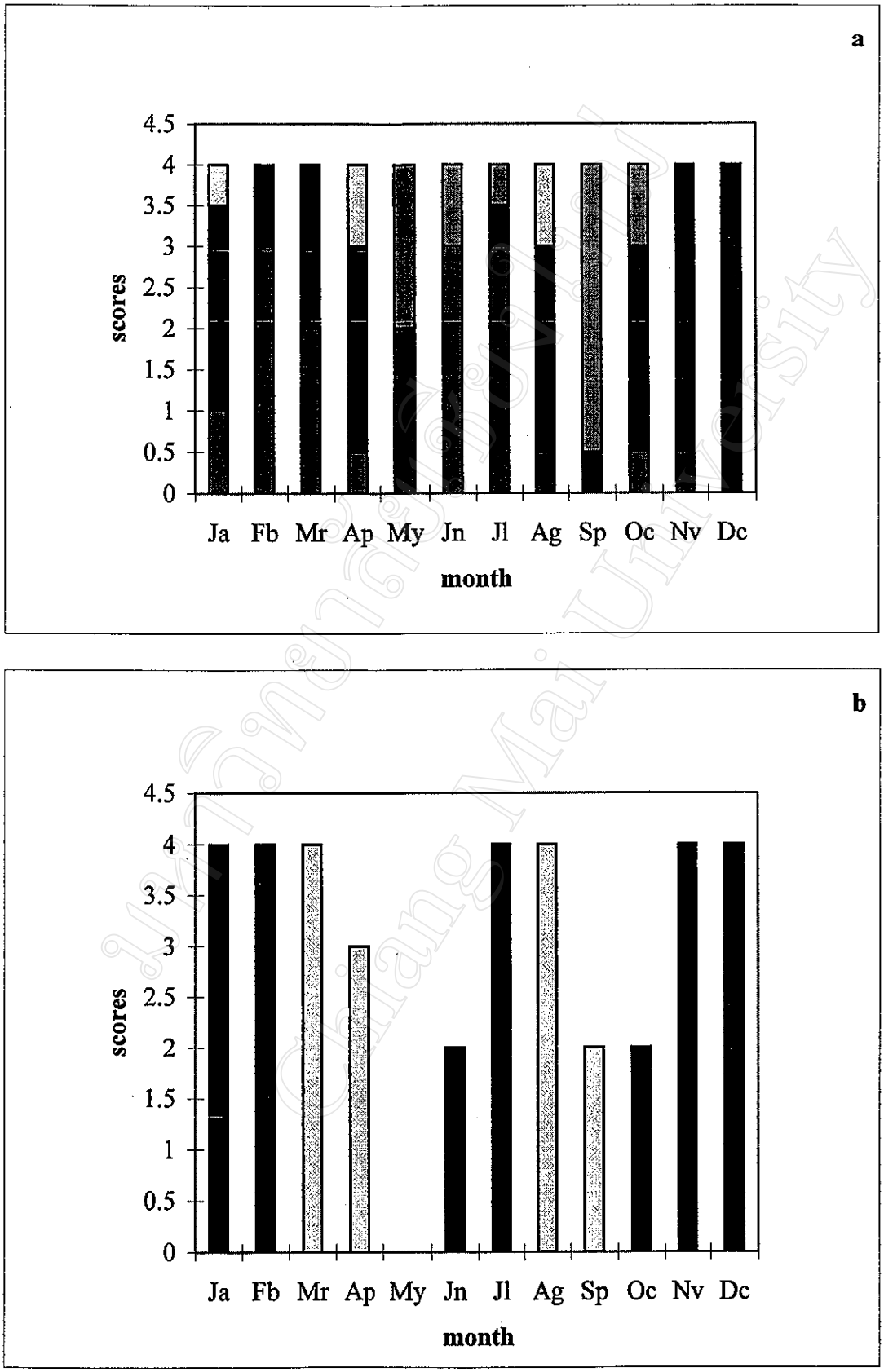


Figure 16. Phenology of *Ficus superba.*

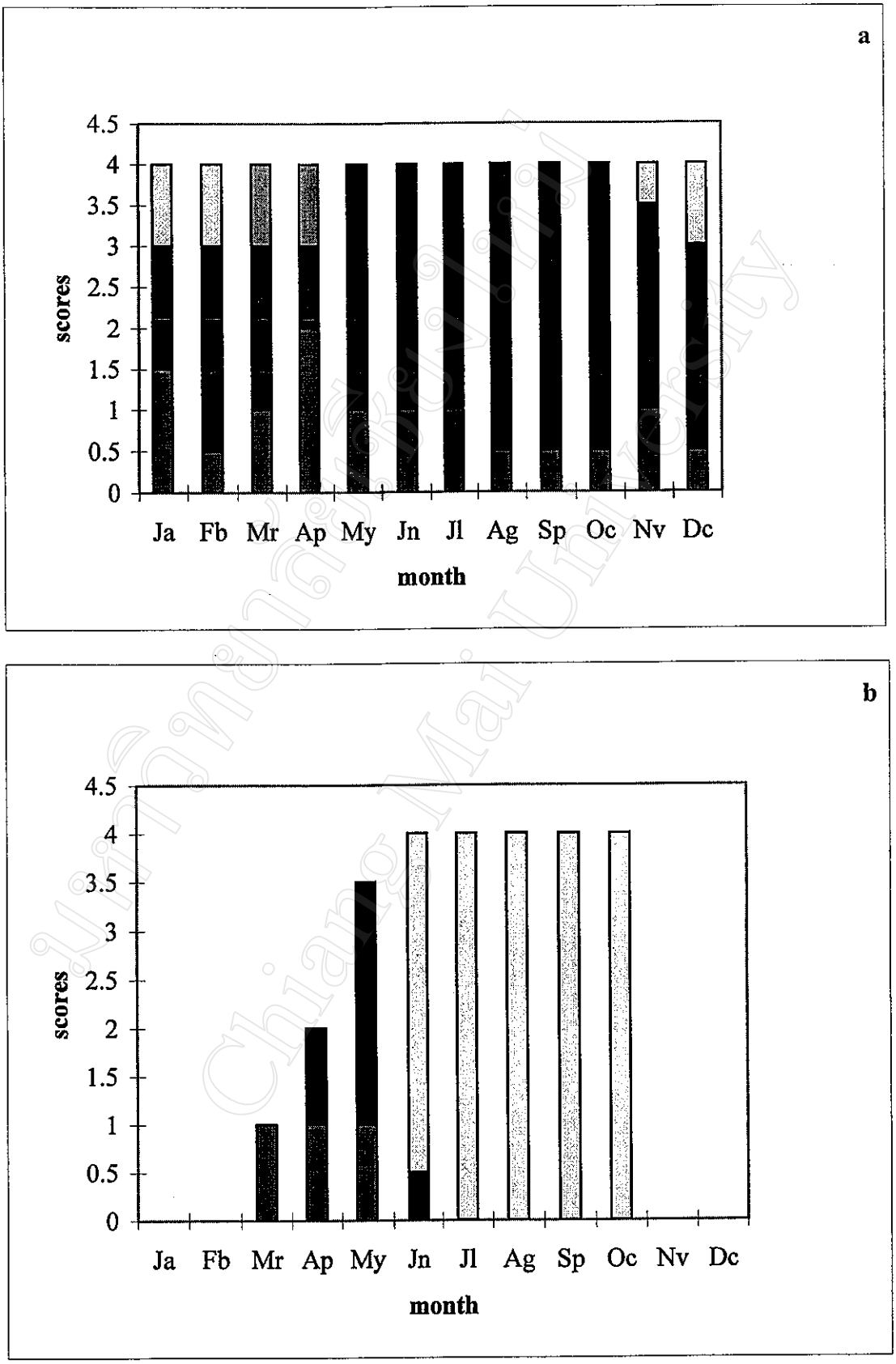


Figure 17. Phenology of *Glochidion acuminatum.*

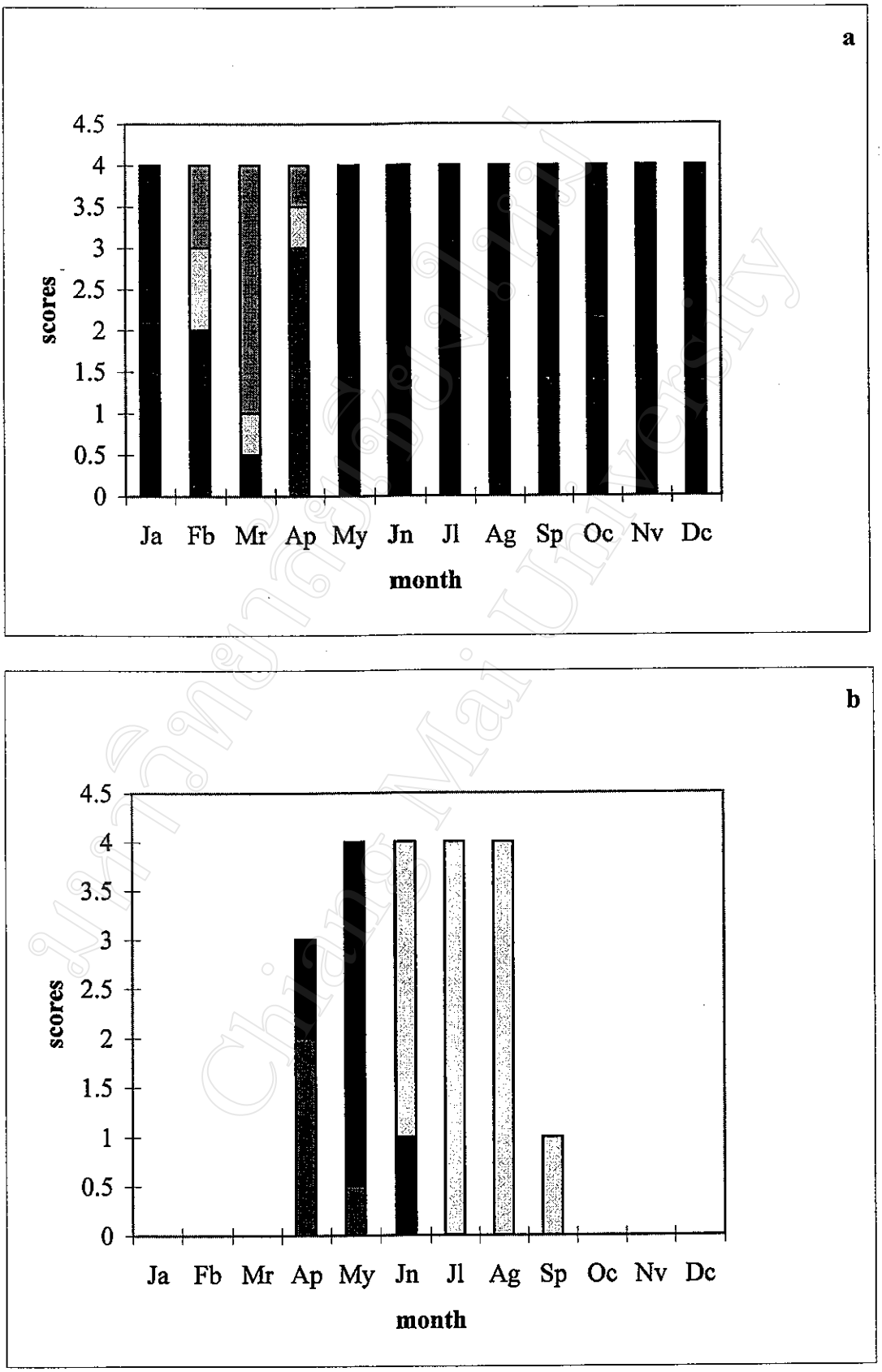


Figure 18. Phenology of *Irvingia malayana.*

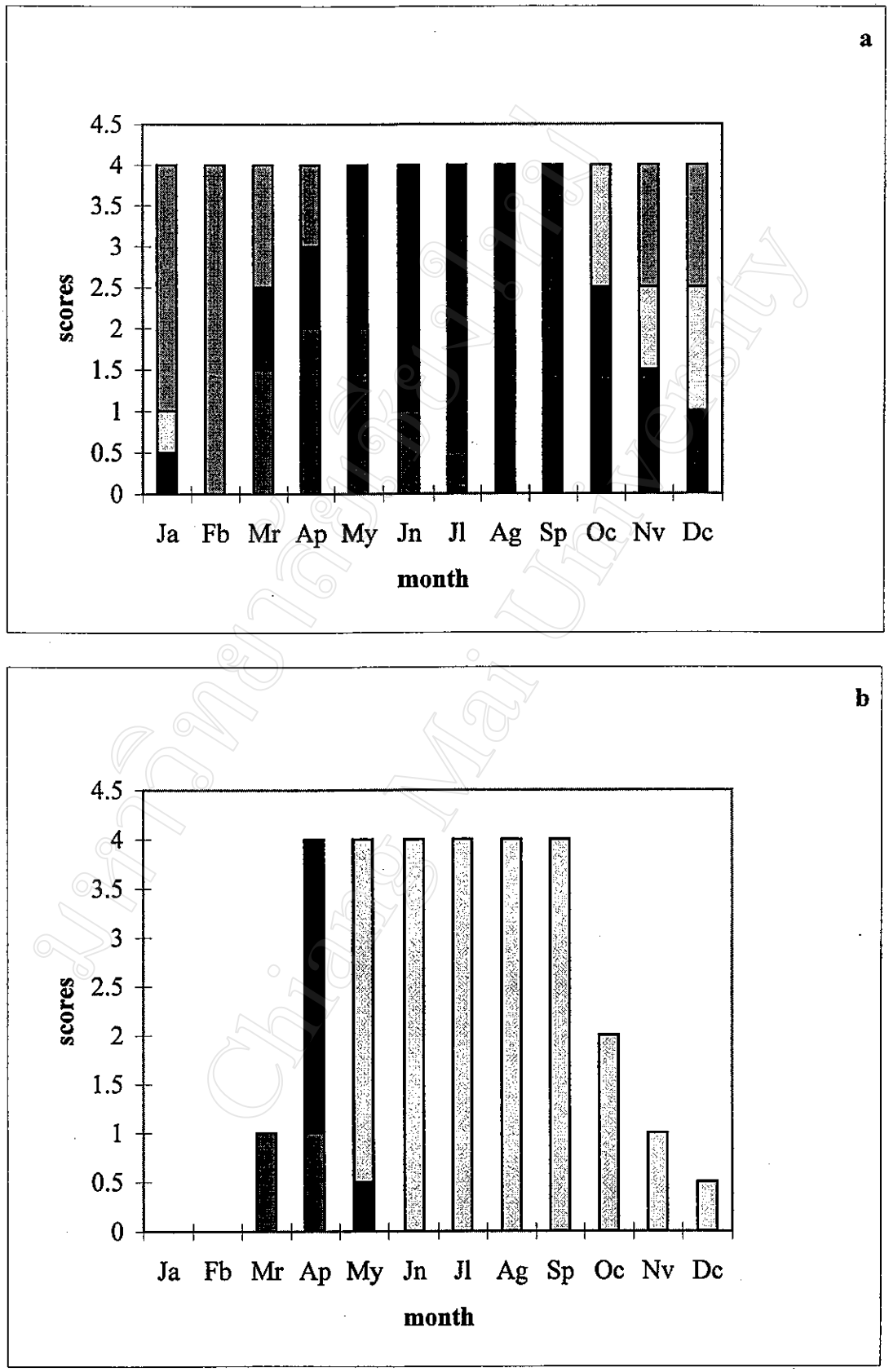


Figure 19. Phenology of *Lagerstroemia speciosa.*

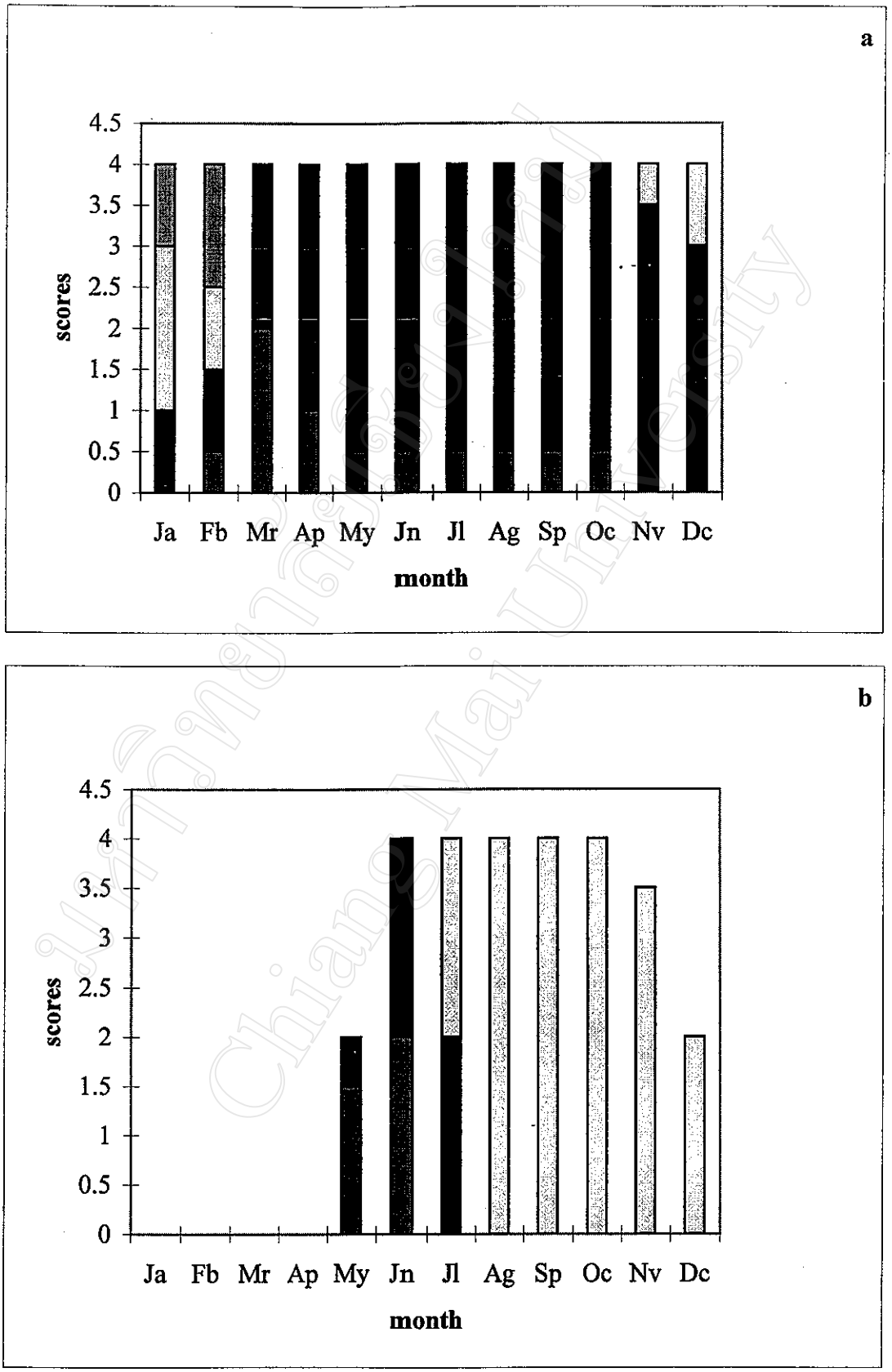


Figure 20. Phenology of *Macaranga kurzii.*

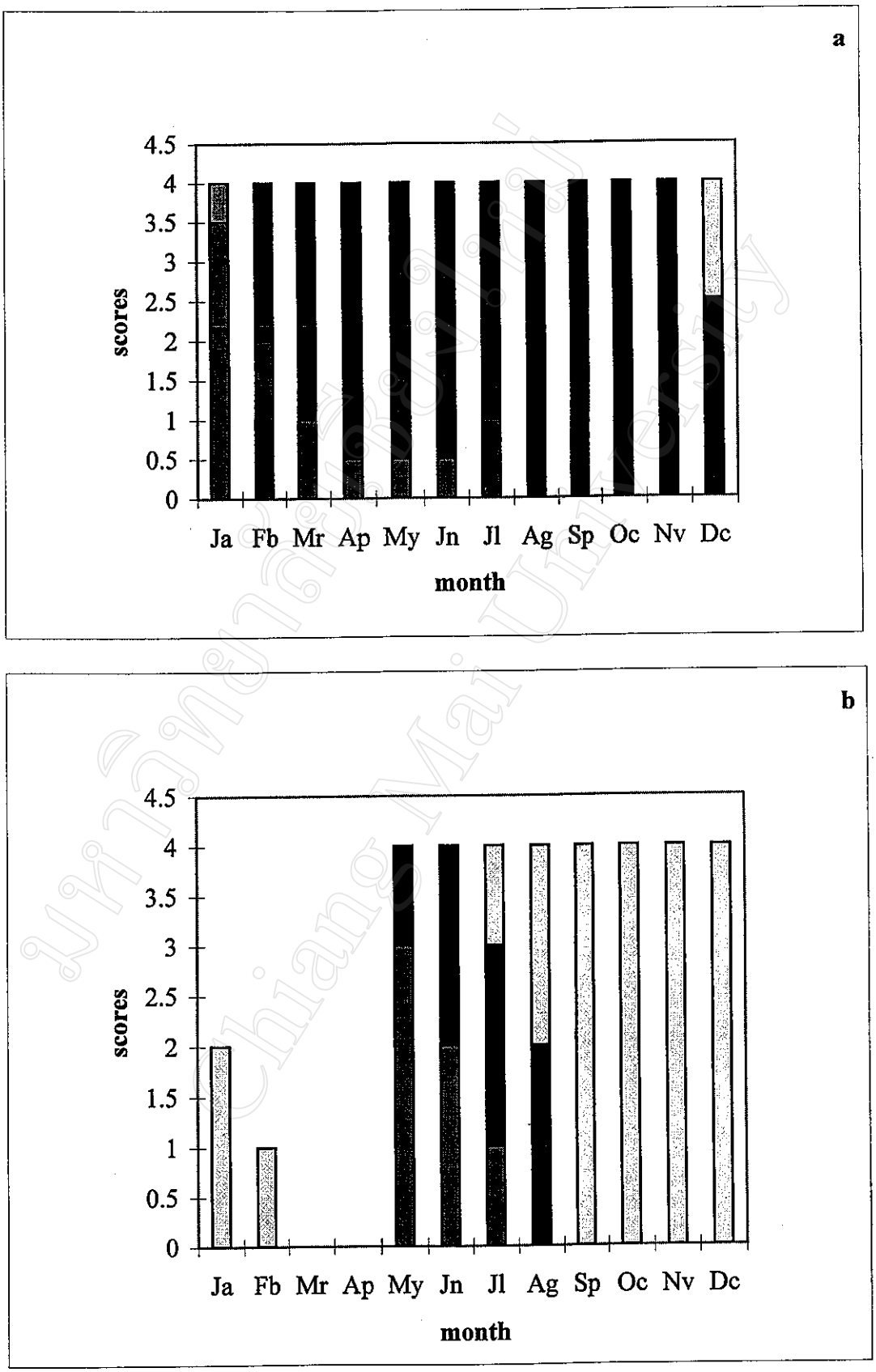


Figure 21. Phenology of *Macropanax dispermus.*

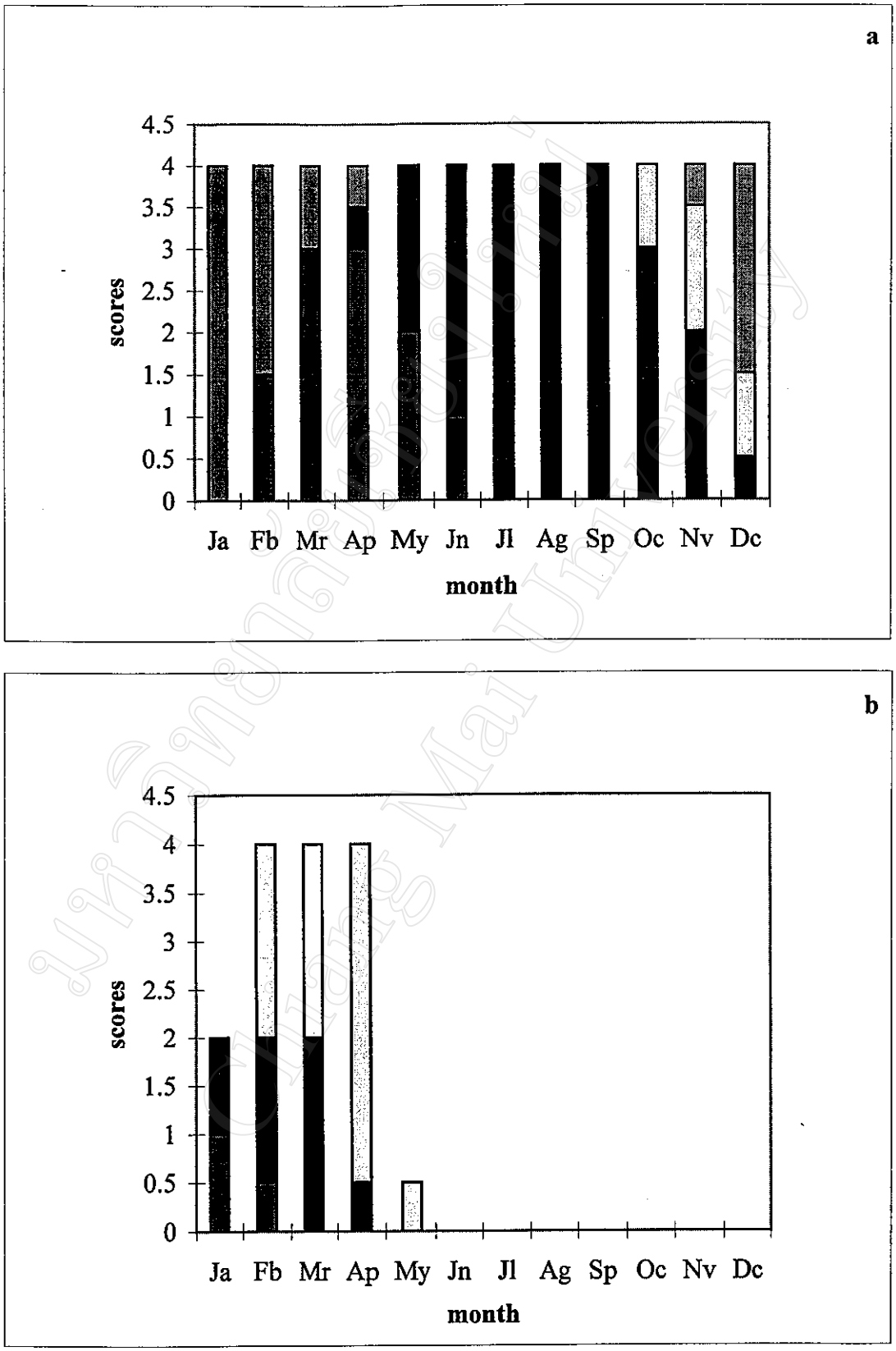


Figure 22. Phenology of *Morus macroura.*

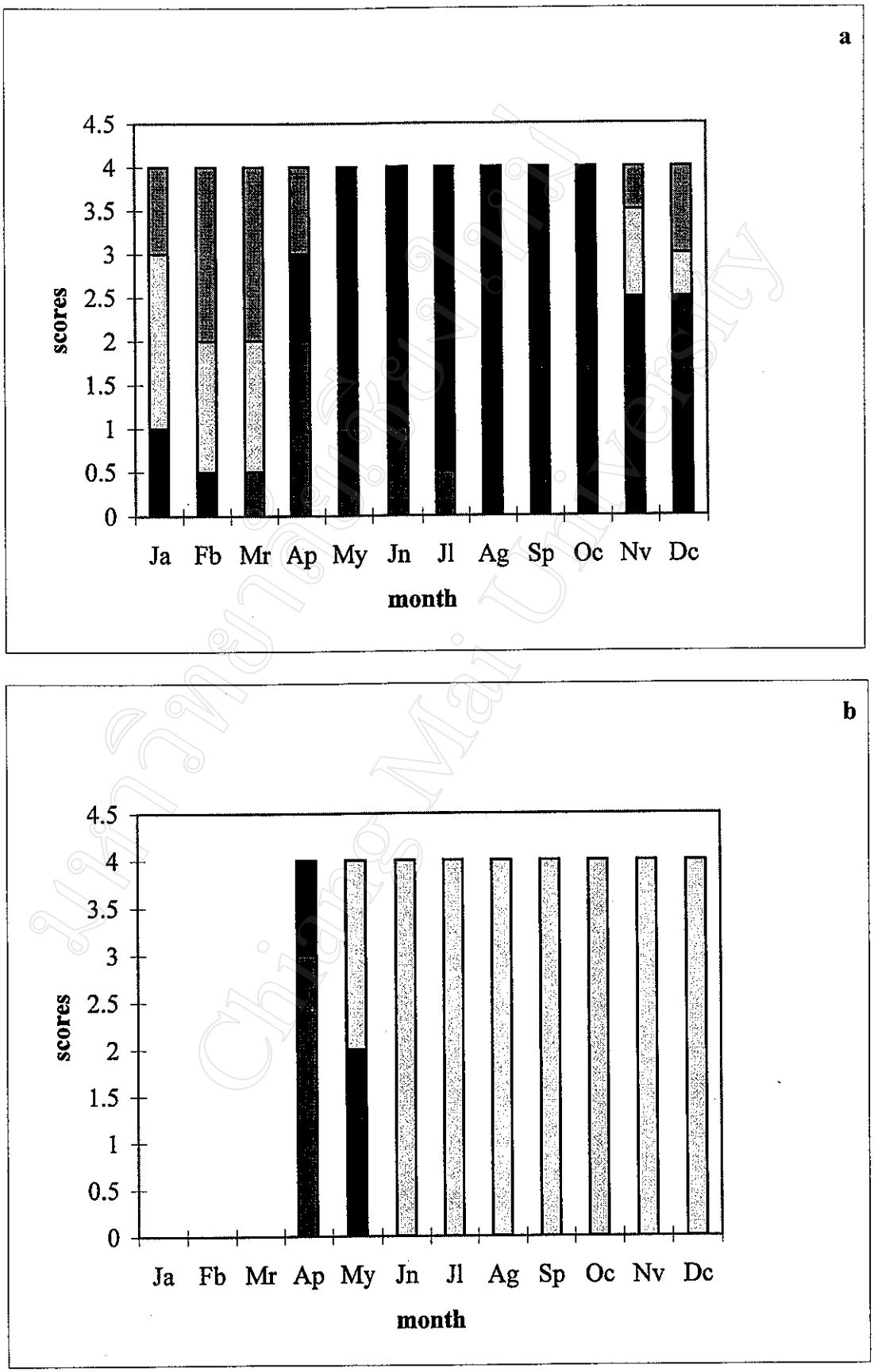


Figure 23. Phenology of *Reevesia pubescens.*

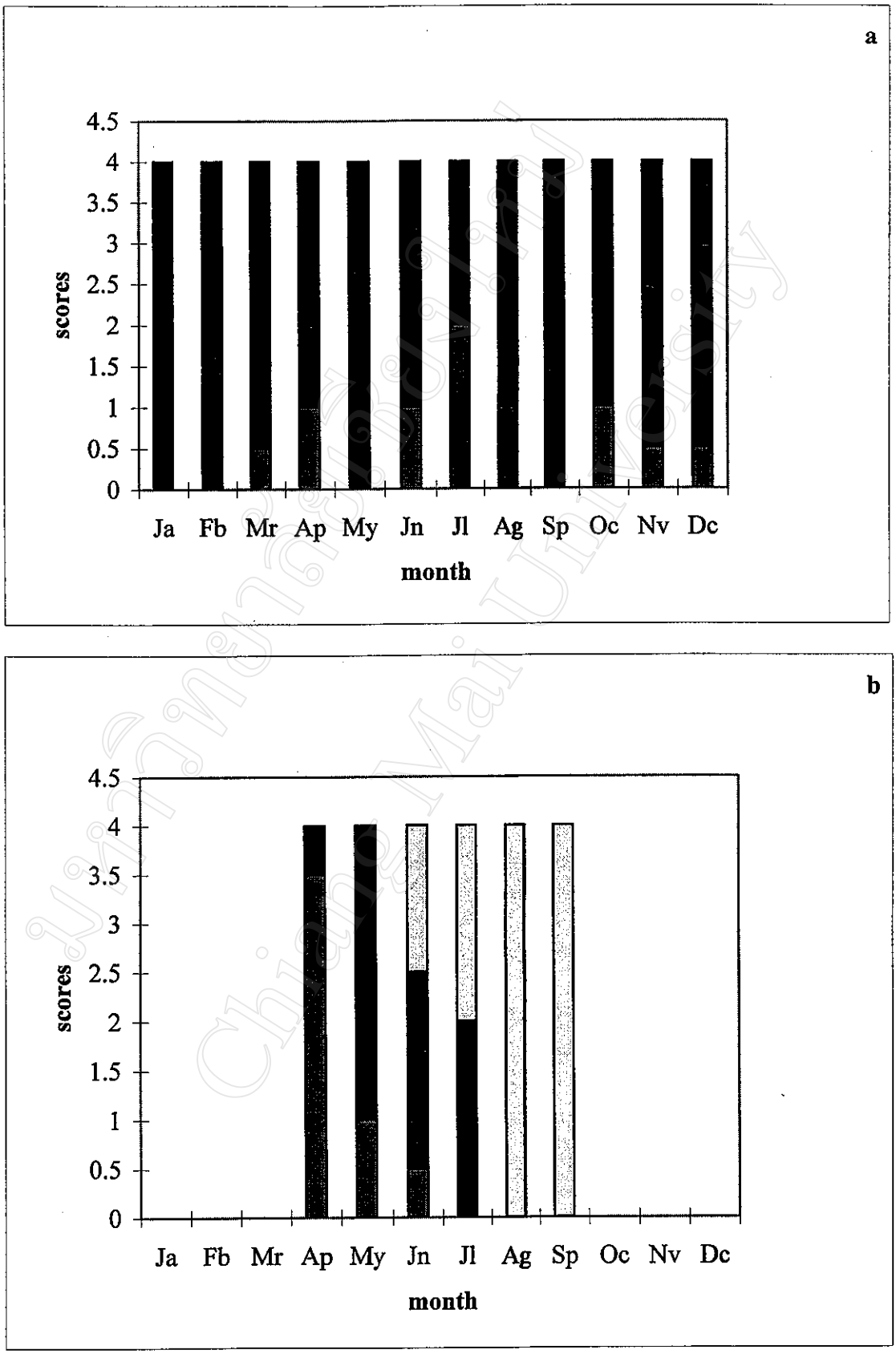


Figure 24. Phenology of *Saurauia roxburghii.*

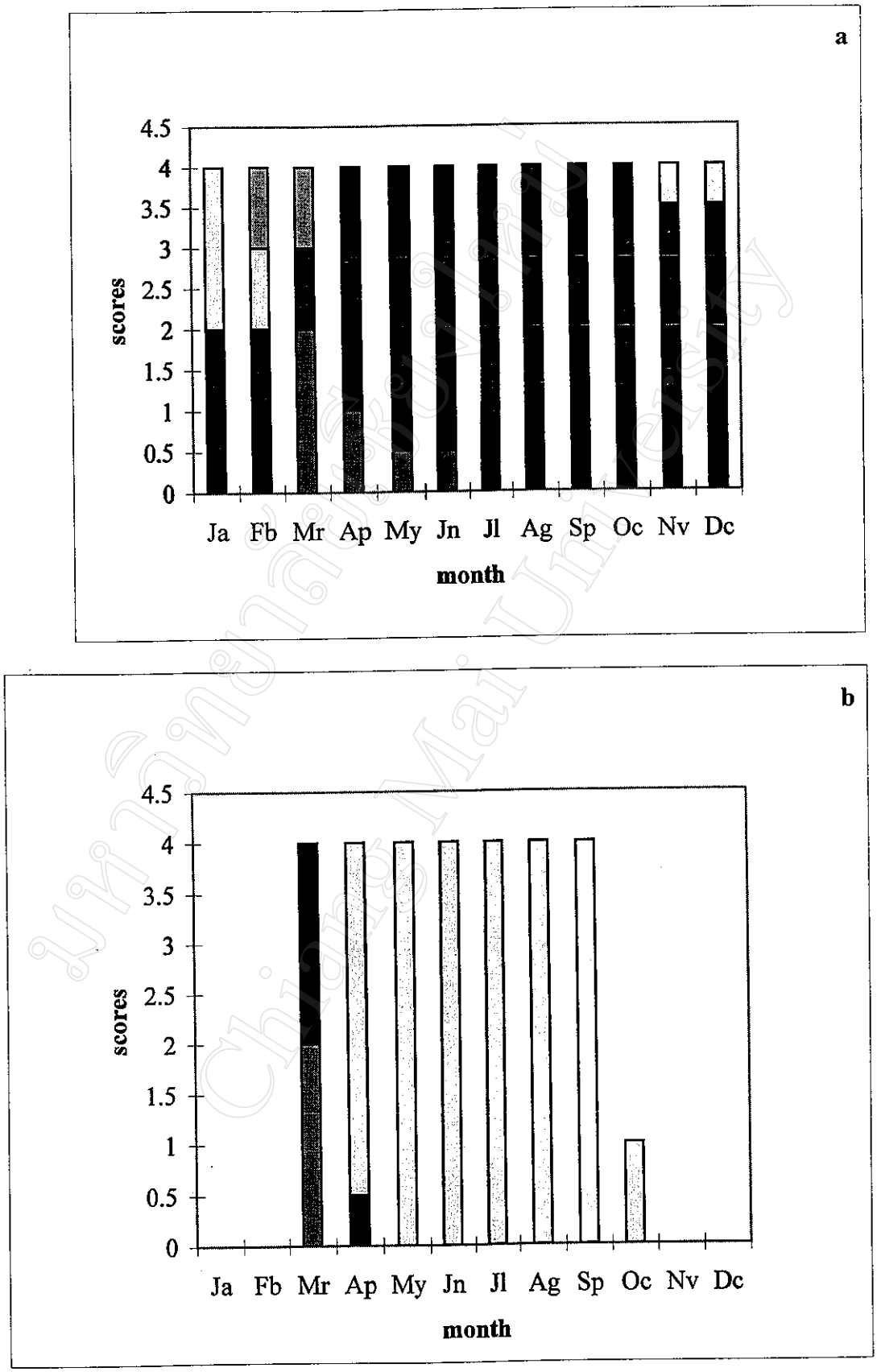


Figure 25. Phenology of *Schleichera oleosa.*

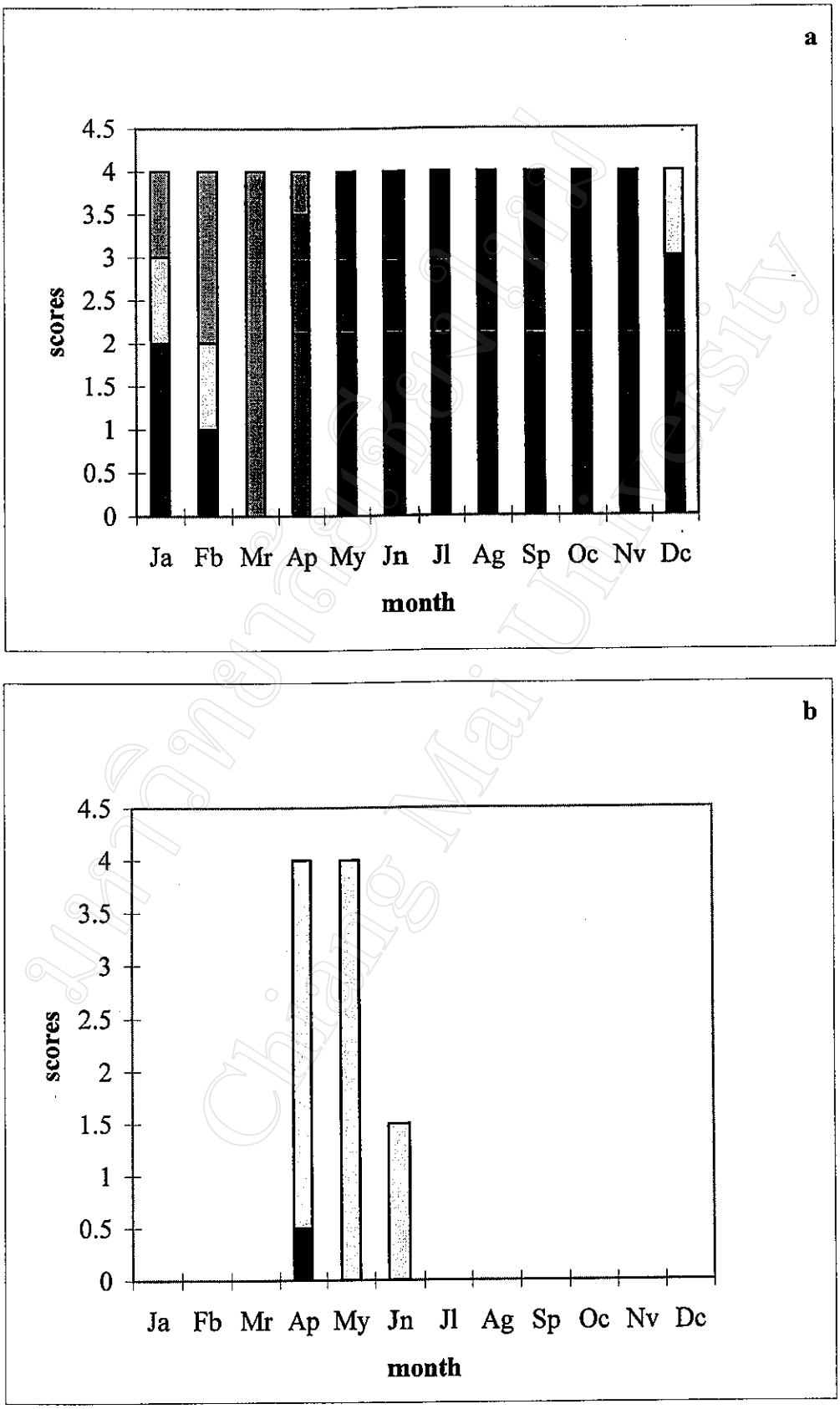


Figure 26. Phenology of *Shorea obtusa.*

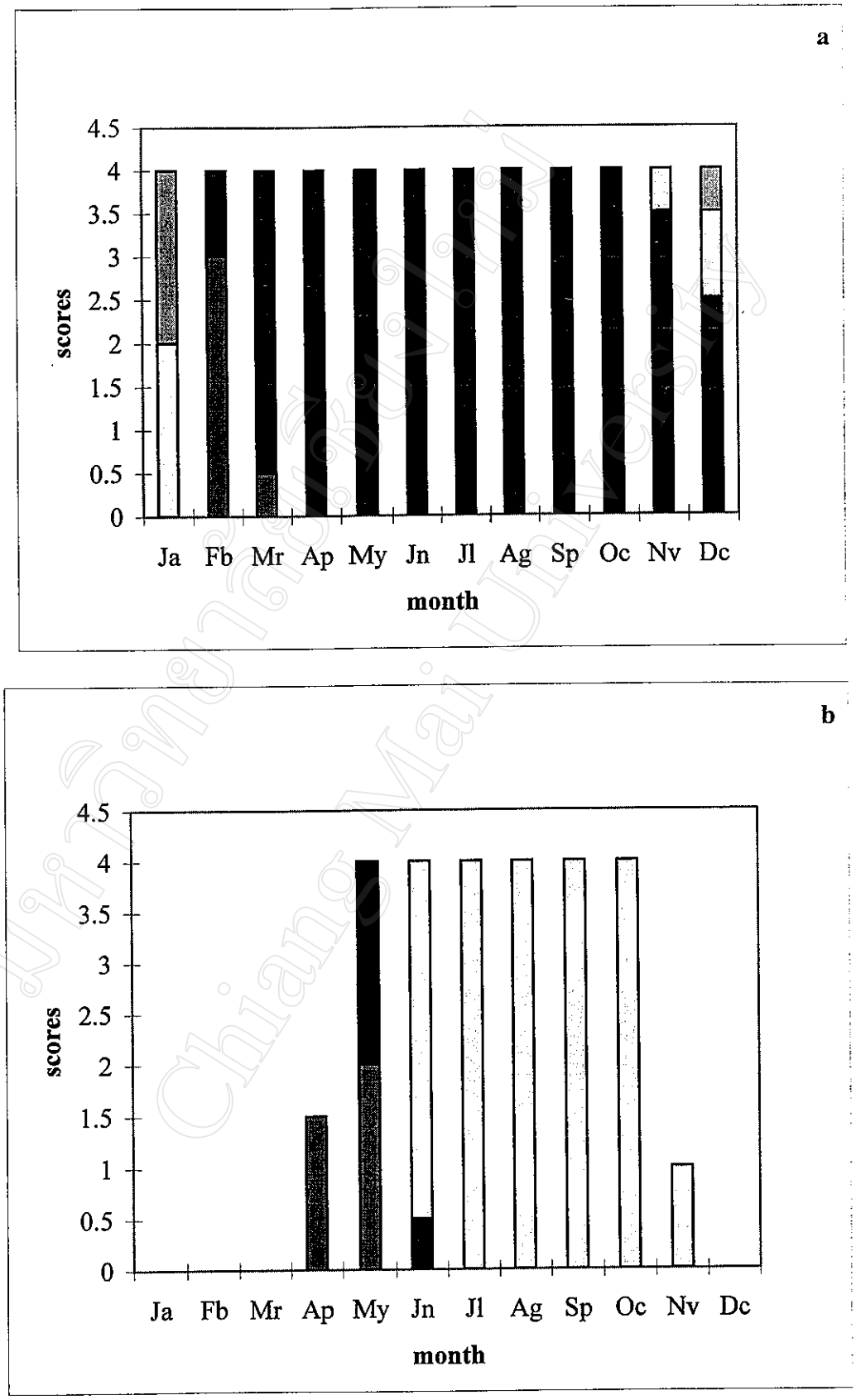


Figure 27. Phenology of *Sindora siamensis.*

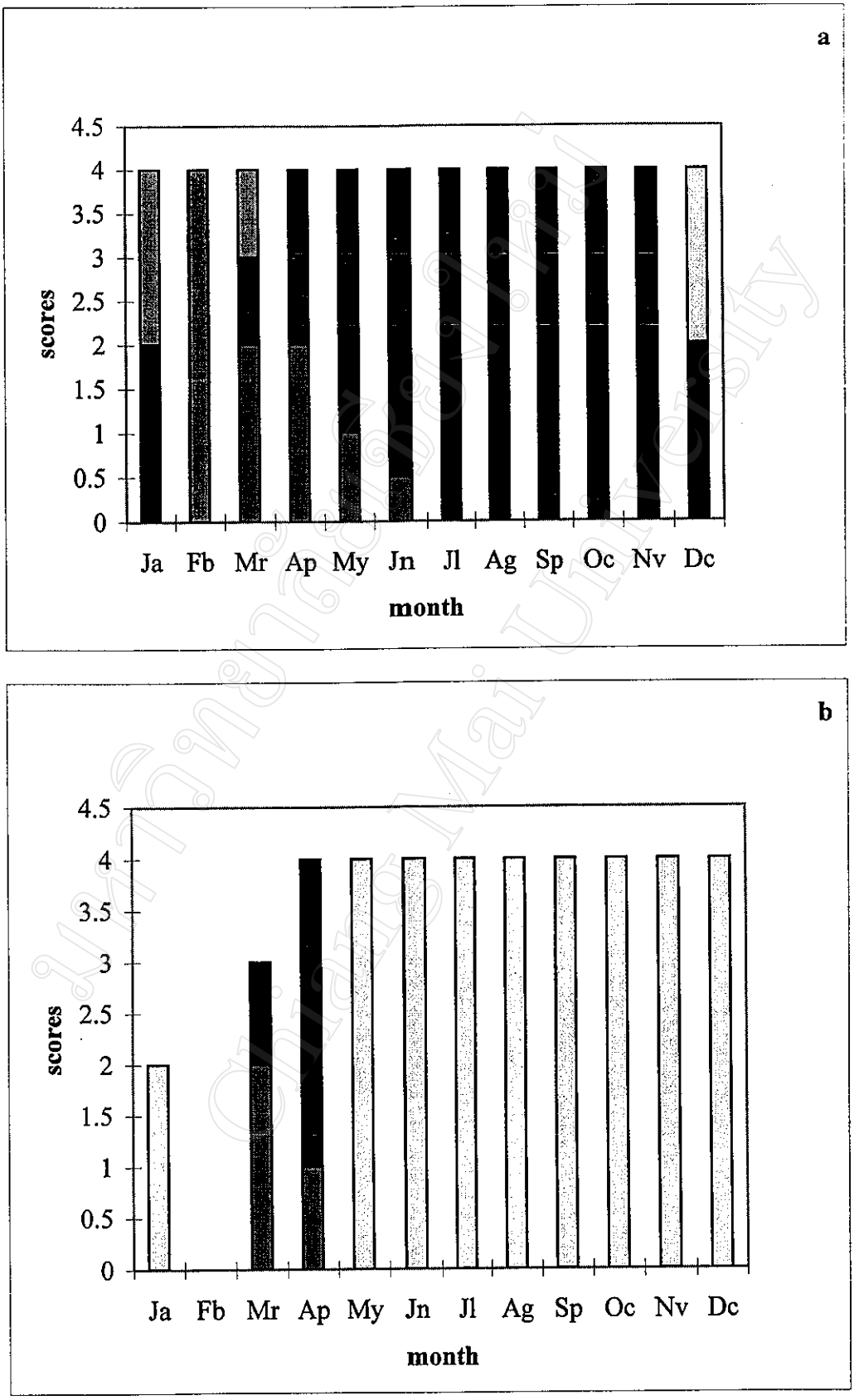


Figure 28. Phenology of *Terminalia bellirica.*

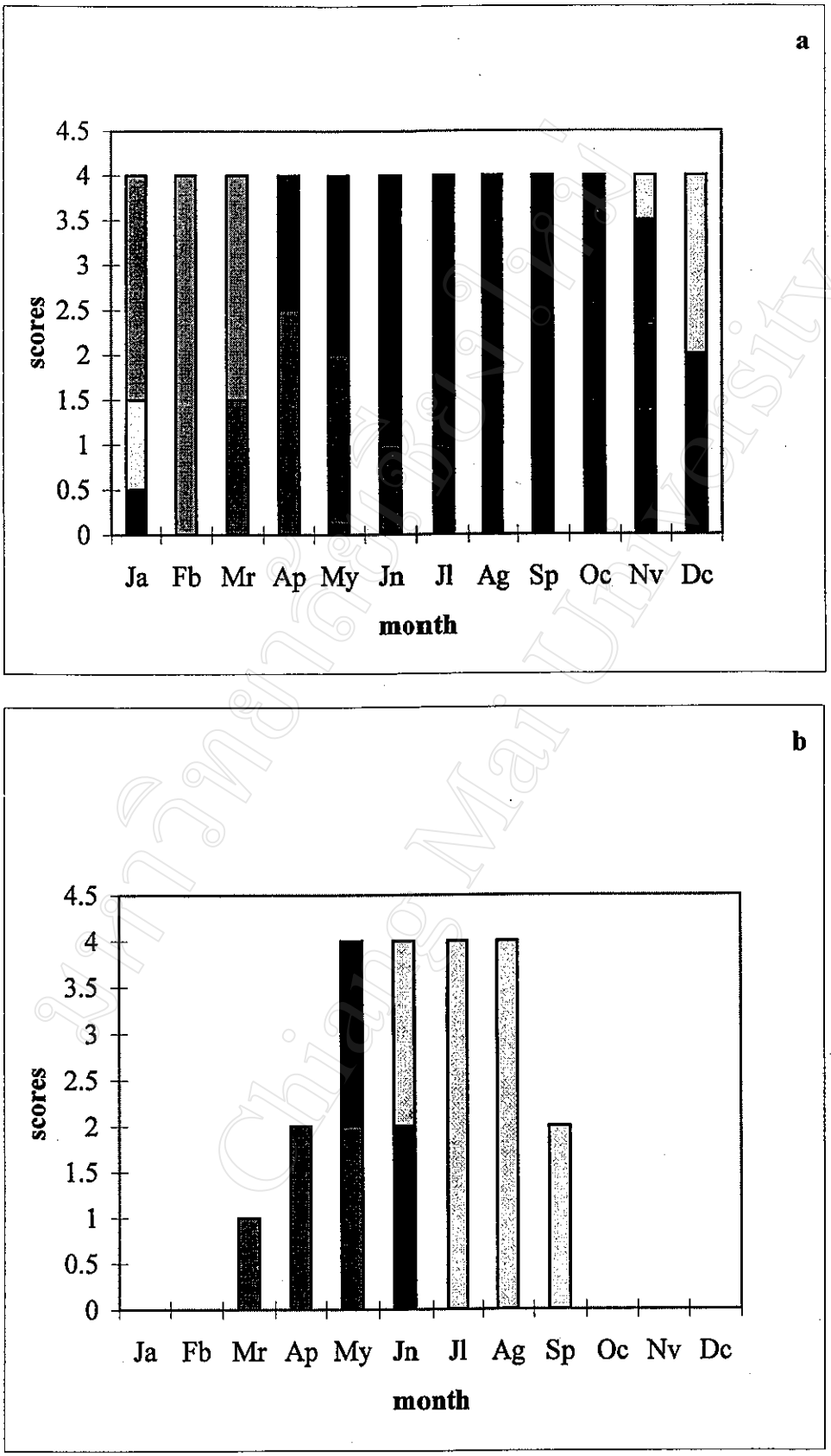


Figure 29. Phenology of *Terminalia chebula.*

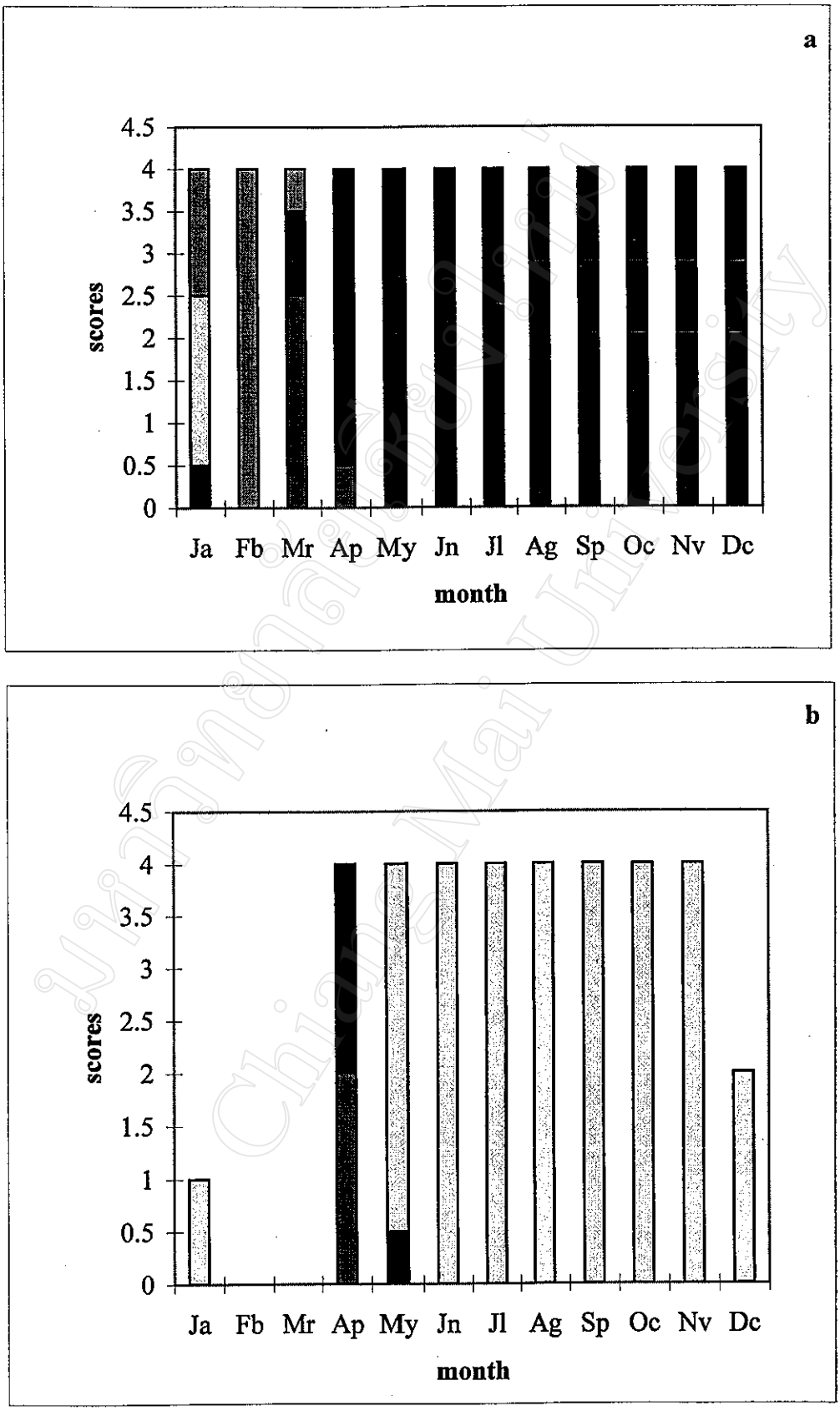


Figure 30. Phenology of *Terminalia mucronata.*

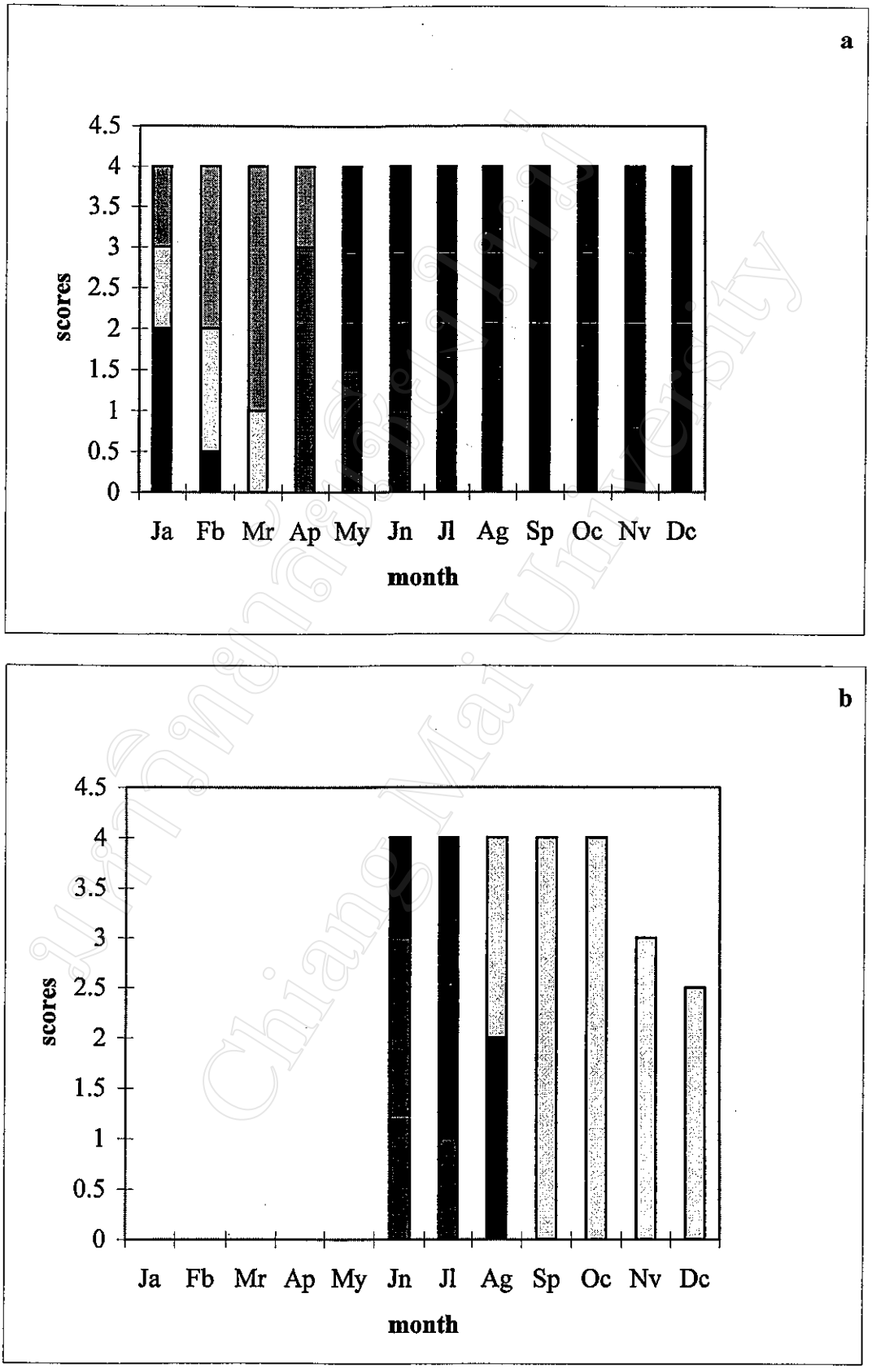


Figure 31. Phenology of *Tetradium glabrifolium.*

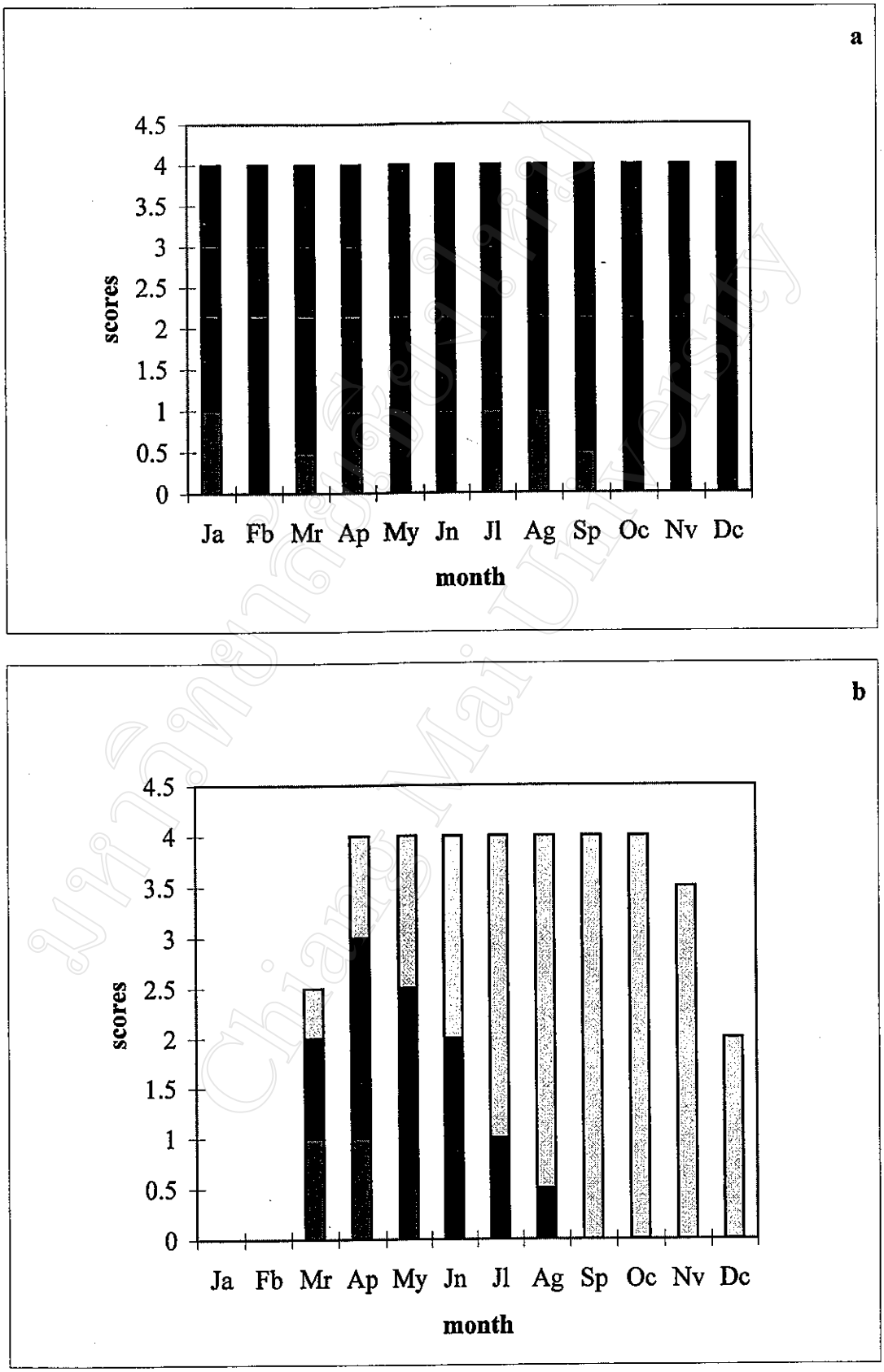


Figure 32. Phenology of *Trema orientalis.*

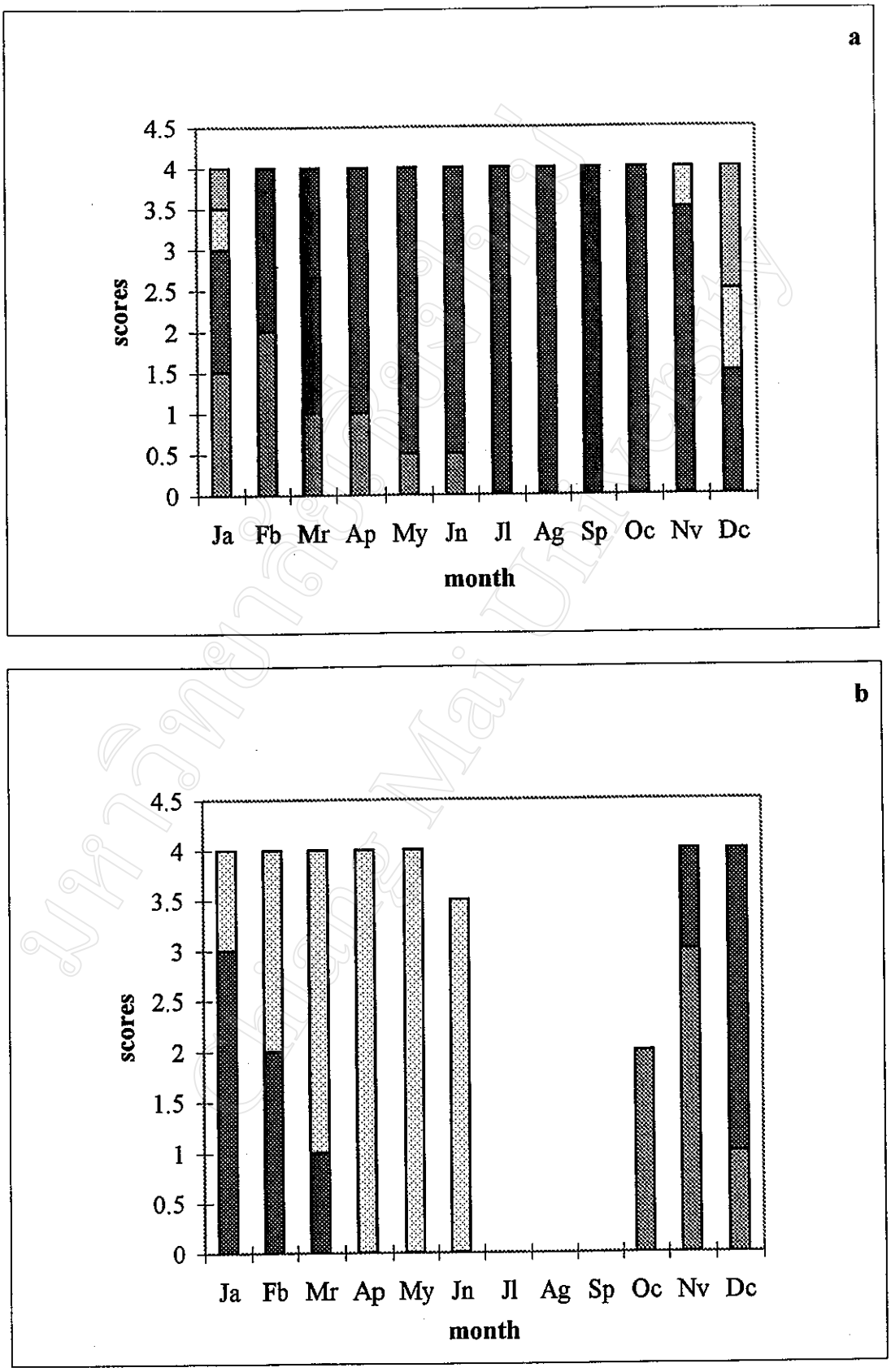
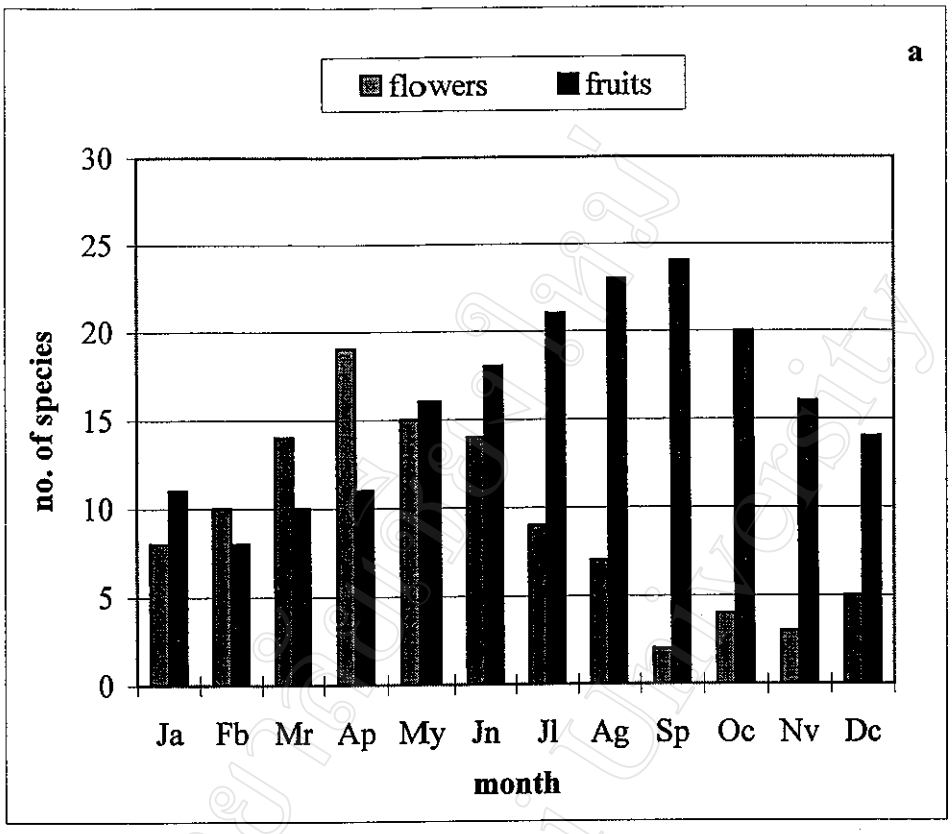


Figure 33. Phenology of *Vaccinium sprengelii.*



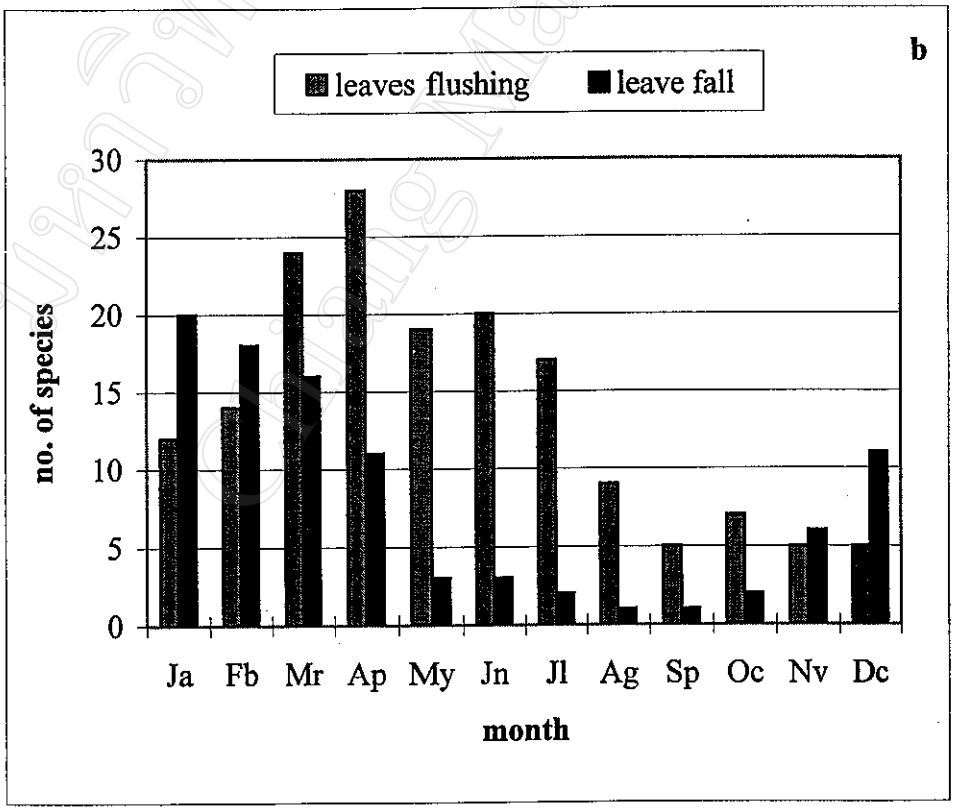


Figure 34. Number of species in flower or in fruit, and in leaf flushing or leaf fall for each month.

a. Number of species in flower or in fruit

b. Number of species in leaf flushing or leaf fall

Table 4. Type of leafing phenology of 32 native tree species.

Deciduous	Evergreen	Tropophyllous	Brevideciduous	Leaf changing
Acrocarpus fraxinifolius	*Debregeasia longifolia*	*Elaeocarpus lanceifolius*	*Irvingia malayana*	*Macaranga kurzii*
Afzelia xylocarpa	*Diospyros undulata*	*Glochidion acuminatum*	*Reevesia pubescens*	*Macropanax dispermus*
Albizia chinensis	*Eurya acuminata*		*Sindora siamensis*	*Schleichera oleosa*
Aporusa villosa	*Ficus lamponga*			*Vaccinium sprengelii*
Betula alnoides	*Saurauia roxburghii*			*Ficus hirta*
Cassia fistula	*Trema orientalis*			
Colona fragrocarpa				
Elaeocarpus prunifolius				
Ficus superba				
Lagerstroemia speciosa				
Morus macroura				
Shorea obtusa				
Terminalia bellirica				
Terminalia chebula				
Terminalia mucronata				
Tetradium glabrifolium				

Table 5. Summary of reproductive and leafing phenology of 32 native forest tree species for each month.

Species	Flowers	Fruits	Leaf flushing	Leaf fall
Acrocapus fraxinifolius	Ja-Mr	Mr-My	Mr-Jn	Ja-Ap
Afzelia xylocarpa	Fb-Ap	My-Ja	Fb-Ap	Dc-Fb
Albizia chinensis	Ap-My	My-Fb	Ap-Jl	Oc-Ap
Aporusa villosa	Ja-Mr	Mr-My	Ap-Jn	Ja-Mr
Betula alnoides	Dc-Fb	Ja-Mr	Ja-Ap	Nv-Ja
Cassia fistula	Fb-My	My-Ja	Ap-My	Fb-Ap
Colona fragrocarpa	Jn-Ag	Jl-Fb	Ap-Ag	Dc-Ap
Debregeasia longifolia	Sp-Dc	Oc-Dc	Ja-Ap, jJl-Ag, Oc, Dc	-
Diospyros undulata	Ap-My	My-Ag	Mr	-
Elaeocarpus lanceifolius	Jn-Ag	Jl-Nv	Ja-Ap	Dc-Ja
Elaeocarpus prunifolius	Ja-Ap	Ap-Sp	Ja-Ap	Ja-Fb
Eurya acuminata	Ag-Oc	Sp-Ap	Ja-Dc	-
Ficus lamponga	Dc-Fb, Jn-Ag	Mr-My, Sp-Oc	Ja, Jn	My-Jn, Nv-Dc
Ficus hirta	Ja-Dc	Ja-Dc	Jl-Mr	My-Ag
Ficus superba	Oc-Fb, Jn-Jl	Mr-Ap, Ag-Sp	Ja-Ag, Oc-Nv	My-Jl, Sp-Oc
Glochidion acuminatum	Mr-Jn	Jn-Oc	Ja-Dc	Mr-Ap
Irvingia malayana	Ap-Jn	Jn-Sp	Ap	Fb-Ap
Lagerstroemia speciosa	Mr-My	My-Dc	Mr-Jl	Nv-Ap
Macaranga kurzii	My-Jl	Jl-Dc	Fb-Oc	Ja-Fb
Macropanax dispermus	My-Ag	Jl-Fb	Ja-Jl	Ja
Morus macroura	Ja-Ap	Fb-My	Fb-Jl	Nv-Ap
Reevesia pubescens	Ap-My	My-Mr	Mr-Jl	Nv-Ap
Saurauia roxburghii	Ap-Jl	Jn-Sp	Mr-Ap, Jn-Ag, Oc-Dc	-
Schleichera oleosa	Mr-Ap	Ap-Oc	Mr-Jl	Fb-Mr
Shorea obtusa	Ap	Ap-Jn	Ap	Ja-Ap
Sindora siamensis	Ap-Jn	Jn-Nv	Fb-Mr	Dc-Ja
Terminalia bellirica	Mr-Ap	My-Ja	Mr-Jn	Ja-Mr
Terminalia chebula	Mr-Jn	Jn-Sp	Mr-Jl	Ja-Mr
Terminalia mucronata	Ap-My	My-Ja	Mr-Ap	Ja-Mr
Tetradium grabrifolium	Jn-Ag	Ag-Dc	Ap-Jl	Ja-Ap
Trema orientalis	Mr-Ag	Mr-Dc	Ja, Mr-Sp	-
Vaccinium sprengelii	Oc-Mr	Ja-Jn	Ja-Jn	Dc-Ja

CHAPTER 3

Propagating Native Forest Tree Species for Forest Restoration from Seed

Abstract

Propagation of high quality seedlings in nurseries in sufficient quantities is one of the most important steps to restoring forest ecosystems. Previous research identified many native forest tree species that are difficult to grow from seed. The research reported here aimed to develop suitable techniques to germinate the seeds of 30 indigenous tree species, of potential value to forest restoration, but which had not been grown successfully in nurseries previously. For the purposes of these study, "acceptable" standard values for the germination parameters were germination percent of ≥ 50%, MLD ≤ 30 days and GP ≤ 60 days. Pre-treatment promoted seed germination for six species (five in the Leguminosea and one of Elaeocarpaceae), three species germinated more rapidly and had more synchronous germination (*Acrocarpus fraxinifolius*, *Albizia chinensis* and *Cassia fistula*). Remaining three species had germination intermediately (*Afzelia xylocarpa*, *Elaeocarpus lanceifolius* and *Sindora siamensis*). Scarification promoted seed germination for *Acrocarpus fraxinifolius*, scarification + soaking for *Afzelia xylocarpa*, scarification and/or scarification + soaking for three species (*Albizia chinensis*, *Elaeocarpus lanceifolius* and *Sindora siamensis*), and scarification and/or acid treatment for 3 minutes for *Cassia fistula*. On the other hand, germination of *Betula alnoides*, *Ficus hirta* and *Schleichera oleosa*, were unacceptably low for all treatments (≤ 20%). Therefore, other seed pre-treatment or other propagations must, therefore, be considered for these species.

Treatments were replicated in deep shade to determine which species were shade-dependent, shade-tolerant or shade-inhibited. Shade-dependence was found for *Elaeocarpus lanceifolius*. Shade-tolerance was found for eighteen species (*Acrocarpus fraxinifolius*, *Afzelia xylocarpa*, *Aporusa villosa*, *Betula alnoides*,

Diospyros undulata, *Elaeocarpus prunifolius*, *Ficus superba*, *Irvingia malayana*, *Macropanax dispermus*, *Morus macroura*, *Saurauia roxburghii*, *Schleichera oleosa*, *Sindora siamensis*, *Terminalia bellirica*, *Terminalia chebula*, *Terminalia mucronata*, *Tetradium glabrifolium* and *Vaccinium sprengelii*). Seven species were shade-inhibited (*Debregeasia longifolia*, *Eurya acuminata*, *Ficus lamponga*, *Ficus hirta*, *Glochidion acuminatum*, *Lagerstroemia speciosa* and *Shorea obtusa*). However, four species produced mixed results (*Albizia chinensis*, *Cassia fistula*, *Reevesia pubescens* and *Trema orientalis*). Germination trails were repeated by sowing seeds in natural soil, in a small gap in natural forest, with no watering, to determine the effects of nursery conditions on seed germination. It was considered likely that regular watering and high light levels in the nursery would increase germination or accelerate it. Fourteen species germinated better in the nursery than in the gap. Five species germinated better in the gap than in the nursery (*Albizia chinensis*, *Elaeocarpus lanceifolius*, *Tetradium glabrifolium*, *Glochidion acuminatum* and *Lagerstroemia speciosa*). Eleven species showed no difference in germination between nursery and gap (*Acrocapus fraxinifolius*, *Afzelia xylocarpa*, *Aporusa villosa*, *Cassia fistula*, *Elaeocarpus prunifolius*, *Schleichera oleosa*, *Sindora siamensis*, *Terminalia bellirica*, *Terminalia chebula*, *Terminalia muconata* and *Trema orientalis*).

3.1 Introduction

Production of native forest tree species for forest restoration requires simple techniques, easily acquired by local communities (Vongkamjan *et al.*, 2001). Native forest tree species produce seeds with a wide range of sizes, shapes, structures, chemical composition, water content and dispersal mechanisms. Also, different species produce seeds at different times of the year. The physiological characteristics of seeds, like basal metabolism at dispersal, development of photosynthesis in the embryo, duration of quiescence, type and periodicity of dormancy, speed of germination, germination display, and longevity in natural,

moist or dry conditions also diverge greatly (Vázquez-Yanes and Orozco-Segovia, 1996). The greatest obstacles to using a wide range of native forest tree species for restoring forest ecosystems is the difficulty of germinating their seeds and propagating high quality seedlings in nurseries in sufficient quantities (Blakesley *et al.*, 2000). These tasks must be carried out at different times and to slightly different degrees adapted to each individual species. Many native tree species have long periods of seed dormancy or low germination rates and there is a lack of knowledge about how to break dormancy and increase germination (Kuarak *et al.*, 2000; Blakesley *et al.*, 2000). Dormancy in nature serves to protect seeds. Dormant seeds, although they may appear to be dead, are in fact alive, but will only germinate after they have been subjected to special natural conditions such as, prolonged exposure to moisture, or rotting of the seed coat (Robbins and Shrestha, 1986; Vázquez-Yanes and Orozco-Segovia, 1996; Mulkey *et al.*, 1996; Baskin and Baskin, 1998; Hardwick, 1999; Singpetch, 2001; Woods, 2001). Also, in seasonal tropical climates, dormancy ensures that seeds germinate when the monsoon has arrived, when an adequate supply of moisture and warmth can be guaranteed for successful growth of seedlings. In the forest of Doi Suthep, most fruits (>50% of species) are available from the mid to the end of the rainy season (Chapter 2). If they germinate immediately, the seedlings might not grow big enough to survive the following dry season. Therefore, many lie dormant until the start of the following rainy season. Dormancy must be broken quickly and seedlings grown fast to produce seedlings big enough for planting ten months after the seeds are ripe. Otherwise seedlings have to be stored in the nursery for one year, wasting time, labour and nursery space (Elliott *et al.*, 2002). In this Chapter, I therefore describe experiments designed to break seed dormancy, by various pre-treatment, to enhance germination success; and partial and deep shade, nursery and natural forest gaps are compared.

3.2 Materials and Methods

3.2.1 Species Selection

The databases of the CMU Herbarium and FORRU were reviewed, to identify native forest tree species of potential value to forest restoration, but which had not previously been germinated in the nursery. Germination trials were carried out on 30 species, selected to represent 3 different seed size classes (small, medium and large). Their characteristics are listed in Table 7.

3.2.2 Study Location

This study was conducted at FORRU's research nursery and in natural forest gaps near the nursery in the vicinity of Doi Suthep-Pui National Park Headquarters (18^0 51'North, latitude and 98^0 54'East, longitude) at about 1000 m elevation in a transitional zone between mixed evergreen-deciduous forest and evergreen forest.

3.2.3 Seed Collection

Data on collection time of seeds for 30 tree species, at elevations ranging from 600 to 1,600 m, are presented in Table 1. Seeds of sixteen species were collected from the ground, whilst those of fourteen species were collected by cutting down small branches with a tree pruning pole. Seed collecting trips were made, when ripe seeds could be collected, according to the phenology data derived from Chapter 2. Seeds were collected from whatever parent trees were discovered to be fruiting each time (Table 6). Fruits were collected only when the seeds within were properly developed and mature. Therefore, fruits collected were inspected properly for ripeness, and those either too young or too old and overripe were discarded. Seed of some species may remain on the trees for considerable periods after ripening, and this may account for some of the discrepancies in the literature on

dates of seed collection. If fruits had been attacked by insects or were mouldy, they were not collected. Care was taken when collecting fruits that had already fallen from the tree, because many were old and often the seeds within had lost viability. Good seed trees were selected, avoiding those that appeared superseded, diseased or generally unhealthy. Whenever possible only the fruits were cut off, not the branches, so that young flowers or fruits were not damaged. If the branches were cut, as few as possible were cut with a sharp knife. No large wounds were made by breaking or tearing down branches, as the tree would then easily became diseased. Collected fruits were transported immediately to FORRU's research nursery for removal of seeds. Ideally, at least 2,100 seeds were collected, to allow for the various treatments and adequate replication. The sowing dates of the seeds of each species are presented in Table 6.

3.2.4 Seed Treatments

For all species, some seeds that had been cleaned and dried already were planted as controls.

Treatment by soaking: seeds were soaked in water overnight. The seeds were sown immediately after soaking, because subsequent drying makes the treatment ineffective.

Treatment by cutting or scarification: the seed coverings were removed by hand by cutting with a sharp knife, scissors, or with a file. Sometimes seeds were cracked or nicked with a hammer or vice, depending on the structure of seed. This was done at the end of the seed furthest from the point at which the seed was attached to the fruit, which was usually indicated by a small scar. This end was where the embryo radicle is normally found. Scarification did not proceed to the point at which seeds were injured. This treatment was not applied to the small seed size group (10 species).

Treatment by both scarification and soaking (scarification + soaking): seeds were scarified first and then soaked in water overnight. This treatment was not applied to the small seed size group (10 species).

Treatment by hot water (heat): seeds were immersed in hot water to make the seed coat more permeable to water. This was done by dropping seeds into about 4 times their volume of hot water and allowing them to cool in the water overnight.

Treatment by acid: acid treatment consisted of the following steps: 1) concentrated sulfuric acid (95 % pure) - was poured into a glass container; 2) seeds were placed in a copper wire mesh container; 3) seeds were immersed in the acid until covered; 4) seeds were soaked in the acid for the required time (30 seconds, 1 minute, and 3 minutes for small seeds; 1 minutes, 3 minutes, and 5 minutes for medium-sized seeds and 3 minutes, 5 minutes, and 10 minutes for large seeds); 5) seeds were removed from the acid and washed over a wire screen, in running water, for 5 to 10 minutes to remove all acid. The seeds were stirred carefully during rinsing; 6) seeds were dried in thin layers in trays unless wet sowing was preferred and 7) seeds were sown after drying. The acid, seeds, and containers were handled with great care to avoid damaging clothing and to avoid skin burns. Care was taken not to splash water into the acid, because the resulting violent reaction might splatter the acid, causing injury.

3.2.5 Sowing the Seeds

After the seeds were treated, they were sown immediately into modular plastic trays which contained forest soil. Different seeds were sown at different depths according to their sizes; about one or two times their diameter under the surface. Seeds were sown in the nursery to determine whether pre-treatments of the seeds stimulated germination. In addition to test the effects of the treatments described above, the effects of shade were also evaluated by placing seed germination trays

(replicated for all seed treatments) on bench tops in 40% sunlight (equivalent to shade levels beneath weeds in deforested sites) and under the benches (2% of full sunlight, equivalent to shade levels beneath an evergreen forest canopy). In addition seed germination experiments in the nursery were replicated under natural conditions in forest gaps, to assess how much nursery conditions (control) enhance germination and to determine levels of seed predation (see Chapter 4). For each species, 108 seeds were divided into three replicate batches of 36 (except, 72 seeds were divided into three replicate batches of 24 for *Schleichera oleosa*, *Diospyros undulata*, *Aporusa villosa*, *Albizia chinensis*, *Saurauia roxburghii* and *Vaccinium sprengelii*) which were randomly assigned to different treatments and watered daily. For each treatment, there were 3 replicates, and a control group sown in the nursery and in the forest gap near the nursery, with 36 seeds (and 24 seeds for six species above) in each replicate. In the forest gap, a caged replicate was used as a control to measure the effects of seed predation. For seven species were caged by dig soil deeply for burring cages before cover with cage again to protect small mammal. (*Elaeocarpus lanceifolius*, *Elaeocarpus prunifolius*, *Irvingia malayana*, *Shorea obtusa*, *Terminalia bellirica*, *Terminalia mucronata* and *Terminalia chebula*) Small seeds were protected from ant predation by being sprayed with an insecticide.

Twenty seeds of each species were saved for measurements of mass and seed size (Table 7). Germination percentage, median length of dormancy (MLD) and germination period (GP) were recorded and an ANOVA with a complete randomized design was used to test the significance of the effects of each treatment and of shade on germination. T-tests were carried out to compare the mean number of seeds that germinated between nursery and natural forest gap conditions.

3.3 Results

The tree species tested included 30 species from 19 different families (Table 12). Most fruits (>50% of all species) are dispersed in the late wet season to early dry season (August-January) (Table 13).

3.3.1 Effects of Pre-treatment

Maximum germination percentages ranged from 19% to 100% (Table 6). However, most species (70% of all species) had mean germination percentages of 62% or greater, while, nine species had low germination percentages (ranging from 19% to 47%). The median length of dormancy (MLD) ranged from 3 days to 266 days. Following the protocol of Elliott *et al.*, 2002, germination was defined as rapid if the MLD occurred within 3 weeks, and slows if the MLD occurred after 12 weeks.

Acrocarpus fraxinifolius

Scarification resulted in the highest germination percentage (90%) and gave the significantly highest mean number of seeds germinating. Also, scarification dramatically accelerated germination (MLD 4 days, compared with 45 days for the control) and reduced GP (5 days, compared with 44 days for the control). Although scarification + soaking resulted in the lowest MLD (3 days), the result did not differ significantly from scarification. Therefore, scarification was the best treatment for this species (Table 8.1).

Afzelia xylocarpa

Scarification + soaking resulted in the highest and most rapid germination. The MLD of scarification + soaking was 30 days, but this result was not significantly different from soaking (32 days), acid 10 minutes (35 days) and 15 minutes (34 days). Pre-treatment had no effect on GP compared to the control. Thus, scarification + soaking were the best treatment for this species (Table 8.2).

Albizia chinensis

Scarification and scarification + soaking resulted in significantly the highest, most rapid and most synchronous germination and were the best treatments for this species (Table 8.3).

Aporusa villosa

Scarification resulted in the highest germination percentage (94%). Pre-treatment either reduced germination compared with the control or had no significant effect. Scarification + soaking, acid treatment for 3 minutes and acid treatment for 5 minutes significantly accelerated germination and acid treatment for 5 minutes significantly reduced GP, but all these treatments also reduced percentage germination to unacceptably low levels. All seeds were killed when treated with acid for 10 minutes. Therefore, the control was the best treatment for this species (Table 8.4).

Betula alnoides

Germination was very low for this species with long MLD and GP's. No treatments significantly improved germination compared with the control. Other seed pre-treatment or vegetative propagation must, therefore, be considered (Table 8.5).

Cassia fistula

No germination occurred with the control or with soaking. Acid treatment for 10 minutes and scarification + soaking resulted in significantly the highest germination percentage (98%). Scarification + soaking resulted in significantly the lowest MLD (6 days), but this result did not differ significantly from acid treatment for 10 minutes, scarification (7 days) and acid treatment for 5 minutes (9 days). Although scarification resulted in the lowest GP (10 days), it did not differ significantly from scarification + soaking, acid treatments (for 5 and 10 minutes) and heat. Some seeds subjected to scarification went moldy, with a white fungus appearing during the first week after sowing. This did not occur with other

treatments. Therefore, both acid treatment for 10 minutes and scarification + soaking were the best treatments and brought about more synchronous germination for this species (Table 8.6).

Debregeasia longifolia

Treatments had no significant effect on germination, or GP and did not significantly accelerate germination compared with the control. Thus, the control was the best treatment for this species (Table 8.7).

Diospyros undulata

No treatments significantly increased germination, and germination remained less than 50%. There is therefore a need to try other methods. The treatments had no significant effects on MLD. Acid treatment for 10 minutes significantly reduced GP (to 1 day), but this may be because only a few seeds germinated. All seeds were killed when treated with acid for 15 minutes. Thus, the control was the best treatment for this species, although new methods to increase germination are needed (Table 8.8).

Elaeocarpus lanceifolius

Previous experiments have shown that poor germination occurred if seeds were scarified using a hammer or a sharp knife to make a small hole in the pyrene wall. So, scarification was done using a sharp knife to completely remove the endocarp (pyrene wall). Scarification and scarification + soaking both resulted in significantly the highest and most rapid germination percentage. Treatments had no significant effect on GP. Thus, scarification and scarification + soaking were the best treatments for this species (Table 8.9).

Elaeocarpus prunifolius

Previous experiments have shown that poor germination occurred if seeds were scarified using a hammer or a sharp knife, to make a small hole in the pyrene wall.

So, scarification was done using a hammer to completely remove the endocarp pyrene wall. No germination occurred with the control, soaking, heat and acid treatment for 5 minutes. Scarification and scarification + soaking resulted in significantly the highest germination percentage and lowest MLD treatments had no significant effect on GP. Therefore, scarification and scarification + soaking were the best treatments to germinate this species (Table 8.10).

Eurya acuminata

No treatments had any effects on any of the germination parameters. At 68%, germination of the control was adequate (Table 8.11).

Ficus hirta

Treatments had no significant effects on any of the germination parameters. Therefore, the control conditions were best for this species (Table 8.12).

Ficus lamponga

No treatments significantly increased germination and heat significantly reduced it. Treatments had no effect on MLD. The significant reduction in GP caused by the heat treatment was probably the result of so few seeds germinating (Table 8.13).

Ficus superba

No treatments significantly increased percentage germination, compared with the control and no treatments had any effects on GP and MLD. Therefore, the control conditions were best for this species (Table 8.14).

Glochidion acuminatum

Soaking, scarification + soaking, acid treatments for 3 and for 5 minutes all significantly increased germination, with soaking giving the best result. Of the treatments that increased germination, only acid treatment for 5 minutes also significantly accelerated it, nearly halving the MLD. Treatments had little or no

effect on GP. The best compromise between high germination and low MLD was probably acid treatment for 5 minutes (Table 8.15).

Irvingia malayana

Heat was the only treatment, which significantly increased germination percentage (96%), although it did not significantly reduce MLD. Both scarification treatments reduced MLD, but they also reduced percentage germination. Previous experiments showed that no germination occurred if seeds were scarified by a sharp knife to completely remove the endocarp pyrene wall. So scarification was done using a sharp knife to make a small hole in the pyrene wall, without destroying the seeds. Treatments had no significant effects on GP. Thus, heat was the best treatment for this species (Table 8.16).

Lagerstroemia speciosa

Soaking and acid treatments (both 5 and 10 minutes) resulted in the highest germination. The treatments did not differ in their effects on MLD. Since acid treatment for 5 minutes resulted in a significantly longer GP than acid treatment for 3 minutes and soaking, these latter 2 treatments were therefore, recommended (Table 8.17).

Macropanax dispermus

No treatments significantly increased or accelerated germination or reduced GP compared with the control. Thus the control conditions were best for this species (Table 8.18).

Morus macroura

No treatments significantly increased germination percentage compared with the control. However, soaking and acid treatments for 30 seconds and for 1 minute all significantly accelerated germination and acid treatment for 1 minute also

significantly reduced GP. Therefore, acid for 1 minute is probably the best treatment for this species (Table 8.19).

Reevesia pubescens

Acid treatments for 3 minutes and 5 minutes resulted in significantly the highest germination percentages (91% and 81% respectively). Scarification resulted in the lowest MLD (15 days); significantly lower than all other treatments. Acid treatments did not significantly reduce MLD, compared with the control. In view of the low percentage germination achieved with scarification, acid treatment for 3 minutes was the best treatment for this species (Table 8.20).

Saurauia roxburghii

All treatments resulted in unacceptably low germination. Soaking and acid treatment for 3 minutes significantly increased germination but only to 38-43% (from 17%). No treatments significantly reduced MLD. Interpretation of the effects of treatment on GP is difficult, since percentage germination of the control was so low. Other seed treatments or vegetative propagation should be tested for this species (Table 8.21).

Schleichera oleosa

Germination of this species was unacceptably low for all treatments (<20%). Other seed treatments or vegetative propagation should be tried for this species (Table 8.22).

Shorea obtusa

No treatments were significantly better than the control (83%) which produced very high, rapid and synchronous germination. Soaking and scarification also produced good results but not significantly better than the control. Heat and acid killed *Shorea obtusa* seeds. Thus, the control was the best treatment and brought about more synchronous germination for this species (Table 8.23).

Sindora siamensis

Scarification and scarification + soaking resulted in significantly the highest and most synchronous germination. These treatments also resulted in most rapid germination, although the results did not differ significantly from the control. Therefore, scarification and scarification + soaking were the best treatments and brought about synchronous germination for this species (Table 8.24).

Terminalia bellirica

Germination was very high for this species (91% for control). Increases in germination caused by treatments were therefore small but one result was significant. Soaking significantly increased germination (by about 9%) and accelerated it (on average by 6 days). Treatments had no significant effects on GP. Therefore, soaking was the best treatment for this species (Table 8.25).

Terminalia chebula

Germination was very low, with no treatment raising the percentage of germination above 40%. Scarification resulted in the highest germination percentage (38%). Previous experiments showed that poor germination occurred, if seeds were scarified using a hammer or a sharp knife to make a small hole in the pyrene wall so, scarification was done using a hammer to completely remove the endocarp (pyrene wall). Only scarification significantly increased germination, compared with the control, albeit only to 38% (from 3%). Pre-treatment did not significantly affect MLD or GP compared to the control. Thus, scarification was the best treatment for this species, but better treatments need to be devised to raise % germination to an acceptable level (Table 8.26).

Terminalia mucronata

Acid treatments for 10 minutes and for 5 minutes both resulted in the highest germination percentage (46% and 42%, respectively). The control resulted in 11% germination. There were no significant differences in MLD or GP among treatments. Therefore, acid treatments for 5 and/or for 10 minutes were the best treatments for this species (Table 8.27).

Tetradium glabrifolium

Germination for this species was generally low. All 3 acid treatments significantly increased germination compared with the control, but only up to 29-41% (compared with 4% for control). Acid treatments for 5 and 10 minutes were equally the most effective at increasing germination. No treatments accelerated germination, compared with the control and no treatments had any effects on GP. Therefore, acid treatments for 5 or 10 minutes were the best for this species (Table 8.28).

Trema orientalis

Acid 3 minutes resulted in significantly the highest germination percentage (98%), dramatically higher than the control. Treatments had no significant effect on MLD and GP. Thus, acid treatment for 3 minutes was the best treatment for this species. Soaking seeds in acid for more than 3 minutes might further increase percentage germination and decrease MLD and GP (Table 8.29).

Vaccinium sprengelii

No treatments significantly increased or accelerated germination. Treatments had no significant effects on GP. Therefore, the control was the best treatment for this species (51%) (Table 8.30).

3.3.2 Effects of Shade

The treatments were replicated in deep shade, to determine which species were shade-tolerant. For the purpose of this study, shade tolerance is defined as no significant change in numbers of seeds germinating and no significant changes in MLD and GP in the deep shade treatments compared with partial shade. A significant increase in the number of seeds germinating and significantly reduced MLD's or GP's with deep shade would indicate shade dependence. Inhibition by deep shade is indicated by a significant reduction in the numbers of seeds germinating and significant increases in MLD and GP. Within each species, results obtained with each seed pre-treatment can be contradictory *e.g.* shade tolerance with some pre-treatment and inhibition with other pre-treatment. Therefore, more weight should be given to the control results, with pre-treatment results considered with less weight. Also, there may be mixed results among the germination parameters *e.g.* seeds germination significantly reduced (inhibition) but MLD unaffected (tolerance). Differences in GP, when seed germination is low, should be ignored. Therefore, value judgments must be made, based on the data presented in Table 8.

The responses of the species to shade are classified in Table 9. Only one species was considered to be shade-dependent, with eighteen classed as shade-tolerant. Seven species were inhibited by shade and four species had mixed results and could not be classified. The mixed results for these four species are detailed below.

Albizia chinensis

Deep shade reduced percent germination of seed (all treatments, except heat and acid treatment for 3-5 minutes), but did not significantly reduce mean number of seeds germinating (all treatments, except control (2-tail sig. ≤ 0.05), soaking (2-tail sig. ≤ 0.05), acid 3 minutes (2-tail sig. ≤ 0.05) and acid treatment for 5 minutes (2-tail sig. ≤ 0.001)). Also shade did not significantly reduce MLD (all treatments,

except soaking (2-tail sig. ≤ 0.01), scarification (2-tail sig. ≤ 0.01) and acid treatment for 3 minutes (2-tail sig. ≤ 0.05)). Furthermore deep shade did not significantly reduce GP (all treatments, except control (2-tail sig. ≤ 0.001) and acid treatment for 5 minutes (2-tail sig. ≤ 0.001).

Cassia fistula

Deep shade reduced percent germination (all treatments, except heat and acid treatment for 3 minutes), but did not significantly reduce the mean number of seeds germinating (all treatments, except scarification (2-tail sig. ≤ 0.05) and acid 3 minutes (2-tail sig. ≤ 0.001)). Also deep shade did not significantly reduce MLD (all treatments, except scarification + soaking, df = 4, 2-tail sig. ≤ 0.05) and did not significantly reduce GP [all treatments, except scarification (2-tail sig. ≤ 0.05), acid 3 minutes (2-tail sig. ≤ 0.001) and acid 5 minutes (2-tail sig. ≤ 0.01)].

Reevesia pubescens

Deep shade reduced percent germination of seed (all treatments, except soaking, scarification + soaking, heat, acid treatment for 3 minutes and acid treatment for 10 minutes), but did not significantly reduce mean number of seeds germinating (all treatments, except soaking (2-tail sig. ≤ 0.05), scarification (2-tail sig. ≤ 0.01), acid 5 minutes (2-tail sig. ≤ 0.001) and acid treatment for 10 minutes (2-tail sig. ≤ 0.001)). Also shade did not significantly reduce MLD [all treatments, except soaking (2-tail sig. ≤ 0.001), scarification + soaking (2-tail sig. ≤ 0.001), acid treatment for 3 minutes (2-tail sig. ≤ 0.001) and acid treatment for 10 minutes (2-tail sig. ≤ 0.05)]. Furthermore deep shade did not significant reduce GP [(all treatments, except scarification + soaking (2-tail sig. ≤ 0.05) and acid treatment for 10 minutes (2-tail sig. ≤ 0.001)].

Trema orientalis

Deep shade reduced percent germination of seed (all treatments), but did not significantly reduce mean number of seed germination [all treatments, except control (2-tail sig. ≤ 0.01), acid 30 seconds (2-tail sig. ≤ 0.05), acid 1 minutes (2-tail sig. ≤ 0.05) and acid 3 minutes (2-tail sig. ≤ 0.001)]. Also shade did not significantly reduce MLD and GP (all treatments).

3.3.3 Effects of Nursery and Natural Forest Gaps

Comparisons of germination response between nursery and forest gap are presented in Table 10.

The responses of the species to nursery and gap conditions are classified in Table 11. Fourteen species germinated better in the nursery. Five species germinated better in the gap, whilst eleven species showed no significant differences in germination response between gap and nursery. Thus, sixteen species might suitable for direct seedling, based on germination (*Acrocarpus fraxinifolius*, *Afzelia xylocarpa*, *Albizia chinensis*, *Aporusa villosa*, *Cassia fistula*, *Elaeocarpus lanceifolius*, *Elaeocarpus prunifolius*, *Glochidion acuminatum*, *Lagerstroemia speciosa*, *Schleichera oleosa*, *Sindora siamensis*, *Trminalia mucronata*, *Terminalia bellirica*, *Terminalia chebula*, *Tetradium glabrifolium* and *Trema orientalis*), but don't forget seed predation (see Chapter 4).

3.4 Discussion

3.4.1 Effects of Pre-treatments

Seeds of 30 native tree species were investigated to find promising pre-treatments, suitable for nursery use and to assess the degree of seed coat dormancy. Dormancy caused by a hard seed-coat may be overcome by applying pre-treatments.

Therefore, species were classified by the responses of their seeds to the pre-treatments applied. Species could be classified into two groups: i) non dormant, those with seeds that germinated best with no pre-treatment and MLD $\leq$ 28 days, and ii) dormant those with seeds whose germination was improved by pre-treatment (see Tables 12). Seeds that germinated well without pre-treatment were generally recalcitrant and/or had thin or soft testas. Rapid, high germination implied that the coat of such seeds was permeable to water. Such species are strong candidates for further investigation into the feasibility of direct seeding, as an alternative to planting seedlings to restore forest to deforested sites. On the other hand, where dormancy is more complex, seeds need specific pre-treatment.

Germination percentages of the 30 native tree species tested (without pre-treatment) ranged from 0 to 94%. The MLD ranged from none to 260 days and GP ranged from none to 136 days. However, for the purposes of this study "acceptable" standard values for the germination parameters were a germination percent of $\geq$ 50%, MLD $\leq$ 30 days and GP $\leq$ 60 days. These values were considered necessary for efficient nursery production of seedlings for forest restoration. For eleven species (or one third of the species tested) treatments applied changed unacceptable values of these parameters (in the control) into acceptable values (*Aporusa villosa*, *Debregeasia longifolia*, *Eurya acuminata*, *Ficus lamponga*, *Ficus superba*, *Macropanax dispermus*, *Morus macroura*, *Reevesia pubescens*, *Shorea obtusa*, *Terminalia bellirica* and *Vaccinium sprengelii*). For one species (*Irvingia malayana*) germination increased above 50% or greater, although MLD and GP remained unacceptable.

Rapid and synchronous germination is good for seedling production since seedlings are the same age and size at planting time. For the purposes of nursery production, Blakesley *et al.* (2002) suggested the germination was defined as rapid if the MLD was 21 days or less, intermediate if the MLD was 22 - 83 days and slow if the MLD was 84 days or more. Likewise, for this study germination was defined as

synchronous if GP was 21 days or less, intermediate if the GP was 22-83 days and prolonged if the GP was 84 days or more. Seven species germinated rapidly (*Debregeasia longifolia*, *Ficus lamponga*, *Ficus superba*, *Morus macroura*, *Reevesia pubescens*, *Shorea obtusa* and *Vaccinium sprengelii*), but only four of the seven had synchronous germination (*Ficus superba*, *Morus macroura*, *Reevesia pubescens* and *Shorea obtusa*). The remaining 3 species of the seven had intermediate germination. Four species had MLD's of between 22 to 83 days or MLD intermediately (*Aporusa villosa*, *Eurya acuminata*, *Macropanax dispermus* and *Terminalia bellirica*). Only one of those four species had synchronous germination (*Aporusa villosa*) and three species had intermediate germination.

A good test of the effectiveness of a seed treatment is whether it changes unacceptable values of germination parameters (for the control) into acceptable values (with the treatment). Pre-treatments did have such an effect on 6 species, converting them from 19 species, into species that could be successfully germinated (*Acrocarpus fraxinifolius*, *Afzelia xylocarpa*, *Albizia chinensis*, *Cassia fistula*, *Elaeocarpus lanceifolius*, and *Sindora siamensis*). Pre-treatment promoted rapid seed germination and brought about more synchronous germination of three species (*Acrocarpus fraxinifolius*, *Albizia chinensis*, and *Cassia fistula*). Remaining three species germinated intermediately, but two species (with pre-treatment) brought about more synchronous germination (*Afzelia xylocarpa* and *Sindora siamensis*) and one species (*Elaeocarpus lanceifolius*) had intermediate germination. Therefore, other seed pre-treatment or other propagations may, therefore, be considered for thirteen from nineteen species.

However, Blakesley *et al.* (2000) suggested some species might qualify as potential framework species due to other attributes, such as high growth rate in containers or good field performance or to be fire-resistant. Three of the thirteen species (*Irvingia malayana*, *Lagerstroemia speciosa* and *Trema orientalis*) had high germination percentages (78-98%), but high MLD (86-149 days) and high GP (48-

150 days). Ten of thirteen tree species had low germination percentages (18-47%) both with and without treatments (*Betula alnoides*, *Diospyros undulata*, *Elaeocarpus prunifolius*, *Ficus hirta*, *Glochidion acuminata*, *Saurauia roxburghii*, *Schleichera oleosa*, *Terminalia chebula*, *Terminalia mucronata*, and *Tetradium glabrifolium*). Germination of three species (*Betula alnoides*, *Ficus hirta* and *Schleichera oleosa*) were unacceptably low for all treatments (≤ 20%). Three of nine species germinated rapidly and synchronously, even though they had low germination percentage: *Diospyros undulata*, *Terminalia mucronata*, and *Ficus hirta*.

Most species of the family Leguminosae exhibit seed dormancy; caused by the seed coat or testa or endocarp dormancy (Baskin and Baskin, 1998) or innate dormancy (Schmidt, 2000) or the embryo coverings (testa) (Bradbeer, 1988). Their seeds had a thick and impermeable testa which prevented water uptake and gaseous exchange. Schmidt (2000) reported that the general structure of the seed-coat consists of four distinct layers: 1) the cuticle is the outermost layer which has a waxy and water-repellent character; 2) macrosclereids or a palisade layer; 3) osteosclereids and 4) a parenchyma layer, which is made up of a layer of little differentiated cells. Schmidt (2000) noted that in seeds, the cells of the palisade layer of the seed-coat take up water, and the softening process spreads from the initial site of imbibition into the whole seed-coat within few hours when submerged in water. Treatments that make the seed coat more permeable to water and gases are scarification, heat (expansion might cause testa to split) and acid. Treatments that wash out or denature chemical inhibitors are; soaking, acid and heat. In addition heat might accelerate seed metabolism and break innate dormancy. *Cassia fistula* responded to scarification + soaking or acid treatments for 10 minutes which removed the waxy seed-coat and enabled the seeds to imbibe water. These results agreed with those of Kobmoo (1990), who achieved 91% germination with scarification and soaking in the water overnight.

Acrocarpus fraxinifolius seeds have testa dormancy. Without any special treatments, and sowing the seeds in forest soil under partial shade resulted in 3% germination, this agreed with Kopachon (1995) and Elliott *et al.* (1996). They found that without any special treatments, sowing the seeds in forest soil, under partial shade, resulted in only 6.9% and 9% germination, respectively. Therefore, seeds required scarification to germinate well (90%). While, acid treatment for 10 minutes gave 39% germination and heat treatment gave 9% germination. These results disagree with those of Sosef *et al.* (1998) who reported that seeds treated with acid for 10 minutes or hot water and left to imbibe in water for 24 hours before sowing in shade, had 80-95% germination. Also, Kopachon (1995) reported that soaking seeds in hot water at 60-70 ^{0}C for 20 minutes, increased germination to 85%.

Afzelia xylocarpa, seeds have physical dormancy and required scarification + soaking to germinate well (96%). Kobmoo (1990) reported that scarification + soaking resulted in 79% germination. Also, *Albizia chinensis* and *Sindora siamensis*, seeds have physical dormancy and required scarification and/or scarification + soaking to germinate well (93-96% and 61-74%, respectively. For *Albizia chinensis* this result agreed with Athaya, 1990; Blain and Kellman, 1991 and Baskin and Baskin, 1998. While, Singpetch (2001) found that scarification by hand and sowing the seeds in sand: rice husk (1:1), achieved 78.3% germination. FORRU (2000) reported that, without any special treatments, under partial shade, the expected germination was least than 20% over 30-179 days. Sosef *et al.* (1998) reported that pre-treatment of seed with boiling water, concentrated sulfuric acid or by nicking the seed-coat is usually recommended overcome dormancy.

Therefore the conclusions of this study, agree with evidence from the literature is that, for legumes, treatments that perforate the outer seed coat can considerably increase and accelerate germination.

Seeds in the family Elaeocarpaceae (*Elaeocarpus lanceifolius* and *Elaeocarpus prunifolius*), seeds have dormancy caused by a tough endocarp, which prevents gaseous exchange (Bradbeer, 1988). Imbibition may take place, but the radicle is unable to split or penetrate its enclosure. Physical restriction of embryo development may be overcome by extracting the seeds from the endocarp. Previous results showed that for seeds of *Elaeocarpus lanceifolius* and *Elaeocarpus prunifolius* complete removal of the seeds by cracking open the endocarp is necessary to increase germination percentage (Vongkamjan, unpublish) and is better than simply nicking the woody endocarp with a small cut. This was also true for *Terminalia chebula* and *Terminalia mucronata*. In contrast, seeds of *Irvingia malayana* and *Terminalia bellirica* rotted if the woody endocarp was cracked to extract the seeds (Baskin and Baskin, 1998). Seeds of this species have a hard woody pericarp (Bradbeer, 1988), which prevents water uptake and gaseous exchange. Therefore, dormancy could be overcome by soaking the seeds in water and hot water; *Terminalia bellirica* required soaking in water for 24 hours to germinate well (100%), while, *Irvingia malayana* responded to soaking in hot water (96%).

Dormancy may be overcome by acid treatment and/or scarification, *e.g. Reevesia pubescens*, *Morus macroura Lagerstroemia speciosa*, *Trema orientalis*, *Glochidion acuminatum*, *Terminalia mucronata* and *Tetradium glabrifolium*. Elliott *et al.* (1996) reported that for *Morus macroura*, sowed in forest soil *without* treatment had 76.4% germination. It was included in this study, because they had small seedlings and grew slowly, so direct seeding in a natural forest gap, and cutting propagation could be tried. After seeds were treated with soaking or acid treatment for 1 minute, 99% germination was achieved. Kobmoo (1990) found that without any special treatments, sowing the seeds of *Lagerstroemia speciosa* in soil: sand: husk rice charcoal (3:2:1) resulted in 51-75% germination. For *Terminalia mucronata*, this result agreed with data from Elliott *et al.* (1996). They reported that non-treated seeds sown in forest soil under partial shade resulted in 13.9%

germination, comparable with the control in my experiment, which resulted in 11% germination.

3.4.2 Effects of Shade

One species (*Elaeocarpus lanceifolius*) was shade-dependent whilst eighteen were shade tolerant (see Table 13). The shade-dependent species and thirteen of the 18 shade tolerance species had medium or large seeds. Large seeds have large food reserves, enabling seedlings to survive a long period in shade for establishment in the new environment before becoming dependent on their own assimilation. Sosef *et al.* (1998) reported that *Acrocarpus fraxinifolius* is a light demander and a pioneer tree, but can tolerate slight shade when young. Might due to germination type is PEF (phanerocotylar epigeal foliaceous) (see Appendix I) must become self-sufficient, by beginning photosynthesis as soon as they germinate.

Therefore, large seed size and shade-dependence or shade-tolerance are often associated. Initially after radicle emergence, a developing seedling acquires all necessary resources from seed reserves and its growth rate is independent of external resource availability. Sork (1987) reported that seedling establishment was influenced also by site and light conditions, but larger seed size facilitates establishment of seedlings under low light conditions. However, the larger-seeded species suffer greater predation (Chapter 4) and have limited to their seed dispersal mechanisms.

Seeds of climax species may germinate (and the seedlings become established) in dim light on the forest floor (*e.g. Shorea obtusa*, *Diospyros undulata*). Furthermore their seedlings may survive longer than those of pioneer species. The pioneer species require high light, associated with gaps in the canopy, for germination and seedling establishment (*e.g. Acrocarpus fraxinifolius*). Baskin and Baskin (1998) noted that the light requirement of pioneer species for germination may vary with

temperature. Sosef *et al.* (1998) noted that *Albizia chinensis* seeds should be sown in full light to assure optimal germination. Four species could not be categorised because they had mixed results. *Trema orientalis* was a pioneer species, with seeds that required light for germination and remained dormant for a long time, even in the continuous presence of available water and appropriate temperatures for germination.

3.4.3 Effects of Nursery and Gaps

Fourteen species responded positively to nursery conditions (see Table 13). In nurseries, artificial watering is normal, but in gaps, direct sowing must be scheduled for the rainy season when conditions for germination and seedling establishment are optimal.

Five species responded positively to gap conditions. All these seeds were dispersed in the late wet-early dry season (*Albizia chinensis*, *Elaeocarpus lanceifolius*, *Glochidion acuminatum*, *Lagerstroemia speciosa*, and *Tetradium glabrifolium*) and included both medium and large seeds and both pioneer and climax species. Eleven species (seven large, three medium and one small seed size) sown in the nursery did not differ significantly in their germination variables from natural forest gaps. Three of the eight species were dispersed in the early wet, five in the late wet and three in the dry season.

Sosef *et al.* (1998) reported that direct sowing is often applied for *Albizia chinensis*, because planting out nursery-grown plants disturbs the long taproot, which develops rapidly in young seedlings. Also, for *Terminalia bellirica*, direct seeding in Java was successful (at 1 m x 3 m) and no weeds could develop under the rather dense crowns.

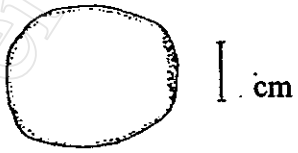
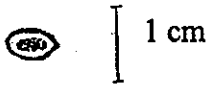
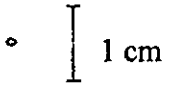
Because *Elaeocarpus prunifolius* showed no difference in response between in the nursery and natural forest gap, because no seeds germinated. Therefore, fifteen species showed promise for direct seedling. Direct sowing is likely to be less successful, in terms of survival rate, than planting, because germinating seeds do not have a competitive advantage over weeds, which established seedlings have. Furthermore, the likelihood of seed predation must take into account and this is covered in Chapter 4. Yet where seeds are relatively cheap, and nursery and planting costs high, or where terrain conditions make field planting difficult, direct seeding using these species could be efficient and warrants further testing as a larger scale.

Further research of seed pre-treatment methods are necessary to determine the required other pre-treatment or other propagation methods for thirteen species. The effect of shade should be considered for planting in other native tree species.

Table 6. Tree species from which seeds were collected and sowing date.

Species	Flowers	Fruits	Dispersal time	Collection month	Collection date	Sowing date
Acrocarpus fraxinifolius	Ja-Mr	Mr-My	My	My-Jl	17/Jl/2001	17/Ag/2001
Afzelia xylocarpa	Fb-Ap	My-Ja	Dc-Ja	Dc-My	19/Ap/2001	27/Jn/2001
Albizia chinensis	Ap-My	My-Fb	Ag-Fb	Ag-Fb	7/Ja/2000	18/My/2000
Aporusa villosa	Ja-Mr	Mr-My	Ap-My	My	10/My/2000	15/My/2000
Betula alnoides	Dc-Fb	Ja-Mr	Fb-Mr	Fb-Mr	15/Fb/2001	20/Mr/2001
Cassia fistula	Fb-My	My-Ja	Dc-Ja	Dc-Ap	16/Ap/2000	25/Sp/2000
Debregeasia longifolia	Sp-Dc	Oc-Dc	Dc	Dc	10/Dc/2000	15/Dc/2000
Diospyros undulata	Ap-My	My-Ag	Jl-Ag	Jl-Ag	10/Ag/2000	17/Ag/2000
Elaeocarpus lanceifolius	Jn-Ag	Jl-Nv	Nv	Nv-Dc	24/Nv/2001	15/Ja/2001
Elaeocarpus prunifolius	Ja-Ap	Ap-Sp	Ag-Sp	Ag-Sp	17/Ag/2001	9/Oc/2001
Eurya acuminata	Ag-Oc	Sp-Ap	Mr-Ap	Mr-Ap	11/Ap/2001	5/My/2001
Ficus lamponga	Dc-Fb, Jn-Ag	Mr-My, Sp-Oc	Mr-My, Sp-Oc	Mr-My, Sp-Oc	30/Mr/2001	1/Ap/2001
Ficus hirta	Ja-Dc	Ja-Dc	Ag-Oc	Ag-Oc	24/Ag/2001	19/Mr/2001
Ficus superba	Oc-Fb, Jn-Jl	Mr-Ap, Ag-Sp	Ap, Ag	Ap, Ag	14/Mr/2001	21/Sp/2001
Glochidion acuminatum	Mr-Jn	Jn-Oc	Sp-Oc	Sp-Oc	19/Sp/2000	26/Sp/2000
Irvingia malayana	Ap-Jn	Jn-Sp	Ag-Sp	Ag-Dc	16/Nv/2000	8/Ja/2001
Lagerstroemia speciosa	Mr-My	My-Dc	Sp-Dc	Sp-Dc	30/Dc/2000	1/Ja/2001
Macropanax dispermus	My-Ag	Jl-Fb	Dc-Fb	Dc-Fb	19/Ja/2001	7/Fb/2001
Morus macroura	Ja-Ap	Fb-My	Ap-My	Ap-Jn	30/Ap/2001	14/Jn/2001
Reevesia pubescens	Ap-My	My-Mr	Ja-Ap	Nv-Ap	1/Nv/2000	17/Nv/2000
Saurauia roxburghii	Ap-Jl	Jn-Sp	Ag-Sp	Ag-Sp	9/Ag/2000	25/Ag/2000
Schleichera oleosa	Mr-Ap	Ap-Oc	Ag-Oc	Ag-Oc	10/Ag/2000	15/Ag/2000
Shorea obtusa	Ap	Ap-Jn	My-Jn	My-Jn	11/My/2001	13/My/2001
Sindora siamensis	Ap-Jn	Jn-Nv	Oc-Nv	Oc-Fb	18/Fb/2001	14/Jn/2001
Terminalia bellirica	Mr-Ap	My-Ja	Dc-Ja	Dc-Fb	26/Ja/2001	29/Mr/2001
Terminalia chebula	Mr-Jn	Jn-Sp	Sp	Sp-Fb	22/Fb/2001	25/My/2001
Terminalia mucronata	Ap-My	My-Ja	Dc-Ja	Dc-Mr	3/Mr/2001	13/Jn/2001
Tetradium glabrifolium	Jn-Ag	Ag-Dc	Oc-Dc	Oc-Dc	10/Dc/2000	12/Mr/2001
Trema orientalis	Mr-Ag	Mr-Dc	Sp-Dc	Sp-Dc	20/Sp/2000	7/Oc/2000
Vaccinium sprengelii	Oc-Mr	Ja-Jn	My-Jn	My-Jl	31/My/2000	2/Jn/2000

Table 7. Thirty tree species seed information.

Species	Seed Data		Illustration
Acrocrarpus fraxinifolius	seed size*	medium	
	weight (g)	0.0337±0.003	
	dispersal method	wind	
	dispersal month	My	
	integument	thick testa	
Afzelia xylocarpa	seed size	large	
	weight (g)	6.2026±2.009	
	dispersal method	animal	
	dispersal months	Dc-Ja	
	integument	thick testa	
Albizia chinensis	seed size	medium	
	weight (g)	0.03010±0.064	
	dispersal method	wind	
	dispersal months	Ag-Fb	
	integument	thick testa	
Aporusa villosa	seed size	medium	
	weight (g)	0.12230±0.017	
	dispersal method	animal	
	dispersal months	Ap-My	
	integument	arill testa	
Betula alnoides	seed size	small	
	weight (g)	0.00009	
	dispersal method	wind	
	dispersal months	Fb-Mr	
	integument	pericarp	

seed size*= small <2 mm, medium 2-14 mm, large >14 mm (diameter)

Table 7. Thirty tree species seed information (continue).

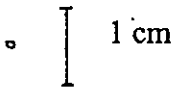
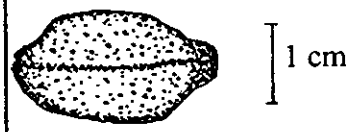
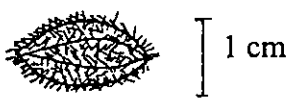
Species	Seed Data		Illustration
Cassia fistula	seed size	medium	 1 cm
	weight (g)	0.16690±0.025	
	dispersal method	animal	
	dispersal months	Dc-Ja	
	integument	thick testa	
Debregeasia longifolia	seed size	small	 1 cm
	weight (g)	0.0001	
	dispersal method	animal	
	dispersal month	Dc	
	integument	testa	
Diospyros undulata	seed size	large	 1 cm
	weight (g)	0.57190±0.200	
	dispersal method	animal	
	dispersal months	Jl-Ag	
	integument	testa	
Elaeocarpus lanceifolius	seed size	large	 1 cm
	weight (g)	2.5459±0.452	
	dispersal method	animal	
	dispersal month	Nv	
	integument	endocarp	
Elaeocarus prunifolius	seed size	large	 1 cm
	weight (g)	0.3524±0.064	
	dispersal method	animal	
	dispersal months	Ag-Sp	
	integument	endocarp	

Table 7. Thirty tree species seed information (continue).

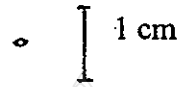
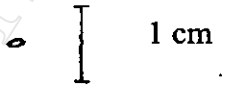
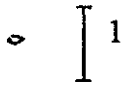
Species	Seed Data		Illustration
Eurya acuminata	seed size	small	 1 cm
	weight	0.00015	
	dispersal method	animal	
	dispersal months	Mr-Ap	
	integument	testa	
Ficus hirta	seed size	small	 1 cm
	weight	0.00021	
	dispersal method	animal	
	dispersal months	Ag-Oc	
	integument	testa	
Ficus lamponga	seed size	small	 1 cm
	weight	0.0001	
	dispersal method	animal	
	dispersal months	Mr-My, Sp-Oc	
	integument	testa	
Ficus superba	seed size	small	 1 cm
	weight	0.00017	
	dispersal method	animal	
	dispersal months	Ap, Ag	
	integument	testa	
Glochidion acuminatum	seed size	medium	 1 cm
	weight	0.0456±0.005	
	dispersal method	animal	
	dispersal months	Sp-Oc	
	integument	arill testa	
Irvingia malayana	seed size	large	 1 cm
	weight	5.3012±0.599	
	dispersal method	animal	
	dispersal months	Ag-Sp	
	integument	endocarp	

Table 7. Thirty tree species seed information (continue).

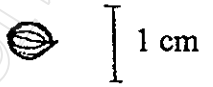
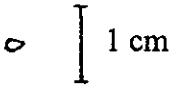
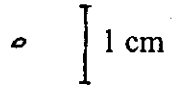
Species	Seed Data		Illustration
Lagerstroemia speciosa	seed size	medium	
	weight	0.0223±0.005	
	dispersal method	wind	
	dispersal months	Sp-Dc	
	integument	wing	
Macropanax dispermus	seed size	medium	
	weight	0.0199±0.003	
	dispersal method	animal	
	dispersal months	Dc-Fb	
	integument	testa	
Morus macroura	seed size	small	
	weight	0.00047	
	dispersal method	animal	
	dispersal months	Ap-My	
	integument	testa	
Reevesia pubescens	seed size	medium	
	weight	0.0493±0.005	
	dispersal method	wind	
	dispersal months	Ja-Ap	
	integument	wing	
Saurauia roxburghii	seed size	small	
	weight	0.00009	
	dispersal method	animal	
	dispersal months	Ag-Sp	
	integument	testa	
Schleichera oleosa	seed size	large	
	weight	0.7066±0.0544	
	dispersal method	animal	
	dispersal dates	Ag-Oc	
	integument	testa	

Table 7. Thirty tree species seed information (continue).

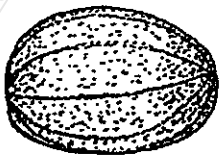
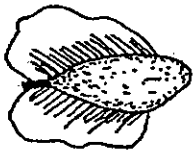
Species	Seed Data		Illustration
Shorea obtusa	seed size	medium	 1 cm
	weight	0.0596±0.0544	
	dispersal method	wind	
	dispersal months	My-Jn	
	integument	pericarp	
Sindora siamensis	seed size	large	 1 cm
	weight	2.1258±0.450	
	dispersal method	animal	
	dispersal months	Oc-Nv	
	integument	thick testa	
Terminalia bellirica	seed size	large	 1 cm
	weight	2.8922±0.287	
	dispersal method	animal	
	dispersal months	Dc-Ja	
	integument	endocarp	
Terminalia chebula	seed size	large	 1 cm
	weight	2.3928±0.284	
	dispersal method	animal	
	dispersal month	Sp	
	integument	endocarp	
Terminalia mucronata	seed size	large	 1 cm
	weight	0.3720±0.113	
	dispersal method	wind	
	dispersal months	Dc-Ja	
	integument	pericarp	
Tetradium glabrifolium	seed size	medium	 1 cm
	weight	0.011±0.003	
	dispersal method	animal	
	dispersal months	Oc-Dc	
	integument	thick testa	

Table 7. Thirty tree species seed information (continue).

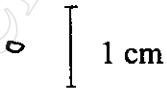
Species	Seed Data		Illustration
Trema orientalis	seed size	small	
	weight	0.0014±0.001	
	dispersal method	animal	
	dispersal months	Sp-Dc	
	integument	endocarp	
Vaccinium sprengelii	seed size	small	
	weight	0.0003	
	dispersal method	animal	
	dispersal months	My-Jn	
	integument	testa	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species.

1) *Acrocarpus fraxinifolius*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=NS)			p^g=***				p^g=*			p^g=NS			Mean[a]		MLD[d]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	1.00	1.73	e	3	45.00	-	c	44.00	-	ns	0.33	0.6	c	1	3.00	-	a	1.00	-	ns	0.561	ns	-		-	
2. soaking	1.00	1.00	e	3	3.00	0.00	a	12.00	15.56	ns	0.00	0.00	c	0	none	none	none	none	none	none	0.158	ns	-		-	
3. scarification	32.33	3.06	a	90	4.00	0.00	a	4.67	0.58	ns	25.00	9.5	a	69	4.00	0.00	a	3.67	1.53	ns	0.274	ns	-		0.349	ns
4. scarification+soaking	27.00	4.00	b	75	2.80	2.08	a	6.67	1.15	ns	22.00	4.6	a	61	3.00	0.00	a	4.00	0.00	ns	0.228	ns	0.876	ns	0.016	*
5. heat	3.33	2.31	e	9	12.67	7.51	b	16.00	16.70	ns	1.00	1.00	c	3	8.00	0.00	b	24.00	32.53	ns	0.184	ns	0.465	ns	0.731	ns
6. acid 3 minutes	2.33	0.58	e	6	4.00	1.73	a	36.67	28.29	ns	1.33	2.3	c	4	3.00	-	a	1.00	-	ns	0.507	ns	0.667	ns	0.389	ns
7. acid 5 minutes	7.67	2.08	d	21	3.00	0.00	a	36.00	27.71	ns	1.33	2.3	c	4	5.50	3.54	ab	1.50	0.71	ns	0.024	*	0.272	ns	0.194	ns
8. acid 10 minutes	14.00	2.00	c	39	3.00	0.00	a	34.67	27.23	ns	12.00	3.00	b	33	5.67	0.58	ab	4.00	0.00	ns	0.391	ns	0.001	**	0.123	ns

[a] The mean number of seeds germinated in 3 replicates

[b] Significant difference at the 0.05 confidence level

(same letter within column were not significantly,

NS: no significant differences among all treatments)

[c] The mean percent seed germination across 3 reps.

[d] Averaged median length of dormancy across 3 reps. (days)

[e] Significant difference at the 0.05 confidence level

(same letter within column were not significantly,

NS: no significant differences among all treatments)

[f] Mean of germination periods across 3 reps. (days)

[g] Significant differencebetween partial shade and deep shade

(*** p<0.001, **p<0.01, *p<0.05; NS, not significant)

[h] t-test comparing between partial shade and deep shade

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

2) *Afzelia xylocarpa*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=*)			(p^g=NS)			p^g=***				p^g=*			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	3.33	2.31	d	9	36.33	4.04	bc	14.67	15.82	ns	2.67	0.58	d	7	37.00	2.65	c	8.00	3.61	ab	0.653	ns	0.823	ns	0.516	ns
2. soaking	3.33	2.08	d	9	32.33	2.08	ab	13.00	15.13	ns	2.67	0.58	d	7	32.33	4.73	ab	6.67	3.21	a	0.621	ns	1.000	ns	0.517	ns
3. scarification	30.00	2.00	b	83	35.33	1.15	bc	13.67	1.15	ns	29.67	2.31	b	82	34.67	1.15	bc	18.00	2.65	bc	0.859	ns	0.519	ns	0.060	ns
4. scarification+soaking	34.67	2.31	a	96	29.67	2.52	a	17.67	3.79	ns	34.33	1.15	a	95	30.33	2.89	a	19.00	1.73	c	0.834	ns	0.778	ns	0.609	ns
5. heat	18.33	4.73	c	51	36.00	3.46	bc	24.00	12.12	ns	14.33	1.15	c	40	37.33	2.31	c	27.33	14.57	c	0.228	ns	0.609	ns	0.776	ns
6. acid 5 minutes	3.00	2.65	d	8	39.33	5.77	c	4.33	3.06	ns	2.67	1.15	d	7	33.67	1.53	abc	6.33	4.62	a	0.851	ns	0.176	ns	0.566	ns
7. acid 10 minutes	3.67	2.31	d	10	34.67	1.15	abc	5.33	4.51	ns	4.67	2.08	d	13	35.67	0.58	bc	6.33	1.53	a	0.607	ns	0.251	ns	0.734	ns
8. acid 15 minutes	1.00	0.00	d	3	34.00	0.00	ab	1.00	0.00	ns	2.33	1.53	d	6	34.33	0.58	abc	5.00	3.46	a	0.205	ns	0.374	ns	0.116	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

3) *Albizia chinensis*

Treatments	Partial shade										Deep shade										t-Test[h]					
	(p^g=***)				(p^g=***)			(p^g=***)			p^g=***				p^g=***			p^g=***			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	1.00	0.00	de	4	30.33	21.55	bc	1.00	0.00	a	7.00	3.00	c	29	31.33	23.29	ab	102.33	18.56	c	0.026	*	0.959	ns	0.001	**
2. soaking	0.33	0.58	e	1	91.00	-	d	1.00	-	a	1.7	0.58	d	7	17.67	4.62	ab	13.67	20.23	ab	0.047	*	0.005	**	0.642	ns
3. scarification	23.00	1.00	a	96	2.67	0.33	a	10.67	6.43	a	23	1.15	a	97	5.00	0.00	a	5.33	0.58	ab	0.725	ns	0.002	**	0.226	ns
4. scarification+soaking	22.33	1.53	a	93	3.00	0.00	a	6.33	0.58	a	23	1.15	ab	94	5.00	0.00	a	7.33	1.53	ab	0.778	ns	-		0.349	ns
5. heat	21.33	2.52	ab	89	25.33	1.45	abc	79.00	11.14	b	19	2.31	b	85	36.33	20.50	b	96.67	14.50	c	0.624	ns	0.409	ns	0.170	ns
6. acid 3 minutes	3.33	1.15	d	14	30.67	6.67	bc	75.67	35.95	b	0.7	0.58	d	3	103.00	33.94	c	1.00	0.00	a	0.023	*	0.042	*	0.069	ns
7. acid 5 minutes	12.33	1.53	c	51	35.67	12.24	c	120.00	3.00	c	0.7	0.58	d	3	87.50	16.26	c	1.00	0.00	a	0.000	***	0.063	ns	0.000	***
8. acid 10 minutes	19.00	2.65	b	79	7.33	1.33	ab	22.00	8.00	a	23	0.58	ab	94	6.67	1.15	a	26.67	4.93	b	0.079	ns	0.678	ns	0.438	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

4) *Aporusa villosa*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=*)			(p^g=*)			p^g=***				p^g=***			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	22.00	1.00	a	92	23.67	5.13	c	19.33	0.58	bc	19.7	2.52	a	82	27.00	1.73	cd	19.67	7.64	ns	0.210	ns	0.346	ns	0.944	ns
2. soaking	19.67	1.53	ab	82	20.00	1.73	abc	20.33	4.16	c	13.3	4.04	b	56	35.00	2.65	e	21.67	3.79	ns	0.064	ns	0.001	**	0.703	ns
3. scarification	22.67	1.53	a	94	20.33	4.51	bc	21.33	3.21	c	11.3	2.31	b	47	32.00	0.00	de	15.33	3.79	ns	0.002	**	0.001	**	0.105	ns
4. scarification+soaking	15.00	6.56	bc	63	17.00	3.61	ab	12.33	4.51	ab	9.33	2.89	bc	39	20.33	4.04	ab	15.33	9.71	ns	0.243	ns	0.346	ns	0.653	ns
5. heat	12.67	2.08	c	53	20.33	4.04	bc	17.00	8.19	abc	6.00	3.00	c	25	28.33	3.51	cd	21.00	7.00	ns	0.034	*	0.061	ns	0.057	ns
6. acid 3 minutes	15.33	3.79	bc	64	15.00	0.00	ab	14.67	2.31	anc	13.00	1.00	b	54	25.00	0.00	bc	20.33	2.89	ns	0.360	ns	-		0.374	ns
7. acid 5 minutes	7.00	1.00	d	29	14.33	1.15	a	10.00	0.00	a	5.33	1.53	c	22	19.00	5.20	a	9.00	1.73	ns	0.189	ns	0.204	ns	-	
8. acid 10 minutes	0.00	0.00	e	0	none	none	one	none	none	none	0.00	0.00	d	0	none	none	no	none	none	none	none		none		none	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

5) *Betula alnoides*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=NS)				(p^g=NS)			(p^g=NS)			p^g=*				p^g=NS			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	7.00	2.65	ns	19	32.67	1.53	ns	14.33	16.44	ns	10.00	3.61	ab	28	32.33	1.15	ns	19.00	6.56	b	0.310	ns	0.778	ns	0.672	ns
2. soaking	4.67	2.08	ns	13	37.67	7.23	ns	20.67	10.26	ns	8.33	6.66	abc	23	35.33	4.04	ns	11.00	2.65	ab	0.414	ns	0.651	ns	0.189	ns
3. heat	2.33	2.08	ns	6	33.50	0.71	ns	17.50	0.71	ns	2.67	2.08	bc	7	35.00	6.08	ns	3.00	2.00	a	0.854	ns	0.763	ns	0.003	**
4. acid 30 seconds	7.00	3.46	ns	19	34.33	2.31	ns	13.33	1.53	ns	15.33	6.11	a	43	32.33	1.15	ns	16.67	10.07	b	0.109	ns	0.251	ns	0.601	ns
5. acid 1 minutes	6.67	1.15	ns	19	33.33	0.58	ns	21.00	9.64	ns	5.33	4.04	bc	15	29.00	6.93	ns	9.00	7.00	ab	0.612	ns	0.341	ns	0.156	ns
6. acid 3 minutes	3.00	0.00	ns	8	33.00	2.65	ns	8.00	8.89	ns	2.00	1.0	c	6	33.33	2.52	ns	2.67	2.89	a	0.158	ns	0.882	ns	0.379	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

6) *Cassia fistula*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=***)			p^g=***				p^g=NS			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	0.00	0.00	e	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
2. soaking	0.00	0.00	e	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
3. scarification	27.00	2.65	b	75	7.33	0.58	a	5.33	0.58	a	16.3	4.62	b	45	7.33	0.58	ns	13.33	4.62	a	0.026	*	1.000	ns	0.041	*
4. scarification+soaking	34.00	1.00	a	94	6.33	0.58	a	6.33	1.53	a	31.3	1.53	a	87	7.67	0.58	ns	10.67	4.62	a	0.065	ns	0.047	*	0.198	ns
5. heat	1.67	0.58	e	5	39.33	3.79	c	9.00	10.58	a	2.00	0.00	c	6	24.67	28.94	ns	36.33	24.68	b	0.374	ns	0.433	ns	0.153	ns
6. acid 3 minutes	8.00	0.00	d	22	16.00	8.66	b	57.33	2.89	b	16.3	1.15	b	45	9.00	0.00	ns	5.33	1.53	a	0.000	***	0.234	ns	0.000	***
7. acid 5 minutes	24.33	2.52	c	68	9.33	1.15	ab	8.00	0.00	a	21.7	4.16	b	60	9.67	0.58	ns	16.00	2.00	a	0.396	ns	0.678	ns	0.002	**
8. acid 10 minutes	35.33	1.15	a	98	6.67	0.58	a	9.33	5.13	a	29.7	7.09	a	82	7.33	0.58	ns	11.33	2.89	a	0.244	ns	0.230	ns	0.588	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

7) *Debregeasia longifolia*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=NS)				(p^g=***)			(p^g=NS)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	34.00	1.73	ns	94	20.33	4.93	a	51.00	5.29	ns	33.33	2.08	ns	93	36.00	5.29	ns	50.33	7.02	ns	0.69	ns	0.020	*	0.9	ns
2. soaking	32.00	1.00	ns	89	25.33	1.15	a	47.67	6.43	ns	33.00	1.15	ns	92	43.67	10.60	ns	47.00	3.61	ns	0.21	ns	0.041	*	0.88	ns
3. heat	32.00	3.61	ns	89	27.00	1.00	a	44.33	5.03	ns	30.67	3.79	ns	85	50.33	2.31	ns	49.33	6.66	ns	0.68	ns	0.000	***	0.36	ns
4. acid 30 seconds	27.33	1.53	ns	76	50.67	9.29	b	55.33	1.53	ns	23.67	6.11	ns	66	54.33	4.62	ns	40.67	10.97	ns	0.37	ns	0.574	ns	0.08	ns
5. acid 1 minutes	32.33	3.06	ns	90	49.33	7.51	b	51.67	5.77	ns	30.00	1.00	ns	83	51.67	4.62	ns	50.00	8.72	ns	0.28	ns	0.670	ns	0.8	ns
6. acid 3 minutes	32.00	4.00	ns	89	20.67	5.69	a	50.67	4.93	ns	30.67	4.62	ns	85	41.33	20.60	ns	55.33	1.53	ns	0.73	ns	0.169	ns	0.19	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

8) *Diospyros undulata*

Treatments	Partial shade										Deep shade										t-Test[h]					
	(p^g=***)				(p^g=NS)			(p^g=*)			p^g=***				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	10.33	1.53	ab	43	18.00	0.00	ns	5.33	2.31	bc	8.33	2.52	b	35	18.00	0.00	ns	6.67	2.31	ns	0.305	ns	-	-	0.519	ns
2. soaking	11.00	1.00	a	45	19.00	1.73	ns	7.67	2.52	c	12.67	3.79	a	53	19.00	1.73	ns	9.00	5.57	ns	0.502	ns	1.000	ns	0.725	ns
3. scarification	7.33	0.58	bc	31	18.00	0.00	ns	4.33	3.51	abc	4.67	2.52	bc	19	19.00	1.73	ns	5.67	4.04	ns	0.148	ns	0.374	ns	0.688	ns
4. scarification+soaking	2.00	1.00	de	8	20.00	1.73	ns	2.33	2.31	ab	3.33	2.52	cd	14	19.00	1.73	ns	2.00	1.73	ns	0.442	ns	0.519	ns	0.851	ns
5. heat	3.00	1.00	de	13	18.00	0.00	ns	7.67	0.58	c	1.67	2.89	cd	7	18.00	-	ns	1.00	-	ns	0.492	ns	-	-	0.010	*
6. acid 5 minutes	4.33	3.79	cd	18	18.00	0.00	ns	2.00	1.73	ab	4.67	2.08	bc	19	17.33	1.15	ns	5.00	1.73	ns	0.900	ns	0.374	ns	0.101	ns
7. acid 10 minutes	3.00	2.65	de	13	18.00	0.00	ns	1.00	0.00	a	0.00	0.00	d	0	none	none	none	none	none	none	0.121	ns	-	-	-	-
8. acid 15 minutes	0.00	0.00	e	0	none	none	none	none	none	none	0.00	0.00	d	0	none	none	none	none	none	none	none	-	none	-	none	-

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

9) *Elaeocarpus lanceifolius*

Treatments	Partial shade										Deep shade										t-Test[h]					
	(p^g=***)				(p^g=***)			(p^g=NS)			p^g=**				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	11.33	5.13	de	31	74.67	8.39	b	60.33	12.42	ns	4.33	1.16	a	12	89.00	14.53	ns	23.33	3.21	ns	0.082	ns	0.213	ns	0.008	**
2. soaking	14.33	2.08	cd	40	70.33	14.15	b	66.33	6.66	ns	0.33	0.58	b	1	91.00	-	ns	1.00	-	ns	0.000	***	0.333	ns	0.014	*
3. scarification	27.00	1.73	ab	75	29.33	1.15	a	50.33	31.72	ns	6.00	1.73	a	17	85.00	6.00	ns	62.67	12.86	ns	0.000	***	0.000	***	0.566	ns
4. scarification+soaking	30.00	3.46	a	83	29.67	4.73	a	41.00	31.95	ns	5.00	5.29	a	14	67.33	33.1	ns	26.00	29.82	ns	0.002	**	0.123	ns	0.584	ns
5. heat	5.67	2.08	e	16	108.33	8.33	c	57.00	18.19	ns	0.00	0.00	b	0	none	none	none	none	none	none	0.009	**	-		-	
6. acid 5 minutes	19.33	7.09	c	54	77.67	5.13	b	56.67	5.86	ns	0.33	0.58	b	1	83.00	-	ns	2.00	-	ns	0.010	*	0.463	ns	0.015	*
7. acid 10 minutes	20.67	3.79	bc	57	73.00	7.21	b	64.33	16.50	ns	0.00	0.00	b	0	none	none	none	none	none	none	0.001	**	-		-	
8. acid 15 minutes	10.00	6.25	de	28	72.67	8.08	b	60.67	36.02	ns	0.33	0.58	b	1	125.00	-	ns	1.00	-	ns	0.056	ns	0.030	*	0.288	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

10) *Elaeocarpus prunifolius*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=**)			p^g=***				p^g=***			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	0.00	0.00	b	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
2. soaking	0.00	0.00	b	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
3. scarification	17.00	4.36	a	47	29.00	1.73	a	30.3	0.58	b	10.00	2.00	a	28	25.67	4.04	a	23.33	8.74	b	0.065	ns	0.259	ns	0.238	ns
4. scarification+soaking	16.00	1.00	a	44	27.00	0.00	a	32.3	16.26	b	7.33	3.51	b	20	28.33	1.53	a	12.00	4.58	ab	0.015	*	0.205	ns	0.105	ns
5. heat	0.00	0.00	b	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
6. acid 5 minutes	0.00	0.00	b	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
7. acid 10 minutes	0.67	0.58	b	2	74.33	8.33	b	1.00	0.00	a	0.00	0.00	c	0	none	none	none	none	none	none	0.116	ns	-		-	
8. acid 15 minutes	0.33	0.58	b	1	none	none	none	none	none	none	0.67	0.58	c	2	81.00	0.00	b	1.00	0.00	a	0.519	ns	-		-	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

11) *Eurya acuminata*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=NS)				(p^g=NS)			(p^g=NS)			p^g= -				p^g= -			p^g= -			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	24.33	1.15	ns	68	23.00	3.61	ns	33.00	14.73	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.000	***	-		-	
2. soaking	25.33	3.51	ns	70	20.33	1.53	ns	36.33	12.58	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.000	***	-		-	
3. heat	22.33	4.04	ns	62	22.67	3.21	ns	41.33	5.77	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.001	**	-		-	
4. acid 30 seconds	23.33	8.50	ns	65	20.67	2.31	ns	30.00	14.00	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.009	**	-		-	
5. acid 1 minutes	24.00	7.94	ns	67	19.33	0.58	ns	32.67	8.50	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.006	**	-		-	
6. acid 3 minutes	27.00	2.65	ns	75	17.33	2.08	ns	40.00	4.36	ns	0.00	0.00	-	0	none	none	none	none	none	none	0.000	***	-		-	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

12) *Ficus hirta*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=NS)				(p^g=NS)			(p^g=NS)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	7.33	4.62	ns	20	19.00	4.00	ns	15.7	12.90	ns	0.33	0.58	ns	1	76.00	-	ns	1.00	-	ns	0.060	ns	0.007	**	0.43	ns
2. soaking	13.00	6.93	ns	36	17.67	2.31	ns	29.7	22.14	ns	3.00	2.65	ns	8	47.50	2.12	ns	49.50	12.02	ns	0.080	ns	0.001	**	0.34	ns
3. heat	11.67	3.06	ns	32	20.00	1.73	ns	38.7	28.59	ns	2.67	1.53	ns	7	64.33	16.07	ns	11.00	13.23	ns	0.010	*	0.009	**	0.2	ns
4. acid 30 seconds	17.67	13.28	ns	49	15.67	1.15	ns	45.7	35.44	ns	6.67	10.7	ns	19	67.00	12.73	ns	22.50	30.41	ns	0.326	ns	0.005	**	0.51	ns
5. acid 1 minutes	11.00	6.08	ns	31	17.00	2.00	ns	19.3	10.97	ns	8.67	10.3	ns	24	57.50	2.12	ns	41.00	29.70	ns	0.752	ns	0.000	***	0.31	ns
6. acid 3 minutes	22.33	6.66	ns	62	16.33	2.31	ns	24.7	26.27	ns	3.00	2.65	ns	8	59.00	0.00	ns	17.00	5.66	ns	0.009	**	0.000	***	0.73	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

13) *Ficus lamponga*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=*)			p^g=NS				p^g=NS			p^g=NS			p^g=	Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]		2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	28.67	2.89	a	80	17.00	0.00	ns	24.33	5.51	bc	16.3	9.3	ns	45	18.33	3.21	ns	17.00	1.00	ns		0.09	ns	0.512	ns	0.09	ns
2. soaking	32.33	3.06	a	90	18.00	1.00	ns	23.33	2.08	bc	13.3	6.4	ns	37	21.33	0.58	ns	13.33	8.33	ns		0.010	*	0.007	**	0.11	ns
3. heat	3.67	0.58	b	10	17.00	5.29	ns	7.00	4.36	a	4.33	2.3	ns	12	22.33	8.39	ns	13.00	7.94	ns		0.65	ns	0.404	ns	0.32	ns
4. acid 30 seconds	31.00	1.00	a	86	17.00	1.73	ns	18.00	4.36	ab	19.7	9.9	ns	55	19.33	3.06	ns	21.67	3.79	ns		0.12	ns	0.314	ns	0.33	ns
5. acid 1 minutes	30.33	2.08	a	84	17.33	0.58	ns	23.00	1.73	bc	16.7	6.4	ns	46	19.00	3.46	ns	18.67	1.53	ns		0.03	*	0.457	ns	0.03	*
6. acid 3 minutes	30.67	2.08	a	85	16.67	1.53	ns	34.33	16.44	c	21.00	3.6	ns	58	19.00	2.00	ns	17.33	1.53	ns		0.02	*	0.184	ns	0.15	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

14) *Ficus superba*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=*)				(p^g=NS)			(p^g=NS)			p^g=NS				p^g=*			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	31	2.52	a	87	11.00	0.00	ns	9.67	4.62	ns	28	9.54	ns	78	13.33	1.53	ab	6.00	0.00	ns	0.590	ns	0.057	ns	0.24	ns
2. soaking	34	1.15	a	94	11.33	0.58	ns	7.67	1.15	ns	32.67	4.16	ns	91	12.00	1.00	a	5.33	1.53	ns	0.709	ns	0.374	ns	0.1	ns
3. heat	24	6.03	b	66	12.67	2.89	ns	7.33	1.53	ns	12.33	18.8	ns	34	16.00	3.61	b	11.33	16.20	ns	0.376	ns	0.279	ns	0.69	ns
4. acid 30 seconds	33	1.53	a	93	11.00	0.00	ns	8.33	2.31	ns	30.00	10.4	ns	83	11.00	0.00	a	4.67	2.52	ns	0.612	ns	-		0.14	ns
5. acid 1 minutes	32	4.62	a	90	11.00	0.00	ns	3.00	1.00	ns	32.67	2.31	ns	91	11.00	0.00	a	7.33	1.15	ns	0.916	ns	-		0.01	**
6. acid 3 minutes	34	2.31	a	94	11.00	0.00	ns	7.00	1.73	ns	31.33	2.52	ns	87	11.00	0.00	a	6.67	2.31	ns	0.302	ns	-		0.85	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

15) *Glochidion acuminatum*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=**)			(p^g=**)			p^g=**				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	7.00	6.25	d	19	168.00	11.31	d	136.00	21.21	b	13.00	8.89	ab	36	182.00	5.20	ns	142.3	92.97	ns	0.393	ns	0.144	ns	0.934	ns
2. soaking	21.67	3.79	a	60	157.33	4.16	cd	165.67	27.30	b	14.7	6.11	a	41	195.33	9.29	ns	102.3	89.37	ns	0.167	ns	0.003	**	0.306	ns
3. scarification	8.33	1.53	cd	23	87.00	47.03	bc	147.67	26.95	b	2.00	1.00	c	6	203.33	175.12	ns	118.00	101.39	ns	0.004	**	0.329	ns	0.650	ns
4. scarification+soaking	15.00	3.00	b	42	132.00	61.02	cd	186.33	7.57	b	5.00	1.00	c	14	194.67	7.09	ns	119.3	98.57	ns	0.005	**	0.152	ns	0.306	ns
5. heat	0.33	0.58	e	1	13.00	-	a	1.00	-	a	0.00	0.00	c	0	none	none	none	none	none	none	0.374	ns	-		-	
6. acid 3 minutes	14.67	2.08	b	41	154.00	19.00	cd	170.67	9.87	b	12.3	2.08	ab	34	182.33	15.31	ns	99.33	73.57	ns	0.242	ns	0.115	ns	0.171	ns
7. acid 5 minutes	13.67	4.16	bc	38	89.67	44.23	bc	172.33	23.01	b	6.33	2.08	bc	18	187.00	10.54	ns	70.00	88.48	ns	0.053	ns	0.021	*	0.125	ns
8. acid 10 minutes	7.33	1.53	d	20	40.00	14.18	ab	148.67	42.15	b	4.67	1.53	c	13	187.00	12.77	ns	136.67	114.89	ns	0.099	ns	0.000	***	0.873	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

16) *Irvingia malayana*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=NS)			p^g=***				p^g=***			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	30.00	1.00	b	83	86.00	5.57	b	62.67	7.64	ns	28.33	2.08	a	79	94.67	4.62	b	52.67	4.93	c	0.279	ns	0.107	ns	0.129	ns
2. soaking	31.00	3.00	ab	86	91.33	6.03	bc	52.67	15.31	ns	31.00	5.19	a	86	104.00	3.46	bc	51.67	7.23	c	1.000	ns	0.034	*	0.923	ns
3. scarification	15.00	3.61	c	42	22.33	0.58	a	36.00	8.19	ns	12.33	6.51	b	34	39.67	13.20	a	34.00	7.94	abc	0.568	ns	0.086	ns	0.776	ns
4. scarification+soaking	16.33	2.08	c	45	30.00	5.20	a	32.00	14.18	ns	10.33	0.58	bc	29	36.00	0.00	a	25.67	8.08	ab	0.009	**	0.116	ns	0.538	ns
5. heat	34.67	0.58	a	96	94.67	4.62	bc	47.67	13.58	ns	30.33	4.62	a	84	104.00	3.46	bc	50.00	8.19	c	0.182	ns	0.049	*	0.811	ns
6. acid 5 minutes	5.33	2.52	d	15	105.00	17.58	c	39.33	16.01	ns	3.67	3.06	d	10	118.00	27.71	c	18.00	18.08	a	0.506	ns	0.530	ns	0.201	ns
7. acid 10 minutes	3.00	1.73	d	8	85.67	18.34	b	39.67	35.92	ns	4.00	1.73	cd	11	110.00	8.66	bc	36.67	12.50	abc	0.519	ns	0.106	ns	0.898	ns
8. acid 15 minutes	3.00	1.00	d	8	82.33	2.31	b	30.33	28.01	ns	8.67	1.15	bcd	24	92.67	7.02	b	41.33	17.62	bc	0.003	**	0.073	ns	0.596	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

17) *Lagerstroemia speciosa*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=**)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	9.67	3.51	bc	27	101.33	5.51	ns	60.00	26.66	ba	3.7	2.52	ns	10	86.67	8.08	ns	22.67	23.71	ns	0.074	ns	0.060	ns	0.144	ns
2. soaking	28.00	8.67	a	78	94.00	8.19	ns	75.00	24.33	b	5.3	5.51	ns	15	91.00	1.41	ns	31.00	14.14	ns	0.019	*	0.659	ns	0.111	ns
3. scarification	4.00	2.00	cd	11	84.00	2.00	ns	40.33	20.03	ba	1.00	1.73	ns	3	91.00	-	ns	65.00	-	ns	0.121	ns	0.094	ns	0.398	ns
4. scarification+soaking	4.00	2.00	cd	11	89.00	19.98	ns	31.33	26.56	ba	0.00	0.00	ns	0	none	none	none	none	none	none	0.026	*	-		-	
5. heat	0.67	0.58	d	2	72.00	0.00	ns	1.00	0.00	a	1.7	2.89	ns	5	86.00	-	ns	55.00	-	ns	0.588	ns	-		-	
6. acid 3 minutes	32.00	2.00	a	89	86.00	2.65	ns	71.33	11.68	b	6.7	6.43	ns	19	83.00	5.20	ns	22.33	11.37	ns	0.003	**	0.423	ns	0.006	**
7. acid 5 minutes	26.67	3.21	a	74	93.33	10.12	ns	185.00	90.21	c	7.00	1.73	ns	19	87.67	0.58	ns	45.67	37.50	ns	0.001	**	0.388	ns	0.069	ns
8. acid 10 minutes	17.33	8.50	b	48	88.00	5.29	ns	68.33	11.15	ba	3.7	2.08	ns	10	86.33	7.64	ns	14.33	20.55	ns	0.054	ns	0.772	ns	0.016	*

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

18) *Macropanax dispermus*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=**)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	24.00	1.00	ab	67	27.67	2.89	ns	23.67	2.52	b	12.3	14.57	ns	34	33.00	12.49	ns	16.00	13.45	ns	0.239	ns	0.511	ns	0.387	ns
2. soaking	27.00	7.94	a	75	29.67	1.15	ns	24.00	3.46	b	19.3	10.07	ns	54	29.33	2.89	ns	20.67	3.51	ns	0.359	ns	0.862	ns	0.307	ns
3. scarification	17.00	2.65	cd	47	30.00	4.58	ns	20.00	6.00	b	16.00	6.00	ns	44	30.00	4.58	ns	20.00	4.36	ns	0.805	ns	1.000	ns	1.000	ns
4. scarification+soaking	18.00	3.00	bcd	50	27.33	6.66	ns	20.33	6.03	b	10.7	4.04	ns	30	31.67	3.06	ns	20.33	9.07	ns	0.065	ns	0.369	ns	1.000	ns
5. heat	1.00	0.00	e	3	33.00	10.15	ns	1.00	0.00	a	0.00	0.00	ns	0	none	none	none	none	none	none	none		none		none	
6. acid 3 minutes	22.00	5.00	abc	61	23.00	0.00	ns	22.67	6.81	b	11.7	10.50	ns	32	24.67	2.31	ns	9.00	8.54	ns	0.199	ns	0.279	ns	0.096	ns
7. acid 5 minutes	13.00	2.65	d	36	23.00	1.00	ns	18.00	10.58	b	6.67	0.58	ns	19	25.33	4.93	ns	16.00	7.21	ns	0.015	*	0.467	ns	0.800	ns
8. acid 10 minutes	0.67	1.15	e	2	19.00	-	ns	13.00	8.08	b	0.00	0.00	ns	0	none	none	none	none	none	none	0.374	ns	-		-	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

19) *Morus macroura*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=*)				(p^g=***)			(p^g=**)			p^g=**				p^g=***			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	35.00	1.73	ab	97	12.67	2.31	b	21.00	8.89	bc	23.67	10.2	b	66	12.33	2.52	b	21.00	8.89	ns	0.131	ns	0.874	ns	1.00	ns
2. soaking	35.67	0.58	a	99	7.67	1.15	a	14.00	8.89	ab	35.67	0.58	a	99	9.00	2.00	a	16.00	9.85	ns	1.000	ns	0.374	ns	0.81	ns
3. heat	23.00	6.25	c	64	21.33	4.04	c	26.67	2.31	c	19.33	2.31	b	54	17.33	0.58	c	21.67	6.03	ns	0.394	ns	0.165	ns	0.25	ns
4. acid 30 seconds	34.33	2.89	ab	95	7.67	0.58	a	15.33	7.51	ab	35.33	0.58	a	98	10.00	1.00	ab	14.33	5.77	ns	0.588	ns	0.025	*	0.86	ns
5. acid 1 minutes	35.67	0.58	a	99	7.00	0.00	a	4.67	3.79	a	35.67	0.58	a	99	9.00	1.73	a	10.33	5.03	ns	1.000	ns	0.116	ns	0.19	ns
6. acid 3 minutes	26.67	10.12	bc	74	9.67	3.06	ab	25.00	3.00	bc	32.00	2.00	a	89	11.33	2.08	ab	21.33	0.58	ns	0.421	ns	0.479	ns	0.11	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

20) *Reevesia pubescens*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=*)			p^g=***				p^g=**			p^g=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	26.33	1.53	b	73	21.00	0.00	bc	17.67	8.08	a	26.33	1.53	c	73	20.33	3.06	a	16.67	1.15	abc	1.000	ns	0.725	ns	0.842	ns
2. soaking	21.67	1.53	c	60	22.33	1.15	bc	43.33	26.86	b	27.00	1.73	c	75	33.33	0.58	c	27.33	12.50	c	0.016	*	0.000	***	0.403	ns
3. scarification	10.00	4.36	c	28	15.00	1.00	a	12.67	4.04	a	9.67	2.52	e	27	23.33	8.74	ab	17.33	5.13	abc	0.914	ns	0.176	ns	0.284	ns
4. scarification+soaking	8.33	3.79	e	23	19.67	1.15	b	11.67	4.04	a	24.67	0.58	cd	69	29.67	1.15	bc	23.67	3.06	bc	0.002	**	0.000	***	0.015	*
5. heat	0.67	1.15	f	2	22.00	-	bc	1.00	-	a	2.00	1.73	f	6	26.50	0.71	abc	8.00	4.24	a	0.329	ns	0.121	ns	0.407	ns
6. acid 3 minutes	32.67	1.53	a	91	21.00	0.00	bc	18.33	2.08	a	34.00	1.00	a	94	32.33	1.15	c	25.67	5.51	bc	0.275	ns	0.000	***	0.097	ns
7. acid 5 minutes	29.33	0.58	ab	81	21.67	1.15	bc	17.00	2.65	a	23.33	0.58	d	65	22.33	4.93	a	14.33	9.24	ab	0.000	***	0.831	ns	0.656	ns
8. acid 10 minutes	16.67	1.53	d	46	23.00	3.46	c	16.33	0.58	a	30.33	0.58	b	84	29.67	1.15	bc	26.33	1.53	c	0.000	***	0.034	*	0.000	***

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

21) *Saurauia roxburghii*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=**)				(p^g=NS)			(p^g=***)			p^g=***				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[c]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	4.00	2.65	c	17	25.00	1.73	ns	4.67	0.58	a	2.67	0.58	c	11	28.00	8.66	ns	19.00	10.82	ns	0.44	ns	0.558	ns	0.084	ns
2. soaking	10.33	2.89	a	43	35.00	6.00	ns	29.33	11.02	b	13.00	4.58	a	54	23.00	0.00	ns	36.67	1.15	ns	0.44	ns	0.026	*	0.315	ns
3. heat	4.00	2.00	c	17	30.33	5.77	ns	10.00	7.81	a	2.33	1.53	c	10	17.00	0.00	ns	12.67	20.21	ns	0.32	ns	0.016	*	0.842	ns
4. acid 30 seconds	3.67	1.53	c	15	21.00	3.46	ns	11.00	9.17	a	6.00	1.73	bc	25	23.67	11.55	ns	14.67	13.28	ns	0.16	ns	0.721	ns	0.714	ns
5. acid 1 minutes	5.33	2.31	bc	22	27.67	8.08	ns	35.67	9.45	b	8.67	2.31	b	36	27.67	8.08	ns	36.00	0.00	ns	0.15	ns	1.000	ns	0.954	ns
6. acid 3 minutes	9.00	1.73	ab	38	28.33	5.86	ns	40.67	5.13	b	4.67	1.53	bc	19	24.00	1.73	ns	28.67	10.02	ns	0.03	*	0.287	ns	0.139	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

22) *Schleichera oleosa*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=NS)			p^g=**				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	4.33	2.08	a	18	259.67	7.09	ns	89.67	107.91	ns	5.33	2.08	a	22	290.33	67.41	ns	129.7	10.79	ns	0.588	ns	0.477	ns	0.558	ns
2. soaking	2.33	1.15	b	10	266.00	9.64	ns	97.67	132.73	ns	0.33	0.58	c	1	256.00	-	ns	1.00	-	ns	0.055	ns	0.464	ns	0.593	ns
3. scarification	2.00	1.00	b	8	182.00	148.23	ns	84.33	133.24	ns	3.00	1.00	ab	13	91.00	134.24	ns	252.00	14.11	ns	0.288	ns	0.475	ns	0.096	ns
4. scarification+soaking	2.00	1.00	b	8	123.00	120.25	ns	106.67	130.12	ns	2.00	1.00	bc	8	101.67	144.12	ns	95.00	142.53	ns	1.000	ns	0.854	ns	0.922	ns
5. heat	1.33	1.15	bc	6	29.00	8.49	ns	14.00	8.49	ns	4.00	2.65	ab	17	47.00	16.00	ns	99.67	148.13	ns	0.185	ns	0.252	ns	0.495	ns
6. acid 5 minutes	1.33	0.58	bc	6	none	none	none	none	none	none	2.33	2.08	bc	8	260.50	6.36	ns	25.00	4.24	ns	0.468	ns	-		-	
7. acid 10 minutes	0.00	0.00	c	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
8. acid 15 minutes	0.00	0.00	c	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

23) *Shorea obtusa*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=*)			p^g=***				p^g= -			p^g=**			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	30.00	2.65	a	83	6.67	0.58	a	2.7	0.58	ab	23	2.08	b	65	7.00	0.00	-	8.00	0.00	b	0.027	*	0.374	ns	0.000	***
2. soaking	28.33	2.89	ab	79	7.00	0.00	a	8.7	0.58	c	29	1.15	a	81	7.00	0.00	-	4.00	2.65	a	0.607	ns	-		0.041	*
3. scarification	27.00	3.61	ab	75	7.00	0.00	a	6.7	3.21	bc	25	4.04	b	69	7.00	0.00	-	8.33	0.58	b	0.497	ns	-		0.427	ns
4. scarification+soaking	25.33	4.62	b	70	7.00	0.00	a	4.7	3.06	abc	24	0.58	b	68	7.00	0.00	-	8.00	0.00	b	0.729	ns	-		0.132	ns
5. heat	0.00	0.00	c	0	none	none	none	none	none	none	0.00	0.00	c	0	none	-	none	none	none	none	none		none		none	
6. acid 3 minutes	0.33	0.58	c	1	14.00	-	b	1.00	-	a	0.33	0.58	c	1	12.00	-	-	1.00	-	a	1.000	ns	-		-	
7. acid 5 minutes	0.00	0.00	c	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	
8. acid 10 minutes	0.00	0.00	c	0	none	none	none	none	none	none	0.00	0.00	c	0	none	none	none	none	none	none	none		none		none	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

24) *Sindora siamensis*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^{K}=***)				(p^{g}=*)			(p^{K}=***)			p^{g}=***				p^{g}=NS			p^{K}=*			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	10.00	1.73	c	28	37.67	14.01	ab	48.67	17.21	b	7.00	1.73	cde	19	32.67	10.07	ns	35.00	18.52	bcd	0.101	ns	0.642	ns	0.402	ns
2. soaking	11.33	0.58	c	31	52.33	11.37	b	55.33	2.08	b	10.00	1.00	c	28	45.33	17.93	ns	42.33	16.17	cd	0.116	ns	0.598	ns	0.239	ns
3. scarification	26.67	6.43	a	74	22.33	0.58	a	5.33	0.58	a	23.33	4.51	a	65	22.00	0.00	ns	7.67	3.79	a	0.503	ns	0.374	ns	0.351	ns
4. scarification+soaking	22.00	4.36	ab	61	22.00	0.00	a	5.67	1.53	a	24.00	1.00	a	67	22.00	0.00	ns	14.00	9.00	ab	0.482	ns	-		0.189	ns
5. heat	18.33	3.79	b	51	24.33	2.08	a	53.67	7.57	b	18.67	2.52	b	52	26.33	0.58	ns	51.00	6.08	d	0.905	ns	0.184	ns	0.659	ns
6. acid 5 minutes	6.67	1.53	cd	19	35.00	19.16	ab	49.33	7.09	b	5.00	0.00	de	14	24.67	2.31	ns	40.33	15.01	cd	0.132	ns	0.406	ns	0.401	ns
7. acid 10 minutes	3.00	1.73	d	8	30.67	10.02	a	18.00	19.98	a	3.00	1.73	e	8	30.00	10.58	ns	18.00	25.16	abc	1.000	ns	0.941	ns	1.000	ns
8. acid 15 minutes	7.67	4.51	cd	21	34.67	10.26	ab	56.33	1.15	b	7.33	3.51	cd	20	25.33	5.77	ns	37.67	11.85	bcd	0.924	ns	0.242	ns	0.053	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

27) *Terminalia mucronata*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=NS)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	4.00	2.65	bc	11	23.67	4.51	ns	12.33	5.86	ns	2.67	1.15	ns	7	19.67	5.69	ns	9.67	9.87	ns	0.469	ns	0.394	ns	0.708	ns
2. soaking	3.33	1.53	bc	9	24.33	11.59	ns	17.00	9.17	ns	2.00	1.00	ns	6	18.67	1.53	ns	11.33	10.50	ns	0.275	ns	0.448	ns	0.520	ns
3. scarification	5.67	2.31	bc	16	27.33	6.43	ns	26.33	0.58	ns	7.00	4.58	ns	19	25.33	7.23	ns	10.33	8.50	ns	0.676	ns	0.738	ns	0.031	*
4. scarification+soaking	2.00	1.00	c	6	29.33	10.02	ns	7.33	8.50	ns	1.33	1.53	ns	4	25.00	7.07	ns	4.00	4.24	ns	0.561	ns	0.639	ns	0.654	ns
5. heat	4.67	0.58	bc	13	27.00	2.65	ns	14.33	6.43	ns	1.67	0.58	ns	5	24.00	6.00	ns	2.00	1.00	none	0.003	**	0.472	ns	0.030	*
6. acid 5 minutes	15.00	2.65	a	42	17.67	0.58	ns	18.00	5.57	ns	5.00	3.61	ns	14	20.00	2.00	ns	8.33	6.66	ns	0.018	*	0.124	ns	0.126	ns
7. acid 10 minutes	16.67	3.21	a	46	21.00	1.73	ns	20.00	4.36	ns	4.33	0.58	ns	12	20.67	4.73	ns	4.00	1.00	none	0.003	**	0.914	ns	0.003	**
8. acid 15 minutes	6.67	2.08	b	19	24.00	4.00	ns	20.67	7.57	ns	4.33	0.58	ns	12	23.67	2.52	ns	11.33	10.21	ns	0.135	ns	0.909	ns	0.272	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

25) *Terminalia bellirica*

	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=***)			(p^g=NS)			p^g=**				p^g=**			p^g=NS			Mean[a]		MLD[b]		GP[f]	
Treatments	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	32.67	2.31	bc	91	23.33	1.15	de	23.00	8.54	ns	35.67	0.58	a	99	23.00	1.00	bc	18.67	3.21	ns	0.094	ns	0.725	ns	0.457	ns
2. soaking	36.00	0.00	a	100	17.00	0.00	ab	20.00	10.39	ns	34.67	1.53	ab	96	16.67	4.16	a	20.00	1.00	ns	0.205	ns	0.896	ns	1.000	ns
3. scarification	33.00	1.73	bc	92	20.00	2.65	bcd	29.67	6.66	ns	34.33	1.53	ab	96	21.00	3.61	bc	19.67	7.37	ns	0.374	ns	0.718	ns	0.156	ns
4. scarification+soaking	34.33	2.08	abc	95	14.67	1.15	a	19.33	9.24	ns	33.33	0.58	abc	93	21.67	0.58	bc	28.33	7.23	ns	0.468	ns	0.001	**	0.255	ns
5. heat	35.00	0.00	ab	97	19.33	2.31	bc	24.67	6.35	ns	33.67	1.15	abc	94	19.33	2.08	ab	21.00	0.00	none	0.116	ns	1.000	ns	0.374	ns
6. acid 5 minutes	32.33	0.58	c	90	22.33	3.79	cde	27.67	5.86	ns	32.33	1.15	bc	90	24.00	0.00	c	26.33	7.64	ns	1.000	ns	0.488	ns	0.822	ns
7. acid 10 minutes	28.67	2.31	d	80	22.67	1.15	cde	31.67	1.15	ns	31.00	1.73	cd	86	24.00	0.00	c	18.33	6.11	none	0.234	ns	0.116	ns	0.021	*
8. acid 15 minutes	25.33	0.58	e	70	24.67	1.15	e	26.33	5.13	ns	28.33	3.79	d	54	23.67	0.58	c	23.33	6.35	ns	0.246	ns	0.251	ns	0.559	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

26) *Terminalia chebula*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=NS)			p^g=***				p^g=*			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	1.00	1.73	b	3	27.00	-	ns	6.00	-	-	1.67	0.58	bc	5	24.67	4.62	a	5.00	6.93	ns	0.561	ns	0.704	ns	0.912	ns
2. soaking	2.33	2.08	b	6	29.50	0.71	ns	20.00	7.07	ns	0.33	0.58	c	1	47.00	-	b	1.00	-	ns	0.184	ns	0.031	*	0.272	ns
3. scarification	13.67	1.53	a	38	16.33	0.58	ns	26.67	14.36	ns	12.00	4.36	a	27	16.33	0.58	a	20.33	15.63	ns	0.566	ns	1.000	ns	0.633	ns
4. scarification+soaking	1.67	1.15	b	2	44.67	10.97	ns	11.67	18.5	ns	5.00	5.19	b	14	20.00	5.00	a	20.33	17.21	ns	0.339	ns	0.024	*	0.584	ns
5. heat	2.00	0.00	b	6	27.33	9.29	ns	7.33	5.51	ns	1.33	0.58	bc	4	24.00	7.81	a	2.00	1.73	ns	0.116	ns	0.659	ns	0.185	ns
6. acid 5 minutes	0.33	0.58	b	1	30.00	-	ns	1.00	-	-	0.00	0.00	c	0	none	none	none	none	none	none	0.374	ns	-		-	
7. acid 10 minutes	0.33	0.58	b	1	35.00	-	ns	1.00	-	-	0.67	1.15	c	2	23.00	-	a	20.00	-	ns	0.678	ns	-		-	
8. acid 15 minutes	0.33	0.58	b	1	27.00	-	ns	1.00	-	-	0.00	0.00	c	0	none	none	none	none	none	none	0.374	ns	-		-	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

28) *Tetradium glabrifolium*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=*)			(p^g=NS)			p^g=NS				p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]	2-tail sig[g]	significant[h]
1. control	1.33	0.58	d	4	39.00	16.00	ab	32.33	54.27	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.016	*	-		-	
2. soaking	3.33	1.53	cd	9	33.67	9.87	a	41.33	45.65	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.019	*	-		-	
3. scarification	8.67	2.52	b	24	66.67	18.48	c	63.67	34.43	ns	4.00	4.00	ns	11	50.50	7.78	ns	23.00	16.97	ns	0.162	ns	0.342	ns	0.231	ns
4. scarification+soaking	6.67	3.06	bc	19	37.00	16.82	ab	65.67	36.86	ns	2.33	2.52	ns	6	39.00	14.14	ns	23.50	20.51	ns	0.131	ns	0.900	ns	0.248	ns
5. heat	2.00	1.00	d	6	56.33	15.31	bc	10.00	7.94	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.026	*	-		-	
6. acid 3 minutes	10.3	4.04	b	29	58.33	3.21	bc	96.33	41.65	ns	0.67	1.15	ns	2	58.00	-	ns	10.00	-	ns	0.016	*	0.937	ns	0.214	ns
7. acid 5 minutes	14.7	1.15	a	41	56.67	4.04	bc	95.67	35.92	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.000	***	-		-	
8. acid 10 minutes	14.7	0.58	a	41	52.33	5.03	ab	76.33	53.48	ns	6.00	5.57	ns	17	40.33	8.39	ns	14.00	12.12	ns	0.055	ns	0.101	ns	0.120	ns

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

29) *Trema orientalis*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)				(p^g=NS)			(p^g=NS)			p^g=NS				p^g=NS			p^g= -			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]	% germ[c]	MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	2.00	0.00	cd	6	189.67	40.05	ns	51.33	69.40	ns	0.3	0.58	ns	1	181	-	ns	1.00	-	-	0.01	**	0.869	ns	0.59	ns
2. soaking	1.00	1.00	d	3	95.50	75.66	ns	61.00	84.85	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.16	ns	-		-	
3. heat	1.00	1.00	d	3	177.00	4.24	ns	11.50	14.85	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.16	ns	-		-	
4. acid 30 seconds	5.67	3.51	b	16	165.00	20.30	ns	163.00	143.82	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.05	*	-		-	
5. acid 1 minutes	4.67	2.08	bc	13	116.33	72.06	ns	96.00	70.93	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.02	*	-		-	
6. acid 3 minutes	35.33	0.58	a	98	149.00	22.91	ns	149.67	17.62	ns	0.00	0.00	ns	0	none	none	none	none	none	none	0.00	***	-		-	

Table 8. Effects of pretreatments, in partial shade and deep shade, on seed germination of 30 tree species (continue).

30) *Vaccinium sprengelii*

Treatments	Partial shade										Deep shade										t-Test [h]					
	(p^g=***)			% germ[c]	(p^g=*)			(p^g=NS)			p^g=*			% germ[c]	p^g=NS			p^g=NS			Mean[a]		MLD[b]		GP[f]	
	Mean[a]	SD	LSD[b]		MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	Mean[a]	SD	LSD[b]		MLD[d]	SD	LSD[e]	GP[f]	SD	LSD[e]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]	2-tail sig[g]	significant[i]
1. control	12.33	1.15	ab	51	18.67	2.31	a	26.67	20.21	ns	8.67	3.79	a	36	22.33	2.89	ns	11.67	3.06	ns	0.18	ns	0.161	ns	0.273	ns
2. soaking	13.33	0.58	a	56	20.67	2.08	abc	11.00	3.46	ns	10.00	1.00	a	42	21.00	2.65	ns	11.67	2.31	ns	0.007	**	0.872	ns	0.795	ns
3. heat	16.00	2.00	a	67	19.33	0.58	ab	18.67	9.82	ns	10.33	3.06	a	43	19.67	2.08	ns	10.67	2.08	ns	0.06	ns	0.802	ns	0.239	ns
4. acid 30 seconds	15.33	2.08	a	64	24.33	5.51	c	31.33	21.57	ns	10.67	1.53	a	44	20.67	2.89	ns	16.67	11.59	ns	0.04	*	0.365	ns	0.358	ns
5. acid 1 minutes	8.67	4.51	b	36	16.67	1.15	a	12.33	4.16	ns	9.00	2.00	a	38	20.00	1.73	ns	20.00	8.66	ns	0.91	ns	0.050	ns	0.239	ns
6. acid 3 minutes	2.00	1.00	c	8	24.00	2.00	bc	12.33	19.63	ns	4.00	0.00	b	17	24.33	5.51	ns	10.33	5.03	ns	0.03	*	0.926	ns	0.873	ns

Table 9. Effect of shade on seed germination of 30 native forest tree species.

Shade dependent (1 species)	Shade tolerant (18 species)	Shade inhibited (7 species)	Mixed results (4 species)
Elaeocarpus lanceifolius	*Acrocarpus fraxinifolius*	*Debregeasia longifolia*	*Albizia chinensis*
	Afzelia xylocarpa	*Eurya acuminata*	*Cassia fistula*
	Aporusa villosa	*Ficus hirta*	*Reevesia pubescens*
	Betula alnoides	*Ficus lamponga*	*Trema orientalis*
	Diospyros undulata	*Glochidion acuminatum*	
	Tetradium glabrifolium	*Lagerstroemia speciosa*	
	Elaeocarpus prunifolius	*Shorea obtusa*	
	Ficus superba		
	Irvingia malayana		
	Macropanax dispermus		
	Morus macroura		
	Saurauia roxburghii		
	Schleichera oleosa		
	Sindora siamensis		
	Terminalia bellirica		
	Terminalia chebula		
	Terminalia mucronata		
	Vaccinium sprengelii		

Table 10. Effects of nursery and natural forest gaps condition on seed germination of 30 tree species.

Species	Nusery			Gaps					Nusery		Gaps				Nusery		Gaps			
	%germ[a]	mean[b]	SD	%germ[a]	mean[b]	SD	2-tail sig[c]	Significant	MLD[e]	SD	MLD[e]	SD	2-tail sig[c]	Significant	GP[f]	SD	GP[f]	SD	2-tail sig[c]	Significant
Acrocarpus fraxinifolius	3	1	1.7	1	0	0.6	0.561	NS	45	-	22	-	-	-	44	-	1	-	-	-
Afzelia xylocarpa	9	3	2.3	19	7	0.6	0.072	NS	36	4.0	42	0.0	0.072	NS	15	15.8	10	2.3	0.617	NS
Albizia chinensis	4	1	0.0	11	3	0.6	0.007	**	30	21.7	53	33.2	0.372	NS	1	0.0	128	78.1	0.048	*
Aporusa villosa	92	22	1.0	78	19	3.8	0.214	NS	24	5.1	15	2.3	0.062	NS	19	0.6	20	1.7	0.561	NS
Betula alnoides	19	7	2.6	21	8	8.1	0.899	NS	33	1.5	95	8.5	0.000	***	14	16.4	2	1.7	0.266	NS
Cassia fistula	0	0	0.0	11	4	3.6	0.127	NS	-	-	25	5.7	-	-	-	-	50	5.0	-	-
Debregeasia longifolia	94	34	1.7	22	8	6.2	0.002	**	20	4.9	159	0.0	0.000	***	51	5.3	5	7.5	0.001	***
Diospyros undulata	43	10	1.5	50	12	2.0	0.315	NS	18	0.0	21	0.0	-	-	5	2.3	15	0.0	0.002	**
Elaeocarpus lanceifolius	31	11	5.1	62	22	4.9	0.055	NS	75	8.4	137	7.5	0.001	***	60	12.4	12	9.2	0.006	**
Elaeocarpus prunifolius	0	0	0.0	0	0	0.0	none	-	-	-	-	-	-	-	-	-	-	-	-	-
Eurya acuminata	68	24	1.2	28	10	3.6	0.003	**	23	3.6	41	22.1	0.229	NS	33	14.7	14	0.0	0.089	NS
Ficus lamponga	80	29	2.9	27	10	3.5	0.002	**	17	0.0	58	5.3	0.000	***	24	5.5	4	4.6	0.008	**
Ficus hirta	20	7	4.6	4	1	0.6	0.089	NS	19	4.0	31	1.7	0.009	**	16	12.9	27	4.6	0.214	NS
Ficus superba	87	31	2.5	18	6	6.5	0.003	**	11	0.0	64	2.1	0.000	***	10	4.6	9	11.3	0.929	NS
Glochidion acuminatum	19	7	6.2	12	4	4.2	0.572	NS	168	11.3	105	127.2	0.556	NS	136	21.2	20	20.6	0.009	**
Irvingia malayana	83	30	1.0	18	6	1.5	0.000	***	86	5.6	29	4.0	0.000	***	63	7.6	33	13.7	0.031	*
Lagerstroemia speciosa	27	10	3.5	54	19	4.6	0.045	*	101	5.5	139	4.6	0.001	***	60	26.7	15	7.5	0.049	*
Macropanax dispermus	67	24	1.0	31	11	7.0	0.033	*	28	2.9	108	8.5	0.000	***	24	2.5	7	6.7	0.014	**
Morus macroura	97	35	1.7	60	22	2.9	0.002	**	13	2.3	47	4.6	0.000	***	21	8.9	19	0.0	0.717	NS
Reevesia pubescens	73	26	1.5	4	1	1.5	0.000	***	7	0.0	10	0.0	-	-	18	8.1	17	21.9	0.934	NS
Saurauia roxburghii	17	4	2.6	50	12	6.1	0.105	NS	25	1.7	21	5.2	0.275	NS	5	0.6	47	4.7	0.000	***
Schleichera oleosa	18	4	2.1	62	16	8.1	0.078	NS	260	7.1	264	13.9	0.656	NS	90	107.9	187	111.8	0.339	NS
Shorea obtusa	83	30	2.6	44	16	8.1	0.044	*	7	0.6	14	7.5	0.152	NS	3	0.6	14	0.0	0.000	***
Sindora siamensis	28	10	1.7	21	8	3.2	0.330	NS	38	14.0	32	12.7	0.611	NS	87	17.2	21	13.5	0.093	NS
Terminalia mucronata	11	4	2.6	19	7	2.1	0.242	NS	24	4.5	20	5.7	0.394	NS	12	5.9	16	4.6	0.406	NS
Terminalia bellirica	91	33	2.3	81	29	7.0	0.438	NS	23	1.2	38	12.1	0.111	NS	23	8.5	35	2.9	0.077	NS
Terminalia chebula	3	1	1.7	1	0	0.6	0.561	NS	27	-	35	-	-	-	6	-	1	-	-	-
Tetradium glabrifolium	4	1	0.6	42	15	7.6	0.035	*	39	16.0	72	0.0	0.023	*	32	54.3	30	20.0	0.948	NS
Trema orientalis	6	2	0.0	5	2	0.6	0.374	NS	190	40.1	100	111.8	0.260	NS	51	69.4	61	103.9	0.900	NS
Vaccinium sprengelii	51	12	1.2	50	12	3.0	0.866	NS	19	2.3	25	2.3	0.024	*	27	20.2	13	2.3	0.320	NS

[a] The average percented of seed germination on 3 replication

[b] The average mean number of seed germination on 3 replication number of seed germination in nursery and natural forest gaps

[c] 2-tail sig of equal variances of independent-sample t test on the mean

[d] significant differences of t-test (*** p<0.001, ** p<0.01, * p<0.05; NS, not significant)

[e] The averaged median length of dormancy (days) across 3 reps. of seed germination on 3 replication.

[f] The averaged germination period (days)

Table 11. Effect of seed germination in the nursery and in the gap of 30 forest tree species.

Better in gap (5 species)	No difference (11 species)	Better in nursery (14 species)
Albizia chinensis	*Acrocarpus fraxinifolius*	*Betula alnoides*
Elaeocarpus lanceifolius	*Afzelia xylocarpa*	*Debregeasia longifolia*
Tetradium glabrifolium	*Aporusa villosa*	*Diospyros undulata*
Glochidion acuminatum	*Cassia fistula*	*Eurya acuminata*
Lagerstroemia speciosa	*Elaeocarpus prunifolius*	*Ficus hirta*
	Schleichera oleosa	*Ficus lamponga*
	Sindora siamensis	*Ficus superba*
	Terminalia mucronata	*Irvingia malayana*
	Terminalia bellirica	*Macropanax dispermus*
	Terminalia chebula	*Morus macroura*
	Trema orientalis	*Reevesia pubescens*
		Saurauia roxburghii
		Shorea obtusa
		Vaccinium sprengelii

Table 12. Treatments analysis.

Species	Family	Seed Size	Inte-gument	Germ. (%)	MLD (days)	GP (days)	Best Treatments	Dormancy
Acrocarpus fraxinifolius	Leguminosae	medium	thick testa	90	4	5	scarification (scar.)	dormancy
Afzelia xylocarpa	Leguminosae	large	thick testa	96	30	18	scar.+soaking (soak.)	dormancy
Albizia chinensis	Leguminosae	medium	thick testa	96, 93	3	11, 6	scar., scar.+soak	dormancy
Aporusa villosa	Euphorbiaceae	medium	arill testa	92	24	19	control	non
Betula alnoides	Betulaceae	small	pericarp	19	33	14	control	dormancy
Cassia fistula	Leguminosae	medium	thick testa	98, 94	7, 6	9, 6	acid 10 mins., scar+soak	dormancy
Debregeasia longifolia	Urticaceae	small	testa	94	20	51	control	non
Diospyros undulata	Ebenaceae	large	testa	43	18	5	control	non
Elaeocarpus lanceifolius	Elaeocarpaceae	large	endocarp	83, 75	30, 29	41, 50	scar.+soak, scar.	dormancy
Elaeocarpus prunifolius	Elaeocarpaceae	large	endocarp	47, 44	29, 27	30, 32	scar., scar.+soak	dormancy
Eurya acuminata	Theaceae	small	testa	68	23	33	control	non
Ficus hirta	Moraceae	small	testa	20	19	16	control	non
Ficus lamponga	Moraceae	small	testa	80	17	24	control	non
Ficus superba	Moraceae	small	testa	87	11	10	control	non
Glochidion acuminatum	Euphorbiaceae	medium	arill testa	38	90	172	acid 5 mins.	dormancy
Irvingia malayana	Irvingiaceae	large	endocarp	96	95	48	heat	dormancy
Lagerstroemia speciosa	Lythraceae	medium	wing	89, 78	86, 94	71, 75	acid 3 mins., soak.	dormancy
Macropanax dispermus	Araliaceae	medium	testa	67	28	24	control	non
Morus macroura	Moraceae	small	testa	99	7	5	acid 1 min.	non
Reevesia pubescens	Sterculiaceae	medium	wing	91	21	18	acid 3 mins.	non
Saurauia roxburghii	Saurauiaceae	small	testa	43, 38	35, 28	29, 41	soak., acid 3 mins.	non
Schleichera oleosa	Sapindaceae	large	testa	18	260	90	control	dormancy
Shorea obtusa	Dipterocarpaceae	medium	pericarp	83	7	3	control	non
Sindora siamensis	Leguminosae	large	thick testa	74, 61	22	5, 6	scar., scar.+soak	dormancy
Terminalia bellirica	Combretaceae	large	endocarp	100	17	20	soak.	dormancy
Terminalia chebula	Combretaceae	large	endocarp	42, 46	18, 21	18, 20	acid 5, 10 mins.	non
Terminalia mucronata	Combretaceae	large	pericarp	38	16	27	scar.	non
Tetradium glabrifolium	Rutaceae	medium	thick testa	41	25, 57	76, 96	acid 10, 5 mins.	non
Trema orientalis	Ulmaceae	small	endocarp	98	149	150	acid 3 mins.	dormancy
Vaccinium sprengelii	Ericaceae	small	testa	51	19	27	control	non

Table 13. Effected of shade, and nursery and gap analysis.

Species	Seed size	Dispersal time	Dispersal Method	Pioneer/ climax	Shade effect	Nursery/ Gap
Acrocarpus fraxinifolius	medium	Early wet	wind	DSGpioneer	tolerant	no difference
Afzelia xylocarpa	large	dry-eary wet	animal	climax	tolerant	no difference
Albizia chinensis	medium	late wet-late dry	wind	pioneer	mix results	gap
Aporusa villosa	medium	eary wet	animal	climax	tolerant	no difference
Betula alnoides	small	late dry	wind	climax	tolerant	nursery
Cassia fistula	medium	eary dry-late dry	animal	climax	mix results	no difference
Debregeasia longifolia	small	eary dry	animal	pioneer	inhibited	nursery
Diospyros undulata	large	eary wet-late wet	animal	climax	tolerant	nursery
Elaeocarpus lanceifolius	large	eary dry	animal	climax/pioneer	dependent	gap
Elaeocarpus prunifolius	large	late wet	animal	climax	tolerant	no difference
Eurya acuminata	small	late dry	animal	pioneer	inhibited	nursery
Ficus hirta	small	late wet	animal	pioneer	inhibited	nursery
Ficus lamponga	small	late dry-eary wet, late wet	animal	climax	inhibited	nursery
Ficus superba	small	late dry, late wet	animal	pioneer	tolerant	nursery
Glochidion acuminatum	medium	late wet	animal	pioneer	inhibited	gap
Irvingia malayana	large	late wet-eary dry	animal	climax	tolerant	nursery
Lagerstroemia speciosa	medium	late wet-eary dry	wind	climax	inhibited	gap
Macropanax dispermus	medium	eary dry-late dry	animal	climax	tolerant	nursery
Morus macroura	small	late dry-eary wet	animal	climax	tolerant	nursery
Reevesia pubescens	medium	eary dry-late dry	wind	pioneer	mix results	nursery
Saurauia roxburghii	small	late wet	animal	DSGpioneer	tolerant	nursery
Schleichera oleosa	large	late wet	animal	climax	tolerant	no difference
Shorea obtusa	medium	eary wet	wind	climax	inhibited	nursery
Sindora siamensis	large	late wet- eary dry-late dry	animal	climax	tolerant	no difference
Terminalia bellirica	large	eary dry-late dry	animal	climax	tolerant	no difference
Terminalia chebula	large	eary dry-late dry	animal	climax	tolerant	no difference
Terminalia mucronata	large	late wet-eary dry-late dry	wind	climax	tolerant	no difference
Tetradium glabrifolium	medium	late wet-eary dry	animal	climax	tolerant	gap
Trema orientalis	small	late wet-eary dry	animal	pioneer	mix results	no difference
Vaccinium sprengelii	small	eary wet	animal	climax	tolerant	nursery

CHAPTER 4

The Effects of Seed Predation on Germination Success

Abstract

This study was carried out to determine the effects of predation on seed germination and which tree species might be suitable for successful direct seeding to restore degraded forestland. Thirty species were tested in a natural forest gap. Seeds were buried in loosened soil under wire cages (49 x 32 x 12 cm^3, 1.1 x 1.3 cm diameter squares) and in plots without wire cages (non-caged) with 3 replications (36 seeds or 24 per replicate). Seeds were monitored for germination and removal by predators weekly for one year. Enclosure of predators by cages increased seed germination only of *Irvingia malayana*. Five species had significantly higher germination outside cages (*Albizia chinensis*, *Macropanax dispermus*, *Shorea obtusa*, *Terminalia bellirica*, and *Terminalia chebula*). Caging seeds had no significant effects on medium length of dormancy (MLD) and germination period (GP) for all species. The mean number of seeds removed was highest for *Elaeocarpus prunifolius*, *Irvingia malayana* (100%), but this value was not significantly different from *Reevesia pubescens* and *Terminalia chebula*. The impact of seed predation on seed germination varied among species, seed size and seed coat. Legumes with tough and thick testas, such as *Afzelia xyocarpa and Albezia chinensis*, tended to be less affected by seed predation. Seven tree species were found favorable for direct seeding *viz. Saurauia roxburghii*, *Vaccinium sprengelii*, *Morus macroura*, *Lagerstroemia speciosa*, *Aporusa villosa*, *Diospyros undulata*, and *Schleichera oleosa*. These species had high germination percentage, no seed predation and low MLD and GP in the forest gap.

4.1 Introduction

Direct seeding into deforested areas is potentially a cheaper and more rapid method of forest restoration than planting trees. This method originally developed in Europe and

North America and now is being increasingly considered for the restoration of tropical forest (Li and Zhang, 1995; Sun and Dickinson, 1995; Hardwick, 1999). However, there are few reported cases in the tropics of direct seeding having been successfully implemented on a large scale to restore degraded forestlands (Hau, 1999; Hardwick, 1999). This might be because seed predation in cleared areas significantly limits seed germination (Sharp, 1995; Blate *et al.*, 1998; Woods, 2001; Hau, 1999; Janzen, 1971). Small mammals and ants are typical seed predators (Woods, 2001; Hardwick, 1999; Sharp, 1995; Nepstad *et al.*, 1990). Seed size, seed traits and species' characteristics are related to the vulnerability of a seed species to seed predators. Nepstad *et al.* (1990) showed that small seeds are more vulnerable to ants than larger ones. Furthermore, predation rates are negatively associated with the thickness and hardness of the seed coat (Blate *et al.* (1998) and large seeds are affected more from seed predation than small seeds (Mack, 1998). In contrast, Hardwick (1999) found that seed weight and size did not correlate with predation rates. Hammond *et al.* (1999) found that seed predation is negatively correlated with the mean length of seasonal dormancy. Several authors have reported that environmental conditions are more important than seed predation in limiting forest regeneration (Hardwick, 1999; Hammond, *et al.*, 1999; Sharp, 1995). High levels of solar radiation in large clearings increase soil and air temperatures and decrease soil moisture content. Some with hard testas (for instance *Symphonia globulifera)* are resistant to high temperatures and may even require them for germination (Hardwick, 1999). The effect of drought on germination is not related to the length of time that a seed is exposed to drought between seed dispersal and germination (Hardwick, 1999).

Seeds may fail to develop into seedlings because they are destroyed by predators before they can germinate. If seeds avoid predation, they may fail to germinate because of the environmental conditions or problems with embryo. Sharp (1995) tested seed predation on Doi Suthep and found 75% of all seeds were predated by three different species of rodents. Seed predation rates in a gap and in nearby forest did not differ significantly. Environmental conditions seemed to be more important than seed predation in limiting forest regeneration. Hardwick (1999) tested the effects

of seed predation on germination in an old clearing in Doi Suthep-Pui National Park. She found that seed predation is a significant limiting factor in cleared areas. In general, the level of predation is not related to seed size, but is related to length of seasonal dormancy. Woods (2001) studied the prevalence of seed predation on seeds subjected to different treatments in the field to determine which treatments best prevent seed predation at FORRU's 2000 planting plots near Ban Mae Sa Mai in the northern part of Doi Suthep-Pui National Park. He reported that most seed predators were ants and their effects varied among seed species. He suggested that successful direct seeding can be best attained using species with a high germination percent, low MLD, and a tough/thick seed coat.

Therefore, the main focus of this experiment was to test seeds of which tree species are most suitable for successful direct seeding and to study the effects of seed predators on seed germination in natural forest gaps.

4.2 Materials and Methods

4.2.1 Study Sites

The dates of sowing seeds were present in Table 14. This study was conducted in natural forest gaps near FORRU's research nursery in Doi Suthep-Pui National Park Headquarters (18^0 51 'North, latitude and 98^0 54 'East, longitude) at about 1000 m elevation, in a transitional zone between mixed evergreen-deciduous forest and evergreen forest. All seeds were prepared at the FORRU nursery before sowing in the plots. Seeds were planted in a gap (about 15.75 x 15 m^2).

4.2.2 Experimental Design

After collection, fruits of each species were brought back to FORRU's research nursery and the seeds extracted and cleaned with water, before drying, to facilitate pulp removal. Seeds were then air-dried overnight or sometimes for 1 to 2 days,

depending on the species. For the ten species with small seeds, an ant repellent was applied before sowing the seeds. Seeds were planted in plots under wire cages (49 x 32 x 12 cm^3, 1.1 x 1.3 cm diameter squares) and without wire cages (non-caged) with 3 replications (36 seeds or 24 seeds per replicate). Weeds were dug up and placed to the side. Seeds were monitored for germination and removal by predators weekly for one year. The percentage seeds removed over 365 days was compared among the 30 species by one-way ANOVA. T-tests (independent samples), were used to determine the effects of cages on seed germination, MLD, and GP using the SPSS computer program.

Germination trials were carried out on 30 species which were selected to represent 3 different seed size classes (small, medium and large). Their characteristics are listed in Table 15. For each species, 108 seeds (3 replicate batches of 36 were sown) or 72 seeds (3 replicate batches of 24 were sown) were divided into three replicate batches of 36 (except, 24 seeds for *Schleichera oleosa*, *Diospyros undulata*, *Aporusa villosa*, *Albizia chinensis*, *Saurauia roxburghii* and *Vaccinium sprengelii*). Seeds were planted in caged plots (49 x 32 cm^2) to prevent seed predation by small mammals. Seeds were protected from ant predation by being sprayed with an insecticide for small seed group. Twenty seeds were saved for measurements of mass and seed dimensions (Table 14). Small seeds defined as those weighing less than 0.01g, medium seeds were between 0.01 to 0.2 g and large seeds were those that weighed more than 0.2 g (fresh weights, including seed coat).

4.3 Results

4.3.1 Effects of Cages on Seed Removal

Rates of seed removal ranged from 0% to 100% (Table 14) and were highly dependent on seed size. All tree species having the smallest seed size class had zero predation, whereas 60% of species in the large seed size class had predation rates of >60%. Notable exceptions in the large seed size class were *Diospyros undulata*, *Schleichera*

oleosa, and *Afzelia xylocarpa* which had zero predation. In the medium seed size class, 6 species (60%) had predation rates of 0 to 0.7% whilst the others had predation rates ranging from 50 to 91%. One-way ANOVA among the large seed size group showed that the mean number of seeds removed was highest for *Elaeocarpus prunifolius* and *Irvingia malayana* (36 seeds), but this result was not significantly higher than for *Terminalia chebula* (32 seeds) ($df = 9$, $F=0.0000$, $p<0.05$). Among the medium sized seeds the mean number of seeds removed was significantly the highest for *Reevesia pubescens* (33 seeds) ($df = 9$, $F= 0.0000$, $p<0.05$). Seven species in the large seed size class suffered predation, whilst only 5 species in the medium size seed class were predated and none of the small seed size species. Altogether, seeds of twelve tree species were predated and the rest (18 species) were totally ignored by seed predators. One-way ANOVA (Table 15) showed the mean number of seeds removed was the highest for *Elaeocarpus prunifolius* and *Irvingia malayana* (36 seeds), this did not differ significantly from *Reevesia pubescens* (33 seeds) and *Terminalia chebula* (32 seeds) ($df = 29$, $F = 0.0000$, $p<0.05$).

4.3.2 Effects of Cages on Seed Germination

Mean germination percentage in caged and non-caged plots is presented in Table 16. All tree species germinated in the forest gap to some extent, except *Elaeocarpus prunifolius*. Seed germination was low in *Shorea obtusa*, due to larvae infestation, and in *Diospyros undulata*, due to mould. For most species, the caging treatment had no effect on germination percentage, but for *Irvingia malayana* caging significantly increased germination, ($df = 4$, 2-tail sig = 0.002) whilst for *Albizia chinensis* ($df = 4$, 2-tail sig = 0.013), *Macropanax dispermus* ($df = 4$, 2-tail sig = 0.003), *Shorea obtusa* ($df = 4$, 2-tail sig = 0.012), *Terminalia bellirica* ($df = 4$, 2-tail sig = 0.000), and *Terminalia chebula* ($df = 4$, 2-tail sig = 0.000)] caging significantly reduced germination percentage.

4.3.3 Effects of Seed Predation on Seed Germination

Predation did not have a significant effect on final germination percentage, except for *Terminalia bellirica* and *Irvingia malayana*. Predation significantly reduced germination percentage of *Terminalia bellirica* (df = 4, 2-tail sig = 0.038) and *Irvingia malayana* (df = 4, 2-tail sig = 0.002) Although predators did not remove *Albizia chinensis* seeds, the non-caged treatment had significantly higher germination than caged seeds (df = 4, 2-tail sig = 0.013).

Thus, seven species are probably suitable for direct seeding in the field without protecting seeds from predators: *Aporusa villosa*, *Diospyros undulata*, *Lagerstroemia speciosa*, *Morus macroura*, *Saurauia roxburghii*, *Schleichera oleosa*, and *Vaccinium sprengelii*. These species have high percentage germination and low rate of predation.

4.4 Discussion

4.4.1 The Effects of Seed Predators on Seed Germination in Natural Forest Gaps

Rates of seed removal were highly dependent on seed size. Large seeds contain high nutrition but also emit more volatile chemicals and are more easily detected by sight. Seven species with large seeds and five species with medium-sized seeds effected removal percentage by predation, except small seed group was not affected. May due to small seeds with poor nutrition and be more difficulty detected by sight. Burial of medium and large seeds of some species did not protect them from predators, but burial probably protect them from environmental extremes. However, burial of small seeds may have helped protect them from ant predation. All small seeds (0.0001 to 0.0014 g) were not predated by ants. Buried seeds may have been difficult to find by ants, as noted by Reader (1993). One medium (*Cassia fistula*) and one large seed species (*Sindora siamensis*) were eaten by snails when seed swelling and pushing over the soil, but had the lowest percentage seed removal (1-2%). However, medium sized seed species [*e.g. Macropanax dispermus*] were predated up to 65%. It due to the

flavor of seeds to attack predator as noted by Woods (2001). Woods noted that only rats and squirrels were able to find and eat seeds below the soil surface by olfactory cues and ants do not predate seeds below the soil surface. Therefore, large and medium sized seeds had higher rate of predation than small seeds and squirrels were found to be the major seed predator near FORRU (direct observation). Sharp (1995) reported that small mammals were about three times more abundant in a large clearing than in the adjacent forest understory. Seed survival is also very dependent on the behavioral responses of individual small mammals and their microhabitat preferences.

On the other hand, predators choose to attack seeds on the basis of characteristics other than seed size and seed mass. For example, *Acrocarpus fraxinifolius*, medium-sized seeds, were predated when the testa softened before germination. Also, the soft, medium-sized wing seeds of *Reevesia pubescens* and *Shorea obtusa* (fruits) were most preferred by predators. Six species with large-sized seeds were most preferred by predators (*Elaeocarpus prunifolius*, *Elaeocarpus lanceifolius*, *Irvingia malayana*, *Terminalia chebula*, *Terminalia mucronata* and *Terminalia bellirica*). Due to their seeds have more food reserve (total calories) per seed available, as noted by Wood (2001). On the other hand, *Afzelia xylocarpa* has large-sized seeds, which predators ignored. They may have been because they have a tough/thick testa and no odor (difficult to eat by predator). Also, *Schleichera oleosa* was not predators, due to its seed coat or seed may be protected by chemical defenses.

Seed predation may be related to the length of dormancy, which agrees with Hardwick (1999). Hardwick (1999) reported the amount of predation at Doi Suthep-Pui National Park was positively related to length of dormancy. For example, all seeds of *Irvingia malayana*, all of seeds were predated before germination (90 days after sowing). On the other hand, seed of three species with a hard testa (*Acrocarpus fraxinifolius*, *Cassia fistula*, and *Sindora siamensis*) were predated when their testas swelled and softened just before germination.

4.4.2 Seed Species Favorable for Successful Direct Seeding

Seven species (*Saurauia roxburghii*, *Vaccinium sprengelii*, *Morus macroura*, *Lagerstroemia speciosa*, *Aporusa villosa*, *Diospyros undulata*, and *Schleichera oleosa*) had a high percentage of germination (46-82%) outside cages. Six species of these were dispersed by animals and only *Lagerstroemia speciosa* by wind. Seeds of six species were dispersed in the wet season and *Lagerstroemia speciosa* was dispersed in the dry season. Successful direct seeding can be best attained using species with a high germination percentage, low or no predator, low MLD and GP. Therefore, five of the seven species are probably suitable for direct seeding. The remaining two species (*Lagerstroemia speciosa* and *Schleichera oleosa*), although they had high germination percentages, they also had high MLD and/or high GP. Seeds of *Lagerstroemia speciosa* were dispersed by wind in the dry season, whilst *Schleichera oleosa* seeds were dispersed by animals in the wet season. Predators were not found for *Albizia chinensis* and non-caged seeds had significantly higher germination than caged ones (df= 4, 2-tail sig = 0.013), and both conditions had low germination percentages. Thus, this species was not suitable for direct seeding in natural forest gaps, except when seeds are scarified before direct sowing, as noted by Wood (2001) and Schmidt (2000). Sosef *et al.* (1998) reported that direct seeding is often done for *Albizia chinensis* with 5-10 seeds per planting hole. This species is also very sensitive to root disturbance and cannot be easily grown in nurseries (Sosef *et al.*, 1998; Schmidt, 2000). Seeds of *Albizia chinensis, Acrocarpus fraxinifolius, Cassia fistula, Sindora siamensis*, and *Afzelia xylocarpa* and some orthodox seeds species can be stored for a long time without serious decline in viability (Willan, 1984; Sosef *et al.*, 1998), but also cutting propagation can be used (Sosef *et al.*, 1998). My results showed that seed dormancy, environmental conditions and seed predation are the three main factors limiting seed germination in natural forest gaps.

Further research on direct seed sowing should use ample space between each seed, because when 36 or 24 seeds were planted in limited area survival and growth of seedlings may be limited, due to competition for nutrients and light, *etc.* Also seeds

are easy to find by predators if they are grouped together. Seeds of some orthodox species should pre-treated (*e.g.* acid treatment, scarification) before sowing in natural forest gap to accelerate germination or can be stored and/or pre-treatment before sowing in the rainy season.

Table 14. Mean percentage seed removal (n=3) of forest tree species placed in evergreen forest on Doi Suthep-Pui National Park over 365 days. Species not sharing same letters in LSD column had significantly different rates of seed predation.

Species	Family	seed mass (g)		seed size	date of	noncage (seed removal)				
		mean	SD	group	sowing	%	mean	SD	LSD	SD*
Betula alnoides	Betulaceae	0.00009	-	small	20/3/2001	0.00	0	0	f	
Debregeasia longifolia	Urticaceae	0.0001	-	small	15/12/2000	0.00	0	0	f	
Saurauia roxburghii	Saurauiaceae	0.00009	-	small	25/8/2000	0.00	0	0	f	
Ficus lamponga	Moraceae	0.00010	-	small	1/4/2001	0.00	0	0	f	
Eurya acuminata	Theaceae	0.00015	-	small	5/5/2001	0.00	0	0	f	
Ficus superba	Moraceae	0.00017	-	small	21/9/2001	0.00	0	0	f	
Ficus hirta	Moraceae	0.00021	-	small	19/3/2001	0.00	0	0	f	
Vaccinium sprengelii	Ericaceae	0.0003	-	small	2/6/2000	0.00	0	0	f	
Morus macroura	Moraceae	0.00047	-	small	14/6/2001	0.00	0	0	f	
Trema orientalis	Ulmaceae	0.00140	0.0010	small	7/10/2000	0.00	0	0	f	
Tetradium glabrifolium	Rutaceae	0.0110	0.0030	medium	12/3/2001	0.00	0	0	f	d
Macropanax dispermus	Araliaceae	0.0199	0.003	medium	7/2/2001	64.81	23.333	8.386	de	bc
Lagerstroemia speciosa	Lythraceae	0.0223	0.005	medium	1/1/2001	0.00	0	0	f	d
Albizia chinensis	Leguminosae	0.03010	0.0640	medium	18/5/2000	0.00	0	0	f	d
Acrocarpus fraxinifolius	Leguminosae	0.0337	0.003	medium	17/8/2001	50.00	18.000	2.000	e	c
Glochidion acuminatum	Euphorbiaceae	0.0456	0.005	medium	26/9/2000	0.00	0	0	f	d
Reevesia pubescens	Sterculiaceae	0.0493	0.005	medium	17/11/2000	90.74	32.667	3.512	ab	a
Shorea obtusa	Dipterocarpaceae	0.05960	0.05439	medium	13/5/2001	76.85	27.233	4.676	bcd	b
Aporusa villosa	Euphorbiaceae	0.12230	0.01742	medium	15/5/2000	0.00	0	0	f	d
Cassia fistula	Leguminosae	0.16690	0.02500	medium	25/9/2000	0.93	0.333	0.577	f	d
Elaeocarpus prunifolius	Elaeocarpaceae	0.35240	0.06400	large	9/10/2001	100.0	36.000	0.000	a	a
Terminalia mucronata	Combretaceae	0.3720	0.113	large	29/3/2001	73.15	26.333	7.371	cd	bc
Diospyros undulata	Ebenaceae	0.57190	0.20000	large	17/8/2000	0.00	0	0	f	d
Schleichera oleosa	Sapindaceeae	0.70660	0.08800	large	15/8/2000	0.00	0	0	f	d
Sindora siamensis	Leguminosae	2.1258	0.4500	large	14/6/2001	1.85	0.667	0.577	f	d
Terminalia chebula	Combretaceae	2.39280	0.28400	large	13/6/2001	87.96	31.667	3.512	abc	ab
Elaeocarpus lanceifolius	Elaeocarpaceae	2.54590	0.4520	large	15/1/2001	62.97	22.667	11.590	de	c
Terminalia bellirica	Combretaceae	2.89220	0.28700	large	25/5/2001	68.52	24.667	7.095	d	bc
Irvingia malayana	Irvingiaceae	5.30120	0.59900	large	8/1/2001	100.0	36.000	0.000	a	a
Afzelia xylocarpa	Leguminosae	6.2026	2.009	large	27/6/2001	0.00	0	0	f	d

LSD*= Significant difference at the 0.05 confidence level of the seed removal roithin seed size group (same letter within column were not significantly).

Table 15. Mean percentage seed germination in caged and non-caged plots.

Species	Dispersal method	Mean[A] (non-caged)			Mean[B] (caged)			LSD (A-B)	Overall[C] (non-caged)			LSD (B-C)
		mean	SD	%	mean	SD	%		mean	SD	%	
Betula alnoides	wind	7.67	8.96	21	7.67	8.08	21	ns	7.67	8.96	21	ns
Debregeasia longifolia	animal	11.67	1.16	32	8.00	6.25	22	ns	11.67	1.16	32	ns
Saurauia roxburghii	animal	11.00	6.93	46	12.00	6.08	50	ns	11.00	6.93	46	ns
Ficus lamponga	animal	12.00	1.73	33	9.67	3.51	27	ns	12.00	1.73	33	ns
Eurya acuminata	animal	10.00	3.61	28	10.00	3.61	28	ns	10.00	3.61	28	ns
Ficus superba	animal	6.00	6.25	17	6.33	6.51	18	ns	6.00	6.25	17	ns
Ficus hirta	animal	2.00	1.73	6	1.33	0.58	4	ns	2.00	1.73	6	ns
Vaccinium sprengelii	animal	12.67	2.52	53	12.00	3.00	50	ns	12.67	2.52	53	ns
Morus macroura	animal	18.33	10.41	51	21.67	2.89	60	ns	18.33	10.41	51	ns
Trema orientalis	animal	1.00	1.73	3	1.67	0.58	5	ns	1.00	1.73	3	ns
Tetradium glabrifolium	animal	8.33	10.12	23	15.00	7.55	42	ns	8.33	10.12	23	ns
Macropanax dispermus	animal	36.00	0.00	100	11.00	7.00	31	**	12.60	8.32	35	ns
Lagerstroemia speciosa	wind	17.67	8.02	49	19.33	4.62	54	ns	17.67	8.02	49	ns
Albizia chinensis	wind	6.67	1.53	28	2.67	0.58	11	**	6.67	1.53	28	**
Acrocarpus fraxinifolius	wind	2.17	2.26	6	0.33	0.58	1	ns	1.08	1.01	3	ns
Glochidion acuminatum	animal	6.00	4.58	17	4.33	4.16	12	ns	6.00	4.58	17	ns
Reevesia pubescens	wind	3.33	3.51	9	1.33	1.53	4	ns	3.33	3.51	9	ns
Shorea obtusa	wind	36.00	0.00	100	15.67	8.15	44	**	8.28	5.74	23	ns
Aporusa villosa	animal	19.67	3.79	82	18.67	3.79	78	ns	19.67	3.79	82	ns
Cassia fistula	animal	2.35	2.51	7	4.00	3.61	11	ns	2.16	2.24	6	ns
Elaeocarpus prunifolius	animal	0.00	0.00	0	0.00	0.00	0	N	0.00	0.00	0	N
Terminalia mucronata	wind	36.00	0.00	100	29.00	7.00	19	ns	9.72	7.31	27	ns
Diospyros undulata	animal	11.00	2.65	46	12.00	2.00	50	ns	11.00	2.65	46	ns
Schleichera oleosa	animal	18.00	4.00	75	15.67	8.08	62	ns	18.00	4.00	75	ns
Sindora siamensis	animal	10.51	2.88	29	7.67	3.22	21	ns	10.51	2.88	29	ns
Terminalia chebula	animal	36.00	0.00	100	6.67	2.08	1	***	4.32	3.53	12	ns
Elaeocarpus lanceifolius	animal	13.33	11.59	37	22.33	4.93	62	ns	13.33	11.59	37	ns
Terminalia bellirica	animal	36.00	0.00	100	0.33	0.58	81	***	11.16	7.33	31	*
Irvingia malayana	animal	0.00	0.00	0	6.33	1.53	18	**	0.00	0.00	0	**
Afzelia xylocarpa	animal	5.67	2.08	16	6.67	0.58	19	ns	5.67	2.08	16	ns

Mean %[A] germination of non-predated seeds in non-caged plots; Mean %[B] germination of cage seeds;
Mean %[C] germination of all seeds sownin non N=have no germination

LSD(A-B)= Significant difference at the 0.05 confidence level of effect of cage
(same letter within column were not significantly).

LSD(B-C)= Significant difference at the 0.05 confidence level of effect of predation
(same letter within column were not significantly).

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 16. Effects of caged and uncaged seeds germination in forest gap conditions.

Species	caged			uncaged			T-Test		caged		uncaged		T-Test		caged		uncaged		T-Test	
	%germ	mean	SD	%germ.	mean	SD	mean	LSD	MLD	SD	MLD	SD	MLD	LSD	GP	SD	GP	SD	GP	LSD
Betula alnoides	21	7.7	8.08	21	7.7	8.96	1.000	ns	95	8.51	95	8.51	1.0	ns	2	1.73	11	8.51	0.16	ns
Debregeasia longifolia	22	8.0	6.25	32	11.7	1.16	0.374	ns	159	0.00	163	7.51	0.4	ns	5.3	7.51	5.3	7.51	1.0	ns
Saurauia roxburghii	50	12.0	6.08	46	11.0	6.93	0.860	ns	21	5.20	29	17.6	0.5	ns	47	4.73	47	4.73	1.0	ns
Ficus lamponga	27	9.7	3.51	33	12.0	1.73	0.360	ns	58	5.29	57	4.62	0.9	ns	3.7	4.62	6.3	4.62	0.52	ns
Eurya acuminata	28	10.0	3.61	28	10.0	3.61	1.000	ns	41	22.1	35	7.51	0.7	ns	14	0.00	14	0.00	-	-
Ficus superba	18	6.3	6.51	17	6.0	6.25	0.952	ns	64	2.12	66	11.0	0.8	ns	9	11.3	8.7	13.3	1.0	ns
Ficus hirta	4	1.3	0.58	6	2.0	1.73	0.561	ns	31	1.73	34	5.13	0.3	ns	27	4.62	26	7.51	0.85	ns
Vaccinium sprengelii	50	12.0	3.00	53	12.7	2.52	0.783	ns	25	2.31	24	7.51	0.8	ns	13	2.31	13	0.00	0.37	ns
Morus macroura	60	21.7	2.89	51	18.3	10.4	0.621	ns	47	4.62	47	4.62	1.0	ns	19	0.00	16	4.62	0.37	ns
Trema orientalis	5	1.7	0.58	3	1.0	1.73	0.561	ns	100	112	228	-	0.4	ns	61	104	206	-	0.35	ns
Tetradium glabrifolium	42	15.0	7.55	23	8.3	10.1	0.412	ns	72	0.00	75	9.29	0.6	ns	30	20.0	11	16.2	0.28	ns
Macropanax dispermus	31	11.0	7.00	100	36.0	0.00	0.003	**	108	8.51	102	4.62	0.3	ns	6.7	6.66	10	12.3	0.7	ns
Lagerstroemia speciosa	54	19.3	4.62	49	17.7	8.02	0.771	ns	139	4.62	142	0.00	0.4	ns	15	7.51	16	5.69	1.0	ns
Albizia chinensis	11	2.7	0.58	28	6.7	1.53	0.013	**	53	33.2	29	14.0	0.3	ns	128	78.1	133	69.8	0.94	ns
Acrocarpus fraxinifolius	1	0.3	0.58	6	2.2	2.26	0.244	ns	22	-	20	2.83	0.7	ns	1	-	3	2.83	0.67	ns
Glochidion acuminatum	12	4.3	4.16	17	6.0	4.58	0.665	ns	105	127	105	127	1.0	ns	20	20.6	69	110	0.5	ns
Reevesia pubescens	4	1.3	1.53	9	3.3	3.5	0.417	ns	96	103.2	41	0.00	0.5	ns	17	21.9	1	0.00	0.42	ns
Shorea obtusa	44	15.7	8.15	100	36.0	0.00	0.012	**	14	7.51	10	0.00	0.4	ns	14	0.00	1	0.00	-	-
Aporusa villosa	78	18.7	3.79	82	19.7	3.79	0.763	ns	15	2.31	15	2.31	1.0	ns	20	1.73	20	1.73	1.0	ns
Cassia fistula	11	4.0	3.61	7	2.4	2.51	0.552	ns	25	5.66	18	15.6	0.6	ns	51	4.95	31	22.6	0.36	ns
Elaeocarpus prunifolius	0	0.0	0.00	0	0.0	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Terminalia mucronata	19	6.7	2.08	100	36.0	0.00	0.000	***	49	4.93	52	5.77	0.6	ns	16	4.62	11	8.00	0.37	ns
Diospyros undulata	50	12.0	2.00	46	11.0	2.65	0.629	ns	21	0.00	21	0.00	-	-	15	0.00	10	4.04	0.12	ns
Schleichera oleosa	62	15.7	8.08	75	18.0	4.00	0.677	ns	264	13.9	247	20.8	0.3	ns	187	112	197	111	0.92	ns
Sindora siamensis	21	7.7	3.22	29	10.5	2.88	0.317	ns	32	12.7	36	9.61	0.7	ns	21	13.5	40	25.2	0.31	ns
Terminalia chebula	1	0.3	0.58	100	36.0	0.00	0.000	***	35	-	31	10.4	0.8	ns	1	-	22	21.5	0.49	ns
Elaeocarpus lanceifolius	62	22.3	4.93	37	13.3	11.6	0.284	ns	137	7.51	141	0.00	0.5	ns	12	9.24	17	0.00	0.5	ns
Terminalia bellirica	81	29.0	7.00	100	36.0	0.00	0.158	ns	38	12.1	20	7.51	0.1	ns	35	2.89	28	12.1	0.35	ns
Irvingia malayana	18	6.3	1.53	0	0.0	0.00	0.002	**	29	4.00	-	-	-	-	33	13.7	-	-	-	-
Afzelia xylocarpa	19	6.7	0.58	16	5.7	2.08	0.468	ns	42	0.00	42	0.00	-	-	9.7	2.31	22	13.3	0.18	ns

CHAPTER 5

Vegetative Propagation of Ten Native Forest Tree Species

Abstract

Restoration of forest ecosystems by tree planting requires a large scale production of planting stock of a wide range of indigenous forest tree species, many of which have never been propagated before. Many of these species have proved difficult to propagate from seed, due to long dormancy periods or seed production too late for seedlings to grow large enough by planting time. Therefore, this chapter focuses on developing a novel cutting propagation technique, with simple, low-cost technology for those native forest tree species which are difficult to grow in nurseries from seed. The technique operates without using mist-spray. Ten species of native forest tree species were propagated by cuttings and placed in the same rooting media (sand: rice husk charcoal, 1:1v/v) with 50% shading. Various chemical treatments were tested to improve rooting success of the cuttings. The effects of various hormone treatments on leafy stem cuttings varied with each species. Seradix #2 produced the best results with *Eurya acuminata*, *Ficus lamponga* and *Ficus hirta*, while Seradix #3 was best with *Debregeasia longifolia* and *Saurauia roxburghii*. IBA 8000 ppm produced the best results with *Colona flagrocarpa*, and *Morus macroura*. IBA:NAA = 1:1 was the best with *Macaranga kurzii* and IBA:NAA = 2:1 or IBA 3000 ppm with *Ficus superba*. However, *Trema orientalis* cuttings rooted most efficiently without any hormone treatment and produced the highest relative performance scores. The species were divided into three broad classes according to comparisons among the species performance scores. *Debregeasia longifolia* had the highest performance. In the medium performance class were *Colona flagrocarpa*, *Ficus hirta*, *Ficus superba*, *Morus macroura*, *Saurauia roxburghii*, and *Trema orientalis*, whilst the low performance class included *Eurya acuminata*, *Ficus lamponga*, and *Macaranga kurzii*. Only *Colona flagrocarpa*, *Debregeasia longifolia*, *Morus macroura*, and

Saurauia roxburghii achieved maximum mean values greater than 60% of survival with roots and shoots.

5.1 Introduction

Despite treatments to increase germination some native forest tree species are difficult to grow from seed, (Hardwick and Elliott, 1992; Kopachon, 1995; Singpetch, 2001) and seedlings of some species grow too slowly to reach a plantable size by the beginning of the rainy season (Blakesley *et al.*, 2000). Vegetative propagation, by leafy stem cuttings, is a potential alternative for production of high quality and uniform planting stock for large-scale reforestation programmes. Generally, cuttings are the most popular method of vegetative propagation of economic tree species (*e.g.* eucalyptus, acacia, pines, teak, *etc.*) and timber species (*e.g.* Dipterocarpaceae) in tropical countries (Rashid *et al.*, 1986; Pong-anant and Wongmanee, 1990; Kantarli, 1993; Hidayat *et al.*, 1995; Ahmad *et al.*, 1998; Klunklin, 1998). Forest restoration programmes require large scale production of high quality planting stock of a wide range of native forest tree species. Many species have limited seed germination (FORRU, 2000; Schmidt, 2000). Propagation by cuttings offers an alternative means of producing planting stock. Mist-spray propagation systems are expensive to set up, compared with non mist-spray propagation systems (Aminah *et al.*, 1995; Klunklin, 1998). The low-technology, non-mist propagation system used by Leakey *et al.* (1990) and Newton *et al.* (1992) has proved successful in the propagation of many tropical timber species. This technique was modified by Kantarli in Thailand in 1993. Thimann and Delisle (1939) noted that successful rooting depends on the presence in cuttings of several cofactors. The effect of hormones on root development in cuttings varies with the type (IBA, NAA, IAA, *etc.*) and concentration of hormones (auxins) (Aminah *et al.*, 1995; Hidayat *et al.*, 1995; Ahmad *et al.*, 1998). Moreover, the presence of leaves on stem cuttings, the tree species, the rooting medium composition, and environmental factors (light intensity, air temperature, *etc.*), can all affect the success of cuttings development propagation (Poulsen and Andersen, 1980; Newton *et al.*, 1992a; Newton and Jones 1993; Aminah *et al.*, 1995; Hidayat *et al.*, 1995; Ahmad

et al., 1998). The aim of the experiments described here was to determine which factors determine the success of producing 10 native forest tree species from leafy stem cuttings, using polyethylene enclosures to provide high humidity.

5.2 Materials and Methods

5.2.1 Species Selection

A review of the information stored in the databases of the CMU Herbarium and FORRU was done to select native forest tree species which could not previously be germinated from seed. Ten native forest tree species (Table 17) were selected for propagation by cuttings. Propagation of leafy stem cuttings was carried out at FORRU's research nursery near the Headquarters of Doi Suthep-Pui National Park. A flow chart of cutting propagation is presented in Figure 35. Medium- sized twigs (juvenile stems) were selected as a source of cuttings. Stock trees were visited weekly, to determine whether they were ready to yield cuttings (see Chapter 2). Cuttings were harvested with a sharp pair of secateurs or a knife, kept in large sacks or black plastic bags, and taken immediately to FORRU's research nursery, where they were watered thoroughly before preparation.

Preparation of cuttings (40 leafy stem cuttings for each treatment)

cutting the base to the heel shape below a node, removing unwanted material (lower leaves, the fragile apical section, *etc.*)

↓

The cuttings were soaked in a dilute fungicide solution (Benlate) for 10 minutes.

↓

The bottom 5-10 mm of the fresh cut base cuttings were dipped in rooting hormone

(for 10 minutes with solution and quick drip with powder hormone).

Figure 35. The flow chart of cutting propagation.

↓

The cuttings were put in the cutting media; i) sand and rice husk charcoal mixed in the ratio 50:50 v/v., ii) a hole in the medium was made with a small stick (not too deep and about the same diameter as the cuttings).

↓

Ten small bags were contained in a big plastic bag (20 x 30")
about one litter water was added, the bags with a tied close, label (species, replication), checked for tears and water level weekly.

↓

Harvesting; collect data after three months or when rooting occurred
percentage of roots and/or shoots, vigour were analyzed, relative performance score, comparisons among species.

↓

Potting of rooted cuttings
cuttings were potted in a mixture of forest soil and organic matter, the ratio of forest soil, peanut husk and coconut husk was 2:1:1, ten potting bags were contained in the old big plastic bag (20x30") and were shaded inside the nursery for about 2 weeks, then take the old big plastic bag off and following shade in the nursery for about 2 weeks.

Figure 35. The flow chart of cutting propagation (continue).

5.2.2 Preparation of Leafy Stem Cuttings

A workplace was prepared in the nursery, with tools and materials ready for preparing the cuttings and auxins. Labels, permanent color pens, record sheets, ties, knife blades, water, fungicide (Benlate), gloves and baskets were prepared. Moderately vigourous juvenile shoots were selected and cut into 10-20 cm long lengths. Juvenile stem (Khun and Dick, 1995) retains its greenish color, has well developed leaves, and the bark of the stem is smooth. The hardened woody part, below of the shoot was

removed. Also the fragile apical section, which is too young and not well developed was removed. The number of nodes or length of cuttings varies with each species. For some species, single-nodes were used, if each node had both a leaf and a bud. For others, two or three nodes were used if the shoots had short internodes, and lacked leaves or buds. For some species, many nodes were used, if the shoots had minute leaves and very short internodes. The presence of a leaf or leaves on the cutting is important for root formation and development. For species, with big leaves, the leaf was cut transversely to half or two thirds of its size, to reduce water loss though transpiration, such as for *Ficus lamponga* (1-2 leaves in half), *Ficus hirta* (1 leaf into two thirds), *Ficus superba* (1-2 leaves in half), *Morus macroura* (1-2 leaves in half) and *Saurauia roxburghii* (1-2 leaves into two thirds). Medium and small leaves on the cuttings were cut into halves, *e.g. Colona flagrocarpa* (2-3 leaves in half), *Debregeasia longifolia* (2-3 leaves in half), *Eurya acuminata* (2-3 leaves in half), *Macaranga kurzii* (1-2 leaves in half) and *Trema orientalis* (2 leaves in half). Cuttings were further prepared by re-cutting the base, through a node, into a heel shape, and removing unwanted material. The bases of the cuttings were then put immediately into a breaker with water. Finally, the whole of the leafy stem cuttings were soaked in a fungicidal solution Benlate (3 g/10 L) for 5-10 minutes to prevent fungal infection.

5.2.3 Preparation of Hormones

Two commonly used, artificial auxins, IBA and NAA, were selected for this experiment. In addition Seradix (IBA hormone, in powdered form) was tested. Two types of Seradix (Seradix #2 and Seradix #3) were selected. Seradix #2 contained 3,000 ppm IBA and Seradix #3 contained 8,000 ppm of IBA. Caution was taken not to apply too much Seradix powder to the base of the cutting which can sometimes stop outgrowth of new roots. Only a single layer on each cuttings. The powder was kept dry and refrigerated before use. The concentrations of IBA tested were 2.5, 5.0, and 8.0 grams/litre (= 2,500, 5,000, and 8,000 ppm) or a 0.25, 0.5, and 0.8% solution. The concentrations of NAA tested were 2.5, and 5.0 grams/litre (= 2,500 and 5,000 ppm) or a 0.25 and 0.5% solution. All hormone preparations were kept in a refrigerator at 5-

10 ^{0}C. Before using (for some treatments) IBA and NAA were mixed together in the ratio of 1:1 or 2,500:2,500 ppm, and 2:1 or 5,000:2,500 ppm. Seven hormone treatments were tested; i) control (no hormone), ii) IBA 3,000 ppm, iii) IBA 8,000 ppm, iv) Seradix #2, v) Seradix #3, vi) IBA:NAA = 1:1 (2,5000:2,500 ppm) and vii) IBA:NAA = 2:1 (5,000:2,500 ppm).

5.2.4 Preparation of Plastic Propagation Bags

Plastic propagation bags were prepared according to the methods described by Kantarli (1993). Leafy stem cuttings were treated with a fungicidal solution Benlate (5.2.2) and with hormones (see 5.2.3) and planted in a rooting medium in small black plastic bags. Ten small black plastic bags were put in a larger plastic bag (20 x 30 cm^{3}). There were four replications of 40 leafy stem cuttings for each treatment and for each species. The rooting medium was sand and rice husk charcoal mixed in the ratio 50:50 v/v. About one liter of water was added to each bag when originally prepared, which created circulating condensation inside. The bags were tied closed and checked for tears and water level weekly.

5.2.5 Experimental Design

A vertical hole about the same diameter as each cutting and 3-5 cm deep was made with a pencil. Cuttings were placed in the hole and the medium was made firm around each by watering. The plastic propagation bags were tied closed. Each plastic propagation bag was labeled with the species of tree, the date of preparation setting, the treatment and the number of the replicate.

A Complete Randomized Design was used to test for significant differences among. Forty cuttings were used with each treatment i.e. for each species propagated *i.e.* 280 cuttings. Seven treatments were tested with four replications of each treatment (10 cuttings per replication). Dead cuttings and dried leaves were removed from the bags weekly, to prevent diseases. Percent rooting, % new shoots, % survival, number of

shoots, number of roots, shoot length and root length, were recorded after 3 months or when roots become visible. At the end of the experiment cuttings were harvested and transplanted into polybags. The harvesting time was used to divide the species into three groups, based on the ease with which they rooted; rapid (31-61 days), medium (85-98 days) and slow (120 + days). The relative performance score (within species) and comparisons among species were calculated.

Relative Performance Score

The relative response (within species) of cuttings to the various treatments applied could be divided into two main components: survival and vigour (see Table 21). The single variable, mean % of serving cuttings that sprouted both roots and shoots, was used to quantify survival, because cuttings that failed to produce shoots and roots would not ultimately contribute towards the production of planting stock. Vigour could be quantified by four variables, the mean numbers of both shoots and roots produced and their mean lengths at the end of the experiments. An index of relative performance was therefore devised that combined both survival and vigour within a single statistic, using the formula below:

$$RPS = 50 \times \left[\frac{Trt\ S}{Max\ S} + \left(\frac{Trt\ NR}{Max\ NR} + \frac{Trt\ NS}{Max\ NS} + \frac{Trt\ RL}{Max\ RL} + \frac{Trt\ SL}{Max\ SL} \right) \times 0.25 \right]$$

RPS relative performance score for each treatment

Max = largest mean value among treatments

Trt = the mean value for each individual treatment

S = mean % survival of cuttings with both new shoots and roots

NR = mean number of roots

NS = mean number of shoots

RL = mean root length

SL = mean shoot length

This results in a score with a maximum value of 100 and a minimum possible value of 0.

Comparisons among Species

Comparisons among species, in the relative ease of producing viable planting stock from cuttings, are more problematic, since experiments on each species took place at different times of the year (due to seasonal variability in availablability of cutting material) and lasted for differing lengths of times. Experiments had to be terminated when cuttings began to outgrow their plastic bags. This occurred after different durations for each species, due to major differences in the rapidity with which cuttings of different species rooted and grew. However, it was possible to devise a broad index that can be used to compare general "ease of cutting propagation" among species, based on the speed with which it was possible to produce a crop of cuttings ready for potting, the relative numbers of cuttings that could be produced from 4 replications (40 bags) and their vigour. This index could then be used to divide the species into 3 broad classes, according to the ease with which planting stock could be produced from leafy stem cuttings: high (>90), medium (40-90) and low (<40). First the treatment that worked best for each species was selected, then the data from that treatment were used to compare among species, using the formula below:

$$33.333 \times \left(\frac{\text{Minimum ND}}{\text{Species ND}} + \frac{\text{Sp S}}{\text{Max Sp S}} + \left(\frac{\text{No S}}{\text{MaxNo S}} + \frac{\text{No R}}{\text{MaxNoR}} + \frac{\text{RL}}{\text{MaxRL}} + \frac{\text{SL}}{\text{MaxSL}} \right) \times 0.25 \right)$$

ND = no days from planting to termination of experiment and potting cuttings

Sp S = mean % survival of cuttings with both new shoots and roots

Max = largest mean value among species

No R = mean no. roots

No S = mean no. shoots

RL = mean root length

SL = mean shoot length

As before, this index had a maximum potential value of 100 and a minimum of 0.

5.3 Results

A summary of the species tested, their phenology and main results are presented in Table 17. The cutting propagation results in detail are presented in Table 18. A one-way ANOVA was used to study the significance of interactions between treatments. Performance scores of survival and vigour of ten tree species are presented in Table 19 and relative performance scores are presented in Table 20.

a) *Colona flagrocarpa*

Chemical treatments had substantial and significant effects on the success of cutting propagation of *Colona flagrocarpa*. With no chemical treatments, only a mean of 10% of cuttings (1 per bag) survived with both roots and shoots. All four IBA and IBA:NAA treatments were equally effective at producing viable planting stock. With regard to vigour, chemicals produced no significant effects on 3 of the four variables of vigour. Only number of roots was significantly increased by 5 of the 6 treatments. IBA 8000 ppm had the greatest effect, raising the number of roots produced during the experiment fourfold, but the mean value was not significantly greater than the other 4 treatments. Calculation of the relative performance score ranked IBA 8000 ppm as the most effective treatment, but all treatments containing IBA were ranked relatively high.

Compared with other species, *Colona flagrocarpa* did fairly well (medium). Only 3 other species (*Debregeasia longifolia*, *Morus macroura*, *Saurauia roxburghii*)

achieved maximum mean values of survival with roots and shoots of greater than 60%. The resulting plants were generally vigourous with healthy root systems. However, rooting occurred very slowly, requiring 120 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. Only two other species (*Eurya acuminata* and *Macaranga kurzii*) took longer. However, with cutting collection in July and potting in November, there would be 7 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year.

b) *Debregeasia longifolia*

Chemical treatments had substantial and significant effects on the success of cutting propagation of *Debregeasia longifolia.* With no chemical treatments, only a mean of 8% of cuttings survived with both roots and shoots. The two Seradix and IBA treatments could be regarded as all equally effective at producing viable planting stock. With regard to vigour, chemicals produced no significant effects on 2 of the four variables of vigour. Only number of shoots and shoot length were significantly increased both by 1 of the 6 treatments. Once again, Seradix #3 had the greatest effect, raising the number of shoots produced during the experiment almost six fold, and the mean value was significantly greater than with the other 5 treatments. Calculation of the relative performance score ranked Seradix #3 as the most effective treatment, but all treatments containing Seradix and IBA were ranked relatively high.

Compared with other species, *Debregeasia longifolia* did very well. Only 3 other species (*Colona flagrocarpa*, *Morus macroura*, *Saurauia roxburghii*) achieved maximum mean values of survival with roots and shoots of greater than 60%. The resulting plants were generally vigourous with healthy root systems. Rooting occurred rapidly, requiring only 32 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. However, with cutting collection in September and potting in November, there would be 7 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting

collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year.

c) *Eurya acuminata*

In general, chemicals reduced cutting performance of this species. With no chemical treatments, a mean of 10% of cuttings survived with both roots and shoots. The Seradix treatments were all equally effective at producing viable planting stock, significantly more so than the control. With regard to vigour, chemicals produced significant effects on all of the four variables of vigour. Seradix #3 had the greatest effect, nearly doubling the number of shoots produced with the mean value significantly greater than that of the control and IBA:NAA treatments. Calculation of the relative performance score ranked Seradix #2 as the most effective treatment, but all treatments containing IBA and/or NAA were ranked relatively lower than control.

Compared with other species, *Eurya acuminata* did not response well to cutting propagation. The resulting plants were generally vigourous with healthy root systems. However, rooting occurred very slowly, requiring 123 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. Only one other species took longer. With cutting collection in March and potting in July, there would be 10 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year. However, other treatments should be tried to increase survival of cuttings with both roots and shoots.

d) *Ficus lamponga*

In general, chemical treatments reduced cutting performance of this species. With no chemical treatments, a mean of 5% of cuttings survived with both roots and shoots. Seradix #2 and IBA: NAA = 2:1 treatments were both equally effective at producing viable planting stock. With regard to vigour, chemicals produced no significant effects on all of the four variables of vigour. Seradix #2 had the greatest effect and the mean

value was greater than the other treatments. Calculation of the relative performance score ranked Seradix #2 as the most effective treatment and IBA 8000 ppm and IBA: NAA = 1:1 treatments were ranked relatively high. However, Seradix #3, IBA 3000 ppm and IBA: NAA = 1:1 treatments resulted in lower performance than the control.

Compared with other species, *Ficus lamponga* responded relatively poorly to cutting propagation, although the resulting plants were generally vigourous. Rooting occurred moderately slowly, requiring 90 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. Five other species took longer. With cutting collection in February and potting in May, there would be 1 month for further development of the potted cuttings to grow for planting out at the start of the first rainy season after cutting collection. It should therefore be not possible to produce viable planting stock. Further experiments using cuttings collected in July to October and try other treatments to should be carried out to increase cutting survival.

e) *Ficus hirta*

Only Seradix had a significant effect on the success of cutting propagation of *Ficus hirta*. With no chemical treatments, only a mean of 5% of cuttings survived with both roots and shoots. Only the number of shoots was significantly increased and only with Seradix #2, which raised the number of shoots produced during the experiment threefold. Calculation of the relative performance score ranked Seradix #2 as the most effective treatment.

Compared with other species, *Ficus hirta* did fairly well. The resulting plants were generally vigourous with healthy root systems. However, rooting occurred moderately slowly, requiring 98 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. Only three other species (*Colona flagrocarpa*, *Eurya acuminata* and *Macaranga kurzii*) took longer. With cutting collection in January and potting in April, there would be 2 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be not possible to produce viable planting stock.

Further experiments, collecting cuttings at other times of the year and trying other treatments to increase cutting survival with both roots and shoots should be attempted.

f) *Ficus superba*

Chemical treatments had substantial and significant effects on the success of cutting propagation of *Ficus superba*. With no chemical treatments, only a mean of 15% of cuttings survived with both roots and shoots. IBA 3000 ppm and IBA:NAA = 2:1 significantly increase % survival with roots and shoots. With regard to vigour, chemicals produced no significant effects on 2 of the four variables of vigour. Only number of roots and shoots were significantly increased by 2 and 1 of the 6 treatments, respectively.

Most axillary buds of rooted cuttings developed into shoots after potting. IBA 3000 ppm had the greatest effect on cuttings surviving with roots. Calculation of the relative performance score ranked IBA:NAA = 2:1 and IBA 3000 ppm as the most effective treatments, but all treatments were ranked high. Thus, IBA:NAA or IBA 3000 ppm were the best treatments for this species.

Compared with other species, *Ficus superba* did fairly well. The resulting plants were vigourous and healthy. Rooting occurred moderately quickly, requiring only 61 days from collection of leafy stem cuttings to transfer of rooted cuttings into pots. However, with cutting collection in October and potting in December, there would be 6 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year.

g) *Macaranga kurzii*

Chemical treatments had no significant effects on the success of cutting propagation of this species. With no chemical treatments, a mean of 23% of cuttings survived with both roots and shoots. Chemicals produced were no significant effects all four

variables of vigour. Calculation of the relative performance score ranked IBA:NAA = 1:1 as the most effective treatment.

Compared with other species, *Macaranga kurzii* did not do well. Rooting occurred very slowly, requiring 130 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. with cutting collection in August and potting in December, there would be 6 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year. However, further treatments need to be developed to increase cutting survival.

h) *Morus macroura*

With no chemical treatments, only a mean of 42.50% of cuttings survived with both roots and shoots. Only IBA 8000 ppm treatments significantly increased production of viable planting stock. With regard to vigour, chemicals produced no significant effects on 2 of the four variables of vigour. Only numbers of roots and length of shoots were significantly increased by 2 and 3 of the 4 treatments, respectively. Most axillary buds of rooted cuttings developed into shoots after potting. Calculation of the relative performance score ranked IBA 8000 ppm as the most effective treatment, but IBA:NAA = 1:1 was also ranked relatively high.

Compared with other species, *Morus macroura* did fairly well. The resulting plants were generally vigourous with healthy root systems. However, rooting occurred moderately slowly, requiring 85 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. However, with cutting collection in July and potting in October, there would be 8 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year.

i) *Saurauia roxburghii*

Chemical treatments had substantial and significant effects on the success of cutting propagation of *Saurauia roxburghii*. With no chemical treatments, only a mean of 38% of cuttings survived with both roots and shoots. Only Seradix #3 significantly increased production of viable planting stock. With regard to vigour, chemicals produced no effects on all of the four variables of vigour. Calculation of the relative performance score ranked only Seradix #3 more effective than the control.

Compared with other species, *Saurauia roxburghii* did fairly well. The resulting plants were vigourous with healthy. However, rooting occurred moderately slowly, requiring 92 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. Four other species took longer. However, with cutting collection in November and potting in February, there would be 4 months for further development of the potted cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce viable planting stock in slightly less than 1 year.

j) *Trema orientalis*

Chemical treatments had no significant effects on the success of cutting propagation of *Trema orientalis*. With no chemical treatments, a mean of 48% of cuttings survived with both roots and shoots. All chemical treatments were ineffective at producing viable planting stock. The control produced the highest number of shoots, root length and shoot length. With mean values significantly greater than the chemical treatments. Calculation of the relative performance score ranked the control as the most effective. All treatments containing rooting hormones were ranked low.

Compared with other species, *Trema orientalis* did fairly well. The resulting plants were generally vigourous and had healthy root systems. Rooting occurred more rapidly than for all other species, requiring only 31 days from collection of leafy stem cuttings to the transfer of rooted cuttings into pots. With cutting collection in March and potting in April, there would be 2 months for further development of the potted

cuttings to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be not possible to produce viable planting stock to grow large enough for planting out at the start of the first rainy season after cutting collection. Further experiment, collecting cuttings at other times of the year should be tried.

5.4 Discussion

Leafing Phenology for Vegetative Propagation

Cuttings of six species were collected from parent trees in the dry season and four in the wet season (see Table 17). The time at which cuttings were harvested from the bags varied among the species and was used to divide the species into three groups, based on the ease which they rooted; rapid, moderate and slow. In most species, application of hormones significantly promoted root and shoot formation. The exception was *Trema orientalis*. This results agrees with those of Rahman (1977); Weaver (1972); Hartmann and Kester (1983) and Thimann and Delisle (1939). However, only 3 species (*Colona fragrocarpa*, *Debregeasia longifolia* and *Morus macroura*) achieved maximum mean values of survival, with roots and shoots, of greater than 60%. Seradix #2 produced the highest relative performance scores with *Eurya acuminata*, *Ficus hirta* and *Ficus lamponga*; Seradix #3 with *Debregeasia longifolia* and *Saurauia roxburghii*; IBA 8000 ppm with *Colona flagrocarpa* and *Morus macroura*; IBA:NAA = 1:1 with *Macaranga kurzii* and IBA:NAA = 2:1 with *Ficus superba*. However, *Trema orientalis* rooted most efficiently without any hormone treatment, with the control producing the highest performance scores. Sometimes hormone application did not increase rooting percentage, but increased numbers of roots. Similar observations with other species were noted by Kantarli (1993). Rashid (1986) and Pong-anant and Wongmanee (1990) reported that the effects of hormones on cuttings varied not only among the species, but also among mother trees within species.

In all situations, the success or failure of cutting propagation is highly dependent on coordinating cutting operations with the optimum juvenile stage of the tissue collected. Three of the tree species studied rooted rapidly from leafy cuttings taken from mature trees. This contrasts with Klunklin (1998), Longman (1993), Hartmann *et al.* (1990) Pong-anant and Wongmanee (1990), Rashid *et al.* (1986), and Libby (1984), who noted that tree species root rapidly from cuttings taken from seedling trees. They found that when cuttings are taken from the crowns of saplings or mature trees, results were poor. Longman (1993) suggested that most species of trees can be rooted from leafy cuttings, but not so many will root from leafless cuttings. Therefore, six of the ten species tested were collected in the winter, to avoid leafless stems. For example, the optimal season of *Morus macroura* for cutting preparation was May to August. Cuttings in October (the beginning of the cool season) failed to root, in a pre-experiment, especially with leafless stem cuttings. However, axillary buds developed into new shoots very well and may be suitable for other vegetative propagation methods (such as tissue culture), in this season, for this species. Hartmann *et al.* (1990) suggested that propagators should avoid stock plants that have been injured by frost or drought, defoliated by insects, stunted by excessive flowering or fruiting, or by lack of soil moisture or proper nutrition. Thus, study of leafing phenology is very important for propagation of forest trees from mature trees.

Vegetative and Seed Propagation

Some species have proved difficult to propagate from seed, due to long periods of seed dormancy. For instance, *Colona fragrocarpa*, *Macaranga kurzii* and *Trema orientalis*. Although, the other seven species in this study could be to propagated from seed, their seedlings are produced too late or they grow too slowly to be large enough by planting time. Also, different species produce seed at different times of the year and they have different growth rates (Elliott *et al.*, 2002). Thus, cuttings can provide a more effective seedling production method. The plants would have 1-10 months for further development after potting to grow large enough for planting out at the start of the first rainy season after cutting collection. It should therefore be possible to produce

viable planting stock of most species in less than 1 year. However, for some of the species that are slow to root (*Eurya acuminata*, *Ficus lamponga* and *Macaranga kurzii*) experiments should be performed on cuttings collected in other months and other treatments should be applied to increase the percent of cuttings surviving with both roots and shoots. For instance, experiments with *Ficus lamponga* cuttings, collected in July-October and *Ficus hirta* cuttings collected in other months (except January) should be carried out.

The purpose of this experiment was specifically to test the best rooting hormone treatments to promote cutting survival with both roots and shoots. A lot of material had to be harvested for each treatment of each species. Examination of the seedlings damaged them, since they had to be removed from the medium to observing rooting. Therefore, there was too little viable material to raise cuttings to plantable size. The next obvious stage of research should be to adopt the best practices outlined in this study grow the trees to a plantable size, and monitor their growth and survival in the field compared with stock raised from seed. Additional future research is needed on 1) comparing the effects of age, number of nodes, and number of leaves of cuttings media, also transfer technique from cutting media to potting media, 2) other propagation methods or other hormone treatments should be tested and 3) choosing clones for genetic improvement.

Table 17. Leafing phenology and cutting collection and performance.

Species	Leaf Flushing	Leaf Fall	Leafing Phenology	Period[a]	Date[b]	Harvesting date[c]	Length[d] (days)	CPS[e]	CPS[f] classes	RPS[g]	RPS[h] classes	Best Treatments
Colona fragrocarpa	ap-ag	dc-ap	deciduous	jn-oc	27/7/2001	24/11/2001	120	44.63	medium	91.17	high	IBA 8000 ppm
Debregeasia longifolia	ja-ap, jl-ag, oc, dc	-	evergreen	mr-oc	30/9/2001	1/11/2001	32	92.70	high	91.81	high	seradix #3
Eurya acuminata	ja-dc	-	evergreen	ja-dc	18/3/2001	19/7/2001	123	27.57	poor	98.17	high	saradix #2
Ficus hirta	ja-mr, jl-dc	my-ag	leaf changing	ja-dc	20/1/2001	28/4/2001	98	43.03	medium	98.74	high	saradix #2
Ficus lamponga	ja, jn	my-jn, nv-dc	deciduous	fb-ap, jl-oc	15/2/2001	16/5/2001	90	24.30	poor	82.61	medium	saradix #2
Ficus superba	ja-ag, oc-nv	my-jl, sp-oc	deciduous	ja-ap, jl-ag, nv-dc	29/10/2000	29/12/2000	61	53.77	medium	84.81	medium	IBA:NAA = 2:1
										83.26	medium	or IBA 3000 ppm
Macaranga kurzii	fb-oc	ja-fb	leaf changing	fb-oc	6/8/2001	14/12/2001	130	27.13	poor	99.85	high	IBA:NAA = 1:1
Morus macroura	fb-jl	nv-ap	deciduous	my-ag	13/7/2001	6/10/2001	85	66.67	medium	98.73	high	IBA 8000 ppm
Saurauia roxburghii	mr-ap, jn-ag, oc-dc	-	evergreen	ja-dc	25/11/2000	25/2/2001	92	52.60	medium	89.73	medium	seradix #3
Trema orientalis	ja, mr-sp	-	evergreen	ja-dc	23/3/2001	23/4/2001	31	69.07	medium	99.06	high	control

Period[a] = During which material for cutting, **Date[b]** = Date Cutting Collection, **Harvesting date[c]** = Cutting Ready for Potting,

Length[d] (days) = Length of Experiment, **CPS[e]** = Comparison among species,

CPS[f] class = Comparison Among Species Classes (high (>90), medium (40-90) and low (<40),

RPS[g] = Relative Cutting Performance Score, **RPS[h] class** = Relative Cutting Performance Score classes (high (>90), medium (40-90) and low (<40).

Table 18. Cutting propagation results of 10 native tree species.

a) *Colona flagrocarpa*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277			No. of shoots p=0.6116			Root leng p=0.0923			Shoot leng. p=0.4715		
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%M	mean[N]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]	mean[J]	SD[C]	LSD[D]	mean[K]	SD[C]	LSD[D]	mean[L]	SD[C]	LSD[D]
1. Control	45	4.50	1.00	c	13	1.25	0.50	d	15	1.50	1.29	c	10	1	0.82	d	1.25	0.50	b	1.04	0.75	ns	16.25	2.36	ns	1.28	0.99	ns
2. Seradix #2	65	6.50	1.29	ab	20	2.00	2.00	cd	53	5.25	0.96	ab	20	2	2.00	cd	3.65	1.78	a	1.35	0.57	ns	11.54	4.40	ns	1.41	0.57	ns
3. Seradix #3	58	5.75	1.71	bc	20	2.00	0.82	cd	35	3.50	1.73	bc	15	1.5	0.58	cd	3.25	1.26	ab	1.13	0.25	ns	18.42	2.47	ns	1.54	0.74	ns
4. IBA 3000 ppm	60	6.00	0.82	bc	35	3.50	1.29	bc	43	4.25	1.89	b	33	3.3	1.26	bc	4.65	2.21	a	1.58	0.43	ns	13.13	5.74	ns	1.89	0.39	ns
5. IBA 8000 ppm	80	8.00	1.41	a	63	6.25	1.50	a	73	7.25	1.71	a	60	6	1.63	a	5.28	1.79	a	1.53	0.27	ns	13.38	1.40	ns	1.81	0.60	ns
6. IBA:NAA= 1:1	55	5.50	1.00	bc	45	4.50	1.73	ab	50	5.00	1.63	ab	43	4.3	1.89	ab	4.82	1.70	a	1.32	0.12	ns	12.18	3.84	ns	3.49	3.68	ns
7. IBA:NAA= 2:1	70	7.00	0.82	ab	50	5.00	1.41	ab	53	5.25	1.71	ab	50	5	1.63	ab	4.65	1.28	a	1.38	0.43	ns	11.66	2.73	ns	1.72	0.37	ns

[A] % of cuttings surviving, [B] mean number of cuttings surviving, [C] Standard deviation,

[D] least significant difference $p < 0.05$ (same letter within colum=not significant different, ns= no significant differences among all treatment),

[E] %of cuttings surviving with roots, [F] mean number of cuttings surviving with roots, [G] %of cuttings surviving with roots & shoots,

[H] mean number of cuttings surviving with roots & shoots, [I] mean number of roots per cutting, [J] mean number of shoots per cutting,

[K] mean length of root per cutting (cm), [L] mean length of shoot per cutting (cm), [M] %of cuttings surviving with shoots,

[N] mean number of cuttings surviving with shoots.

Table 18. Cutting propagation results of 10 native tree species (continue).

b) *Debregeasia longifolia*

Treatments	Survival		p=0.0135		Rooting		p=0.0004		With shoot		p=0.0025		Roots+Shoots		p=0.0006		No. of roots		p=0.0277		No. of shoots		p=0.6116		Root leng		p=0.0923		Shoot leng.		p=0.4715	
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	8	0.75	0.96	c	7.5	0.75	0.96	c	7.5	0.75	0.96	c	7.5	0.75	0.96	c	9.25	10.75	ns		1.50	1.73	b		13.63	15.84	ns		2.79	3.31	c	
2. Seradix #2	43	4.25	1.89	b	43	4.25	1.89	b	42.5	4.25	1.89	b	43	4.25	1.89	b	19.48	9.54	ns		2.80	0.24	b		40.94	19.37	ns		6.80	1.27	ab	
3. Seradix #3	68	6.75	2.63	a	68	6.75	2.63	a	67.5	6.75	2.63	a	68	6.75	2.63	a	16.42	4.54	ns		8.39	3.57	a		29.65	5.33	ns		6.68	0.58	ab	
4. IBA 3000 ppm	48	4.75	1.50	ab	48	4.75	1.50	ab	47.5	4.75	1.50	ab	48	4.75	1.50	ab	20.39	2.99	ns		2.61	0.42	b		32.50	8.46	ns		8.99	2.07	a	
5. IBA 8000 ppm	45	4.50	0.58	ab	45	4.50	0.58	ab	45	4.50	0.58	ab	45	4.50	0.58	ab	20.45	3.07	ns		2.79	0.53	b		32.60	8.46	ns		8.12	1.53	ab	
6. IBA:NAA= 1:1	25	2.50	0.58	bc	25	2.50	0.58	bc	25	2.50	0.58	bc	25	2.50	0.58	bc	20.21	4.18	ns		2.71	0.58	b		32.29	13.87	ns		7.41	1.25	ab	
7. IBA:NAA= 2:1	25	2.50	1.91	bc	25	2.50	1.91	bc	25	2.50	1.91	bc	25	2.50	1.91	bc	18.00	6.98	ns		3.13	0.69	b		34.58	13.90	ns		6.21	1.94	b	

Table 18. Cutting propagation results of 10 native tree species (continue).

c) *Eurya acuminata*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277				No. of shoots p=0.6116				Root leng p=0.0923				Shoot leng. p=0.4715			
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	75	7.50	1.00	a	10	1.00	1.41	abc	73	7.25	0.96	a	10	1.00	1.41	abc	1.42	1.64	b		1.41	0.15	bc		0.71	0.88	b		2.66	0.33	ab	
2. Seradix #2	38	3.75	1.50	b	18	1.75	0.96	a	38	3.75	1.50	b	18	1.75	0.96	a	10.33	6.77	a		2.12	0.72	ab		3.83	2.92	a		3.55	0.38	a	
3. Seradix #3	50	5.00	1.41	b	13	1.25	0.50	ab	48	4.75	1.26	b	13	1.25	0.50	ab	11.13	5.72	a		2.50	0.60	a		3.62	2.59	a		2.87	0.31	ab	
4. IBA 3000 ppm	35	3.50	1.29	b	0	0.00	0.00	c	35	3.50	1.30	b	0	0.00	0.00	c	0.00	0.00	b		1.83	0.58	ab		0.00	0.00	b		2.46	0.44	abc	
5. IBA 8000 ppm	30	3.00	0.82	b	2.5	0.25	0.50	bc	30	3.00	0.82	b	3	0.25	0.50	bc	1.00	2.00	b		1.79	0.63	abc		0.50	1.00	b		2.04	1.30	bc	
6. IBA:NAA= 1:1	50	5.00	1.83	b	0	0.00	0.00	c	48	4.75	2.06	b	0	0.00	0.00	c	0.00	0.00	b		1.49	0.34	bc		0.00	0.00	b		2.57	0.69	abc	
7. IBA:NAA= 2:1	28	2.75	2.50	b	0	0.00	0.00	c	25	2.50	2.52	b	0	0.00	0.00	c	0.00	0.00	b		0.96	0.75	c		0.00	0.00	b		1.48	1.28	c	

Table 18. Cutting propagation results of 10 native tree species (continue).

d) *Ficus hirta*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277			No. of shoots p=0.6116			Root leng p=0.0923			Shoot leng. p=0.4715		
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]	mean[J]	SD[C]	LSD[D]	mean[K]	SD[C]	LSD[D]	mean[L]	SD[C]	LSD[D]
1. Control	8	0.75	0.50	bc	5	0.50	0.58	b	8	0.75	0.50	bc	5	0.50	0.58	b	0.50	0.58	ns	0.75	0.50	b	0.50	0.58	ns	0.38	0.25	ns
2. Seradix #2	45	4.50	3.32	a	45	4.50	3.32	a	45	4.50	3.32	a	45	4.50	3.32	a	10.44	7.52	ns	2.25	1.50	a	7.53	6.14	ns	3.69	3.63	ns
3. Seradix #3	5	0.50	0.58	bc	3	0.25	0.50	b	5	0.50	0.58	bc	3	0.25	0.50	b	12.75	25.50	ns	0.50	0.58	b	3.63	7.25	ns	1.88	3.12	ns
4. IBA 3000 ppm	30	3.00	3.83	ab	20	2.00	4.00	ab	30	3.00	3.83	ab	20	2.00	4.00	ab	2.67	5.34	ns	1.25	1.50	ab	2.25	4.50	ns	2.06	2.49	ns
5. IBA 8000 ppm	8	0.75	0.96	bc	5	0.50	0.58	b	8	0.75	0.96	bc	5	0.50	0.58	b	1.50	2.38	ns	0.50	0.58	b	3.25	5.85	ns	1.88	2.84	ns
6. IBA:NAA= 1:1	0	0.00	0.00	c	0	0.00	0.00	b	0	0.00	0.00	c	0	0.00	0.00	b	0.00	0.00	ns	0.00	0.00	b	0.00	0.00	ns	0.00	0.00	ns
7. IBA:NAA= 2:1	5	0.50	1.00	bc	0	0.00	0.00	b	5	0.50	1.00	bc	0	0.00	0.00	b	0.00	0.00	ns	0.25	0.50	b	0.00	0.00	ns	1.38	2.75	ns

Table 18. Cutting propagation results of 10 native tree species (continue).

e) *Ficus lamponga*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277			No. of shoots p=0.6116			Root leng p=0.0923			Shoot leng. p=0.4715		
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]	mean[J]	SD[C]	LSD[D]	mean[K]	SD[C]	LSD[D]	mean[L]	SD[C]	LSD[D]
1. Control	15	1.50	0.58	cd	5	0.50	0.58	ns	15	1.50	0.58	cd	5	0.50	0.58	bc	2.50	2.89	ns	1.130	0.25	ns	4.75	5.5	ns	2.34	1.67	ns
2. Seradix #2	33	3.25	1.50	abc	18	1.75	0.96	ns	18	1.75	0.96	bcd	18	1.75	0.96	ab	1.99	1.84	ns	1.280	0.84	ns	5.28	2.3	ns	1.37	0.62	ns
3. Seradix #3	20	2.00	0.82	bcd	18	1.75	1.26	ns	5	0.50	0.58	d	2.5	0.25	0.50	c	8.25	5.56	ns	0.330	0.47	ns	6.92	5.2	ns	0.29	0.59	ns
4. IBA 3000 ppm	13	1.25	0.96	d	7.5	0.75	0.96	ns	13	1.25	0.96	d	7.5	0.75	0.96	bc	3.75	4.5	ns	0.750	0.5	ns	4.06	4.9	ns	1.19	0.94	ns
5. IBA 8000 ppm	38	3.75	0.96	ab	13	1.25	0.50	ns	30	3.00	0.82	abc	13	1.25	0.50	abc	1.91	0.91	ns	1.210	0.53	ns	2.78	1.6	ns	1.40	0.43	ns
6. IBA:NAA= 1:1	40	4.00	1.41	a	5	0.50	0.58	ns	40	4.00	1.41	a	5	0.50	0.58	bc	2.08	2.5	ns	1.360	0.29	ns	3.50	4.1	ns	2.14	0.56	ns
7. IBA:NAA= 2:1	48	4.75	1.71	a	23	2.25	1.50	ns	33	3.25	1.50	ab	18	2.50	1.73	a	2.35	2.44	ns	0.960	0.36	ns	3.23	2	ns	1.84	1.19	ns

Table 18. Cutting propagation results of 10 native tree species (continue).

f) *Ficus superba*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277				No. of shoots p=0.6116				Root leng p=0.0923				Shoot leng. p=0.4715			
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	60	6.00	1.87	abc	58	5.80	2.05	abc	18	1.80	2.39	b	15	1.80	2.39	b	10.7	3.64	b		0.42	0.44	bc		8.46	2.39	ns		0.81	0.8	ns	
2. Seradix #2	50	5.00	1.73	bcd	50	5.00	1.73	bcd	18	1.80	1.10	b	18	1.80	1.10	b	18.3	5.6	a		0.43	0.37	bc		8.89	1.69	ns		0.90	0.7	ns	
3. Seradix #3	56	5.60	1.67	abc	56	5.60	1.67	abc	18	1.80	1.30	b	18	1.80	1.30	b	22.5	4.32	a		0.28	0.18	c		7.79	1.26	ns		0.62	0.6	ns	
4. IBA 3000 ppm	72	7.20	0.84	a	72	7.20	0.84	a	42	4.20	0.84	a	42	4.20	0.84	a	10.7	1.87	b		0.71	0.28	ab		8.81	1.74	ns		1.36	0.5	ns	
5. IBA 8000 ppm	34	3.40	1.52	d	34	3.40	1.52	d	22	2.20	0.84	b	22	2.20	0.84	b	8.17	2.05	b		0.96	0.47	a		7.62	1.78	ns		2.44	2	ns	
6. IBA:NAA= 1:1	42	4.20	1.79	cd	38	3.80	2.28	cd	28	2.80	2.05	ab	28	2.80	2.05	ab	11.3	3.59	b		0.83	0.24	ab		7.63	2.80	ns		1.90	1.4	ns	
7. IBA:NAA= 2:1	62	6.20	0.84	ab	62	6.20	0.84	ab	42	4.20	1.30	a	42	4.20	1.30	a	12.4	3.26	b		0.7	0.26	abc		10.9	2.04	ns		1.05	0.1	ns	

Table 18. Cutting propagation results of 10 native tree species (continue).

g) *Macaranga kurzii*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277				No. of shoots p=0.6116				Root leng p=0.0923				Shoot leng. p=0.4715			
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	30	3.00	1.15	ns	23	2.25	0.50	ns	30	3.00	0.5	ns	23	2.25	0.50	ns	3.83	3.17	ns		1.56	0.13	ns		3.75	1.06	ns		4.66	1.35	ns	
2. Seradix #2	28	2.75	0.50	ns	25	2.50	0.58	ns	28	2.75	0.6	ns	25	2.50	0.58	ns	4.83	3.79	ns		1.88	0.37	ns		3.69	1.16	ns		3.58	0.63	ns	
3. Seradix #3	25	2.50	1.91	ns	25	2.50	1.91	ns	25	2.50	1.9	ns	25	2.50	1.91	ns	4.25	3.18	ns		1.47	1.04	ns		3.44	2.34	ns		2.6	1.77	ns	
4. IBA 3000 ppm	13	1.25	0.50	ns	10	1.00	0.82	ns	13	1.25	0.8	ns	10	1.00	0.82	ns	7.88	8.07	ns		0.88	0.63	ns		4.00	2.97	ns		4.38	1.59	ns	
5. IBA 8000 ppm	23	2.25	2.87	ns	20	2.00	2.45	ns	23	2.25	2.5	ns	20	2.00	2.45	ns	2.28	2.71	ns		0.67	0.82	ns		3.12	3.70	ns		3.71	4.35	ns	
6. IBA:NAA= 1:1	23	2.25	0.96	ns	20	2.00	0.82	ns	23	2.25	0.8	ns	20	2.00	0.82	ns	13.29	6.90	ns		1.25	0.50	ns		7.19	2.23	ns		5.31	1.44	ns	
7. IBA:NAA= 2:1	25	2.50	1.00	ns	20	2.00	1.15	ns	25	2.50	1.2	ns	20	2.00	1.15	ns	6.33	5.27	ns		1.67	0.39	ns		7.67	3.08	ns		5.11	1.77	ns	

Table 18. Cutting propagation results of 10 native tree species (continue).

h) *Morus macroura*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277				No. of shoots p=0.6116				Root leng p=0.0923				Shoot leng. p=0.4715			
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	90	9.00	0.82	a	90	9.00	0.82	a	43	4.25	1.89	b	43	4.25	1.89	b	5.33	1.82	c		0.51	0.26	ns		12.79	2.19	ns		5.348	1.672	bc	
2. Seradix #2	48	4.75	2.22	c	38	3.75	2.06	b	25	2.50	1.73	bc	23	2.25	1.89	bc	5.06	2.29	c		0.91	0.81	ns		13.28	5.14	ns		7.888	4.818	ab	
3. Seradix #3	13	1.25	1.50	d	10	1.00	1.15	c	5	0.50	0.58	c	5	0.50	0.58	c	4.75	6.38	c		0.50	0.58	ns		9.31	11.05	ns		1.375	1.702	c	
4. IBA 3000 ppm	55	5.50	1.73	bc	50	5.00	2.16	b	30	3.00	3.46	bc	30	3.00	3.46	bc	7.65	4.79	bc		0.85	0.59	ns		12.13	1.87	ns		5.32	4.308	bc	
5. IBA 8000 ppm	78	7.75	0.96	ab	78	7.75	0.96	a	75	7.50	1.29	a	75	7.50	1.29	a	13.8	4.84	ab		1.15	0.19	ns		16.62	1.22	ns		10.8	1.575	a	
6. IBA:NAA= 1:1	45	4.50	1.73	c	40	4.00	1.41	b	43	4.25	1.50	b	45	4.00	1.41	b	14.3	1.68	a		1.35	0.44	ns		16.36	6.69	ns		7.965	3.869	ab	
7. IBA:NAA= 2:1	50	5.00	1.41	c	40	4.00	1.83	b	40	4.00	1.83	b	35	3.50	1.73	b	5.64	3.49	c		0.99	0.15	ns		10.28	7.60	ns		2.573	1.743	c	

Table 18. Cutting propagation results of 10 native tree species (continue).

i) *Saurauia roxburghii*

Treatments	Survival p=0.0135				Rooting p=0.0004				With shoot p=0.0025				Roots+Shoots p=0.0006				No. of roots p=0.0277			No. of shoots p=0.6116			Root leng p=0.0923			Shoot leng. p=0.4715		
	%[A]	mean[B]	SD[C]	LSD[D]	%[E]	mean[F]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	%[G]	mean[H]	SD[C]	LSD[D]	mean[I]	SD[C]	LSD[D]	mean[J]	SD[C]	LSD[D]	mean[K]	SD[C]	LSD[D]	mean[L]	SD[C]	LSD[D]
1. Control	38	3.75	1.71	bc	38	3.75	1.71	b	38	3.75	1.71	bc	38	3.75	1.71	b	15.94	5.95	a	1.71	0.48	ab	3.26	0.68	a	6.64	3.07	a
2. Seradix #2	43	4.25	1.89	b	25	2.50	1.29	bcd	43	4.25	1.89	b	25	2.50	1.29	bcd	7.78	6.03	bc	2.01	0.68	a	2.05	1.54	abc	6.24	2.29	a
3. Seradix #3	75	7.50	0.58	a	65	6.50	1.00	a	75	7.50	0.58	a	65	6.50	1.00	a	11.25	3.13	ab	1.32	0.46	ab	2.68	0.45	ab	6.07	0.67	a
4. IBA 3000 ppm	53	5.25	2.22	ab	33	3.25	1.50	bc	48	4.75	1.50	ab	33	3.25	1.50	bc	5.56	2.24	bc	1.24	0.22	b	1.03	0.29	cd	4.91	1.99	ab
5. IBA 8000 ppm	38	3.75	2.50	bc	15	1.50	1.29	cd	38	3.75	2.50	bc	15	1.50	1.29	cd	5.27	6.00	bc	1.15	0.17	b	1.29	1.30	bcd	2.99	2.47	bc
6. IBA:NAA= 1:1	10	1.00	2.00	c	5	0.50	1.00	d	10	1.00	2.00	c	5	0.50	1.00	d	2.19	4.38	c	0.31	0.63	c	0.45	0.91	d	0.77	1.53	c
7. IBA:NAA= 2:1	38	3.75	2.36	bc	20	2.00	2.16	bcd	38	3.75	2.36	bc	20	2.00	2.16	bcd	3.87	4.33	c	1.49	0.45	ab	0.85	0.88	cd	2.78	0.86	bc

Table 18. Cutting propagation results of 10 native tree species (continue).

j) *Trema orientalis*

Treatments	Survival				p=0.0135	Rooting				p=0.0004	With shoot				p=0.0025	Roots+Shoots				p=0.0006	No. of roots			p=0.0277	No. of shoots			p=0.6116	Root leng			p=0.0923	Shoot leng.			p=0.4715
	%[A]	mean[B]	SD[C]	LSD[D]		%[E]	mean[F]	SD[C]	LSD[D]		%[G]	mean[H]	SD[C]	LSD[D]		%[G]	mean[H]	SD[C]	LSD[D]		mean[I]	SD[C]	LSD[D]		mean[J]	SD[C]	LSD[D]		mean[K]	SD[C]	LSD[D]		mean[L]	SD[C]	LSD[D]	
1. Control	73	7.25	1.50	a		48	4.75	2.22	a		70	7.00	1.83	a		48	4.75	2.22	a		3.11	1.27	ns		1.53	0.35	a		22.80	11.40	a		6.36	2.31	a	
2. Seradix #2	73	7.25	1.50	a		38	3.75	1.26	ab		65	6.50	0.58	ab		38	3.75	1.26	ab		1.57	0.60	ns		1.81	0.36	a		17.56	5.40	ab		4.18	1.04	abc	
3. Seradix #3	73	7.25	0.96	a		33	3.25	1.71	ab		55	5.50	1.29	abc		33	3.25	1.71	ab		1.53	0.99	ns		0.95	0.24	b		8.60	5.77	bc		3.16	1.46	bc	
4. IBA 3000 ppm	48	4.75	2.22	bc		33	3.25	0.96	ab		43	4.25	2.75	bcd		30	3.00	1.41	abc		2.77	1.89	ns		1.73	0.23	a		13.06	6.25	abc		4.92	1.36	ab	
5. IBA 8000 ppm	58	5.75	1.50	ab		23	2.25	1.26	bc		50	5.00	2.16	abc		23	2.25	1.26	bcd		0.91	1.16	ns		1.54	0.43	a		6.04	3.39	c		3.32	1.74	bc	
6. IBA:NAA= 1:1	35	3.50	1.00	c		10	1.00	0.82	c		30	3.00	1.15	cd		10	1.00	0.82	cd		1.25	1.40	ns		1.50	0.46	a		10.38	12.38	bc		4.40	1.25	ab	
7. IBA:NAA= 2:1	28	2.75	1.50	c		7.5	0.75	0.50	c		18	1.75	1.50	d		7.5	0.75	0.50	d		2.13	2.96	ns		0.52	0.44	b		4.19	3.10	c		1.83	1.84	c	

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species.

a) *Colona flagrocarpa*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	10.00	8.33	1.250	1.040	16.250	1.280	19.82	40.7149	49.05
2. Seradix #2	20.00	16.67	3.650	1.350	11.540	1.410	17.95	36.8735	53.54
3. Seradix #3	15.00	12.50	3.250	1.130	18.420	1.540	24.34	50.0000	62.50
4. IBA 3000 ppm	32.50	27.08	4.650	1.580	13.130	1.890	21.25	43.6524	70.74
5. IBA 8000 ppm	60.00	50.00	5.280	1.530	13.380	1.810	22.00	45.1931	95.19
6. IBA:NAA= 1:1	42.50	35.42	4.820	1.320	12.180	3.490	21.81	44.8028	80.22
7. IBA:NAA= 2:1	50.00	41.67	4.650	1.380	11.660	1.720	19.41	39.8726	81.54

[A] %of cuttings surviving with shoots & roots [B] calculated of survival, [C] mean number of roots per cutting,

[D] mean number of shoots per cutting, [E] mean length of root per cutting (cm), [F] mean length of shoot per cutting (cm),

[G] sum C-F, [H] calculated of vigour, [I] Success ranking.

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

b) *Debregeasia longifolia*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	7.50	5.556	9.25	1.50	13.63	2.79	27.17	19.3980	24.95
2. Seradix #2	42.50	31.481	19.48	2.80	40.94	6.80	70.02	50.0018	81.48
3. Seradix #3	67.50	50.000	16.42	8.39	29.65	6.68	61.14	43.6554	93.66
4. IBA 3000 ppm	47.50	35.185	20.39	2.61	32.50	8.99	64.49	46.0511	81.24
5. IBA 8000 ppm	45.00	33.333	20.45	2.79	32.60	8.12	63.96	45.6727	79.01
6. IBA:NAA= 1:1	25.00	18.519	20.21	2.71	32.29	7.41	62.62	44.7176	63.24
7. IBA:NAA= 2:1	25.00	18.519	18.00	3.13	34.58	6.21	61.92	44.2177	62.74

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

c) *Eurya acuminata*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	10.00	28.57	1.42	1.41	0.71	2.66	6.20	15.4076	43.979
2. Seradix #2	17.50	50.00	10.33	2.12	3.83	3.55	19.83	49.2793	99.279
3. Seradix #3	12.50	35.71	11.13	2.50	3.62	2.87	20.12	50.0000	85.714
4. IBA 3000 ppm	0.00	0.00	0.00	1.83	0.00	2.46	4.29	10.6610	10.661
5. IBA 8000 ppm	2.50	7.14	1.00	1.79	0.50	2.04	5.33	13.2455	20.388
6. IBA:NAA= 1:1	0.00	0.00	0.00	1.49	0.00	2.57	4.06	10.0895	10.090
7. IBA:NAA= 2:1	0.00	0.00	0.00	0.96	0.00	1.48	2.44	6.0636	6.064

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

d) *Ficus hirta*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	5.00	5.56	0.50	0.75	0.50	0.38	2.130	4.4542	10.010
2. Seradix #2	45.00	50.00	10.44	2.25	7.53	3.69	23.910	50.0000	100.000
3. Seradix #3	2.50	2.78	12.75	0.50	3.63	1.88	18.760	39.2304	42.008
4. IBA 3000 ppm	20.00	22.22	2.67	1.25	2.25	2.06	8.230	17.2104	39.433
5. IBA 8000 ppm	5.00	5.56	1.50	0.50	3.25	1.88	7.130	14.9101	20.466
6. IBA:NAA= 1:1	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.0000	0.000
7. IBA:NAA= 2:1	0.00	0.00	0.00	0.25	0.00	1.38	1.630	3.4086	3.409

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

e) *Ficus lamponga*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	5.00	14.29	2.500	1.130	4.750	2.340	10.720	33.9455	48.231
2. Seradix #2	17.50	50.00	1.990	1.280	5.280	1.370	9.920	31.4123	81.412
3. Seradix #3	2.50	7.14	8.250	0.330	6.920	0.290	15.790	50.0000	57.143
4. IBA 3000 ppm	7.50	21.43	3.750	0.750	4.060	1.190	9.750	30.8740	52.303
5. IBA 8000 ppm	12.50	35.71	1.910	1.210	2.780	1.400	7.300	23.1159	58.830
6. IBA:NAA= 1:1	5.00	14.29	2.083	1.360	3.500	2.140	9.083	28.7603	43.046
7. IBA:NAA= 2:1	17.50	50.00	2.348	0.960	3.230	1.840	8.378	26.5304	76.530

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

f) *Ficus superba*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[H]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	15.0	17.857	10.69	0.42	8.46	0.81	20.380	32.6289	50.486
2. Seradix #2	18.0	21.429	18.28	0.43	8.89	0.90	28.500	45.6292	67.058
3. Seradix #3	18.0	21.429	22.54	0.28	7.79	0.62	31.230	50.0000	71.429
4. IBA 3000 ppm	42.0	50.000	10.70	0.71	8.81	1.36	21.580	34.5501	84.550
5. IBA 8000 ppm	22.0	26.190	8.17	0.96	7.62	2.44	19.190	30.7237	56.914
6. IBA:NAA= 1:1	28.0	33.333	11.27	0.83	7.63	1.90	21.630	34.6302	67.964
7. IBA:NAA= 2:1	42.0	50.000	12.37	0.7	10.85	1.05	24.970	39.9776	89.978

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

g) *Macaranga kurzii*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	22.50	45.00	3.83	1.56	3.75	4.66	13.800	25.5178	70.518
2. Seradix #2	25.00	50.00	4.83	1.88	3.69	3.58	13.980	25.8506	75.851
3. Seradix #3	25.00	50.00	4.25	1.47	3.44	2.6	11.760	21.7456	71.746
4. IBA 3000 ppm	10.00	20.00	7.88	0.88	4.00	4.38	17.140	31.6938	51.694
5. IBA 8000 ppm	20.00	40.00	2.28	0.67	3.12	3.71	9.780	18.0843	58.084
6. IBA:NAA= 1:1	20.00	40.00	13.29	1.25	7.19	5.31	27.040	50.0000	90.000
7. IBA:NAA= 2:1	20.00	40.00	6.33	1.67	7.67	5.11	20.780	38.4246	78.425

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

h) *Morus macroura*

Treatments	Cuttings surviving with shoots & roots		Vigour						
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	Total[I]
1. Control	42.50	28.33	5.33	0.51	12.79	5.35	23.978	28.2787	56.612
2. Seradix #2	22.50	15.00	5.06	0.91	13.28	7.89	27.138	32.0055	47.006
3. Seradix #3	5.00	3.33	4.75	0.50	9.31	1.38	15.935	18.7935	22.127
4. IBA 3000 ppm	30.00	20.00	7.65	0.85	12.13	5.32	25.950	30.6050	50.605
5. IBA 8000 ppm	75.00	50.00	13.8	1.15	16.62	10.8	42.395	50.0000	100.000
6. IBA:NAA= 1:1	45.00	30.00	14.3	1.35	16.36	7.97	39.975	47.1459	77.146
7. IBA:NAA= 2:1	35.00	23.33	5.64	0.99	10.28	2.57	19.483	22.9774	46.311

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

i) *Saurauia roxburghii*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B']	
1. Control	37.50	28.85	15.94	1.71	3.26	6.64	27.550	50.0000	78.846
2. Seradix #2	25.00	19.23	7.78	2.01	2.05	6.24	18.080	32.8131	52.044
3. Seradix #3	65.00	50.00	11.25	1.32	2.68	6.07	21.320	38.6933	88.693
4. IBA 3000 ppm	32.50	25.00	5.56	1.24	1.03	4.91	12.740	23.1216	48.122
5. IBA 8000 ppm	15.00	11.54	5.27	1.15	1.29	2.99	10.700	19.4192	30.958
6. IBA:NAA= 1:1	5.00	3.85	2.19	0.31	0.45	0.77	3.720	6.7514	10.598
7. IBA:NAA= 2:1	20.00	15.38	3.87	1.49	0.85	2.78	8.990	16.3158	31.700

Table 19. Performance scores of survival (50%) and vigour (50%) of 10 forest tree species (continue).

j) *Trema orientalis*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[B]	
1. Control	47.50	50.00	3.11	1.53	22.80	6.36	33.801	50.0000	100.000
2. Seradix #2	37.50	39.47	1.57	1.81	17.56	4.18	25.117	37.1547	76.628
3. Seradix #3	32.50	34.21	1.53	0.95	8.60	3.16	14.239	21.0627	55.273
4. IBA 3000 ppm	30.00	31.58	2.77	1.73	13.06	4.92	22.480	33.2532	64.832
5. IBA 8000 ppm	22.50	23.68	0.91	1.54	6.04	3.32	11.808	17.4662	41.150
6. IBA:NAA= 1:1	10.00	10.53	1.25	1.50	10.38	4.40	17.525	25.9238	36.450
7. IBA:NAA= 2:1	7.50	7.89	2.13	0.52	4.19	1.83	8.668	12.8214	20.716

Table 20. Relative performance score of 10 forest tree species.

a) *Colona flagrocarpa*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	10.00	8.33	1.250	1.040	16.250	1.280	0.70	26.97	35.30
2. Seradix #2	20.00	16.67	3.650	1.350	11.540	1.410	0.98	32.54	49.20
3. Seradix #3	15.00	12.50	3.250	1.130	18.420	1.540	0.94	34.90	47.40
4. IBA 3000 ppm	32.50	27.08	4.650	1.580	13.130	1.890	1.33	39.73	66.81
5. IBA 8000 ppm	60.00	50.00	5.280	1.530	13.380	1.810	1.80	41.17	91.17
6. IBA:NAA= 1:1	42.50	35.42	4.820	1.320	12.180	3.490	1.56	43.33	78.74
7. IBA:NAA= 2:1	50.00	41.67	4.650	1.380	11.660	1.720	1.55	36.83	78.50

[A] %of cuttings surviving with shoots & roots, [B] calculated of survival score, [C] mean number of roots per cutting, [D] mean number of shoots per cutting, [E] mean length of root per cutting (cm), [F] mean length of shoot per cutting (cm), [G] sum C-F, [H] calculated of vigour score, [I] Total performance score.

Table 20. Relative performance score of 10 forest tree species (continue).

b) *Debregeasia longifolia*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	7.50	5.556	9.25	1.50	13.63	2.79	0.43	16.04	21.59
2. Seradix #2	42.50	31.481	19.48	2.80	40.94	6.80	1.39	38.66	70.14
3. Seradix #3	67.50	50.000	16.42	8.39	29.65	6.68	1.81	41.87	91.87
4. IBA 3000 ppm	47.50	35.185	20.39	2.61	32.50	8.99	1.47	39.47	74.66
5. IBA 8000 ppm	45.00	33.333	20.45	2.79	32.60	8.12	1.42	38.56	71.90
6. IBA:NAA= 1:1	25.00	18.519	20.21	2.71	32.29	7.41	1.10	36.92	55.44
7. IBA:NAA= 2:1	25.00	18.519	18.00	3.13	34.58	6.21	1.06	35.23	53.75

Table 20. Relative performance score of 10 forest tree species (continue).

c) *Eurya acuminata*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	10.00	28.57	1.42	1.41	0.71	2.66	0.96	20.88	49.46
2. Seradix #2	17.50	50.00	10.33	2.12	3.83	3.55	1.92	48.17	98.17
3. Seradix #3	12.50	35.71	11.13	2.50	3.62	2.87	1.63	47.61	83.33
4. IBA 3000 ppm	0.00	0.00	0.00	1.83	0.00	2.46	0.36	17.81	17.81
5. IBA 8000 ppm	2.50	7.14	1.00	1.79	0.50	2.04	0.52	19.03	26.17
6. IBA:NAA= 1:1	0.00	0.00	0.00	1.49	0.00	2.57	0.33	16.50	16.50
7. IBA:NAA= 2:1	0.00	0.00	0.00	0.96	0.00	1.48	0.20	10.01	10.01

Table 20. Relative performance score of 10 forest tree species (continue).

d) *Ficus hirta*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	5.00	5.56	0.50	0.75	0.50	0.38	0.25	6.89	12.44
2. Seradix #2	45.00	50.00	10.44	2.25	7.53	3.69	1.95	48.74	98.74
3. Seradix #3	2.50	2.78	12.75	0.50	3.63	1.88	0.61	27.73	30.51
4. IBA 3000 ppm	20.00	22.22	2.67	1.25	2.25	2.06	0.85	20.72	42.94
5. IBA 8000 ppm	5.00	5.56	1.50	0.50	3.25	1.88	0.43	16.12	21.68
6. IBA:NAA= 1:1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7. IBA:NAA= 2:1	0.00	0.00	0.00	0.25	0.00	1.38	0.12	6.06	6.06

Table 20. Relative performance score of 10 forest tree species (continue).

e) *Ficus lamponga*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	5.00	14.29	2.500	1.130	4.750	2.340	0.98	35.53	49.82
2. Seradix #2	17.50	50.00	1.990	1.280	5.280	1.370	1.60	32.61	82.61
3. Seradix #3	2.50	7.14	8.250	0.330	6.920	0.290	0.73	29.72	36.86
4. IBA 3000 ppm	7.50	21.43	3.750	0.750	4.060	1.190	0.94	26.68	48.11
5. IBA 8000 ppm	12.50	35.71	1.910	1.210	2.780	1.400	1.22	27.21	62.92
6. IBA:NAA= 1:1	5.00	14.29	2.083	1.360	3.500	2.140	0.95	33.69	47.97
7. IBA:NAA= 2:1	17.50	50.00	2.348	0.960	3.230	1.840	1.53	29.02	79.02

Table 20. Relative performance score of 10 forest tree species (continue).

f) *Ficus superba*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	15.0	17.86	10.69	0.42	8.46	0.81	0.86	25.62	43.47
2. Seradix #2	18.0	21.43	18.28	0.43	8.89	0.90	1.04	30.99	52.42
3. Seradix #3	18.0	21.43	22.54	0.28	7.79	0.62	0.99	28.71	50.13
4. IBA 3000 ppm	42.0	50.00	10.7	0.71	8.81	1.36	1.65	33.26	83.26
5. IBA 8000 ppm	22.0	26.19	8.17	0.96	7.62	2.44	1.29	38.80	64.99
6. IBA:NAA= 1:1	28.0	33.33	11.27	0.83	7.63	1.90	1.38	36.22	69.55
7. IBA:NAA= 2:1	42.0	50.00	12.37	0.7	10.85	1.05	1.68	34.81	84.81

Table 20. Relative performance score of 10 forest tree species (continue).

g) *Macaranga kurzii*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	22.50	45.00	3.83	1.56	3.75	4.66	1.67	39.20	84.20
2. Seradix #2	25.00	50.00	4.83	1.88	3.69	3.58	1.77	39.27	89.27
3. Seradix #3	25.00	50.00	4.25	1.47	3.44	2.6	1.62	31.91	81.91
4. IBA 3000 ppm	10.00	20.00	7.88	0.88	4.00	4.38	1.19	40.07	60.07
5. IBA 8000 ppm	20.00	40.00	2.28	0.67	3.12	3.71	1.31	26.49	66.49
6. IBA:NAA= 1:1	20.00	40.00	13.29	1.25	7.19	5.31	1.98	59.85	99.85
7. IBA:NAA= 2:1	20.00	40.00	6.33	1.67	7.67	5.11	1.82	51.71	91.71

Table 20. Relative performance score of 10 forest tree species (continue).

h) *Morus macroura*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	42.50	28.33	5.33	0.51	12.79	5.35	1.07	25.76	54.09
2. Seradix #2	22.50	15.00	5.06	0.91	13.28	7.89	0.94	32.27	47.27
3. Seradix #3	5.00	3.33	4.75	0.50	9.31	1.38	0.41	17.44	20.78
4. IBA 3000 ppm	30.00	20.00	7.65	0.85	12.13	5.32	1.00	30.24	50.24
5. IBA 8000 ppm	75.00	50.00	13.8	1.15	16.62	10.8	1.95	48.73	98.73
6. IBA:NAA= 1:1	45.00	30.00	14.3	1.35	16.36	7.97	1.53	47.12	77.12
7. IBA:NAA= 2:1	35.00	23.33	5.64	0.99	10.28	2.57	0.96	25.27	48.61

Table 20. Relative performance score of 10 forest tree species (continue).

i) *Saurauia roxburghii*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%[A]	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	37.50	28.85	15.94	1.71	3.26	6.64	1.54	48.71	77.56
2. Seradix #2	25.00	19.23	7.78	2.01	2.05	6.24	1.15	38.59	57.82
3. Seradix #3	65.00	50.00	11.25	1.32	2.68	6.07	1.77	39.73	89.73
4. IBA 3000 ppm	32.50	25.00	5.56	1.24	1.03	4.91	1.01	25.76	50.76
5. IBA 8000 ppm	15.00	11.54	5.27	1.15	1.29	2.99	0.67	22.09	33.63
6. IBA:NAA= 1:1	5.00	3.85	2.19	0.31	0.45	0.77	0.21	6.90	10.74
7. IBA:NAA= 2:1	20.00	15.38	3.87	1.49	0.85	2.78	0.72	21.10	36.49

Table 20. Relative performance score of 10 forest tree species (continue).

j) *Trema orientalis*

Treatments	Cuttings surviving with shoots & roots		Vigour						Total[I]
	%^	Survival score[B]	No roots[C]	No shoots[D]	Root length[E]	Shoot length[F]	Sum[G]	Vigour score[H]	
1. Control	47.50	50.00	3.11	1.53	22.80	6.36	1.95	49.06	99.06
2. Seradix #2	37.50	39.47	1.57	1.81	17.56	4.18	1.51	37.43	76.91
3. Seradix #3	32.50	34.21	1.53	0.95	8.60	3.16	1.15	24.31	58.52
4. IBA 3000 ppm	30.00	31.58	2.77	1.73	13.06	4.92	1.42	40.54	72.11
5. IBA 8000 ppm	22.50	23.68	0.91	1.54	6.04	3.32	0.95	24.60	48.28
6. IBA:NAA= 1:1	10.00	10.53	1.25	1.50	10.38	4.40	0.80	29.93	40.45
7. IBA:NAA= 2:1	7.50	7.89	2.13	0.52	4.19	1.83	0.52	18.20	26.10

CHAPTER 6

Ecological Relationships

Abstract

Associations between ecological variables and the most successful treatments to break seed dormancy and promote development of shoots and roots by cuttings were tested with the Pearson chi-square test. Seed pre-treatments had the greatest effects on seeds with thick integuments ($p=0.001$), large and medium sized seeds ($p=0.028$) and those with dormancy ($p=0.017$). Dispersal mode, dispersal season, tree type, forest type, response to shade, nursery/gap and seed predation were not significantly associated with pre-treatment responses. Shade tolerance was strongly associated with climax tree species ($p=0.000$). High levels of seed predation were significantly associated with large seed size ($p=0.004$) and thick integument (endocarp) ($p=0.030$), shade tolerance ($p=0.022$) and climax tree species ($p=0.006$). Tree type, dispersal mode and seed dormancy were not significantly associated with predation levels. None of the ecological variables tested had any significant association with the outcome of chemical treatments to promote rooting and shooting of leafy stem cuttings.

6.1 Introduction

The data in previous chapters show the best treatments to propagate only individual single tree species. However, they do not say anything about how to propagate other tree species. The ecology of a species affects its morphology and physiology, as each species has evolved to adapt to conditions within its own habitat. Morphology and physiology determine a species' response to treatments. Therefore, a species' ecology might serve as a useful indicator of likely responses to horticultural treatments. The existence of such relationships would allow prediction of which horticultural treatments might be most successful for tree species that have never been grown in

nurseries (Blakesley *et al.*, 2000). From ecological principles, it might become possible to develop indicators of horticultural practices most likely to succeed.

Relationships among variables such as seed size, seed integuments, and dispersal time and dispersal mode have been reported before (Jansen, 1969; Jackson, 1981; Jansen and Boe, 1991; Saverimuttu and Westoby, 1996; Blate *et al.*, 1998; Hardwick, 1999; Hau, 1999; Seiwa, 2000). Relationships between seed size and seed germination were reported by Jensen and Boe (1991). Also, Pakkad (2002) studied relationships between seed characters with germination behavior and early seedling growth of some species as indicators of field performance. Blate *et al.* (1998) reported that in a South Asian rainforest, the rate of predation is negatively associated with the thickness and hardness of the seed coat. Hau (1999) found that the mean percentage seed removal of *Choerospondias axillaris* and *Elaeocarpus sylvestris* by seed predators on degraded hillsides in Hong Kong was not significantly related to seed size. However, no previous authors have attempted to link such characteristics with application of horticultural techniques.

In this chapter, I test for association between ecological variables and responses to seed pre-treatments and chemical treatment of cutting propagation, to see if results presented in previous chapters have broader applicability.

6.2 Methods

To test for association between ecological variables and the most successful treatments to break seed dormancy and promote development of shoots and roots by cuttings, the Pearson chi-square test of association was performed (Dytham, 1999). Ten variables were tested for their association with best seed pre-treatments and ten for their association with best cutting propagation treatments. Seed size was divided into 3 classes (Table 23), integument into 6 classes, dormancy into 2 classes; tree type, forest type, and response to shade were classified into 4 classes, performance in

nursery/gap was classified into 3 classes and susceptibility to predation was classified into 2 classes. These variables were tested for their association with best treatment, classified into 13 classes.

Tree successional status was defined as "pioneer" or "climax" according to J. F. Maxwell (pers. com.). The main habitat of each tree species was obtained from Maxwell and Elliott (2001). Seeds were divided into 3 size classes. Large seeds were >14 mm, medium 2-14 mm, and small <2 mm. The data were taken from Hardwick (1999) and Pakkad (1997). Dispersal mode (wind or animal) and integument were taken from J. F. Maxwell (pers. com.) and Hardwick (1999). Forest type data came from Maxwell and Elliott (2001). All other variables were taken from my own observations (Chapter 2) and experiments (Chapters 3-5).

The reasons why these variables were select are explained as follows. Seed size was considered likely to affect germination because small seeds may absorb water and gas more quickly than larger sized seeds. Therefore, special attention should be taken in using seed size for the prediction of germination.

Dispersal season should affect seed germination. Since germination at unfavorable times i.e. the dry season is prevented by dormancy. Thus, seeds that must overcome dormancy should be germinated by several pre-treatments.

Dispersal mode (wind and animal) also might have an indirect effect. The most important dispersal in evergreen forest seems to be by animals. Passage through an animal gut affects germination. Dispersal by wind requires seeds to be very light and small which can affect germination.

Integuments (seed coverings) were defined as thick (thick testa, endocarp, pericarp, arill testa) or thin (thin testa and/or wing). The seed coats (or other covering structures) are impermeable to the entry of moisture or gases. If a species has evolved

a very thick seed coat, it may require scarification of the seed coat before water can enter the seed and initiate germination. In species with thin seed coats, light may be able to penetrate into the dormant embryo. The embryo may then either use the presence of light or the absence of light to trigger its germination process.

Dormancy was defined as the number of days between seed sowing and germination of the median seed of control group > 28 days. None or low dormancy was defined as the MLD <28 days.

Tree successional status was defined as "pioneer, deciduous secondary growth pioneer (DSG pioneer), climax, or pioneer/climax" tree species. Pioneer tree species germinate and establish in recently disturbed sites and that complete their life cycle without being over topped by neighboring trees. Their seeds usually have dormancy. Light stimulus or regularly fluctuating temperatures often break dormancy. Thus, it is expected that they required pre-treatments to germinate. On the other hand, the climax seeds are recalcitrant and germinate rapidly under poor light conditions. The seeds are often large and should not require pre-treatment. Disturbed secondary growth pioneer tree species (DSG pioneer) develop naturally on land abandoned after cultivation. Pioneer/climax tree species were defined as species which could not be categorized, or those found in both pioneer and climax forest.

The main habitat of each tree species were evergreen, deciduous, mixed evergreen and deciduous and evergreen + pine forest. Evergreen forest found the canopy is higher and denser than in the others forest type. The light intensity at ground level was 60% while in the Deciduous was 82%. These species are often to be recalcitrant seed and germinate rapidly under poor light conditions. Deciduous forest has an open canopy with high light intensity, compared to evergreen forest. These species should require a light stimulus or regularly fluctuating temperatures to break dormancy. Evergreen + pine forest has a much more open canopy than Evergreen forest. These species should require light stimulus more than the evergreen forest species and less than mixed

evergreen and deciduous forest to germinate. Mixed evergreen + deciduous forest has a slightly more closed canopy than deciduous forest. These species should require a light stimulus and a lower temperature than deciduous forest to break dormancy.

Responses to shade, nursery/gap and predators were defined in Chapters 3 and 4. Some seeds are stimulated by light, and others are inhibited by light during germination. Enzymes required for germination are often light activated. So shade response is likely to affect response to pre-treatments. Plant strategy is strongly related to seed strategy. A plant that has evolved to live in a particular habitat must have seeds that can disperse to, germinate and establish in that habitat. Therefore, all the parameters selected above might be useful to predict the success of seed propagation.

Ten variables were tested for their association with best cutting propagation treatments (Table 27). Leaf flushing was divided into 10 month classes. Leaf fall was divided into 7 month classes. Leafing phenology was defined as "deciduous or evergreen or leaf changing". The period during which material for cutting was divided into the seven month classes. Date of cutting collection, length of experiment and date at which cuttings were ready for potting were divided into 10 classes. Comparison among species: high class was defined as scores >90, medium as scores 40-90 and poor as scores <40. Also, relative cutting performance score: high class was defined as scores >90, medium as scores 40-90 and low as scores <40. The variables were tested for their association with best treatment, classified into 6 classes. The data were taken from Chapters 2 and 5.

Leaf flushing, leaf fall, leafing phenology (defined in Chapter 2) were considered the main variables which influence the rooting of cuttings. Especially, the juvenility of the shoots is very important for rooting of cuttings. Published results suggest that trees species can be rooted from leafy cuttings, but not so many will root from leafless cuttings. These results indicate that rooting of cutting is related to photosynthetic activity during propagation. Also, the period during which materials for cutting and

date of cutting collection were might affect cutting success. This might be due to in early dry season, physiological dormancy developing inside the plant body. Therefore, leafing phenology was considered likely to be associated with vegetative propagation success. Length of experiment, date when cuttings were ready for potting, comparison among species classes and relative cutting performance score classes might also affect rooting of cuttings and were therefore tested for association with cutting treatments.

The SPSS computer program was used to perform the Pearson chi-square test of association between each ecological variable in turn with the most successful seed pre-treatment or cutting propagation treatment.

6.2 Results

Ecological Variables Associated with Best Seed Pre-treatments

The results of the chi-square tests of association between ecological parameters and best treatments for seed propagation are shown in Table 24. Few ecological variables were significantly associated with best seed pre-treatments. Seed pre-treatments had the greatest effects on seeds with thick integuments ($p=0.001$), large and medium sized seeds ($p=0.028$) and seeds with dormancy ($p=0.017$). Thus, the large and medium, hard coated seeds with dormancy responded to pre-treatments that removed seed coat dormancy to encourage seed germination.

Prolonged seed dormancy was significantly associated with better seed germination under gap conditions than in nursery ($p=0.039$) and was strongly associated with seeds with thick integuments ($p=0.024$).

Thick seed integuments were also strongly associated with animal dispersal ($p=0.000$). Small seed size was significantly associated with better seed germination in the nursery ($p=0.006$), compared with forest gap and thin integument ($p=0.003$).

In summary, therefore, seed species that responded well to pre-treatments were those with large and medium seed sizes which had thick seed integument dormancy. In contrast, dispersal mode, dispersal season, tree type, forest type, shade, nursery/gap and predator were not significantly associated with pre-treatment success.

Ecological Variables Affecting Shade Tolerance

Shade tolerance was strongly associated with climax tree species (p=0.000). Seed size, dispersal season, dispersal mode, integument, dormancy, pre-treatment, forest type, predation and nursery/gap had no association with shade tolerance.

Ecological Variables Affecting Seed Predation

High levels of seed predation were significantly associated with the large seed size group (p=0.004), thick integument (endocarp) (p=0.030), shade tolerance (p=0.022) and climax tree species (p=0.006). Tree type, dispersal mode and seed dormancy were not significantly associated with predation levels.

Ecological Variables Affect Cutting Propagation

None of the ecological variables tested had any significant association with the outcome of chemical treatments to promote rooting and shooting of leafy stem cuttings.

6.3 Discussion

Seed Germination

In general, the seed species studied could be divided into two groups: those that germinated well without pre-treatments and those that required pre-treatment. Chi-

square test results showed that pre-treatments had the most significant effects on large and medium size seeds (p=0.028) with long dormancy (p=0.017) and thick integuments (p=0.001). Since most of the treatments acted on the outside of the seeds to break seed dormancy, the association between seed pre-treatment and these variables was expected. Thick integument was significantly associated with long seed dormancy. Thus hard coated seeds coat have dormancy and they required pre-treatment to encourage seed germination. This result agrees with those of Hardwick and Elliott (1992), Kopachon (1995), Hardwick (1997), RORRU (1998), Singpetch (2001) and Vongkamjan *et al.* (2001).

Non-dormant tree seed species tended to germinate better in the nursery, whilst dormant seeds did better under gap conditions. Small seeds tended to have short dormancy, because water could diffuse to the embryo and/or gas exchange could occur rapidly. The embryos of smaller seed were therefore stimulated by water faster than in bigger seeds. Also, in the nursery, there was regular watering, and high light levels. Because these seeds are generally recalcitrant, so they could therefore germinate immediately after sowing. Dormant seeds required pre-treatment to break seed dormancy. Thick seed integument was associated with animal dispersal, more than with wind dispersal. Animal-seed dispersers influence the germination of many tree species, by the way in which seeds are treated in animals, guts (Traveset, 1998). Pre-treatment was therefore required for this group. For example, scarification or acid treatments were required to encourage germination of animal dispersed seeds of evergreen forest species, and heat or soaking for deciduous forest species. Small-size and light weight are necessary for dispersal by wind. Small seed size was significantly associated with better seed germination in nursery conditions. These seeds have thin integuments, that water and gas can enter quickly to initiate germination more easily than larger seeds, as noted by Koning (1994).

Although, small seeds had low predation rates, they could not germinate well in the gap because of the unsuitable of environment (shade, lack of water, more competition of weeds, *etc.*).

High seed predation was significantly associated with large seed size and thick integument (endocarp), because large seeds were found easily by predators and contain substantial food reserves as noted by Wood (2001). Blate *et al.* (1998) and Mack (1998) reported that large seeds are affected more by seed predation than small ones. Some seeds have evolved to develop a thick seed coat as protection, until they germinate. Large seeded species may fail to develop into seedlings because they are destroyed by predators. If thin small seeds avoid predation, they may fail to germinate because of environmental conditions. High levels of solar radiation, in large clearings, may increase soil and air temperatures and decrease soil moisture content, but some small seeds are resistant to high temperatures and may even require them for germination. Hammond (1999) reported that the seed predation is negatively correlated with the mean length of seasonal dormancy. High seed predation was significantly associated with the large seed size group and thick integument (endocarp). Therefore, seeds must be protected from predators before sowing seeds in the forest gaps.

Vegetative Propagation

The statistical tests failed to show any association between ecological variables related to leafing and response to chemical treatments to promote root/shoot production by cuttings. This may have been due to the low number of species tested and the wide range of various responses to the different treatments, resulting in very small numbers of species in each class of ecological variable and response to treatments. If this experiment is repeated, I recommend at least 30 species should be tested.

Table 21. Ecological variables tested for their effects on seed propagation of 32 native tree species.

Species	Family	Seed size[1,5,7]	Disp. Season[2]	Disp. Mode[1,3]	Integument[3,7]	Dormancy[5]
Acrocarpus fraxinifolius	Leguminosae	medium*	Early wet	wind	thick testa	dormancy
Afzelia xylocarpa	Leguminosae	large	dry-eary wet	animal	thick testa	dormancy
Albizia chinensis	Leguminosae	medium	late wet-late dry	wind	thick testa	dormancy
Aporusa villosa	Euphorbiaceae	medium	eary wet	animal	arill testa	non
Betula alnoides	Betulaceae	small	late dry	wind	pericarp	dormancy
Cassia fistula	Leguminosae	medium	eary dry-late dry	animal	thick testa	dormancy
Debregeasia longifolia	Urticaceae	small	eary dry	animal	testa	non
Diospyros undulata	Ebenaceae	large	eary wet-late wet	animal	testa	non
Elaeocarpus lanceifolius	Elacocarpaceae	large	eary dry	animal	endocarp	dormancy
Elaeocarpus prunifolius	Elaeocarpaceae	large	late wet	animal	endocarp	dormancy
Eurya acuminata	Theaceae	small	late dry	animal	testa	non
Ficus hirta	Moraceae	small	late wet	animal	testa	non
Ficus lamponga	Moraceae	small	late dry-eary wet, late wet	animal	testa	non
Ficus superba	Moraceae	small	late dry, late wet	animal	testa	non
Glochidion acuminatum	Euphorbiaceae	medium	late wet	animal	arill testa	dormancy
Irvingia malayana	Irvingiaceae	large	late wet-eary dry	animal	endocarp	dormancy
Lagerstroemia speciosa	Lythraceae	medium	late wet-eary dry	wind	wing	dormancy
Macropanax dispermus	Araliaceae	medium	eary dry-late dry	animal	testa	non
Morus macroura	Moraceae	small	late dry-eary wet	animal	testa	non
Reevesia pubescens	Sterculiaceae	medium	eary dry-late dry	wind	wing	non
Saurauia roxburghii	Saurauiaceae	small	late wet	animal	testa	non
Schleichera oleosa	Sapindaceae	large	late wet	animal	testa	dormancy
Shorea obtusa	Dipterocarpaceae	medium	eary wet	wind	pericarp	non
Sindora siamensis	Leguminosae	large	late wet- eary dry-late dry	animal	thick testa	dormancy
Terminalia bellirica	Combretaceae	large	eary dry-late dry	animal	endocarp	dormancy
Terminalia chebula	Combretaceae	large	eary dry-late dry	animal	endocarp	non
Terminalia mucronata	Combretaceae	large	late wet-eary dry-late dry	wind	pericarp	non
Tetradium glabrifolium	Rutaceae	medium	late wet-eary dry	animal	thick testa	non
Trema orientalis	Ulmaceae	small	late wet-eary dry	animal	endocarp	dormancy
Vaccinium sprengelii	Ericaceae	small	eary wet	animal	testa	non

1 = Hardwick (1999); *small < 2 mm, medium 2-14 mm, large >14 mm (diameter), 2=data in Chapter 2, 3=J.F. Maxwell (personal communicate), 4= Maxwell and Elliott (2001), 5= data in Chapter 3, 6=data in Chapter 4, 7= data from Pakkad (1997).

Table 21. Ecological variables tested for their effects on seed propagation of 32 native tree species (continue).

Species	Best treatment[4]	Tree type[3]	Forest type[4]	Shade[5]	Nurs./Gap[5]	Predator[6]
Acrocarpus fraxinifolius	scarification (scar.)	DSGpioneer	evergreen (e)	tolerant	no difference	50
Afzelia xylocarpa	scar.+soaking (soak.)	climax	deciduous (d)	tolerant	no difference	0
Albizia chinensis	scar., scar.+soak	pioneer	e+pine forest	mix results	gap	0
Aporusa villosa	control	climax	mixed e+d	tolerant	no difference	0
Betula alnoides	control	climax	e+pine forest	tolerant	nursery	0
Cassia fistula	acid 10 mins., scar+soak	climax	d	mix results	no difference	0.3
Debregeasia longifolia	control	pioneer	e	inhibited	nursery	0
Diospyros undulata	control	climax	mixed e+d	tolerant	nursery	0
Elaeocarpus lanceifolius	scar.+soak, scar.	climax/pioneer	e	dependent	gap	63
Elaeocarpus prunifolius	scar., scar.+soak	climax	e	tolerant	no difference	100
Eurya acuminata	control	pioneer	e	inhibited	nursery	0
Ficus hirta	control	pioneer	e	inhibited	nursery	0
Ficus lamponga	control	climax	e	inhibited	nursery	0
Ficus superba	control	pioneer	e	tolerant	nursery	0
Glochidion acuminatum	acid 5 mins.	pioneer	e	inhibited	gap	0
Irvingia malayana	heat	climax	d	tolerant	nursery	100
Lagerstroemia speciosa	acid 3 mins., soak.	climax	d	inhibited	gap	0
Macropanax dispermus	control	climax	e	tolerant	nursery	65
Morus macroura	acid 1 min.	climax	e	tolerant	nursery	0
Reevesia pubescens	acid 3 mins.	pioneer	e	mix results	nursery	91
Saurauia roxburghii	soak., acid 3 mins.	DSGpioneer	e	tolerant	nursery	0
Schleichera oleosa	control	climax	d	tolerant	no difference	0
Shorea obtusa	control	climax	d	inhibited	nursery	77
Sindora siamensis	scar., scar.+soak	climax	d	tolerant	no difference	1.9
Terminalia bellirica	soak.	climax	d	tolerant	no difference	69
Terminalia chebula	acid 5, 10 mins.	climax	d	tolerant	no difference	73
Terminalia mucronata	scar.	climax	e	tolerant	no difference	88
Tetradium glabrifolium	acid 10, 5 mins.	climax	e	tolerant	gap	0
Trema orientalis	acid 3 mins.	pioneer	e+d	mix results	no difference	0
Vaccinium sprengelii	control	climax	e+pine forest	tolerant	nursery	0

Table 22. Transformation variables of ecological factors tested for their effects on seed propagation of 32 native tree species.

Species	Family	Seed size	Disp. season	Disp. mode	Integument	Dormancy	Best treatment	Tree type	Forest type	Shade	Nurs/Gap	Predator
Acrocarpus fraxinifolius	Leguminosae	2	1	1	1	2	2	2	1	2	1	2
Afzelia xylocarpa	Leguminosae	3	5	2	1	2	2	3	3	2	1	1
Albizia chinensis	Leguminosae	2	5	1	1	2	2	1	2	4	3	1
Aporusa villosa	Euphorbiaceae	2	1	2	4	1	1	3	4	2	1	1
Betula alnoides	Betulaceae	1	6	1	3	2	1	3	2	2	2	1
Cassia fistula	Leguminosae	2	5	1	1	2	2	3	3	4	1	1
Debregeasia longifolia	Urticaceae	1	4	2	5	1	1	1	1	3	2	1
Diospyros undulata	Ebenaceae	3	2	2	5	1	1	3	4	2	2	1
Elaeocarpus lanceifolius	Elaeocarpaceae	3	4	2	2	2	2	4	1	1	3	2
Elaeocarpus prunifolius	Elaeocarpaceae	3	3	2	2	2	2	3	1	2	1	2
Eurya acuminata	Theaceae	1	6	2	5	1	1	1	1	3	2	1
Ficus hirta	Moraceae	1	3	2	5	1	1	1	1	3	2	1
Ficus lamponga	Moraceae	1	2	2	5	1	1	3	1	3	2	1
Ficus superba	Moraceae	1	3	2	5	1	1	1	1	2	2	1
Glochidion acuminatum	Euphorbiaceae	2	3	2	4	2	2	1	1	3	3	1
Irvingia malayana	Irvingiaceae	3	4	2	2	2	2	3	3	2	2	2
Lagerstroemia speciosa	Lythraceae	2	5	1	6	2	2	3	3	3	3	1
Macropanax dispermus	Araliaceae	2	4	2	5	1	1	3	1	2	2	2
Morus macroura	Moraceae	1	1	2	5	1	2	3	1	2	2	1
Reevesia pubescens	Sterculiaceae	2	5	1	6	1	2	1	1	4	2	2
Saurauia roxburghii	Saurauiaceae	1	3	2	5	1	2	2	1	2	2	1
Schleichera oleosa	Sapindaceae	3	3	2	5	2	1	3	3	2	1	1
Shorea obtusa	Dipterocarpaceae	2	1	1	3	1	1	3	3	3	2	2
Sindora siamensis	Leguminosae	3	5	2	1	2	2	3	3	2	1	1
Terminalia bellirica	Combretaceae	3	5	2	2	2	2	3	3	2	1	2
Terminalia chebula	Combretaceae	3	5	2	2	1	2	3	3	2	1	2
Terminalia mucronata	Combretaceae	3	5	1	3	1	2	3	1	2	1	2
Tetradium glabrifolium	Rutaceae	2	4	2	1	1	2	3	1	2	3	1
Trema orientalis	Ulmaceae	1	4	2	2	2	2	1	4	4	1	1
Vaccinium sprengelii	Ericaceae	1	1	2	5	1	1	3	2	2	2	1

Table 23. Eleven variables tested for their association with seed pre-treatment effects.

Seed size	Disp. season	Disp. mode	Integument	Dormancy	Best treatment	Succession Status	Forest type	Shade	Nurs./Gap	Predation
1=small 2=medium 3=large	1=early wet 2=wet 3=late wet 4=eary dry 5=dry 6=late dry	1=wind 2=animal	1=thick testa 2=endocarp 3=pericarp 4=arill testa 5=thin testa 6=wing	1=non 2=dormancy	1=control 2=soak 3=soak, acid 3 mins 4=scar 5=scar+soak 6=scar, scar+soak 7=heat 8=acid 1 min 9=acid 3 mins 10=acid 3 mins,soak 11=acid 5 mins 12=acid 5, 10 mins 13=acid 10 mins, scar+soak	1=pioneer 2=DSGpioneer 3=climax 4=climax/pioneer	1=evergreen 2=deciduous 3=e+pine forest 4=mixed e+d	1=dependent 2=tolerant 3=inhibited 4=mix results	1=no diff 2=nursery 3=gap	1=non predator 2=predator

Table 24. Chi-square test among the best treatments and ecological relationship on seed propagation of 32 forest tree species.

	Best Treatment				Seed Size				Dispersal Season				Dispersal Mode				Integument			
parametor	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.
Seed size	0.424	0.424	0.028	*					0.212	0.215	0.199	ns	0.000	0.000	0.014	*	-0.474	-0.454	0.003	**
Dispersal season	0.209	0.209	0.245	ns	0.056	0.055	0.252	ns					0.038	0.056	0.817	ns	-0.253	-0.239	0.238	ns
Dispersal mode	-0.146	-0.146	0.424	ns	0.000	0.000	0.014	*	-0.206	-0.281	0.077	ns					0.140	0.113	0.000	***
Integument	-0.546	-0.533	0.001	**	-0.474	-0.454	0.003	**	-0.253	-0.239	0.238	ns	0.140	0.113	0.000	***				
Dormancy	0.434	0.434	0.017	*	0.409	0.409	0.079	ns	0.330	0.320	0.455	ns	-0.191	-0.191	0.295	ns	-0.566	-0.551	0.024	*
Best treatment					0.424	0.424	0.028	*	0.209	0.209	0.245	ns	-0.146	-0.146	0.424	ns	-0.546	-0.533	0.001	**
Tree type	0.133	0.117	0.503	ns	0.533	0.542	0.136	ns	-0.113	-0.046	0.588	ns	0.038	0.056	0.817	ns	-0.256	-0.233	0.866	ns
Forest types	0.126	0.117	0.561	ns	0.373	0.369	0.143	ns	0.020	0.088	0.170	ns	0.000	-0.028	0.252	ns	-0.247	-0.256	0.561	ns
Shade	0.012	-0.068	0.085	ns	-0.375	-0.417	0.073	ns	0.216	0.191	0.715	ns	-0.421	-0.387	0.108	ns	0.086	0.164	0.361	ns
Nusery/gap	-0.118	-0.178	0.001	**	-0.291	-0.336	0.002	**	0.018	-0.039	0.277	ns	-0.052	-0.077	0.721	ns	0.286	0.335	0.016	*
Predator	0.339	0.339	0.063	ns	0.583	0.583	0.004	**	0.168	0.193	0.225	ns	-0.277	-0.277	0.129	ns	-0.426	-0.386	0.040	*

r= Pearson's R, c= Spearman Correlation, p= Pearson chi-square probability,

2-tail sig.= Significant difference among variables (***p≤ 0.001, **p≤ 0.01, *p≤ 0.05; ns, not significant).

Table 24. Chi-square test among the best treatments and ecological relationship on seed propagation of 32 forest tree species (continue).

	Dormancy				TreeType				ForestType				Shade				Nursery/Gap				Predator			
parametor	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.	r	c	p	2-tail sig.
Seed size	0.409	0.409	0.079	ns	0.533	0.542	0.136	ns	0.373	0.369	0.143	ns	-0.375	-0.417	0.073	ns	-0.291	-0.336	0.002	**	0.583	0.583	0.004	**
Dispersal season	0.330	0.320	0.455	ns	-0.113	-0.046	0.588	ns	0.000	-0.028	0.252	ns	0.216	0.191	0.715	ns	0.018	-0.039	0.277	ns	0.168	0.193	0.225	ns
Dispersal mode	-0.191	-0.191	0.295	ns	0.038	0.056	0.817	ns	0.000	-0.028	0.252	ns	-0.421	-0.387	0.108	ns	-0.052	-0.077	0.721	ns	-0.277	-0.277	0.129	ns
Integument	-0.566	-0.551	0.024	*	-0.256	-0.233	0.866	ns	-0.247	-0.256	0.561	ns	0.086	0.164	0.361	ns	0.286	0.335	0.016	*	-0.426	-0.386	0.040	*
Dormancy					0.140	0.145	0.700	ns	0.305	0.327	0.086	ns	0.041	-0.004	0.335	ns	-0.114	-0.168	0.004	**	0.191	0.191	0.296	ns
Best treatment	0.434	0.434	0.017	*	0.133	0.117	0.503	ns	0.126	0.117	0.561	ns	0.012	-0.068	0.085	ns	-0.118	-0.178	0.001	**	0.339	0.339	0.063	ns
Tree type	0.140	0.145	0.700	ns					0.298	0.310	0.374	ns	-0.621	-0.614	0.000	***	-0.175	-0.159	0.199	ns	0.355	0.350	0.209	ns
Forest types	0.305	0.327	0.086	ns	0.298	0.310	0.374	ns					0.080	0.033	0.779	ns	-0.177	-0.188	0.201	ns	0.000	0.000	0.083	ns
Shade	0.041	-0.004	0.335	ns	-0.621	-0.614	0.000	***	0.080	0.033	0.779	ns					0.112	0.176	0.060	ns	-0.143	-0.188	0.291	ns
Nusery/gap	-0.114	-0.168	0.004	**	-0.175	-0.159	0.199	ns	-0.177	-0.188	0.201	ns	0.112	0.176	0.060	ns					-0.349	-0.359	0.125	ns
Predator	0.191	0.191	0.296	ns	0.355	0.350	0.209	ns	0.000	0.000	0.083	ns	-0.143	-0.188	0.291	ns	-0.349	-0.359	0.125	ns				

Table 25. Ecological variables tested for their effects on vegetative propagation of 10 native tree species.

Species	Leaf Flushing[1]	Leaf Fall[1]	Leafing[1] Phenology	Period[a]	Date[b] collection	Harvesting date[c]	Length[d] (days)	Class[e]	Class[f]	Best Treatments
Colona fragrocarpa	Ap-Ag	Dc-Ap	deciduous	Jn-Oc	27/Jl/2001	24/No/2001	120	medium	high	IBA 8000 ppm
Debregeasia longifolia	Ja-Ap, Jl-Ag, Oc, Dc	-	evergreen	Mr-Oc	30/Sp/2001	1/No/2001	32	high	high	seradix #3
Eurya acuminata	Ja-Dc	-	evergreen	Ja-Dc	18/Mr/2001	19/Jl/2001	123	poor	high	saradix #2
Ficus hirta	Ja-Mr, Jl-Dc	My-Ag	leaf changing	Ja-Dc	20/Ja/2001	28/Ap/2001	98	medium	high	saradix #2
Ficus lamponga	Ja, Jn	My-Jn, Nv-Dc	deciduous	Fb-Ap,Jl-Oc	15/Fb/2001	16/My/2001	90	poor	medium	saradix #2
Ficus superba	Ja-Ag, Oc-Nv	My-Jl, Sp-Oc	deciduous	Ja-Ap, Jl-Ag, Nv-Dc	29/Oc/2000	29/Dc/2000	61	medium	medium medium	IBA:NAA = 2:1 or IBA 3000 ppm
Macaranga kurzii	Fb-Oc	Ja-Fb	leaf changing	Fb-Oc	6/Ag/2001	14/Dc/2001	130	poor	high	IBA:NAA = 1:1
Morus macroura	Fb-Jl	Nv-Ap	deciduous	My-Ag	13/Jl/2001	6/Oc/2001	85	medium	high	IBA 8000 ppm
Saurauia roxburghii	Mr-Ap, Jn-Ag, Oc-Dc	-	evergreen	Ja-Dc	25/No/2000	25/Fb/2001	92	medium	medium	seradix #3
Trema orientalis	Ja, Mr-Sp	-	evergreen	ja-dc	23/Mr/2001	23/Ap/2001	31	medium	high	control

1=data in Chapter 2, Period[a] = During which material for cutting, Date[b] = Date Cutting Collection,
Harvesting date[c] = Cutting Ready for Potting, Length[d] (days) = Length of Experiment,
class[e]= Comparison Among Species Classes (high (>90), medium (40-90) and poor (<40),
class[f] = Relative Cutting Performance Score classes (high (>90), medium (40-90) and low (<40).

Table 26. Transformed variables of ecological factors tested for their effects on vegetative propagation of 10 native tree species.

Species	Leaf Flushing[1]	Leaf Fall[1]	Leafing[1] Phenology	Period[a]	Date[b] collection	Harvesting date[c]	Length[d] (days)	Class[e]	Class[f]	Best Treatments
Colona fragrocarpa	1	10	7	7	6	8	8	2	3	4
Debregeasia longifolia	2	4	1	5	8	7	2	3	3	3
Eurya acuminata	2	1	1	1	3	5	9	1	3	2
Ficus hirta	3	3	5	1	1	3	7	2	3	2
Ficus lamponga	1	5	3	3	2	4	5	1	2	2
Ficus superba	1	6	4	2	9	10	3	2	2	6
Macaranga kurzii	2	8	2	4	7	9	10	1	3	5
Morus macroura	1	7	6	6	5	6	4	2	3	4
Saurauia roxburghii	2	9	1	1	10	1	6	2	2	3
Trema orientalis	2	2	1	1	4	2	1	2	3	1

1=data in Chapter 2, Period[a] = During which material for cutting, Date[b] = Date Cutting Collection,
Harvesting date[c] = Cutting Ready for Potting, Length[d] (days) = Length of Experiment,
class[e] = Comparison Among Species Classes (high (>90), medium (40-90) and poor (<40),
class[f] = Relative Cutting Performance Score classes (high (>90), medium (40-90) and low (<40).

Table 27. Ten variables tested for their association with hormone treatment effects on cutting propagation.

Leaf Flushing[1]	Leaf Fall[1]	Leafing[1] Phenology	Period[a]	Date[b] collection	Harvesting date[c]	Length[d] (days)	Class[f]	Class[g]	Best Treatments
1=Ja-Dc	1=-	1=deciduous	1=Ja-Dc	1=20/Ja/2001	1=25/Fb/2001	1=31	1=poor	1=low	1=control
2= Ja, Mr-Sp	2=Ja-Fb	2=evergreen	2=Ja-Ap,Jl-Ag,Nv-Dc	2=15/Fb/2001	2=23/Ap/2001	2=32	2=medium	2=medium	2=seradix#2
3=Ja-Mr, Jl-Dc	3=My-Jn,Nv-Dc	3=leaf changing	3=Fb-Ap,Jl-Oc	3=18/Mr/2001	3=28/Ap/2001	3=61	3=high	3=high	3=seradix#3
4=Ja-Ap,Jl-Ag,Oc,Dc	4=My-Jl,Sp-Oc		4=Fb-Oc	4=23/Mr/2001	4=16/My/2001	4=85			4=IBA 8000 ppm
5=Ja,Jn	5=My-Ag		5=Mr-Oc	5=13/Jl/2001	5=19/Jl/2001	5=90			5=IBA:NAA = 1:1
6=Ja-Ag,Oc-Nv	6=Nv-Ap		6=My-Ag	6=27/Jl/2001	6=6/Oc/2001	6=92			6=IBA:NAA = 2:1
7=Fb-Jl	7=Dc-Ap		7=Jn-Oc	7=6/Ag/2001	7=1/No/2001	7=98			or IBA 3000 ppm
8=Fb-Oc				8=30/Sp/2001	8=24/No/2001	8=120			
9= Mr-Ap,Jn-Ag,Oc-Dc				9=29/Oc/2000	9=14/Dc/2001	9=123			
10=Ap-Ag				10=25/No/2000	10=29/Dc/2000	10=130			

1=data in Chapter 2, Period[a] = During which material for cutting, Date[b] = Date Cutting Collection,
Length[d] (days) = Length of Experin CPS[e] = Comparison among species, Harvesting date[c] = Cutting Ready for Potting,
class[f]= Comparison Among Species Classes (high (>90), medium (40-90) and poor (<40),
class[g]= Relative Cutting Performance Score classes (high (>90), medium (40-90) and low (<40).

Chapter 7

Conclusions and Recommendations

The main objectives of this study were to develop appropriate techniques to propagate indigenous forest tree species for forest restoration projects and to explore relationships between the ecology of the species tested and best horticultural practices. Recommendations arising from this study, to imp rove horticultural practices to grow trees for forest restoration are summarized below.

Recommendation for 32 Experiment Species

Acrocarpus fraxinifolius

Scarification is recommended for this species. Seed germination of 90% within only 5 days can be achieved after this pre-treatment. Seeds should be sown in shade.

Afzelia xylocarpa

Before sowing seeds, the aril should be removed. Scarification + soaking in water for 24 hours is recommended to achieve a germination rate of 96% in 18 days. The seeds should be sown in shade.

Albizia chinensis

Pre-treatment of seeds with scarification or soaking in water overnight can overcome dormancy. Pre-treated seeds gave 93-96% germination within 6-11 days. Seeds can be sown in partial shade or deep shade.

Aporusa villosa

It can be propagated by seed, including by direct sowing in forest gaps. The time of seed collection is important for germination success. The seeds are recalcitrant and cannot tolerate drying out. Seeds germinate well (92%) and germination is completed within 19 days without pre-treatment. Seeds should be sown in shade in the nursery.

Betula alnoides

This species has a very low maximum percentage germination (19% in 14 days) without pre-treatment. Seeds should be sown in shade. Alternative seed treatments or vegetative propagation should be investigated.

Cassia fistula

Scarification and soaking in the water over night or soaking in sulfuric acid for 10 minutes can be used to overcome seed dormancy. Germination of about 94-98% within 6-9 days can be achieved after these pre-treatments. Seeds should be sown in partial shade or deep shade.

Colona flagrocarpa

This species is very difficult to propagate by seed, so cutting propagation, with IBA 8000 ppm, is recommended for this species.

Debregeasia longifolia

This species is easily propagated by seed and by cuttings. Seeds have a high germination rate without pre-treatment (94% in 51 days). Seeds should be sown in partial shade. Leafy stem cuttings treated with Seradix #3 and planted in rice hush charcoal: river sand (1:1) showed 68% rooting success.

Diospyros undulata

Seeds are recalcitrant and loose viability very rapidly. Seeds should be sown in shade. A maximum germination rate of 43% within 5 days can be achieved without pre-treatments. Seeds can also be sown directly in forest gaps.

Elaeocarpus lanceifolius

Seeds must be sown in the deep shade. Special techniques were required to extract the pyrenes with complete removal by cracking open the endocarp. This method is necessary to increase germination percentage and is better than simply nicking the woody endocarp with a small cut. Pyrenes of this species showed about 75-83% germination in 41-50 days after scarification or scarification and then soaking in water over night.

Elaeocarpus prunifolius

This species is very difficult to propagate from seed. Scarification (the endocarp had been removed) or scarification with soaking in water for 24 hours increased germination to only 44-47% in 30-32 days. Seeds should be sown in shade.

Eurya acuminata

This species can be propagated by seed (68% within 33 days) without pre-treatment. Seeds should be sown in partial shade. This species can also be propagated by cuttings (18% with Seradix #2).

Ficus hirta

Ficus hirta has low percentage germination (20% within 16 days). Seeds should be sown in partial shade. Leafy stem cuttings were successful (45%) with Seradix #2 being the best treatment.

Ficus lamponga

This species can easily be propagated by seed. Seed had a germination rate of about 80% in 24 days without pre-treatment. Seeds should be sown in partial shade. Cuttings were less successful (23% of the roots) after they were treated with IBA: NAA = 2:1.

Ficus superba

Ficus superba can be propagated from seed (87% within 10 days) and vegetatively. Seeds germinated well without pre-treatments, but seedlings grew slowly. Seeds should be sown in shade. IBA 3000 ppm encouraged high rooting of cuttings (72%). IBA: NAA (2:1) resulted in 42% of cuttings developing shoots and roots.

Glochidion acuminatum

Soaking in concentrate sulfuric acid for 5 minutes is the best treatment for this species, resulting in 38% germination in 172 days. Seeds should be sown in partial shade.

Irvingia malayana

Soaking in hot water is recommended for this species, resulting in 96% germination in 48 days. Seeds should be sown in shade.

Lagerstroemia speciosa

Soaking in water or soaked in sulfuric acid for 3 minutes resulting in 78-89% germination in 71-75 days is recommended for this species. Seeds should be sown in partial shade. Seed can also be sown directly in the field.

Macaranga kurzii

Seeds have delayed germination. Also, cuttings propagation was not very successful (25%) after treatment with Seradix #2 and #3. Alternative techniques are recommended for research.

Macropanax dispermus

Viability of the seeds is short, so they should be sown immediately. Seeds should be sown in shade. Seeds had 67% germination in 24 days without pre-treatment.

Morus macroura

This species can be easily propagated by seed (99% within 5 days) after pre-treatment by soaking in sulfuric acid for 1 minute. Seeds should be sown in shade. It can also be successfully propagated by leafy stem cuttings (90% of roots) without rooting hormone. Also, it was suitable for direct seeding in the forest gap.

Reevesia pubescens

Treatment with sulfuric acid for 3 minutes resulting in 91% in 18 days is recommended for this species. Seeds could be sown in partial shade or deep shade.

Saurauia roxburghii

This species had low percentage germination (38-43% within 29-41 days). Seeds should be sown in shade. Propagation from leafy stem cutting was more successful. Seradix #3 was the best treatment to encourage rooting about 65%. It was suitable for direct seeding.

Schleichera oleosa

Seeds have delayed germination. The germination rate was very low (18% in 90 days) without pre-treatment. Seeds should be sown in shade. Seed can also be sown directly in the forest gap. However, alternative methods of propagation should be investigated.

Shorea obtusa

Seeds rapidly lose their viability. Mature seeds germinate well (about 83%) immediately after collection without pre-treatment. Seeds should be sown in partial shade. Germination was completed within 3 days.

Sindora siamensis

Scarification or scarification + soaking are recommended seed pre-treatments. Using these methods, the germination rate was about 61-74% within 5-6 days. Seeds should be sown in shade.

Terminalia bellirica

Soaking in water is recommended resulting in 100% germination in 20 days after pre-treatment. Seeds should be sown in shade.

Terminalia chebula

The seeds should sown in the shade. Special techniques are required to extract the pyrenes with complete removal by cracking open the endocarp. Pyrenes of this species show about 42-46% germination in 18-20 days after scarification by soaking in sulphuric acid for 5-10 minutes. Seeds should be sown in shade.

Terminalia mucronata

Seeds have no dormancy, and the germination rate is often low (38% in 27 days). Scarification by hand and extract the pyrenes with complete removal by cracking open the endocarp was the best treatment for this species. Seeds should be sown in shade.

Tetradium glabrifolium

Seeds had often low germination rate (41% in 76-96 days) after pre-treatment. Soaking seeds in sulphuric acid for 5-10 minutes is the best treatment for this species. Seeds should be sown in shade.

Trema orientalis

Seeds contain an impervious testa which must be ruptured by sulphuric acid for 3 minutes before they will germinate (98% in 150 days). Seeds could be sown in partial shade or deep shade. Cuttings were less successful, but had the 48% with roots after no hormone treatments.

Vacinium sprengelii

Cleaned seeds should be sown as soon as possible after collection. Seeds showed about 51% germination in 27 days without pre-treatment. Seeds should be sown in shade. It was suitable for direct seeding.

Recommendation for Other Species.

Seed pre-treatment had the greatest effect on germination of seeds with thick integument (seed coat). Scarification, scarification + soaking and heat were the best treatments that promoted germination of these seeds with thick integuments, including pyrenes covered by woody endocarps. *Trema orientalis*, seeds had an endocarp. Thus, its seeds required scarification by sulphuric acid treatment for 3 minutes to encourage

seed germination. Seeds of *Acrocarpus fraxinifolius*, *Albizia chinensis*, *Cassia fistula* and *Lagerstroemia speciosa* required scarification and/or scarification + soaking or acid treatment for 3-10 minutes, to break the thick testa and wing to encourage seed germination.

Small non dormant-seeds tend to germinate better in the nursery, whilst dormant seeds do better under gap conditions.

Seed predation has the greatest effects on seed germination with large and medium seed covered with thick integuments.

Seed propagation should test pre-treatments with thick integuments tree species. Seeds of climax tree species should be sown in shade. Small non dormant-seeds should be germinated in the nursery. Also, medium or large seeds of climax tree, covered with thick integuments should be protected from predator.

Field experiments should test the feasibility of direct seeding of the following seven species; *Aporusa villosa*, *Diospyros undulata*, *Lagerstroemia speciosa*, *Morus macroura*, *Saurauia roxburghii*, *Schleichera oleosa* and *Vaccinium sprengelii*.

Only five tree species achieved maximum mean values of survival with roots of greater than 60%. IBA 8000 ppm was the best treatment for *Colona flagrocarpa* and *Morus macroura*. The cuttings of *Debregeasia longifolia* and *Saurauia roxburghii* responded best to Seradix #3. IBA 3000 ppm or IBA: NAA=2:1 is the best treatment for *Ficus superba*.

None of the ecological variables tested had any association with the outcome of chemical treatments to promote rooting and shooting of leafy stem cuttings.

Further research should test IBA 8000 ppm and Seradix #3 on other forest tree species.

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Appendix I. Seedling Descriptions

1. *Acrocarpus fraxinifolius* Wight *ex* Arn. (Leguminosae, Caesalpinioideae)

Development: The radicle and hypocotyl emerge from one end of the seed. The hypocotyl becomes erect, the cotyledons spread, and the testa splits and drops off. Early growth is very rapid.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, subcoriaceous, spreading, elliptic, tip broadly rounded, gradually narrowing to the base, sessile; entire, glabrous, venation pinnate, dark green above, light green beneath; 14 x 10 mm

Radicle: slender, very finely puberulous, whitish-brown, turning to dark brown with age, root hairs brown

Hypocotyl: terete, whitish, turning brownish-light green with age, glabrous, to 5.6 cm long

Epicotyl: terete, slender, very finely puberulous, green, 1-1.5 cm long.

Eophylls: alternate, once pinnate, leaflets 5, lower 3 alternate, upper pair opposite; leaflet blades thin, ovate, tip acute, base ranging from symmetrically rounded in the alternate ones, upper pair oblique, entire; venation pinnate, midnerve with 4-5 secondary nerves on each sides; finer venation reticulate; main nerves on both sides and margins finely ciliolate; petiolules *c.* 0.5 mm long; petiole (infrajugal axis) *c.* 9 mm long, axes puberulous, terminal (ultrajugal) extension *c.* 1.25 mm long

Terminal bud sericeous

Figure 1

Voucher: Vongkamjan S 1

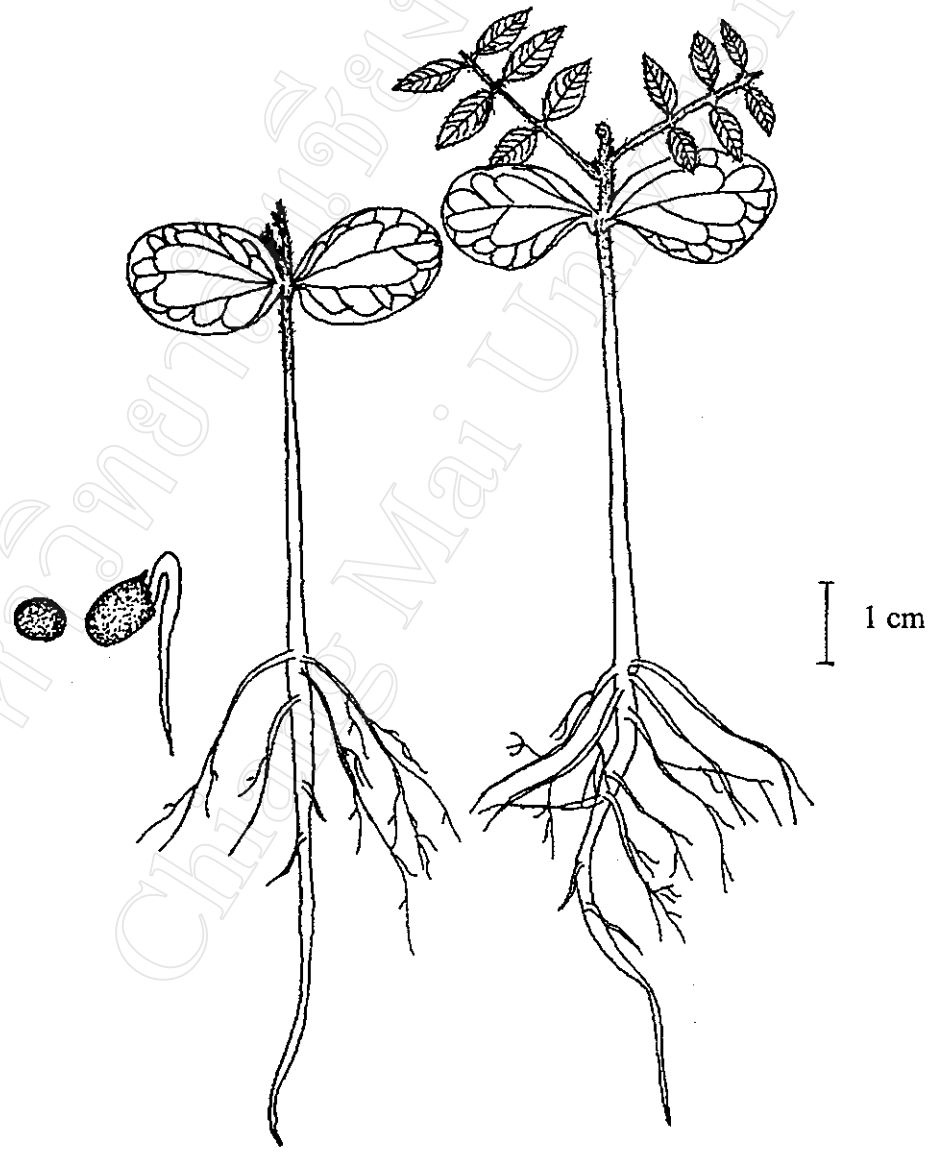

Figure 1. *Acrocarpus fraxinifolius* Wight *ex* Arn.

2. *Afzelia xylocarpa* (Kurz) Craib (Leguminosae, Caesalpinioideae)

Development: The radicle and hypocotyl emerge from one end the seed. By the swelling of the cotyledons the testa ruptures irregularly and is shed. The cotyledons are carried high above the soil by the initially nodding hypocotyl which rapidly becomes erect.

Germination type: PER (phanerocotylar epigeal reserve storage)

Paracotyledons leaves: 2, opposite, sessile; blades obovate 0.8-1.2 cm thick; apex rounded, base obtuse and slightly oblique; flat and slightly concave dorsally, convex ventrally glabrous, reddish-green, 2-2.4 x 3.4-3.8 cm

Radicle: slender, fibrous, pale brown when young turning to dark brown, root hairs pale brown

Cotyledons: paired, erect, plano-convex, apex broadly rounded, narrowed at the base 27-30 x 17-18 mm

Hypocotyl: terete, whitish to light green, glabrous, 5 mm thick

Epicotyl : slender, glabrous, 7-8 cm long, 2 mm thick

Eophylls: opposite, once pinnate; leaflets 2 opposite, pairs; axes glabrous, leaflet blades thin oblong, tip acuminate, base acute margin entire; venation pinnate, secondary nerves 16-19 on each side of the midrib, finer venation reticulate; glabrous, 66 x 20 mm; petiolules pulvinate, 2 mm long; axes glabrous; infrajugal axis (petiole) 28-35 mm, ultrajugal extension *c.* 11 mm

Stipules narrowly triangular, *c.* 4-5 mm long

Figure 2

Voucher: Vongkamjan S 2

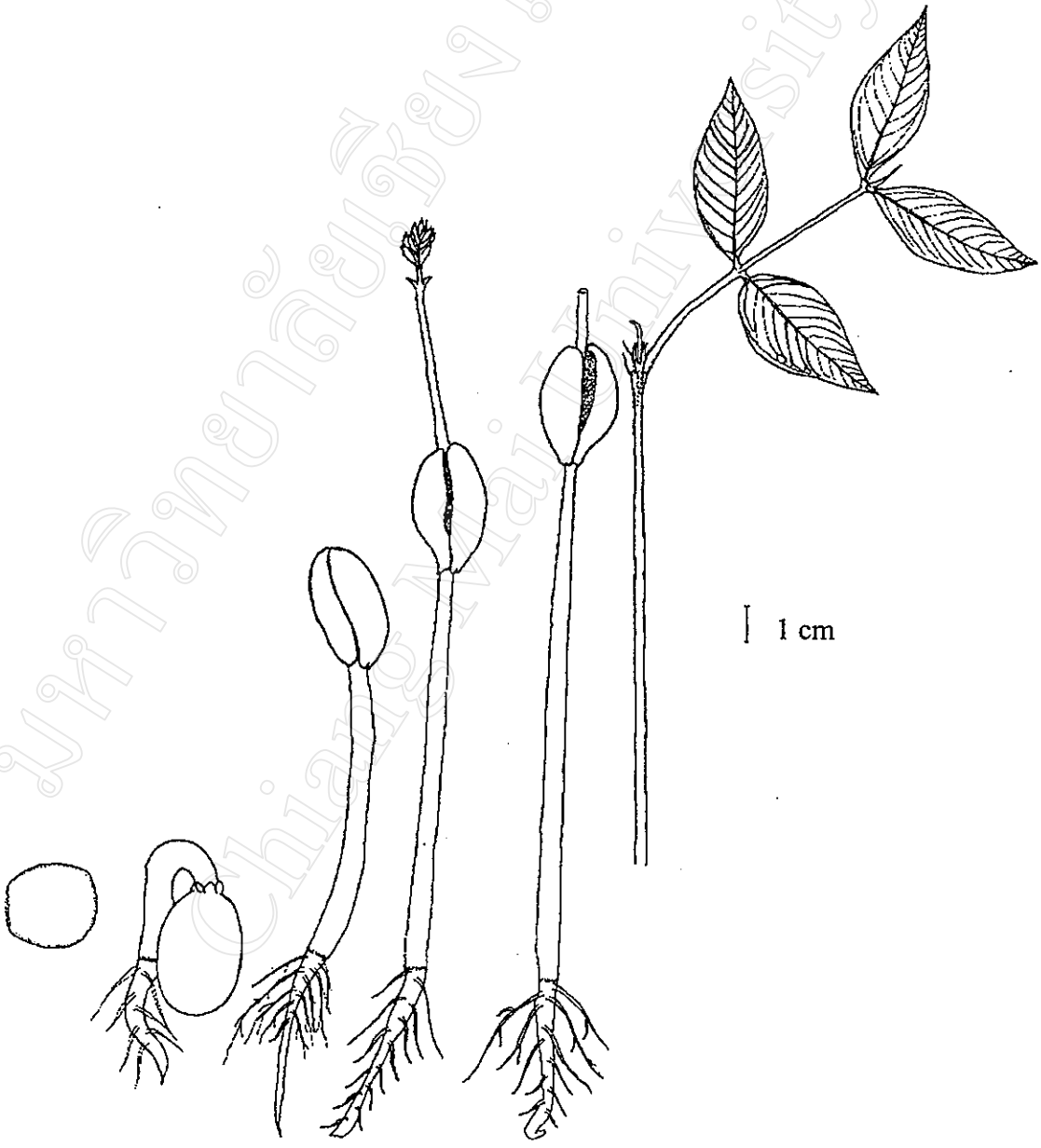

Figure 2. *Afzelia xylocorpa* (Kurz) Craib

3. *Albizia chinensis* (Osb.) Merr. (Leguminosae, Mimosoideae)

Development: The radicle and hypocotyl emerge from one end of the seed. By the swelling of the cotyledons the testa ruptures irregularly and is shed. The cotyledons are carried high above the soil by the initially nodding hypocotyl which rapidly becomes erect.

Germination type: PER (phanerocotylar epigeal reserve storage)

Radicle: slender, white turning to brownish-white, with many slender or slightly sinuous branches; root hairs brownish-white

Hypocotyl: light green turning to pink-white and green, glabrous, 3.2-3.5 cm long

Cotyledons: paired, erect, plano-convex, thick, coriaceous; oblong; apex obtuse, base sagittate; margin entire; glabrous; light pink-green dorsally, light pink-green ventrally, sessile

Eophylls: opposite, once-pinnate with 5 pairs of opposite leaflets and a terminal one; the next leaf is bifoliate with leaflets similar to the pinnate leaf and with 5 pairs of secondary leaflets which are oblong, apex and base rounded, entire, venation pinnate, secondary nerves 3-5 on each side of the midrib, mid green above and light green below, 9 x 3 mm

Figure 3

Voucher: Vongkamjan S 3

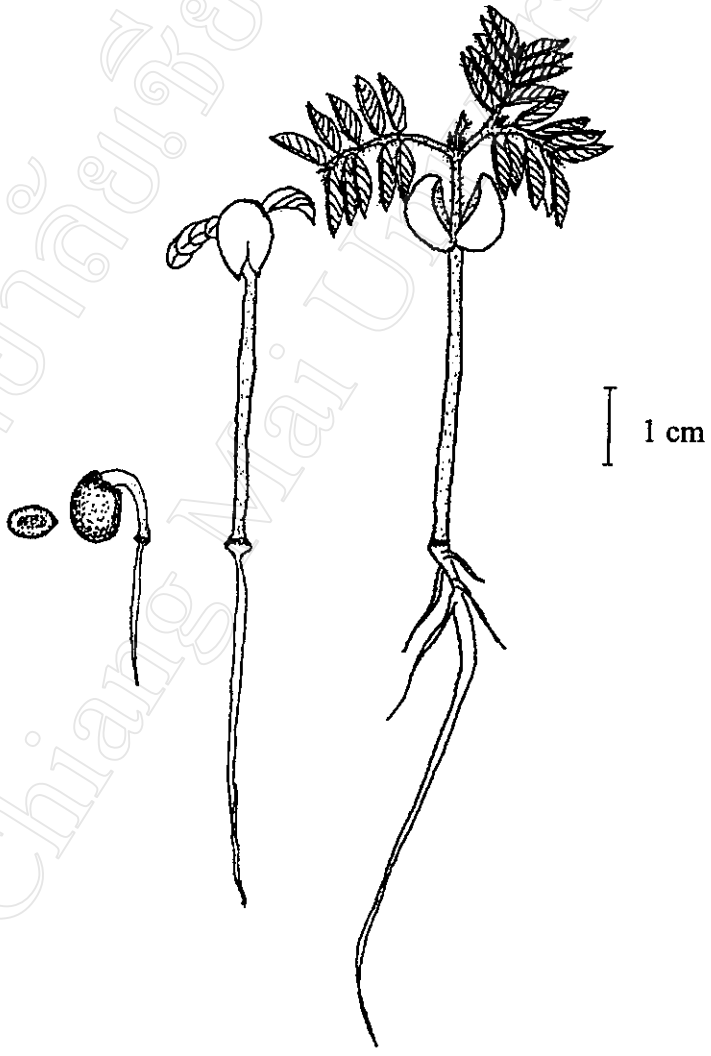

Figure 3. *Albizia chinensis* (Osb.) Merr.

4. ***Aporusa villosa*** **(Lindl.) Baill. (Euphorbiaceae)**

Development: The radicle and hypocotyl emerge from one end of the seed. After establishment of the radicle the enclosed cotyledons are carried up by the hypocotyl which becomes erect and the testa is shed by the spreading of the cotyledons.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, green, simple, blades elliptic, apex irregularly broadly rounded and emarginate; base truncate, abruptly narrowed into the petiole; margin entire, glabrous, venation pinnate, dark green above, light green below 1.9 x 1.9-2 cm; petiole glabrous, 2 mm long

Radicle: long, slender, flexuous, brownish-green, with many long, slender, branched, brownish-cream root hairs

Hypocotyl: rapily elongating, green, turning brownish

Epicotyl: terete, densely, minutely, brownish sericeous elongating to 1.2 cm long

Eophylls: 2, simple, spiral, subcoriaceous; apex lanceolate, base truncate; dark-green, above, green below, 3.2-4 x 1.5-1.6 cm, midnerve sunken above, secondary nerves pinnate, 4-6 pairs on each side of the midnerve; finer vein reticulate, arching and joining the other veins at the margin; light green above, light green below; margin entire; petiole, densely sericeous, light green, 4-7 mm long

Figure 4

Voucher: Vongkamjan S 4

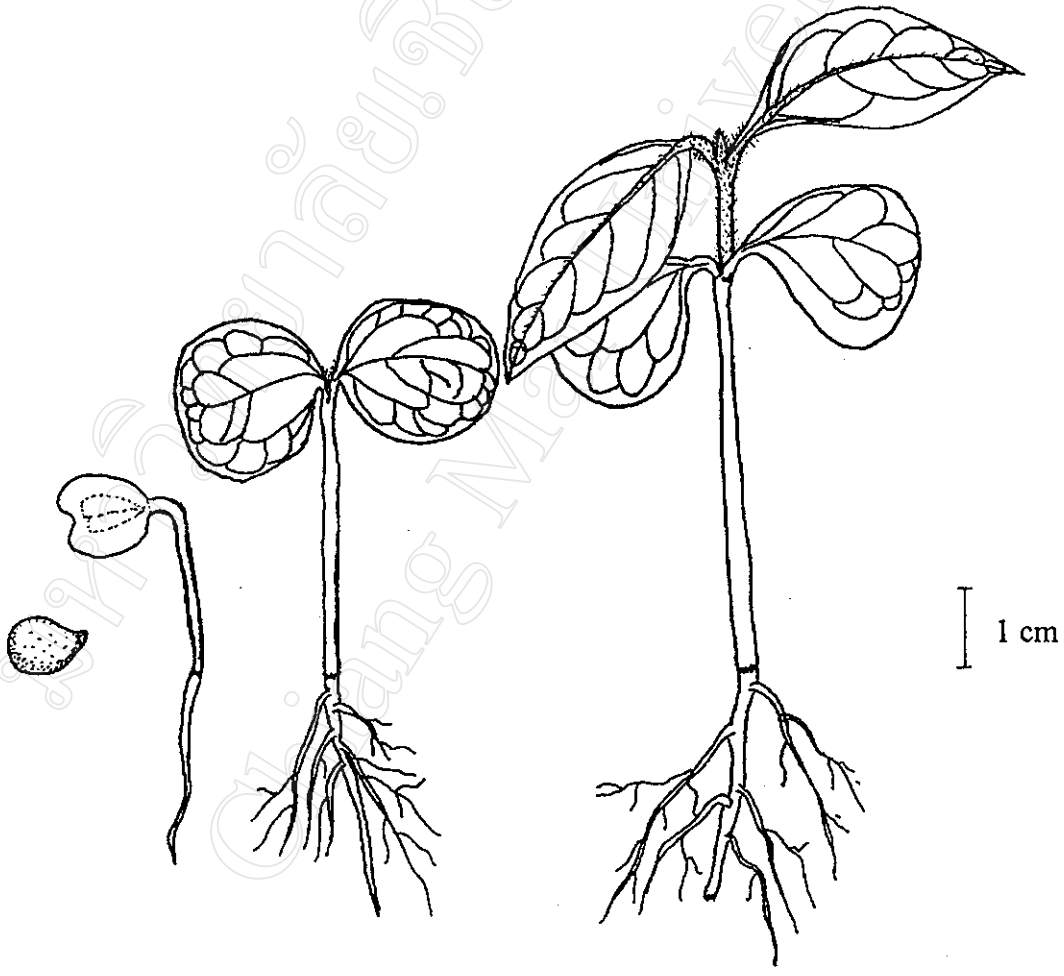

Figure 4. *Aporusa villosa* (Lindl.) Baill.

5. *Betula alnoides* Ham. *ex* D. Don (Betulaceae)

Development: The radicle and hypocotyl emerge from the small winged fruit. By spreading the cotyledons free themselves from the testa and are carried above the soil by the hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: opposite, elliptic, apex and base obtuse, margin entire, glabrous; light yellow-green above, pale light yellow-green below; 2-3 x 2 mm; venation obscure, only the midrib visible; petiole *c.* 1 mm long

Radicle: with many long slender, branched, whitish-brown root hairs

Hypocotyl: finely white sericeous, light green-pink

Epicotyl: finely white sericeous, light green-pink

Eophylls: simple, spirally arranged, elliptic; apex acute, base cuneate; margin dentate, sparsely white sericeous above, light green and sparsely white sericeous along the midrib below; green above, light green below; 4.5-5 x 4 mm, secondary venation pinnate, with 3-5 pairs of alternate veins; petiole light green-pink, 1 mm long, minutely white sericeous

Stipules finely white sericeous, light green, 0.5 mm long

Figure 5

Voucher: Vongkamjan S 5

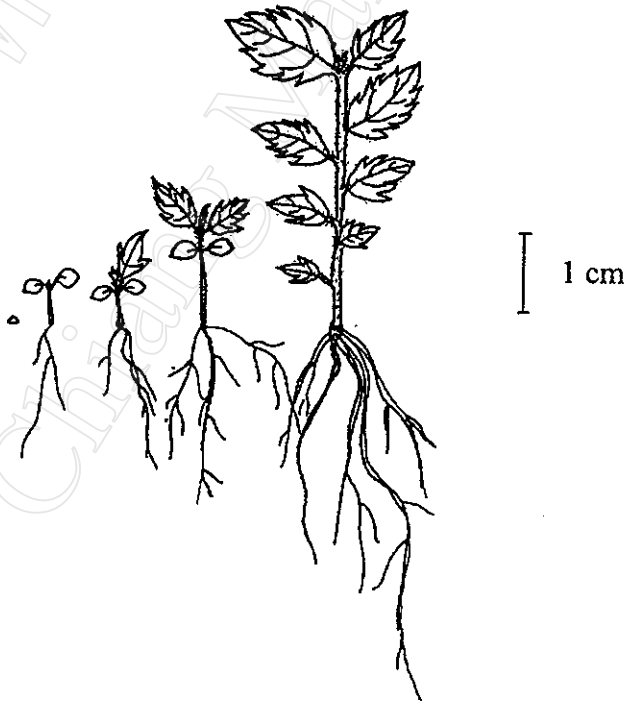

Figure 5. *Betula alnoides* Ham. *ex* D. Don

6. *Cassia fistula* L. (Leguminosae, Caesalpinioideae)

Development: The radicle and hypocotyl emerge from one end of the seed. By the swelling of the cotyledons the testa ruptures irregularly and is shed. The cotyledons are carried high above the soil by the initially nodding hypocotyl which rapidly becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, simple, opposite, slightly succulent, sessile, spreading, elliptic; apex broadly rounded, base obtuse, with 3 main nerves from the base, finer venation obscure; margins entire; glabrous; dark green above, light green below; 2-2.2 x 1.4 cm

Radicle: slender, fibrous, whitish-brown, turning to dark brown with age, root hairs numerous

Hypocotyl: terete, finely puberulous; whitish-light green, turning brownish-light green, 5-5.2 cm long

Epicotyl: terete, erect, puberulous, green, 2-2.2 cm long

Eophylls: alternate, once pinnate, with 2 pairs of opposite leaflets; leaflet blades thin, oblong; apex acuminate, base acute; margins entire; venation pinnate, secondary nerves 3-5 on each side of the midnerve; finer venation reticulate; glabrous and dark green above, puberulous and light green below; 8-9 x 19-22 mm petiolules 2-3 mm long, petiole *c.* 1 cm long; stipules subulate, 1 mm long

Figure 6

Voucher: Vongkamjan S 6

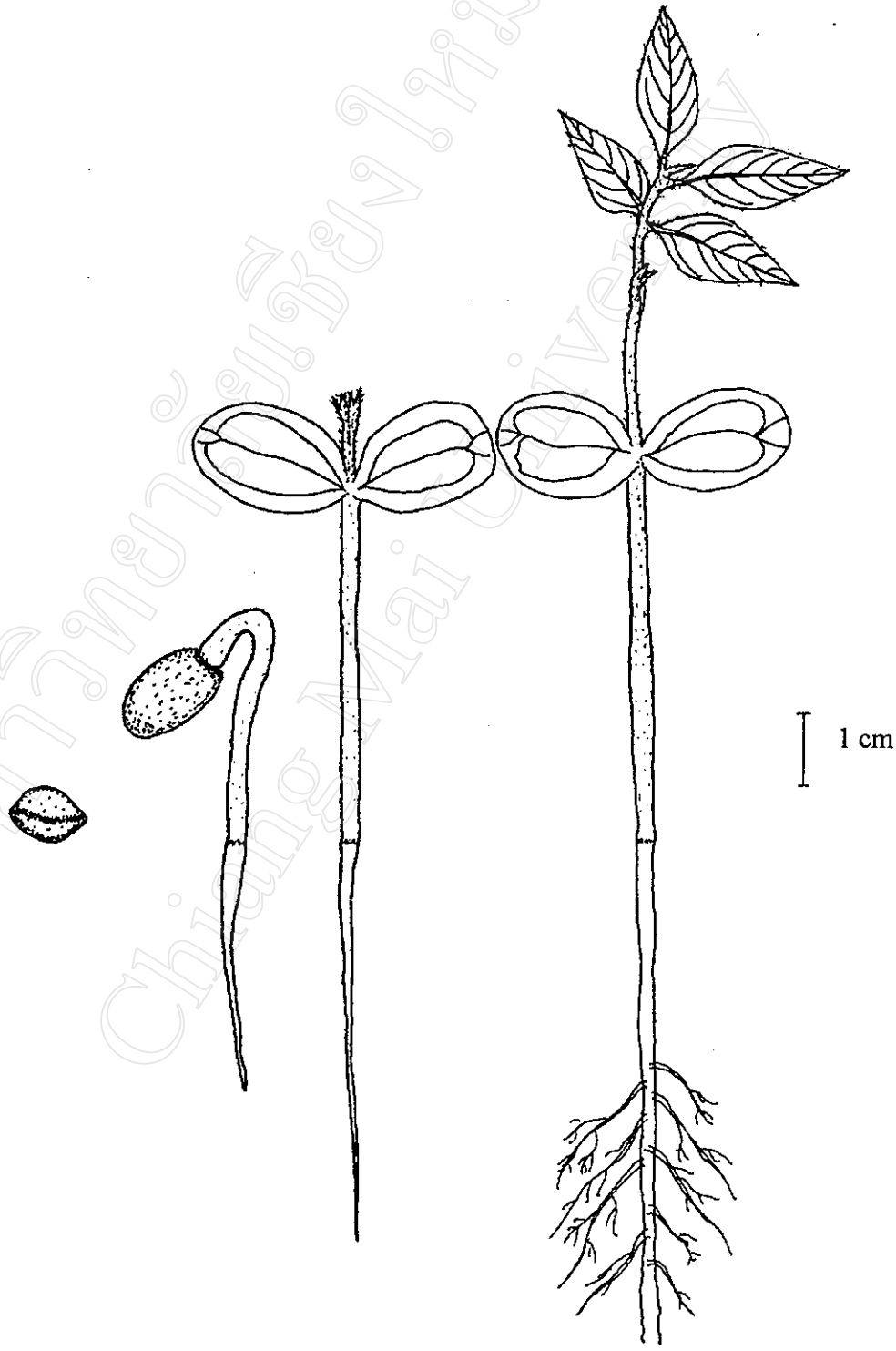

Figure 6. *Cassia fistula* L.

7. *Debregeasia longifolia* (Burm. f.) Wedd. (Urticaceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves by spreading from the testa and are carried above the soil by the hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: opposite, ovate, apex retuse, base obtuse; margin entire, light green, finely white sericeous; venation very obscure, trinerved, pale light green; 3 x 2 mm; petioles pale light green, densely finely white sericeous, 0.5 mm long

Radicle: indistinct, with many long slender, branched, whitish-brown root hairs

Hypocotyl: finely white sericeous, pale whitish-green, turning to pale light green with age

Epicotyl: finely white puberulous, pale light green

Eophylls: simple, opposite, thin, blades ovate, apex acute, base truncate, margin crenate-serrate, finely and sparsely white sericeous, light green above, light green to silver grey and densely, finely white sericeous below; venation pinnate, pale light green, secondary veins 3 on each side of the midrib, 6 x 3 mm; petiole white sericeous, pale light green-pink, 2 mm long

Figure 7

Voucher: Vongkamjan S 7

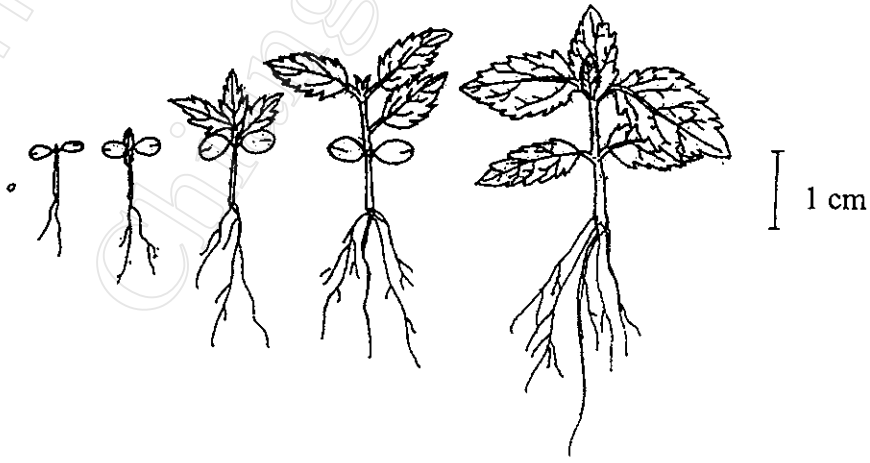

Figure 7. *Debregeasia longifolia* (Burm. f.) Wedd.

8. *Diospyros undulata* Wall. *ex* G. Don var. *cratericalyx* (Craib) Bakh. (Ebenaceae)

Development: The radicle and hypocotyl pierce the testa from one end of the seed. The elongating hypocotyl pushes the testa and cotyledons above the soil. The testa and endosperm are shed by the expanding cotyledons.

Germination type: PEF (phanerocotylar epigeal foliaceous), with non-photosynthetic, evanescent cotyledons

Paracotyledons: 2, opposite, sessile; blades thin, elliptic, apex and base rounded, margins entire, reflexed and the margins nearly touching; with 5 main nerves from the base, glabrous, whitish-pale maroon, 15 x 5 mm; caducous when the 2^{nd} -3^{rd} eophylls appear

Radicle: long, slender, fibrous, black

Hypocotyl: terete, slightly succulent, glabrous whitish-green, turning grayish or brownish-green, 6.5-6.8 cm long

Epicotyl: terete, glabrous, 1-1.5 cm long

Eophylls: simple, opposite; blades thin, ovate; apex acute, base obtuse; margins entire; venation pinnate, secondary nerves 5 pairs, finer venation reticulate; glabrous, glossy brown when young, turning glossy dark green above, green below; 2.8-3 x 1 cm; petiole 1.5-2 mm long

Figure 8

Voucher: Vongkamjan S 8

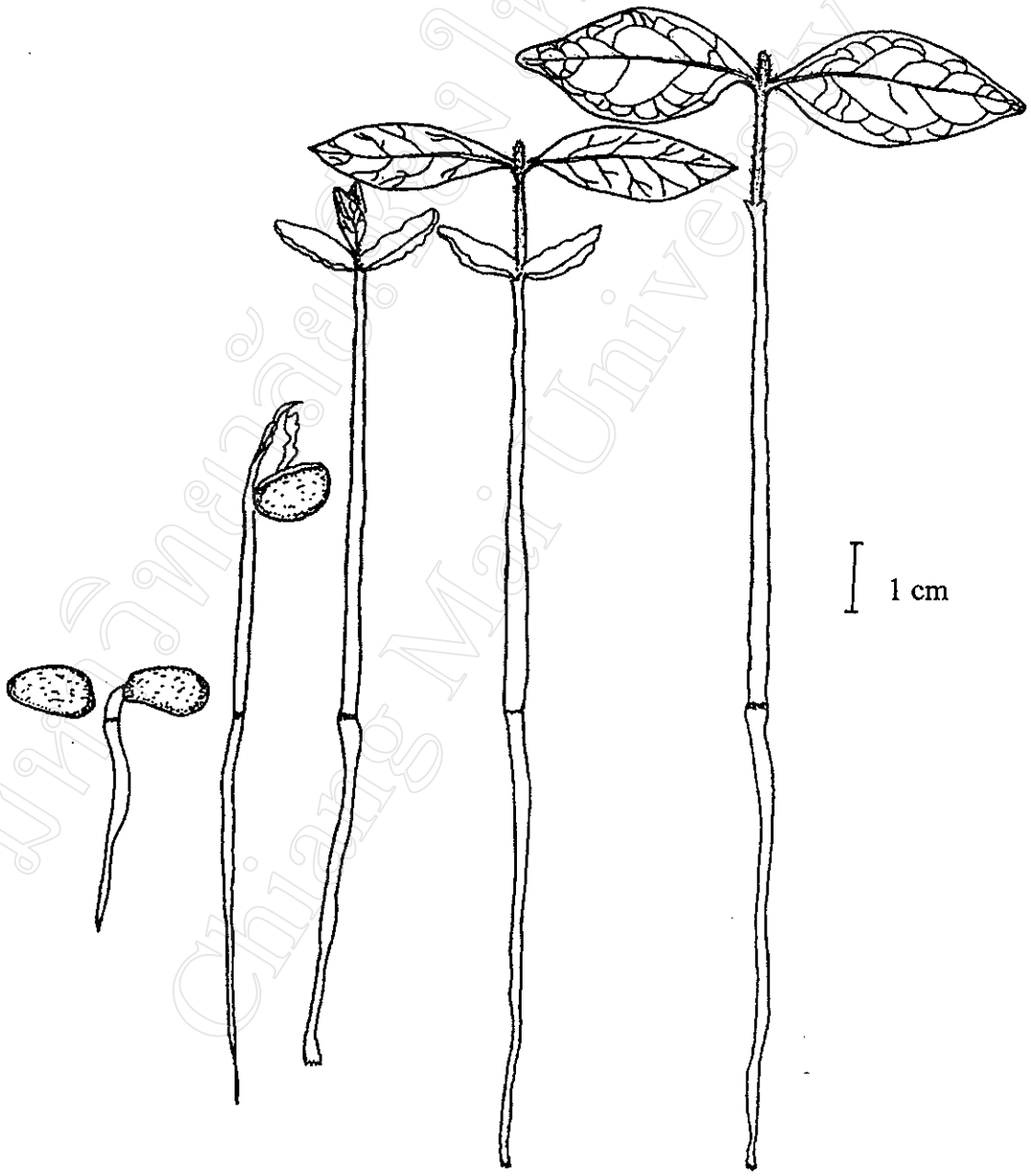

Figure 8. *Diospyros undulata* Wall. *ex* G. Don var. *cratericalyx* (Craib) Bakh.

9. *Elaeocarpus lanceifolius* Roxb. (Elaeocarpaceae)

Development: the endocarp splits longitudinally, the hypocotyl and radicle emerge from the slit, after establishment of the radicle, the hypocotyl becomes erect, pulling the paracotyledons, and epicotyl free and a short resting stage occurs, then with expands and the paracotyledons spread

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, thin, glabrous; elliptic, apex rounded and obtuse, base obtuse, margin entire, venation pinnate, distinct, basal nerves two, extending to the margins about the middle of the blade, other nerves 2 pairs, glabrous, dark green above, light green below, 4-5.5 x 2-3 cm; petioles 3-4 mm long

Radicle: sturdy, fleshy, creamy-white, turning brown, with many long, slender, much-branched, creamy-white root hairs

Hypocotyl: glabrous, bright light green

Epicotyl: very finely puberulous

Eophylls: simple, alternate, youngest blades elliptic, apex acuminate, base acute densely sericeous, rapidly glabrescent, margin: lower ½ of blade entire, upper ½ with shallow, spaced serrations; midnerve sunken above, raised below; secondary venation, pinnate with 3-4 alternate nerves on each side of the midnerve, arching below the margin, tertiary venation reticulate, drying with a fine bullate texture, 75-80 x 30-35 mm; petiole very finely puberulous, exstipulate

Figure 9

Voucher: Vongkamjan S 9

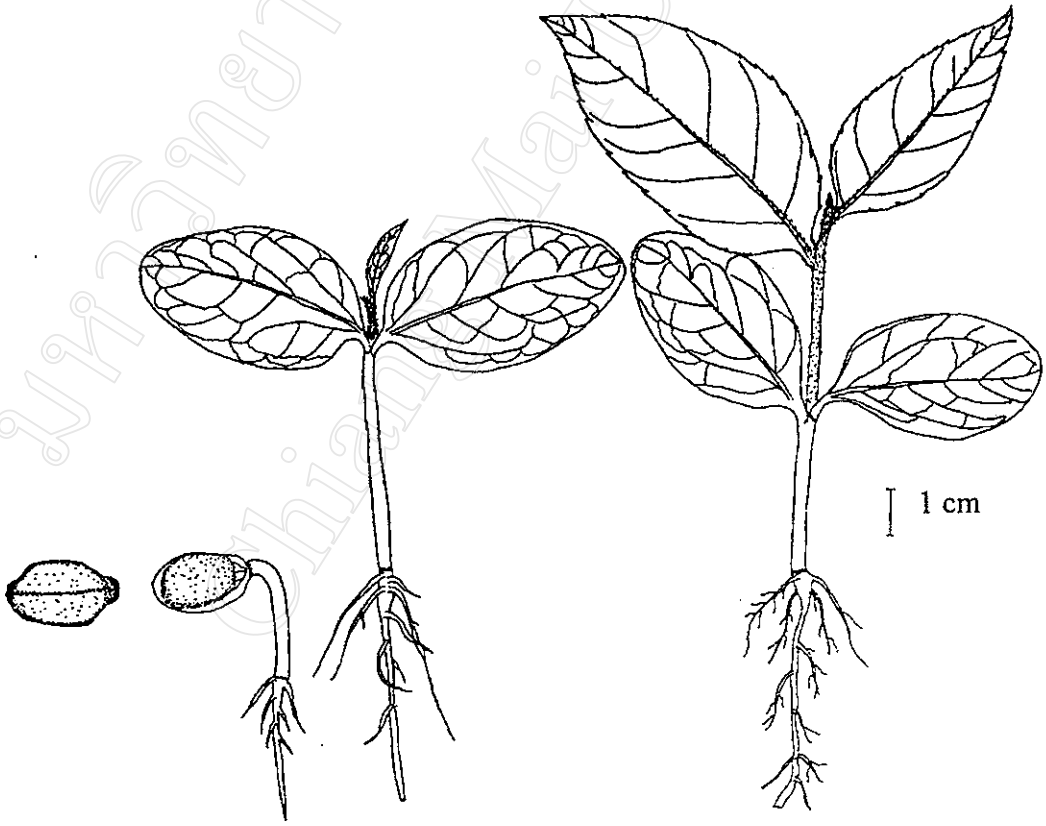

Figure 9. *Elaeocarpus lanceifolius* Roxb.

10. *Elaeocarpus prunifolius* Wall. *ex* C. Muell. (Elaeocarpaceae)

Development: The radicle and hypocotyl emerge from one end of the pyrene, which splits longitudinally. The hypocotyl becomes erect, carrying the enclosed cotyledons above the soil. The cotyledons are enclosed in the pyrene, after which the testa and endocarp are shed by expanding of the cotyledons.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, sessile; blades thin, lanceolate, apex and base obtuse, margins entire; midnerve distinct, other nerves obscure; glabrous; light green above, pale light green beneath; 7.8 x 2.7 cm

Radicle: long, fibrous, brownish, with few, finely-branched root hairs

Hypocotyl: terete, slender, glabrous, brownish-green, turning green; 3.2-5.5 cm long

Epicotyl: terete, glabrous, reddish, turning brownish-green, up to *c.* 2 mm long

Eophylls: 2, opposite, simple; blades thin, ovate-oblong; apex caudate, base acute and decurrent on the petiole, margins serrate; venation pinnate, midnerve sunken above, raised below; with 5-7 secondary nerves on each side of the midnerve, finer venation reticulate, glabrous; orange-red when young, turning green above, pale green below; *c.* 47 x 15 mm; petiole *c.* 2 mm long

Figure 10

Voucher: Vongkamjan S 10

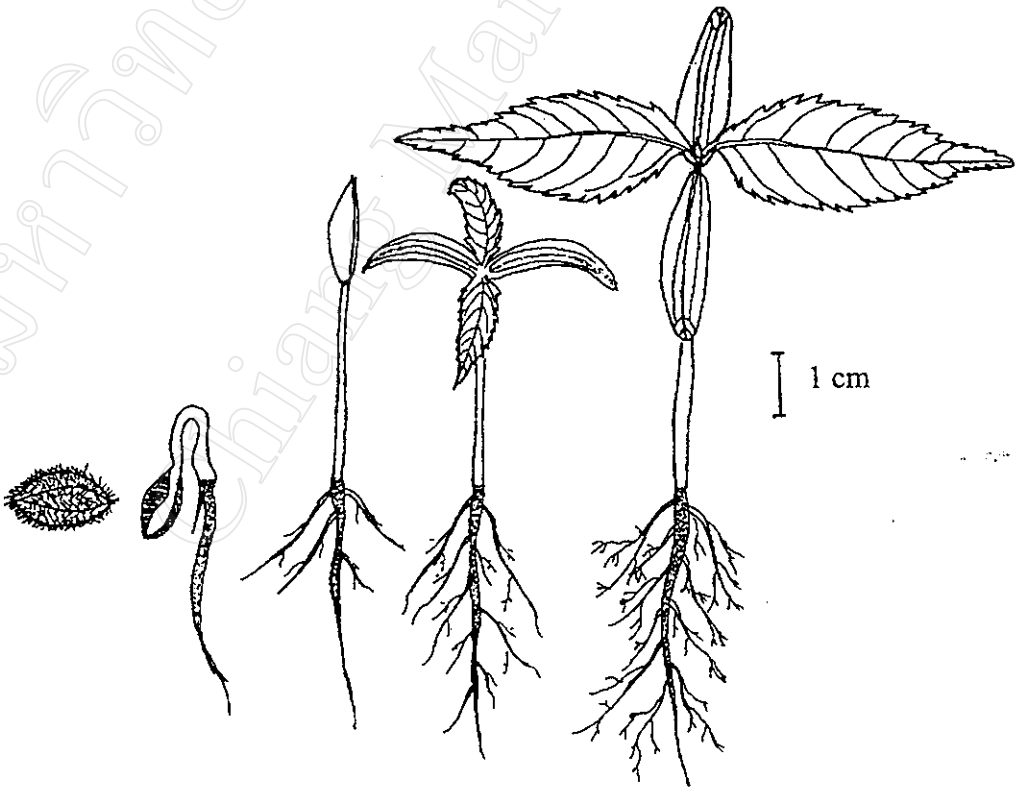

Figure 10. *Elaeocarpus prunifolius* Wall. *ex* C. Muell.

11. *Eurya acuminata* DC. var. *wallichiana* Dyer (Theaceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (planerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, 4 x 6-7 mm, thin blades ovate; apex minutely retuse, base acute, margin entire, glabrous, venation very obscure, pinnate, green above, light green below; petioles, glabrous light green, 1 mm

Radicle: slender with many long slender, branched, whitish brown root hairs

Hypocotyl: with finely white puberulous, pale light green

Epicotyl: finely white puberulous, light green

Eophylls: simple, spirally arranged; thin ovate, apex obtuse, base acute, venation pinnate, with 4-6 alternate veins on each side of the midnerve; green above, light green below; petioles light green, 1-2 mm long

Figure 11

Voucher: Vongkamjan S 11

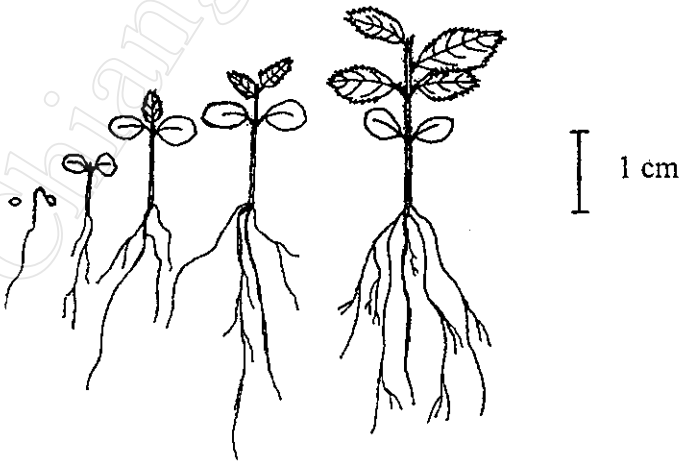

Figure 11. *Eurya acuminata* DC. var. *wallichiana* Dyer

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

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite; blades thin, broadly elliptic to suborbicular; apex obtuse to shallowly emarginate, base obtuse; margins entire and finely hirsute; venation pinnate, secondary veins 3-4 pairs, finer venation reticulate; glabrous on both sides; mid green above, light green below; *c.* 4 x 3 mm; petioles densely finely hirsute, *c.* 0.5 mm long

Radicle: slightly sinuous, whitish, becoming light brown with age, root hairs fibrous, whitish-brown

Hypocotyl: terete, sparsely finely hirsute, light green, 4-5 mm long

Epicotyl: terete, densely hirsute, light green, *c.* 0.5-1 mm long

Eophylls: simple, alternate; blades thin, broadly ovate, apex acute, base obtuse to truncate; margins serrate, venation pinnate, midnerve prominent and raised below; secondary veins 3-4 pairs, finer venation reticulate, scattered hirsute on both sides and densely so along the main nerves and margins; light green above, pale light green below; *c.* 8-9 x 6-7 mm; petiole 1 mm long

Stipules lanceolate, hirsute, *c.* 0.5 mm long

Figure 12

Voucher: Vongkamjan S 12

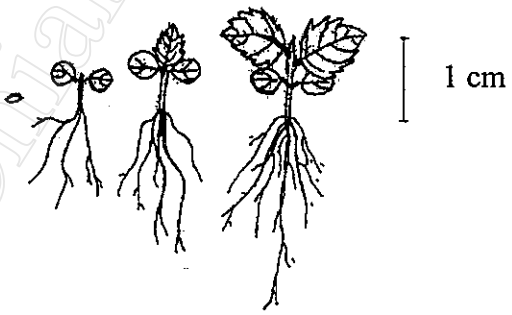

Figure 12. *Ficus hirta* Vahl var. *roxburghii* (Miq.) King

13. *Ficus lamponga* Miq. (Moraceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite; blades thin, suborbicular; apex obtuse and shallowly emarginate, base obtuse; margins entire and finely ciliolate; venation pinnate with 2 pairs of secondary veins, glabrous; green above, light green below; *c.* 4 x 3 mm; petiole 1 mm long

Radicle: light brown, slightly sinuous; root hairs fibrous, brown

Hypocotyl: terete, puberulous, light green when young, turning brownish-light green, *c.* 4-7 mm long

Epicotyl: terete, densely hirsute, green, *c.* 1.5-2 mm long

Eophylls: simple, alternate; blades thin, elliptic; apex acute, base obliquely obtuse on the lower two blades and symmetrically obtuse on the upper ones; margins entire on the two lower one and serrate on the upper ones; venation pinnate, secondary nerves 5-6 pairs, midnerve prominent and raised below; finer venation reticulate; hirsute on both sides; green above, pale green below; 8 x 7 mm, petioles hirsute, light green, *c.* 1 mm long

Stipules lanceolate, hirsute, *c.* 1-1.5 mm long

Figure 13

Voucher: Vongkamjan S 13

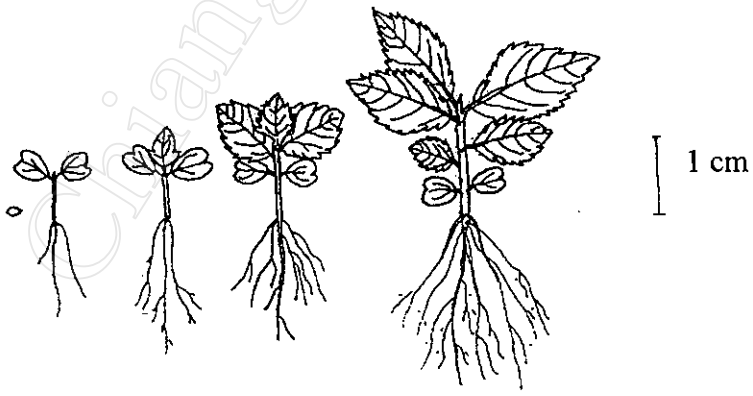

Figure13. *Ficus lamponga* Miq.

14. *Ficus superba* (Miq.) Miq. var. *superba* (Moraceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect, milky sap.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, simple, opposite; blades thin, orbicular; apex broadly rounded to shallowly emarginate, base rounded; margins entire; venation pinnate with 2 pairs of secondary nerves. *c.* 5 x 4 mm; glabrous; green above, pale green below; petioles *c.* 0.5-0.7 mm long

Radicle: brown; root hairs fibrous, brown

Hypocotyl: terete, scabrous, light green, up to 11 mm long

Epicotyl : terete, scabrous, up to 4 mm long

Eophylls: simple, opposite to subopposite, decussate; blades thin, ovate, apex acute, base truncate to shallowly cordate; margins serrate, distinct in the upper half; venation pinnate, midnerve sunken above, raised below, with 3-5 pairs of secondary nerves; glabrous; green above, light green below; *c.* 8.5-7 mm; petioles *c.* 1 mm long

Stipules broadly ovate, *c.* 0.3 mm long

Figure 14

Voucher: Vongkamjan S 14

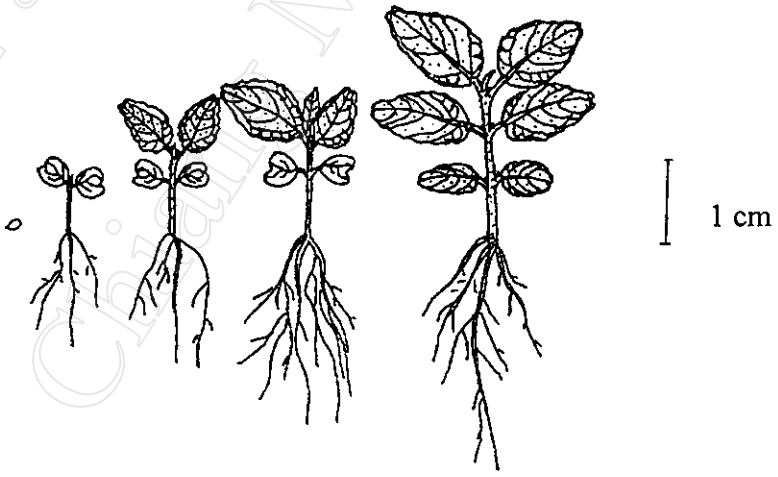

Figure 14. *Ficus superba* (Miq.) Miq. var. *superba*

15. *Glochidion acminatum* M. – A. var. *siamense* A.S. (Euphorbiaceae)

Development: The radicle and hypocotyl emerge from the seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, simple; oblong; apex broadly rounded, base acute; margins entire, glabrous; glossy dark green above, light green below; 10 x 5 mm; petioles 1 m long

Radicle: slender, slightly sinuous, whitish brown, turning brown with age; root hairs densely branching, brown

Hypocotyl: terete, puberulous, light green, turning brownish-green, 3.9-4.9 cm long

Epicotyl: terete, slender, puberulous, light green *c.* 3-7 mm long

Eophylls: simple, spirally, arranged; blades thin, obovate; apex broadly acute, base cuneate and decurrent on the petiole; margins entire; venation pinnate, with 3-5 secondary nerves on each side of the midnerve, finer venation reticulate; glabrous; green above, pale green below; *c.* 18-30 x 10-18 mm

Figure 15

Voucher: Vongkamjan S 15

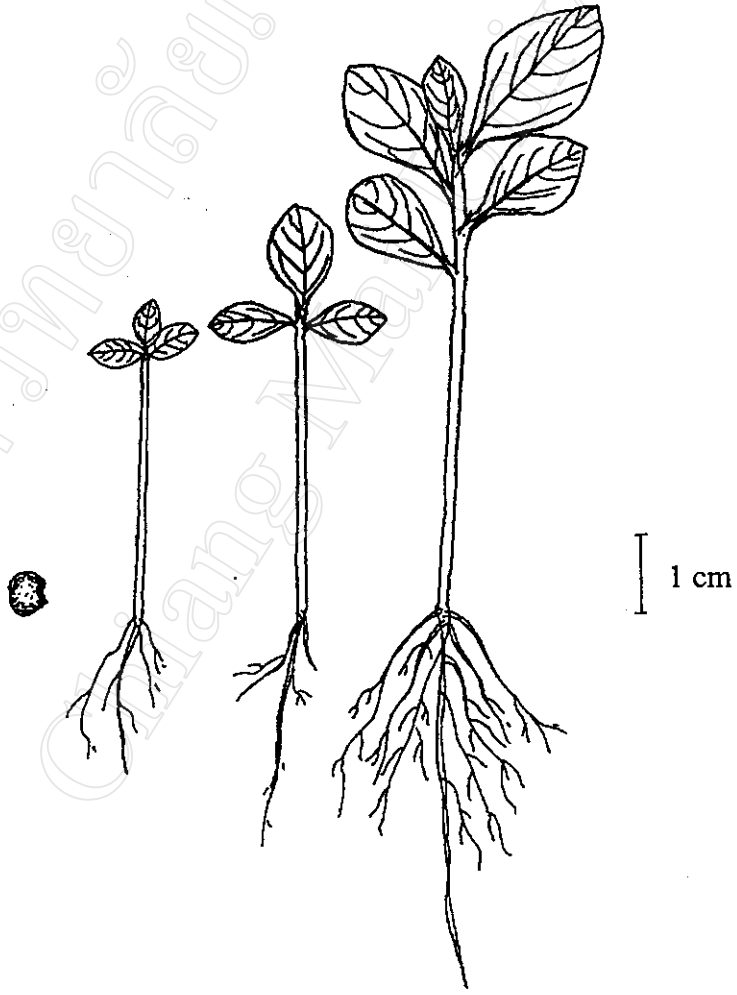

Figure 15. *Glochidion acuminatum M.-A.* var. *siamense* A.S.

16. *Irvingia malayana* Oliv. *ex* Benn. (Irvingiaceae)

Development: The thick fibrous endocarp (pyrene) splits along the margins of the valves. The radicle emerges from the tip of the pyrene. The cotyledonary petioles elongate, bringing the plumule free from the envelopments after which the epicotyl starts elongating.

Germination type: CHR (cryptocotylar hypogeal reserve storage), infrequently with a hypocotyl, sometime (less) PHR (planerocotylar hypogeal reserve storage)

Cotyledons: 2, parallel, succulent, not known when shed, elliptic, sessile, fleshy, dark reddish-brown outside, whitish inside; glabrous

Paracotyledons: 2, opposite, simple, elliptic; tip sharply acute, base acute; venation pinnate, secondary nerve 7-8 on each side of the midnerve, arching below the margin, finer venation reticulate, glabrous, 27 x 19 mm; petiole glabrous; purplish-red when young, turning green; glabrous, *c.* 4 mm long; stipules, 2 interpetiolar connate, soon dropping, narrowly triangular, top acute, margin entire, sticky, parallel-nerved

Radicle: whitish to pale brown, brown in older seedlings; root hairs densely branching, whitish to pale brown

Hypocotyl: thick, whitish and turning light brown, glabrous, 1-2 mm. long

Epicotyl: terete, glabrous, 2.5 mm thick

Eophylls: thin oblong; tip acute, base rounded; glabrous venation pinnate, secondary nerves 9-10 mm on each side of the midnerve, arching below the margin; finer venation reticulate 45-55 x 21-27 mm; petiole *c.* 4 mm

Figure 16

Voucher: Vongkamjan S 16

Figure 16. *Irvingia malayana* Oliv. *ex* Benn.

17. *Lagerstroemia speciosa* (L.) Pers. var. *speciosa* (Lythraceae)

Development: The radicle and hypocotyl emerge from the winged seed. The cotyledons free themselves from the seed by spreading and are carried above the soil. The hypocotyl becomes erect and the cotyledons spread.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons (cotyledonary leaves): 2, thin, opposite, simple; blades thin oblong-elliptic, tip broadly rounded, shallowly emarginate, with a minute mucro in the sinus, base acute; entire, glabrous; venation obscue, pinnate, secondary nerves 3 on each side of the midnerve 7 x 8-9 mm, petioles green, 7 x 8-9 mm 1-1.5 mm long

Radicle: slender, flexuous, brownish-cream, with many branhed, brownish-cream root hairs.

Hypocotyl: 4-angled glabrous, green, turning brownish and brown-light green with age

Epicotyl: sharply 4-angled, light green, terete, glabrous, to 8 mm long

Eophylls: simple, alternate; blades oblong; tip acute, base decurrent and merging with the indistinct petiole, margin entire, venation obscue, pinnate, secondary nerves 6-7 on each side of the midnerve, astomosing and looping below the margin, finer venation reticulate, 7 x 8-9 mm, terminal bud, glabrous

Figure 17

Voucher: Vongkamjan S 17

Figure 17. *Lagerstroemia speciosa* (L.) Pers. var. *speciosa*

18. *Macropanax dispermus* (Bl.) O.K. (Araliaceae)

Development: The radicle and hypocotyl emerge from the seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect, and the cotyledons expand.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, simple; blades suborbicular to broadly obovate; apex rounded, base acute; margins entire; with 3 main nerves from the base, finer venation reticulate; glabrous; green above, pale green below; 1.7-2 x 1.4-1.6 cm; petioles light green, 3-3.5 mm long

Radicle: slender, flexuous, whitish-brown, turning brown with age; root hairs long, slender, light brown

Hypocotyl: terete, glabrous, light green, upto 5.2-5.8 cm long

Epicotyl: green, glabrous, up to 2 mm long

Eophylls: simple, alternate; blades broadly ovate; apex acute, base obtuse; margins doubly serrate; with 3 main nerves from the base, upper half of midnerve with 3-4 pairs of secondary nerves, finer venation reticulate; sparsely setulose along the margins and main nerves above, glabrous below; dark green above, pale green below; petioles concave dorsally, convex ventrally, glabrous, light green, 7-15 mm long

Figure 18

Voucher: Vongkamjan S 18

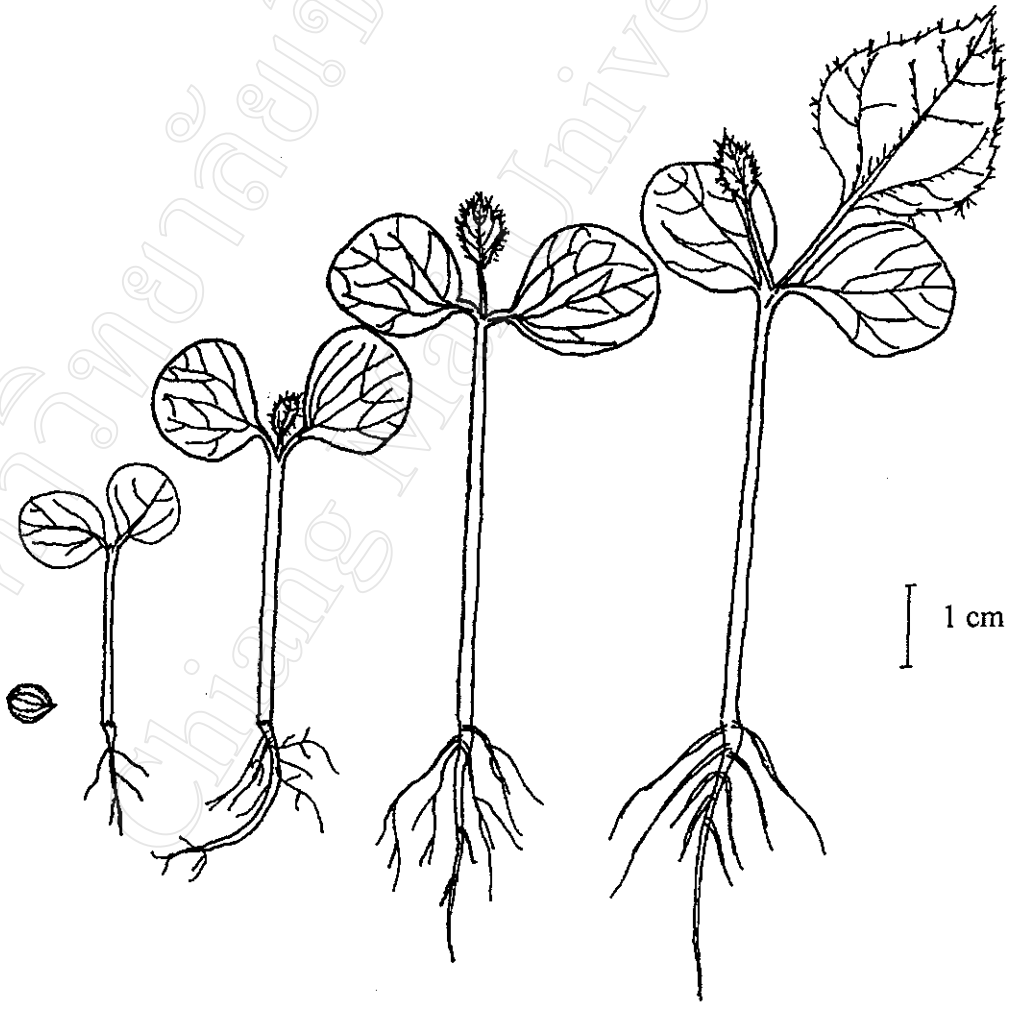

Figure 18. *Macropanax dispermus* (Bl.) O.K.

19. *Morus macroura* Miq. (Moraceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: opposite; blades ovate, apex acute, base obtuse; margin entire, glabrous, pale light yellow-green dorsally, pale light green ventrally; venation obscure, only the midnerve visible, pale light green, 3-4 x 6-7 mm; petiolate 1 mm

Radicle: indistinct, with many long slender, branched, whitish-brown root hairs

Hypocotyl: finely light yellow-green, light brown sericeous

Epicotyl: puberulous, light green

Eophylls: 2, opposite, simple; blades thin, ovate; apex acute, base obtuse; margin sharply serrete; venation pinnate, light green, with 5-6 alternate arching secondary veines on either side of the midnerve; bright mid-green dorsally, dull light green ventrally; 7 x 13 mm, sericeous; petioles pale light green, finely white sericeous; 4-5 mm long;

stipules light green, 0.5 mm long

Figure 19

Voucher: Vongkamjan S 19

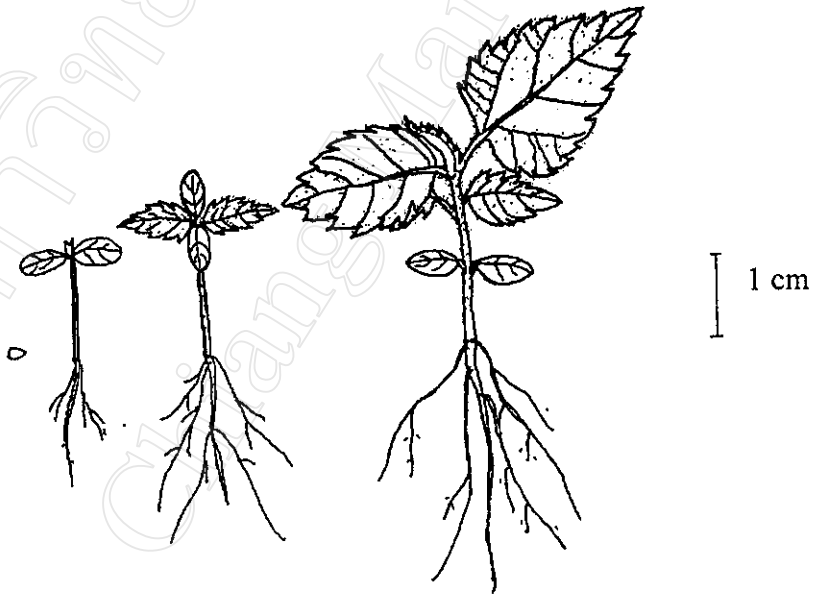

Figure 19. *Morus macroura* Miq.

20. *Reevesia pubescens* Mast. var. *siamensis* (Craib) Anth. (Sterculiaceae)

Development: The radicle and hypocotyl emerge from one end of the winged seed. The hypocotyls then becomes erect and the cotyledons spread, by which the testa and wing are shed, the cotyledons then expand.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, simple, spreading; blades thin, broadly ovate, apex obtuse to rounded, base truncate to cordate; margins entire; venation pinnate, secondary nerves 5-6 pairs, finer venation reticulate; very finely puberulous on both sides; green above, pale green below; 2.5 x 2.4 cm; petioles 4 mm long

Radicle: sturdy, slender, flexuous, brownish-cream, with many branched, brownish-cream root hairs

Hypocotyl: terete, slender, finely puberulous, whitish-green, 5-5.8 cm long.

Epicotyl: terete, finely puberulous, to *c.* 2-3 mm long

Eophylls: simple, alternate; blades elliptic; apex acuminate, base obtuse; margins serrate; venation pinnate, secondary nerves 3-5 pairs; finely puberulons; yellowish-green above, paler below; 1-2.3 x 0.5-1 cm; petioles whitish-green, *c.* 2-3 m long

Figure 20

Voucher: Vongkamjan S 20

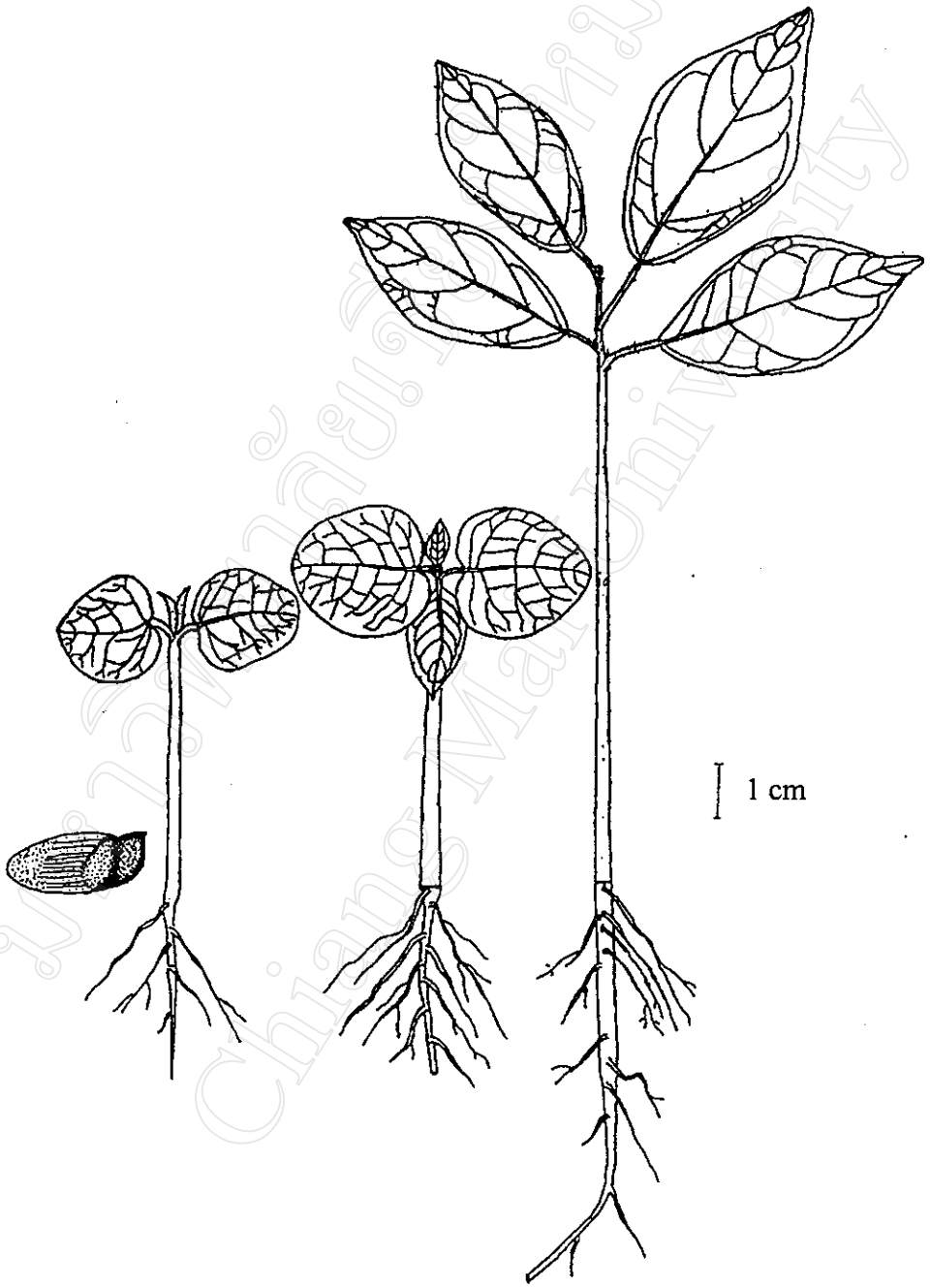

Figure 20. *Reevesia pubescens* Mast. var. *siamensis* (Craib) Anth.

21. *Saurauia roxburghii* Wall. (Saurauiaceae)

Development: The radicle and hypocotyl emerge from the small seed. By spreading the cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, simple; blades thin, ovate to suborbicular; apex rounded and slightly retuse, base obtuse; margins entire; venation pinnate, secondary nerves 2-3 pairs, finer venation indistinct; finely puberulous both sides, light green on both sides, 4 x 3-4 mm; petiole up to *c.* 0.5 mm long

Radicle: indistinct, with many long slender, branched, whitish-brown root hairs

Hypocotyl: terete, finely puborulous, pale light green, up to *c.* 5 mm long

Epicotyl: terete, densely setulose, pale light green, 5-8 mm long

Eophylls: simple, alternate; blades thin ovate; apex acute, base attenuate; margins sharply serrate; venation pinnate, secondary nerves 3-6 pairs, finer venation scalariform, finest venation reticulate, midnerve prominent, raised and long setulose on both sides, especially along the main nerves; light green above pale light green below; petioles light green, *c.* 1.5-2 mm long

Figure 21

Voucher: Vongkamjan S 21

Figure 21. *Saurauia roxburghii* Wall.

22. *Schleichera oleosa* (Lour.) Oken (Sapindaceae)

Development: The radicle and hypocotyl emerge from one end of the seed; the cotyledons swell, cracking and sheding the testa, and are carried above the soil by the hypocotyl which becoming erect.

Germination type: PER ((phanerocotylar epigeal reserve storage)

Cotyledons: thick, initially oblong, tip broadly rounded, base slightly narrowed, carinate, pinkish-light brownish, *c.* 12 x 6 mm; rapidly accresent and becoming lanceolate, slightly spreading (c.45°), brownish-greenish, *c.* 30 x 9 mm

Cotyledonary petiole: 1.5-2 mm long

Radicle: terete, *c.* 3.5 mm diameter at the insertion, tapering to the tip, whitish-brown and turning brown; root hairs patent

Hypocotyl: terete, densely very finely puberulous with simple hairs, pinkish-light green and turning light green-brownish; initially *c.* 4 mm thick, rapidly elongating

Epicotyl: similar to the hypocotyl, light green, *c.* 2 mm diameter at the insertion

Eophylls: first eophylls alternate, palmately trifoliate; leaflets thin, lanceolate, tips acute, bases acute, lateral ones asymmetrically so; entire; venation pinnate, distinct on both sides, sunken above, raised underneath; midnerve with 14-16 spreading; secondary nerves on each side, arching below the margin; finer venation reticulate; both sides sparsely setulose on the midnerve, less so to glabrous on the secondary nerves, otherwise glabrous; margins setulose; green above, lighter green below; 6.5-10 x 3.25-3.5 cm; petioles puberulous, 25-27 mm long; petiolules *c.* 1 (lateral leaflets) – 2 (terminal leaflet) mm long

Terminal and axilary buds densely puberulous

Figure 22

Voucher: Vongkamjan S 22

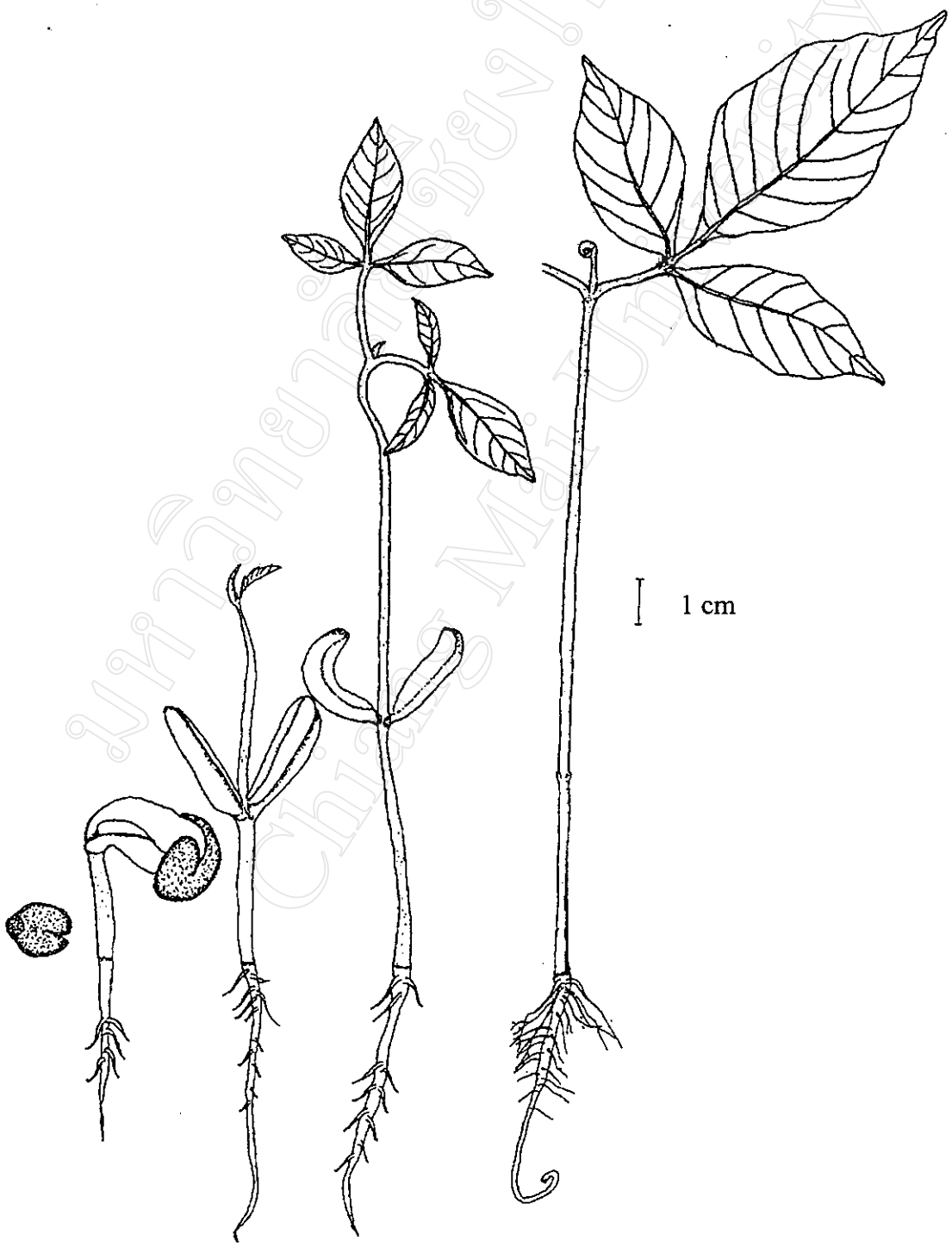

Figure 22. *Schleichera oleosa* (Lour.) Oken

23. *Shorea obtusa* Bl. (Dipterocarpaceae)

Development: The radicle and hypocotyl emerge from the apex of the nut between the calyx wings, form a curve, and penetrate the soil, after establishment of the radicle the cotyledons are pulled free from the fruit and spread.

Germination type: PER (phanerocotylar epigeal reserve storage)

Paracotyledons: 2, opposite, succulent, petiolate, blade thickly coriceous, bilobed, each lobe plano-convex, elliptic, in outline, apex broadly rounded, base acute, glabrous entire, *c.* 10 x 8 mm. petiole erect, glabrous, *c.* 18 mm long, 1 mm thick finest venation reticulate, midnerve sparsely puberulous above, more densely so below, terminal buds puberulous

Radicle: long, slender, fibrous, brownish, with numerous rather small, thin, creamy-white root hairs.

Hypocotyl: terete, brownish, puberulous, 35 mm

Epicotyl: terete, puberulous, greenish to orange or red, 2.6-3.8 cm long

Eophylls: elliptie, tip and base acute, otherwise similar to the cotyledonary leaves (paracotyledons) petioles similar to the cotyledonary leaves.

Seedling leaves: 2, opposite, simple, thin elliptic, tip obtuse, base broadly rounded, margin entire, venation pinnate, secondary nerves 5-6 slightly a secondary pairs, finest venation reticulate, midnerve sparsely puberulous above, more densely so below, turning green, petiole terete, densely puberulous, *c.* 4 mm long, **Terminal bud**, puberulous **stipules** subulate, *c.* 2 mm long

Figure 23

Voucher: Vongkamjan S 23

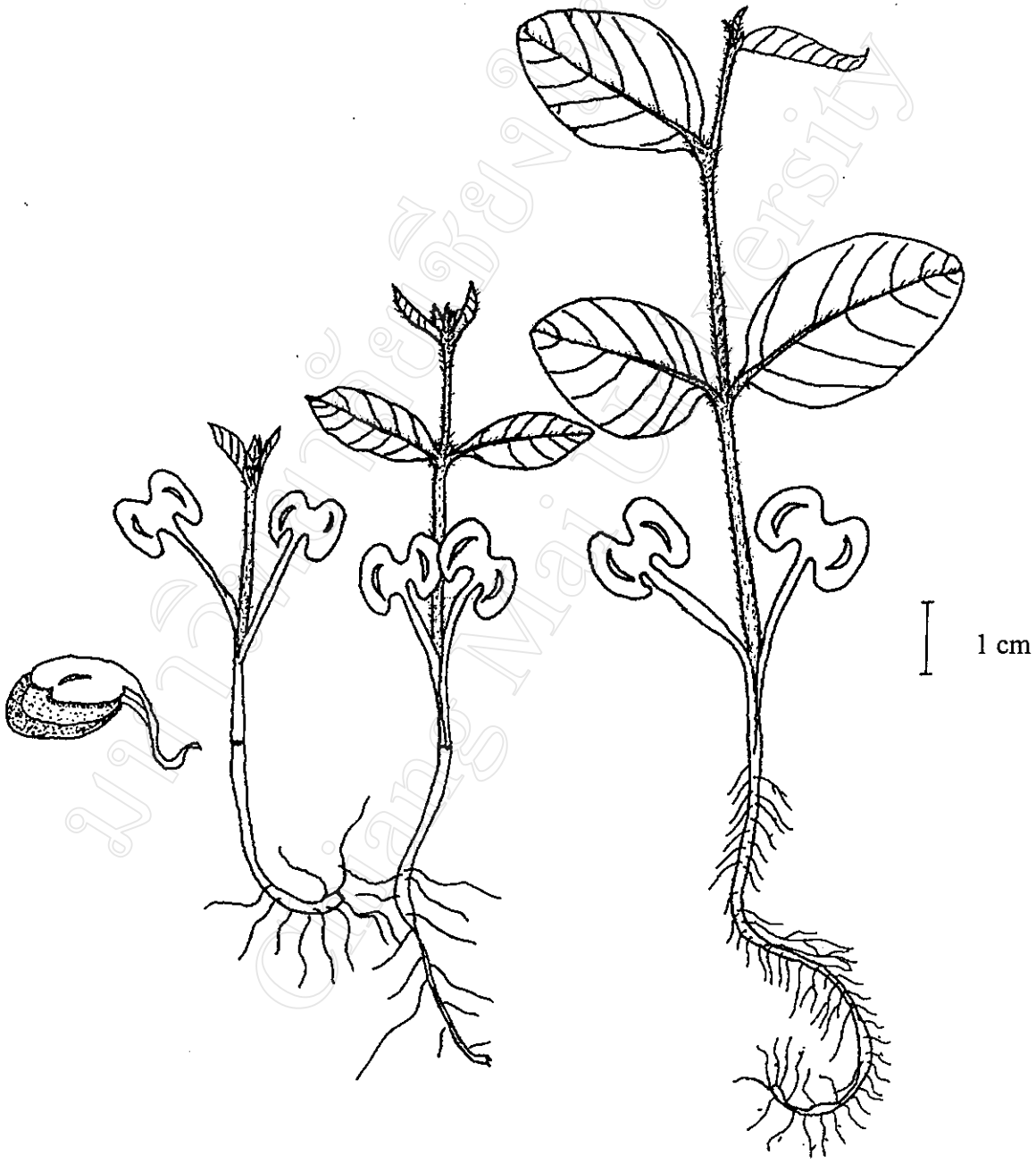

Figure 23. *Shorea obtusa* Bl.

24. *Sindora siamensis* Teysm. *ex* Miq. var. *siamensis* (Leguminosae, Caesalpinioideae)

Development: The radicle and hypocotyl emerge from one end the large seed. The cotyledons swell, the testa ruptures irregularly, and is shed. The cotyledons are carried high above the soil by the initially cernuous hypocotyl which rapidly becomes erect.

Germination type: PER (phanerocotylar epigeal reserve storage)

Paracotyledons: 2, opposite, sessile; blades obovate 3-5 mm thick; apex rounded, base obtuse and slightly oblique; flat and slightly concave dorsally, convex ventrally glabrous, reddish-green, 2-2.5 x 2 cm

Radicle: long, slender, fibrous, pale brown when young turning to dark brown, slightly sinuous much-branched, pale brown root hairs

Hypocotyl: terete, slightly succulcut, finely puberulous, reddish-pink, 6-7 cm long

Epicotyl: slender, slightly succulent, sparsely puberulous, greenish-brown, 3.8 cm long

Eophylls: alternate; once pinnate, with 2 pairs of leaflets; leaflet blades thin, obovate; apex retuse, base asymmetrically acute; margins entire; venation pinnate, midnerve prominent and raised below, with 11-14 pairs of secondary nerves; finer venation reticulate; glabrous, brownish-green when young, turning dark green above, green below, 7.5-8.5 x 4-5.5 cm; petiolules 2.5-3 mm long; petioles 2-2.2 cm long, ultrajugal axis 2.8-3 cm long; stipules filiform, *c.* 5-6 mm long

Figure 24

Voucher: Vongkamjan S 24

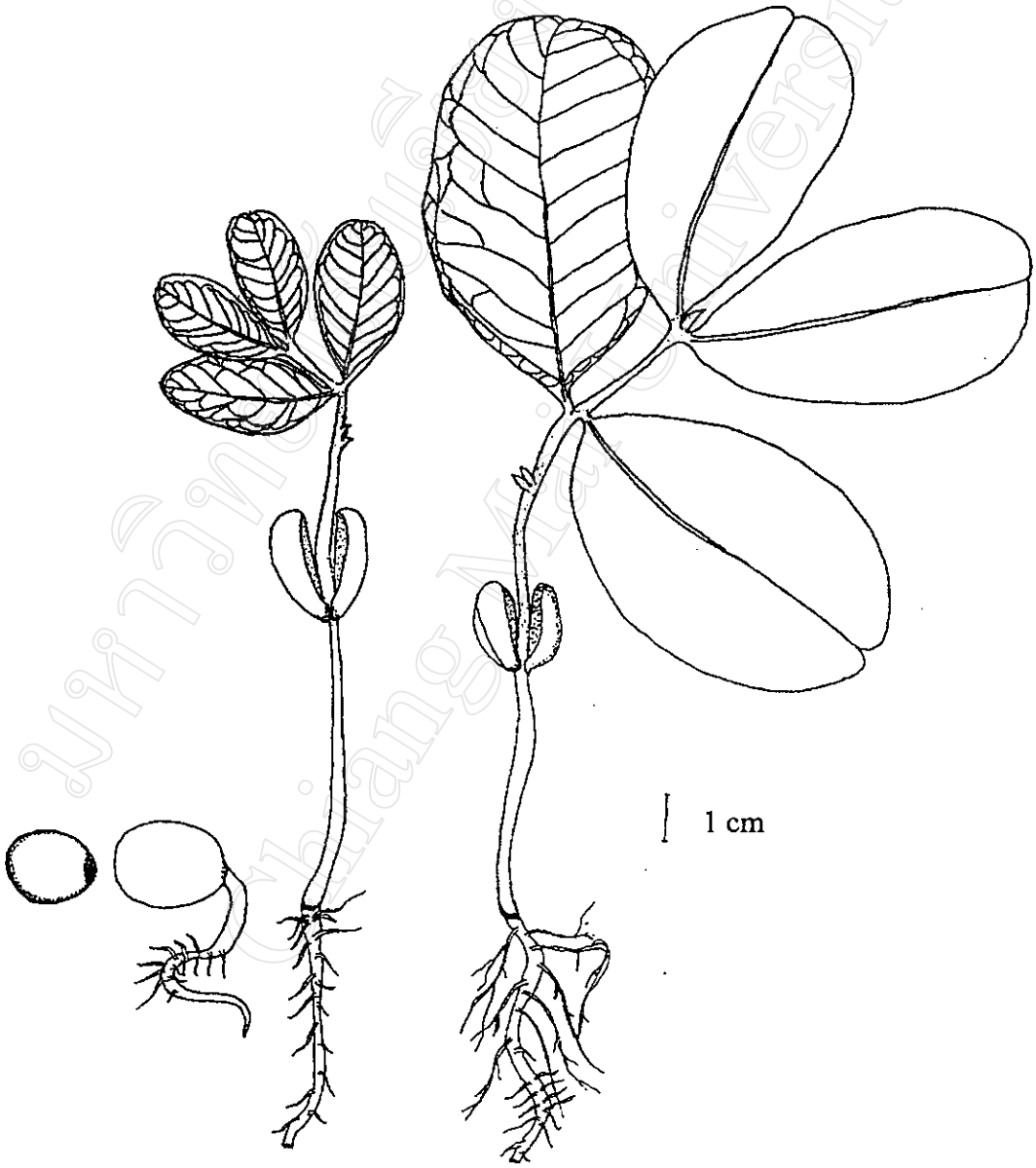

Figure 24. *Sindora siamensis* Teysm. *ex* Miq. var. *siamensis*

25. *Terminalia bellirica* (Gaertn.) Roxb. (Combretaceae)

Development: The radicle emerges from one end of the pyrene, the endocarp splitting at this place. The cotyledonary petioles elongates, bringing the plumule free from the envelopments after which the epicotyl starts elongating.

Germination type: CHR (cryptocotylar hypogeal reserve storage)

Cotyledonary petioles: erect, terete, glabrous, *c.* 10 mm long, 3 mm thick

Paracotyledons: merely splitting, erect, not spreading

Radicle: *c.*3 mm thick at insertion

Hypocotyl: none

Epicotyl: terete, glabrous, with several spaced, spirally arranged eophylls

Eophylls: blades thin, simple, ovate-oblong; tip acute, base cuneate; venation pinnate, distinct; main venation sunken above, raised underneath; midnerve with 6-7 alternate, ascending secondary nerves on each side; tips looping and anastomosing well below the margin; finer venation reticulate; glabrous above, with fine, scattered, glabrescent puberulence on the main nerves underneath; entire; lowest (smallest) blade 4.5 x 2 cm, tthe upper one largest *c.* 10 x 4 cm; petioles finely puberulous, *c.* 4 mm long

Terminal buds: subulate, finely puberulous, *c.* 9 mm long

Figure 25

Voucher: Vongkamjan S 25

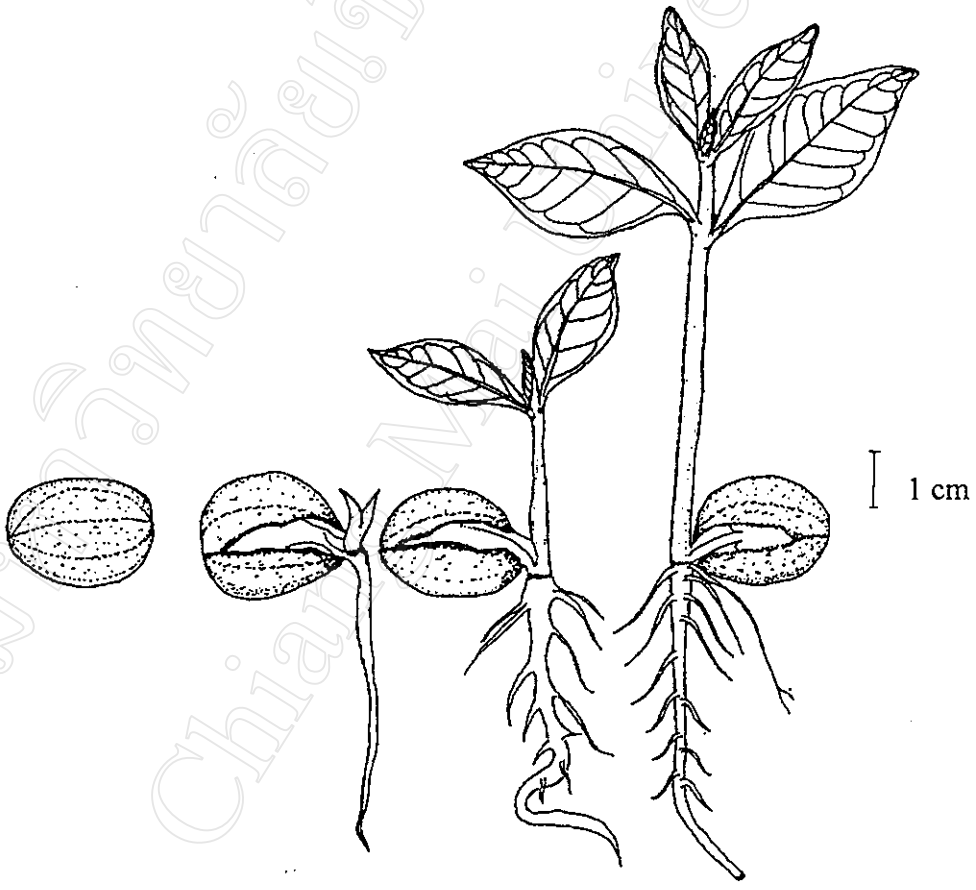

Figure 25. *Terminalia bellirica* (Gaertn.) Roxb.

26. *Terminalia chebula* Retz. var. *chebula* (Combretaceae)

Development: The fibrous endocarp splits along the margin of the valves. The radicle and hypocotyl emerge from one end of the seed. The hypocotyl becomes erect, by which the cotyledons are raised above the soil and become exposed.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite; blades broadly obovate; apex truncate, base obtuse; margins entire, secondary venation with 5-7 main nerves from the base, finer venation reticulate, glabrous; dark green above, light green below; 3.4-3.7 x 2.2-3 cm; petiole pilose, 1 cm long

Radicle: sturdy, fleshy, brownish, with many long slender, creamy-white root hairs

Hypocotyl: terete, densely pilose, pale cream, 10-12 mm long

Epicotyl: terete, densely pilose, cream-light green, up to 3.3 cm long

Eophylls: opposite, simple; blades ovate to elliptic; apex acute, base cuneate; margins entire; venation pinnate, midnerve prominent and raised below; secondary nerves 4-5 pairs, finer venation reticulate, densely pilose on both sides; dark green above, light green below; 17-18 x 8-10 mm; petioles densly pilose, 4 mm long

Figure 26

Voucher: Vongkamjan S 26

Figure 26. *Terminalia chebula* Retz. var. *chebula*

27. *Terminalia mucronata* Craib & Hutch. (Combretaceae)

Development: The fibrous endocarp splits along the margin of the valves. The radicle and hypocotyl emerge from one end of the winged fruit. The hypocotyl becomes erect, by which the cotyledons are raised above the soil and become exposed

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite; blades thick, suborbicular to broadly obovate; apex truncate, base obtuse; margins entire; main venation with 5-7 main nerves from the base, secondary nerves pinnate, finer venation reticulate; glabrous on both sides; dark green above, light green below; 2-2.2 x 1.5-2 cm; petioles densely hooked pilose as on the hypocotyl, 3-4 mm long

Radicle: sturdy, fleshy, brownish, with many long slender, creamy-white root hairs

Hypocotyl: terete, densely hooked pilose, pale cream, 1.5-1.6 cm long.

Epicotyl: terete with similar hairs as on the hypocotyls and petiole, brownish-green, *c.* 1.7 cm long

Eophylls: simple, alternate; blades elliptic; apex acute, base cuneate and slightly oblique; margins entire; venation pinnate, midnerve sunken above, raised below, secondary nerve 4 pairs, finer venation reticulate; pilose on both sides, especially along the main nerves and margins; yellowish-green above, paler below; 2.3 x 1.4 cm; petioles densely pilose, 4 mm long

Figure 27

Voucher: Vongkamjan S 27

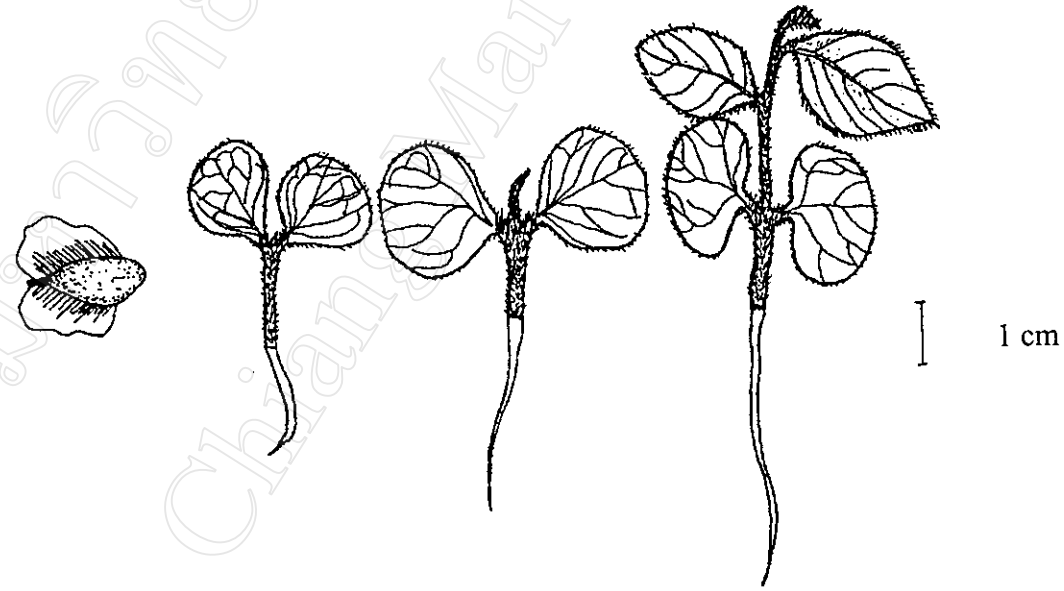

Figure 27. *Terminalia mucronata* Craib & Hutch.

28. *Tetradium glabrifolium* (Champ. *ex* Bth.) T. Hart. (Rutaceae)

Development: The radicle and hypocotyl pierce the testa at one end of the seed, the hypocotyl becomes erect and the cotyledons are pulled free and expand.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, simple, opposite, blades suborbicular; apex rounded, base broadly acute; margins finely crenulate with tiny black punctate aromatic glandular dots in the crenation sinuses; venation palmate with 4 main nerves; glabrous; dark green above, pale green below, 9-11.5 x 7-10 mm; petiole ciliolate, 2-4 mm long

Radicle: slender, whitish turning brownish with age, with a few short, slender, whitish-brown root hairs

Hypocotyl: terete, slender, ciliolate with numerous punctate gland dots, whitish-green to green, turning purplish-green

Epicotyl: slender, terete, ciliolate, whitish-green, turning light green, 1.5 mm long

Eophylls: once odd pinnate, lowest pair opposite, upper ones alternate; leaflets 3, lower 2 opposite and the terminal one; lower pair of leaflet blades similar to the terminal one, but smaller and the bases oblique, 14-16 x 4-5 mm, petiolules *c.* 1 mm long; terminal leaflet blade thin, lanceolate; apex acuminate, base cuneate and decurrent on the petiolule; margins crenulate, sparsely ciliolate and with punctate glandular dots in the crenation sinuses; venation pinnate with 8-10 pairs of secondary nerves, finer venation reticulate; ciliolate and with scattered glandular dots on both sides; glossy green above, dull light green below, *c.* 20-23 x 6-8 mm; petiolules *c.* 2-3 mm long, petiole ciliolate, 8 mm long

Figure 28

Voucher: Vongkamjan S 28

Figure 28. *Tetradium glabrifolium* (Champ. *ex* Bth.) T. Hart.

29. *Trema orientalis* (L.) Bl. (Ulmaceae)

Development: The radicle and hypocotyl emerge from the small seed. By spreading the cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl which becomes erect then the cotyledons expand.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, blades thin; ovate; apex obtuse and minutely retuse; base acute; margins entire; venation obscurely pinnate; densely sericeous on both sides; green above, pale green below; 7-16 x 4-6 mm; petioles densely gray sericeous 1-1.5 mm long

Radicle: short, slender, flexuous, whitish-brown, with many long, slender, shortly branched, whitish-brown root hairs

Hypocotyl: terete, densely gray sericeous, whitish-light green, turning grayish-green, 1.5-2 cm long

Epicotyl: terete, densely sericeous as on the hypocotyls and paracotyledons, green, *c.* 1-1.5 mm long

Eophylls: simple, alternate; blades thin, ovate; apex acuminate to cuspidate, base asymmetrically obtuse; margins serrate; venation pinnate, midnerve sunken above, raised below, secondary veins 3-5 pairs, finer venation reticulate; densely grayish sericeous on both sides; green above, pale green below; 8 x 18 mm; petioles sericeous, 2 mm long

Figure 29

Voucher: Vongkamjan S 29

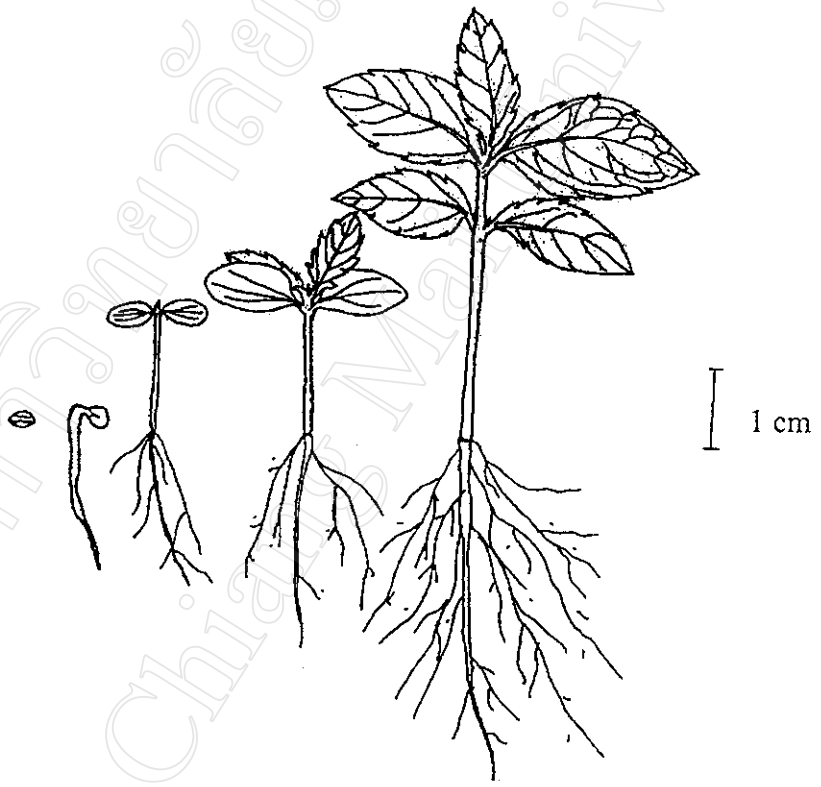

Figure 29. *Trema orientalis* (L.) Bl.

30. *Vaccinium sprengelii* (D. Don) Sleum. (Ericaceae)

Development: The radicle and hypocotyl emerge from the small seed. The cotyledons free themselves from the testa by spreading and are carried above the soil by the elongating hypocotyl, which becomes erect.

Germination type: PEF (phanerocotylar epigeal foliaceous)

Paracotyledons: 2, opposite, green; blades thin, elliptic; apex obtuse, base acute; margins entire; venation obscurely pinnate; glabrous; mid green above, light green below; *c.* 8 x 4.5 mm; petioles *c.* 0.5 mm long

Radicle: indistinct, slender, creamy-white turning light brown with age, with a few slender creamy-white root hairs

Hypocotyl: terete, slender, finely puberulous, light green, turning reddish, 8-12 mm long

Epicotyl: terete, finely puberulous, green, turning pale reddish, 1-1.5 mm long

Eophylls: simple, spirally arranged; blades subcoriaceous, ovate; apex acute, and base obtuse; margins finely serrate; venation pinnate, midnerve prominent and raised below; secondary nerves 3-5 pairs, finer venation reticulate, sunken above, main nerves on both sides and margin finely ciliolate; dull dark green above, light green below; 6 x 4 mm; petioles puberulous, 1.5 mm long

Figure 30

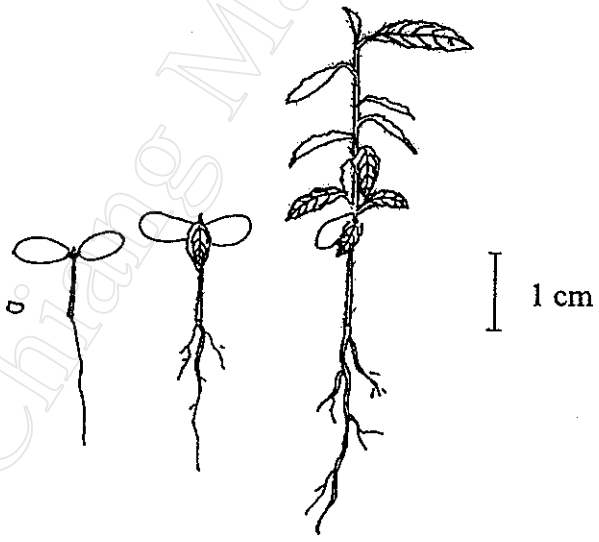

Figure 30. *Vaccinium sprengelii* (D. Don) Sleum.

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