Seed Dispersal of Two Native Forest Tree Species and Seed Germination of *Terminalia chebula* Retz.

Khwankhao Sinhaseni

Bachelor of Science
Biology

Department of Biology, Faculty of Science
Chiang Mai University

2005

Seed Dispersal of Two Native Forest Tree Species and Seed Germination of *Terminalia chebula* Retz.

Khwankhao Sinhaseni
4405126

A special project report submitted
in partial fulfillment of the requirements
for the degree of

Bachelor of Science
Department of Biology, Faculty of Science
Chiang Mai University
2005

Seed Dispersal of Two Native Forest Tree Species and

Seed Germination of *Terminalia chebulai* Retz.

Khwankhao Sinhaseni

This special project has been approved to be a partial

fulfillment of the requirements for

the Degree of Bachelor of

Science in Biology

Examining Committee :

....Chairperson

(Lecturer Dr. Stephen Elliott)

....Member

(Lecturer Dr. Sutthathorn Suwannaratana)

....Member

(Lecturer Dr. Prasit Wangpakapattanawong)

18 May 2005

Acknowledgement

First and foremost, I express my gratitude and respect to my advisor of special project and chairperson of my examining committee, Dr. Stephen Elliott. He gave me recommendations and suggestion, without which I could not have completed my research.

I am sincerely indebted to lecturer Dr. Sutthathorn Suwannaratana, my examining committee member for her suggestions and corrections in report, especially Thai part, as well as the best counselor for everything.

The author also expresses my thanks to lecturer Dr. Prasit Wangpakapattanawong, my examining committee member and my general advisor for his suggestions and corrections with his kindness.

Likewise, sincere thanks to the staff of the Forest Restoration Research Unit, Mr.Cherdsak Kuarak, Miss Panitnart Tunjaif and Mrs. Tonglao Sritong for suggestions, planting and care during the all seedling process and myself.

The author is grateful to the Faculty of Science, Chiang Mai University, particularly to Department of Biology and all staff for a lot of assistance so that this study can be successful.

The author is especially grateful to Miss Pimonrat Tiansawat, my best friend and my partner, for mental support and kindly help in the field work of this research together and give wonderful words for me.

Special thanks to all her Biology Major friends and colleagues, especially Pee Tor, Kae, Kaee, Namm, Mameaw, Pee Bomb, Wut, Title, Earn and Run for sharing the precious time and helping hands during the data collection. Moreover, my heartfelt thank to Golf for help everything. Also thanks to Bee for our good vehicles.

Above all these, I am blessed with love, patience and encouragement of my parents, grandmother, aunt Ae and brother for their understanding and mental support in everytime.

Khwankhao Sinhaseni

Author

Research Title	Seed Dispersal of Two Native Forest Tree Species and Seed Germination of *Terminalia chebula* Retz.
Author	Miss Khwankhao Sinhaseni
B.S.	Biology

Examination Committee

Lecturer Dr. Stephen	Elliott	Chairperson
Lecturer Dr. Sutthathorn	Suwannaratana	Member
Lecturer Dr. Prasit	Wangpakapattanawong	Member

Abstract

Forest restoration using native forest trees (the so called "framework tree species") requires a detailed knowledge of the dispersal ecology of native forest tree species. This project was conducted in Doi Suthep-Pui National Park, Chiang Mai Province. The first part was to determine seed attractiveness to wildlife of *Gmelina arborea* Roxb. and *Terminalia chebula* Retz. var. *chebula* and their seed dispersal mechanisms by direct observation with binoculars in the natural habitat. Attractiveness to seed-dispersing wildlife is an essential characteristic of framework species, which accelerates biodiversity recovery. Two squirrel species, *Callosciurus finlaysoni* and *Tamiops mcclellandi* dispersed seeds of both tree species, whilst *Callosciurus erythaeus* was an additional disperser of *T. chebula.*

The second part of the project investigated optimal pre-sowing seed treatments to maximize germination of *Terminalia chebula* seeds. The four different pre-sowing treatments tested were i) kept at ambient temperature in water for 2 days, ii) seeds dipped in 0.01 M sulfuric acid for 10 seconds, iii) heated in water to 70 °C and iv) seeds scarified by cutting a small wound in the testa. Percent germination resulting from dipping in sulfuric acid and soaking in hot water was lower than the control. Percent germination of the two treatments: scarification by hand and soaking

in water for two days was not significantly different from the control group. However, Median Length of Dormancy (MLD) of the seeds subjected to scarification was significantly reduced.

หัวข้อปัญหาพิเศษ การแพร่กระจายเมล็ดพันธุ์ของพรรณไม้ท้องถิ่นสองชนิด และการงอกของเมล็ดสมอไทย

ชื่อผู้เขียน นางสาว ขวัญข้าว สิงหเสนี

วิทยาศาสตรบัณฑิต สาขาวิชาชีววิทยา

คณะกรรมการสอบปัญหาพิเศษ

อาจารย์ ดร. สตีเฟน เอลเลียต ประธานกรรมการ
อาจารย์ ดร. สุทธาธร สุวรรณรัตน์ กรรมการ
อาจารย์ ดร. ประสิทธิ์ วังภคพัฒนวงศ์ กรรมการ

บทคัดย่อ

การฟื้นฟูป่าโดยใช้พืชท้องถิ่น ที่เรียกว่าพรรณไม้โครงสร้าง (framework tree species) อาศัยความรู้ละเอียดเกี่ยวกับนิเวศวิทยาของการกระจายพันธุ์ของพรรณไม้ท้องถิ่น ในการทำปัญหาพิเศษในครั้งนี้ได้ศึกษาบริเวณอุทยานแห่งชาติดอยสุเทพ-ปุย (จ. เชียงใหม่) ส่วนแรกเป็นการศึกษากลไกการกระจายเมล็ดของต้นซ้อ (*Gmelina arborea* Roxb.) และ สมอไทย (*Terminalia chebula* Retz. var. *chebula*) ในสภาพธรรมชาติ โดยใช้กล้องส่องทางไกลดูปฏิสัมพันธ์ระหว่างสัตว์ป่าและพืช พบว่าสัตว์ที่เป็นตัวช่วยกระจายเมล็ดของพืชทั้ง 2 ชนิด คือ กระรอกหลากสี (*Callosciurus finlaysoni*) และ กระเล็น (*Tamiops mcclellandi*) กระรอกท้องแดง (*Callosciurus erythaeus*) ยังช่วยในการกระจายเมล็ดของสมอไทยด้วย

ในการทดลองส่วนที่ 2 เป็นการหาวิธีเพิ่มประสิทธิภาพการงอกของต้นสมอไทย มาทดสอบหาวิธีการเร่งการงอก 4 วิธีการคือ i) การแช่น้ำที่อุณหภูมิปกติ เป็นเวลา 2 วัน ii) จุ่มในกรดซัลฟูริก ความเข้มข้น 0.01 โมลาร์ เป็นเวลา 10 วินาที iii) ต้มในน้ำอุณหภูมิถึง 70 องศาเซลเซียส และ iv) ตัดบางส่วนของเปลือกหุ้มเมล็ด ผลการทดลอง พบว่า กลุ่มที่ใช้กรดซัลฟูริก และกลุ่มที่ผ่านการต้มนั้น ร้อยละการงอกของเมล็ดสมอไทยลดลงเมื่อเทียบกับชุดควบคุม ส่วนในการแช่น้ำ 2 วัน และการตัดบางส่วนของเปลือกหุ้มเมล็ด ให้ค่าร้อยละการงอกไม่แตกต่างจากชุดควบคุม แต่ค่า Median Length of Dormancy (MLD) ของชุดที่ตัดบางส่วนของเปลือกหุ้มเมล็ด นั้นลดลงอย่างมีนัยสำคัญ

Table of contents

List of tables

List of Figures

Chapter 1

Introduction

Forests of southeast Asia are known for their high biodiversity, arguably among the highest in the world (FAO, 2001b). However, it is generally accepted that the forests of Thailand have been reduced from about 53 percent in 1960 (Bhumibamon, 1986) to 28.9 percent in 2000 (FAO, 2001a). Fire, encroachment and illegal logging are serious problems, causing deforestation. The Thai government manages forest areas by protecting what is left, for example by creating national parks, the national reserved forest. However, many of these areas were already deforested before they received protected status.

Animals and plants are essential components of forest ecosystems and have important relationships with each other. These lead to complete forest ecosystem but the protecting forest areas can't recover the necessary components.

Therefore, replanting native forest tree species to recreate natural forest ecosystems is an important activity to increase forested areas and create habitats for animals.

In the past, government policy used to plant single species of economic trees for reforestation, e.g. *Eucalyptus*. This creates uniform monocultures of little value for biodiversity. In contrast, natural forest ecosystems are complex and diverse, so *Eucalyptus* plantations do not support the mechanisms of natural forest succession.

Therefore, the Forest Restoration Research Unit (FORRU), was established in 1994, to develop ways to recreate original forest ecosystems. There have been many tree planting schemes in the evergreen forests in northern Thailand. FORRU selects indigenous forest tree species for planting with i) high survival and growth rates when planted out in deforested sites; ii) dense spreading crowns to shade out weeds and iii) which provide resources attractive to seed-dispersing wildlife (FORRU, 1998). Tree species with such characteristics are termed "framework" species, which accelerate natural forest regeneration.

For 10 years, FORRU has worked to establish experimental nurseries and trial plots in Doi Suthep-Pui National Park. Trial plots on evergreen forest land now support more than 60 incoming tree species and many seed dispersing animals, including more than 80 bird species and mammals such as civet, hog badger and barking deer.

This project focused on one particular framework tree species, *Gmelina arborea*, native tree species of evergreen forests, to determine its attractiveness to wildlife and its seed dispersal mechanisms

Now FORRU is expanding its research into deciduous forests, so additional information about the process of natural succession in such forest ecosystems is urgently needed. Moreover, the details of plant species are necessary to forest restoration planning. Thus, this research seed dispersal by animals and treatments for seed germination of *Terminalia chebula*, a native tree species of deciduous forest, to provide data to determine if it might function as framework tree species. Moreover, it would be useful to increase the number of these trees because the fruits of this species are an Indian medicine and used on a regular basis in Buddhism of Thailand (Stanglmeier, 2001)

Objectives

1. To determine the seed dispersal mechanisms of the native forest tree species, *Terminalia chebula* Retz. and *Gmelina arborea* Roxb.

2. To determine the optimal treatments to maximize seed germination of *Terminalia chebula* Retz.

Chapter 2

Literature review

Seed dispersal

The function of any plant is to grow and eventually to reproduce itself. One of the most essential processes in plant reproduction is the production and dispersal of seeds (Elliott, 2000). The definition of seed dispersal is that it is an active (dynamic) process of transportation, differentiating it from the result it leads to: the passive (static) state of distribution (Van der Pijl, 1972).

The two main reasons for dispersal are i) escaping competition from the parent tree and ii) escaping seed or seedling predators. If seeds are dispersed too far away from the parent, however, it is likely that they will be deposited in an unsuitable habitat. Therefore, there is an optimum dispersal distance, not too far but not too near the parent plant (Elliott, 2000).

Seeds can be dispersed by wind, by animals (both on the outside of animals and through ingestion), by gravity, by water and by explosive fruits. Most tree species in the tropics are dispersed by animals rather than the other forms (wind, water, *etc.*) of dispersal (Wunderle, 1997).

Brown (2001) concluded that the main animal vectors for seed dispersal are vertebrates and ants. Vertebrate seed dispersers include birds, bats, primates, rodents, bear, tortoises and fish. Rodents are primarily dispersers of non-fleshy fruits as a consequence of seed predation activities. The effectiveness of these organisms as dispersers depends upon the fate of the seeds.

The characteristics of the fruits themselves are significant in determining which animals disperse them (Jordano, 1995; Corlett; 1996 referred to by Kitamura *et al.*, 2002). Seed and fruit size limits the variety of frugivores that can disperse the seeds (Leight-on and Leighton, 1997 referred to by Kitamura *et al.*, 2002).

Corlett (1998) suggested that very small fruits (<8 mm equatorial diameter) are available to all fruit-eating vertebrates, although large animals find them uneconomical to harvest, unless high fruit densities or clustering allow intake of many fruits per bite (Welch *et al.*, 1997 referred to by Corlett, 1998). Small fruits (8-13 mm) are potentially available to all but few tiny bird species, such as White-eyes and Flower-peckers. Larger fruits can be swallowed whole by progressively fewer bird species. The squirrels of the oriental region have a great diversity of diets, but most species seem to eat some fleshy fruits and/or the seeds they contain. Seed dispersal by squirrels can happen in several ways. First, seeds can be swallowed and defecated intact. Although there is no direct evidence for this in the literature, it seems unlikely that squirrels can destroy all the seeds in fruits such as figs. Emmons *et al*. (1991) suggested that *Callosciurus notatus* and other squirrels may be important dispersal agents for *Raffesia keithii*, a parasitic plant of the ground flora. Secondly, seeds could be deliberately cached and subsequently forgotten. The widespread squirrel *Callosciurus erythraeus* scatter-hoards seeds in the surface soil, at least in Taiwan (Chou *et al.*, 198 referred to by Corlett, 19985). Seeds may also be dispersed when a squirrel transports a seed and/or fruit away from the parent tree in their mouth and drops it either deliberately or accidentally (Ridlet, 1930 referred to by Corlett, 1998).

Wenny and Levey (1998) studied directional seed dispersal of *Ocotea endresiana* by following birds until they regurgitated or defecated seeds for determination of the actual sites where seed were deposited and monitoring of seedling survival. Bellbirds play a significant role in seed dispersal by providing directed dispersal to suitable sites.

Kitamura *et al.* (2004) studied seed dispersal of *Aglaia spectabilis* with three methods including i) observation of tree canopies with binoculars, ii) camera trapping to determine frugivores as seed dispersers or predators on the forest floor by installation of an automatic photographic monitoring system and iii) the thread-marking method was used to trace individual samples removed by animals: each sample was attached to one end of a nylon threat (20 cm long). Four hornbill and one pigeon species were seed dispersers, whereas two squirrel species dropped the seeds on the ground. Three mammal species were identified as seed predators.

Seed dispersal by vertebrates is a key process in the dynamics of natural vegetation and in forest succession on degraded tropical forestland (Corlett, 1998).

Seed germination

Seed germination is defined as the emergence of the radicle through the seed coat. Common garden seeds germinate if given just water and reasonably warm temperatures (Konning, 1994). Common vegetable garden seeds generally lack any kind of dormancy. The seeds are ready to sprout. All they need is some moisture to get their biochemistry activated, and temperature warm enough to allow the chemistry of life to proceed. Seeds taken from the wild, however, are frequently endowed with deeper forms of dormancy.

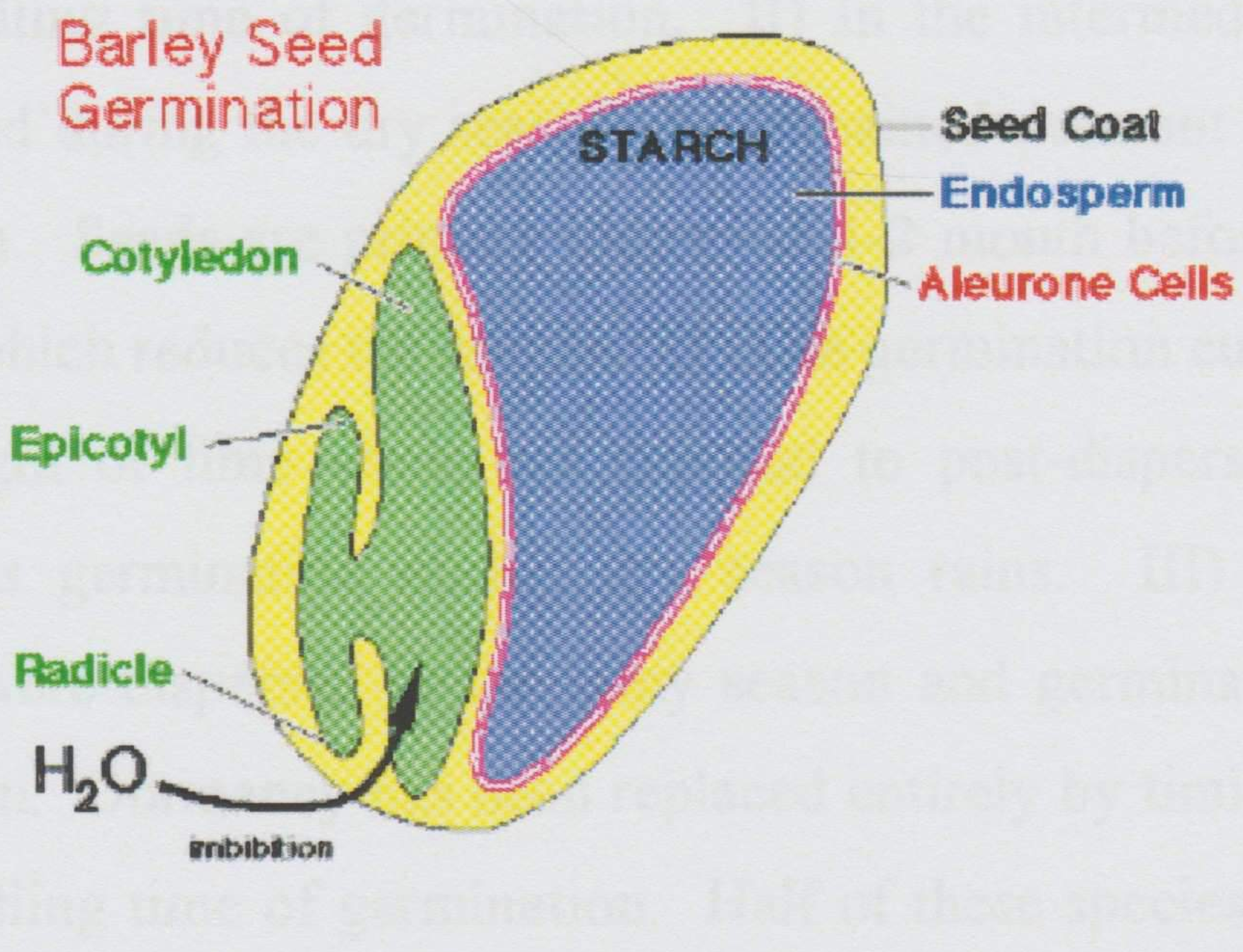

Figure 1 Germination process beginning with water transportation into seed (Koning, 1994).

Elliott (2000) defined dormancy as a period, during which viable seeds delay germination, despite having conditions that are normally favorable for the later stages of germination and seedling establishment. The tissue surrounding the embryo can bring about dormancy by restricting the transport of water or oxygen into the seed, by mechanical restricting expansion of the embryo or by containing chemicals that metabolically inhibit the chemical changes necessary to initiate germination.

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

Garwood (1983) reported that seed germination at the community level in Panama could be divided in three distinct syndromes. I) In the delayed-rainy syndrome, seed were dispersed in the rainy season but were dormant until the beginning of the next rainy season 4-8 months later. Dormancy is the primary mechanism controlling time of germination. II) In the intermediate-dry syndrome, seed were dispersed during the dry season and remained dormant until the beginning of the rainy season. Seeds are primary dispersed 1-2 month before the beginning of the rainy season, which reduces the number of false germination cues encountered and decreases the length of time seeds are exposed to post-dispersal predation while dormancy prevents germination during dry season rains. III) In the rapid-rainy syndrome, seeds were dispersed in the rainy season and germinated during, but not early in, that season. Dormancy has been replaced entirely by timing of dispersal as a mechanism controlling time of germination. Half of these species germinated in less than two weeks, the rest germinated in 2-16 weeks.

Konning (1994) report that seeds with a very thick seed coat may require scarification of that seed coat before water can enter the seed and initiate germination. Perhaps the coat has to be gnawed at by animals, or frozen and thawed repeatedly to crack the coat, perhaps the seed is swallowed whole by the disperser. The thick seed coat protects the dormant embryo as it passes through the animal's digestive system. The weakening of the seed coat through digestion means that the seed is ready to sprout when it gets deposited (along with a bit of fertilizer) by the disperser somewhere new in the environment.

Singpetch (2001) studied the effects of different treatments on germination of native trees on Doi Suthep 9 species such as *Albizia chinensis* (Obs.) Merr., *Aporusa villosa* (Lindl.) Baill., *Bauhinia variegate* L., *Ficus abelii* Miq., *Ficus glaberrima* Bl., *Ficus hirta* Vahl., *Macaranga denticulate* (Bl.) M.-A., *Rhus chinesis* Mill. and *Terminalia alata* Hey. ex Roth with heat, scarification by acid and scarification by hand. Percent germination of *T. alata* was the highest, when seeds were scarified by acid (H_2SO_4)

Rattanakul (2003) suggested scarification of the seed coat as pre-sowing treatment of *Terminalia chebula* Retz. He achieved percent germination of 70-80.

Rodrigo (2001) planted *Terminalia chebula, Aegle marmelos*, *Terminalia bellirica*, *Pterocarpus marsupium*, *Azadiraclita indica*, *Phyllanthus emblica* and *Tamarindus indica* to revitalize degraded forest land. Seed germination beds were watered daily, and the necessary shade was provided to all seed beds, to minimize transpiration during the day time. His results showed that six years later planted trees in the area had 98% survival for, with trees reaching a height more than 4.5 m.

Species studied

1. *Terminalia chebula* Retz. var. *chebula*

Common name: Myrobalan, Hardad, Chebulic myrobalan, Haritaki

Thai name: สมอไทย

Family: Combretaceae

This is an endangered (Ramakrishnappa, 2002), deciduous tree species. This species is an important tree of the pharmaceutical trade. It grows to approximately 25 m tall, with a diameter at breast height of up to 80 cm and a girth of 1-2 m. The size of bole varies a lot depending on soil and water conditions (Stanglmeier, 2002).

Barks: Dark brown to gray, rough, with irregular scales.

Leaves: broadly ovate, elliptic or ovate elliptic 5-15 cm long, 3-10 cm broad, the apex is acute or abruptly acuminate, the base is rounded with two or more glands near to the short petioles (1-3 cm). On the upper surface, the leaves are glabrous, on the lower brownish pubescent, especially along the midrib and secondary veins, white hairs are present along the leaf margin and the young petioles. The young shoots and leaves are densely covered by rusty-coloured hairs (Stanglmeier, 2002).

Flowers: The 3-6 cm long inflorescences appear in the axils or in terminal panicles, with small hermaphrodite, yellowish-white strong smelling flowers of 0.3-0.4 cm diameter. Flowers from April to May (Savithasuri, 2004).

Fruits: Yellowish-green to orange-brown, glabrous drupe, ovoid to globose, varying in size, shape and color depending in habitat, variation and origin; 2.5 - 4 by 1.5 - 2.5 cm, with faint to prominent 5-angular ridges. The edible pulp covers a hard, wrinkly, ellipsoid pyrene of 1.5 - 2 cm by 0.5 - 0.7, which encloses a small, slightly bitter, but edible seed, which is much liked by insects and rodents (Stanglmeier, 2002). Fruiting occurs in October to January (ripe in September-December). The seed has long dormancy (Rodrigo, 2001).

Figure 2 Fruit and seed of *Terminlia chebula*

Habitat: dry, hot and rocky areas in deciduous forest, at elevations from 100 to 2,000 m above sea level in Thailand, but in India up to 1,800 m (Himalayas), often establishing in the middle or on the lower parts of mountain slopes. Temperature tolerance 0-50°C (highly adaptable species), where average annual rainfall is with in the range 750-3,000 mm.

Uses: wood suitable for furniture and agricultural tools because durable in exposed situations and resistant to humidity. Fruit contains astringent substances tannic acid, chebulinic acid, gallic acid etc. Resin and the purgative principle of the nature of anthraquinone and sennoside are also present. Moreover, it contains a constituent, which has a wide antibacterial and antifungal properties, which inhibits growth of *E.coli*, the most common organism responsible for urinary tract infections. The fruit pulp exhibits laxative properties. *T. chebula* has been found to influence dermal wound healing and shows possible inhibitory activity against HIV-I. Besides its medicinal value, *the T. chebula* tree is of social forestry importance (Ulaganatha, 2005 referred to by Stanglmeier, 2002).

Distribution: India, south China, Burma, Laos, Veitnam and Thailand (Stanglmeier, 2002)

Figure 3 Fruit and leaf of *Terminalia chebula*

2. *Gmelina arborea* Roxb.

Common name: Yemane

Thai name: ซ้อ

Family: Verbenaceae

A common, fast-growing, medium-sized, deciduous tree, up to 30 m tall, dbh up to 64 cm, with a dense crown (Forest Restoration Research Unit, 2000)

Bark: thin, brown with cream lenticels when young, becoming grey, finely roughened initially becoming shallowly cracked and flaking with age.

Leaves: opposite, decussate, simple; blades thin, ovate, apex acute, base shallowly cordate, margin entire; 13 - 21 x 13 - 16 cm; above dark green with many tiny hairs, falling off with age, with a pair of distinct basal glands; below dull light green with abundant woolly hairs; midrib with 5-7 pairs of mostly opposite secondary veins, the lowest pair basal; tertiary venation scalariform; finer venation reticulate; petiole 6-8 mm long.

Flowers: inflorescences mostly appearing when the tree is leafless, terminal, paniculate, 10-20 cm long, axes brown and hairy; flowers numerous, 3 cm long; corolla red brown outside, cream-yellow inside; anthers light yellow; filaments yellow, slightly fragrant; stigma and style yellow

Fruit/seed: an obovoid drupe, bright green when unripe, yellow when ripe, 20-24 mm in diameter, containing 1-4 pyrenes, each with 1 seed; dispersed by animals. Fruiting occurs 3-4 years after planting.

Figure 4 Fruit (left) and flower (Right) of *Gmelina arborea*

Habitat: secondary growth in almost all forest types, establishes naturally in disturbed areas, sometimes planted; elevation 250-1500 m (Forest Restoration Research Unit, 2000).

Uses: high value timber for floors, ceilings, furniture, carvings, musical instruments, boats and tools. Also used for plywood, veneers, pulp, paper, fuel and charcoal. The unripe fruits are used to make an infusion to treat stomach ailments. All parts are used in Hindu medicine. A yellow dye is extracted from the fruits and wood ash. The fruit is very attractive to insects and is eaten by deer and cattle. Leaves are used for silkworm culture and as cattle-fodder (Forest Restoration Research Unit, 2000).

Folk medicine: the root decoction is used in folk remedies for abdominal tumors in India. Reported to be anodyne, demulcent, lactagogue, refrigerant, stomachic, and tonic, gmelina is a folk remedy for anasarca, anthrax, bilious disorder, bites, blood disorders, cholera, colic, convulsions, delirium, diarrhea, dropsy, dyspepsia, epilepsy, fever, gout, ,gravel, headache, hemorrhage, intoxication, madness, phthisis, rat bites, rheumatism, rinderpest, septicemia, smallpox, snakebite, sores, sore throat, splenitis, stomachic, swelling and urticaria (Duke, 1983). Deeming the fruits alterative, aphrodisiac, astringent, diuretic, and tonic, Ayurvedics prescribe them for alopecia, anemia, consumption, leprosy, strangury, thirst and vaginal discharges; the flowers for blood disorders and leprosy; the root, deemed anthelmintic, apertif, laxative, and stomachic, for abdominal pains, burning sensations, fever, hallucinations, piles, thirst and urinary discharges (Duke, 1983).

Distribution: throughout Thailand, India south to Sri Lanka, Indo-China, Myanmar and Malaysia (Elliott *et al.*, 2003).

Seedling: (Elliott *et al.*, 2003)

Cotyledonary leaves: opposite, elliptic, apex obtuse and shallowly emarginate, base acute, margin entire; inside mid-green with abundant white glandular hairs; outside pale light green with sparse white glandular hairs; venation pinnate, very faint; petiole light green-white, grooved, 9 mm long,

Stem: hypocotyl light bright green, paler at base, with light striations and with abundant white glandular hairs; epicotyl and internodes light bright green, with abundant white glandular hairs disappearing with age.

Leaves: opposite, simple; blades papery; first blades ovate, apex acuminate, base acute; thereafter ovate to deltoid, apex a acuminate, base cuneate to truncate, margin with several shallow lopes on each side; first three blades 44 x 30, 75 x 60 and 72 x 60 mm; above mid-green with sparse tiny white hairs that disappear with age; below pale light green-grey, hairless.

Venation: pinnate, light green with a pair of basal veins and 7-8 secondary veins on either side of the midrib.

Petiole: pale light green-pink, with tiny white hairs, 35 mm long.

Stipules: Absent

Propagation recommendations: collect yellow fruits in March-June. Remove the fruit flesh by hand. Wash and soak the pyrenes in water for 12-24 hours before sowing them 2-5 cm apart shallowly in trays, in partial shade; expected GR up to 83%, over 18-32 days. Prick out the seedlings when the first leaf pair has expanded, 4-12 days after germination. May require pruning and reduced fertilizer application to prevent seedlings outgrowing their containers. Saplings should be ready for planting in second planting season after germination (Elliott *et al*., 2003).

Chapter 3

Materials and Methods

Part I: Observation of seed dispersal

Materials

1. Binoculars
2. Hide
3. Guide to the birds of Thailand (Lekagul and Round, 1991)
4. A guide to the Large Mammals of Thailand (Parr, 2003)
5. Camera
6. Note book for recording data

Methods

Five fruiting trees of *Terminalia chebula* were located between the Chiang Mai Zoo and Chiang Mai University (elevation 400 m above sea level) and observed between 16th-22th October 2004. Five *Gmelina arborea* trees were selected in their natural forest habitats on Doi Suthep near the headquarters of Doi Suthep-Pui National Park (elevation 1000 m above sea level) and the Hauy Kaew Botanic Arboratum (elevation 400 m above sea level) and observed on 26th-31st March 2005. The trees were identified to species level by collecting specimens and comparing them with herbarium specimens at the herbarium of Biology Department, Chiang Mai University.

Descriptive data of the trees and their surrounding habitat (tree height, girth at breast height (GBH), slope, altitude *etc.*) were recorded, as well as the phenological condition of the trees. Any animals visiting the trees were observed with binoculars and identified with the Guide to the birds of Thailand (Lekagul and Round, 1991) and the guide to the Large Mammals of Thailand (Parr, 2003). Recorded data included the species names of animals, behavior, time spent in the tree and feeding patterns were recorded. Photographs of the animals were taken.

Figure 5 Study sites of *Terminalia chebula*

Figure 6 Guide books for identification of animals

Observations were made for a total of 50 hours (10 hours per tree), rotating among the trees every hour. Observation times were for 5 hours in the morning (5 AM – 10 AM) and 5 hours in the evening (2 PM – 7 PM). While observing animal interactions, the observers were in a hide.

Table 1 Description of observed trees

Tree NO.	Tree species	Elevation(m) above sea level	Girth (m)	Height (m)	Canopy width (m)	Fruiting score*
1	*T. chebula*	400	1.40	20.70	10.55	3
2	*T. chebula*	400	2.00	23.76	11.10	2.5
3	*T. chebula*	400	1.00	18.00	12.60	2
4	*T. chebula*	400	1.10	23.76	9.40	2
5	*T. chebula*	400	0.75	6.25	6.20	2.5
1	*G. arborea*	1020	0.83	25.17	13.60	4
2	*G. arborea*	1020	0.60	34.64	10.10	4
3	*G. arborea*	400	1.40	34.85	12.00	3
4	*G. arborea*	400	1.10	25.50	7.10	2
5	*G. arborea*	400	2.80	29.28	10.20	2

Note * Phenological state of fruit available in observed period. The score indicates the quantity of fruits available in the tree (score '0' = none and '4' = maximum fruiting score)

<u>Part II: Seed germination of ***T. chebula*** **Retz**. in the nursery</u>

Materials

1. Plastic sheet
2. Cutter mounted on a long pole
3. Large bags
4. Forest soil
5. Seeds of *Terminalia chebula*
6. Trays
7. 0.01 M solution of sulfuric acid
8. Nail cutter

Methods

This experiment was carried out at the Forest Restoration Reseach Unit (FORRU) tree nursery, located at Assoc. Prof. Dr. Vilaiwan Anusarnsunthorn's house on Tumpol Suthep, Amper Muang, Chiang Mai at 390 m elevation. Experiments were to determine pre-treatments to maximize seed germination of *Terminalia chebula*.

Figure 7 FORRU's nursery

Seed collection: 1500 ripe fruits of *T. chebula* were collected from 5-10 trees, using a cutter and mixed together in a large bag to ensure randomness of seed selection for germination experiments. *T. chebula* fruits are drupes about 2 cm in diameter. The flesh of the fruits was peeled from the seeds.

The seeds were washed with water and spreaded out on paper to dry. After that, the seeds were maintained in water at ambient temperature. The quality of the seeds was checked by the floatation method. Seeds that floated were discarded and those which sank were selected for germination.

Four presowing treatments were applied:

1. 100 seeds were soaked in water at ambient temperature for 2 days.

2. 100 seeds were dipped in 0.01 M sulfuric acid (pH = 2) for 10 seconds.

3. 100 seeds were maintained in ambient temperature water and heated to 70 °C.

4. 100 seeds were scarified by cutting a small hole in the testa (opposite end to embryo) with a nail cutter.

Figure 8 Seeds after soaking in acid

After the seeds had been treated, they were sown in seed germination trays. Each treatment was replicated three times. In addition to these treatments, three replicates of control seeds (100 per replicate) soaked in water at ambient temperature for 30 min were also sown. Blocks of 4 treatment trays, along with a control tray, were positioned randomly on benches in FORRU's nursery. The nursery was slightly shaded and had good air circulation.

Therefore, the experimental design was a randomized complete block design (RCD), with 4 treatments and a control group, replicated three times. The numbers of germinated seeds were counted weekly for 5 months. Percent germination was calculated as follows:

$$\text{Percent germination} = \frac{\text{total number of seed germination X 100}}{\text{Number of all seed sowing}}$$

Median Length of Dormancy (MLD) was as the numbers of days from sowing to germination of the median seed calculated. Both percent germination and MLD were analyzed by paired t-test (two-sample assuming equal variances), comparing treatments with controls.

Chapter 4

Results

Seed dispersal

Terminalia chebula Retz. var. *chebula* (combretaceae)

During observations of five trees, in the morning (5-10 AM) and in the evening (2-7 PM) all together 50 hours, 2 bird species and 3 squirrel species were seen interacting frequently with the trees, mostly during the periods of 7.30-10 AM and 3.30-5 PM.

The 3 squirrel species were the Variable Squirrel (*Callosciurus finlaysoni*), the Pallas's Squirrel (*Callosciurus erythaeus*) and the Burmese Striped Tree Squirrel (*Tamiops mcclellandi*). These squirrels differed in their activities and feeding patterns.

Callosciurus finlaysoni was a common visitor. They jumped from other trees into *T. chebula*, picked the fruits with their forepaws and suddenly moved out into other trees. Mostly, they gnawed at the fruits before dropping the seeds (Figure 10), but sometimes they carried the fruits away in their mouths.

Callosciurus erythaeus moved from neighboring *T. chebula* trees into the observed trees. Then they picked off the fruits with their mouths and nibbled on them immediately. However, mostly they moved out of the observed trees before gnawing on the fruit bodies and seed coats, whilst sitting on the branches of neighboring trees (Figure 9). Then they dropped the other fruit parts and seeds to the ground. Sometimes they took the fruits far away, dropping them while traveling (Figure 10 and 11).

Tamiops mcclellandi was an uncommon visitor. They came from neighboring trees and collected the fruit with their forepaws. The fruits were consumed immediately and the parts of fruits were discharged. Then they went away.

Figure 9 Feeding pattern of *Callosciurus erythaeus*

Figure 10 Part of fruit was thrown by *C. finlaysoni* or *C. erythaeus*

Figure 11 Body of fruit was gnawed by squirrel

The two bird species were the Brown-cheeked Fulvetta (*Alcippe poioicephala*) and the Greater Coucal (*Centropus sinensis*), which used the trees only for perching or hunting for insects. They did not seem to be attracted to the fruits. Both bird species are omnivores and occasionally consume fruits.

***Gmelina arborea* Roxb. (Verbenaceae)**

A lot of animals visited *G. arborea* during the observation periods including both birds and squirrels. Although, many bird species visited the observed *G. arborea* trees, only 4 species fed on the fruits by pecking at them.

Table 2 Birds' species and their activities with *Gmelina arborea*

Bird species	Activity
Dicrurus aeneus	P V I
Pycnonotus atriceps	P
Pycnonotus melanicterus	P
Dicrurus macrocercus	V I
Dicrurus paradiseus	V H I
Pycnonotus blanfordi	V
Pericrocotus divaricatus	V
Hypsipetes propinquus	V
Nectarinia jugularis	V
Pycnonotus jocosus	P
Centropus sinensis	V
Acridotheres javanicus	V I

P = Pecking at the fruits
V = Visiting but no feeding on fruits
H = Habitat (nesting) in Tree No. 4
I = finding insects (insectivore)

Birds in the family Dicruridae (Figure 13) and *Acridotheres javanicus* (Figure 12) are insectivores so they were probably going after insects attracted to the fruits of

G. arborea. However, the scars from bird pecking induced splitting of the fruits. Moreover, two *Dicrurus paprdiseus* nested in the observed tree No. 4 (Figure 14).

Figure 12 *Acridotheres javanicus* visited *Gmelina arborea*

Figure 13 *Dicrurus aeneus* interacted with *Gmelina arborea*

Figure 14 *Dicrurus paradiseus* and their nest on *Gmelina arborea*

Figure 15 Seeds, splitting from fruits of *Gmelina arborea*, were pecked by birds

Birds of the family Pycnonotidae are usually efficient dispersers of seeds. However, they pecked at and swallowed the immature fruits of *G. arborea* (Figure 16).

Figure 16 *Pycnonotus melanicterus* on *Gmelina arborea*

Two species of squirrels interacted with the fruiting trees, the Variable Squirrel (*Callosciurus finlaysoni*) (Figure 17) and Burmese Striped Tree Squirrel (*Tamiops* *mcclellandi*) (Figure 18). They were common visitors. They picked the fruits with their paws and ate the fruit bodies immediately, before throwing away the seeds. Sometimes, they passed through the observed trees to reach other trees. Moreover, *Callosciurus finlaysoni* slept on the branches of one of the observed trees (Tree No.3).

Figure 17 *Callosciurus finlaysoni* fed on *Gmelina arborea*

Figure 18 *Tamiops mcclellandi* jumped from *Gmelina arborea* to neighbor trees

Seed germination in the nursery

The data presented in table 3 and figure 20 show that for *T. chebula*, scarification was the best pre-sowing treatment, which accelerated germination and maximized germination percent, although a germination rate of 50% was barely acceptable.

Table 3 Percent germination and MLD of *Terminalia chebula*

treatment	Percent germination		MLD(days)	
	Mean	SD	Mean	SD
control	43.0	3.5	46	2.1
Water for 2 days	43.0	9.9	46	1.5
acid	0.7	1.2	91*	52.5
Hot water	4.3	1.5	54	20.5
scarification	50.3	5.5	38	3.6

Note * In the third treatment (dipping in sulfuric acid), seeds germinated only one replication (T3R3).

Figure 19 *Terminalia chebula* Seedling

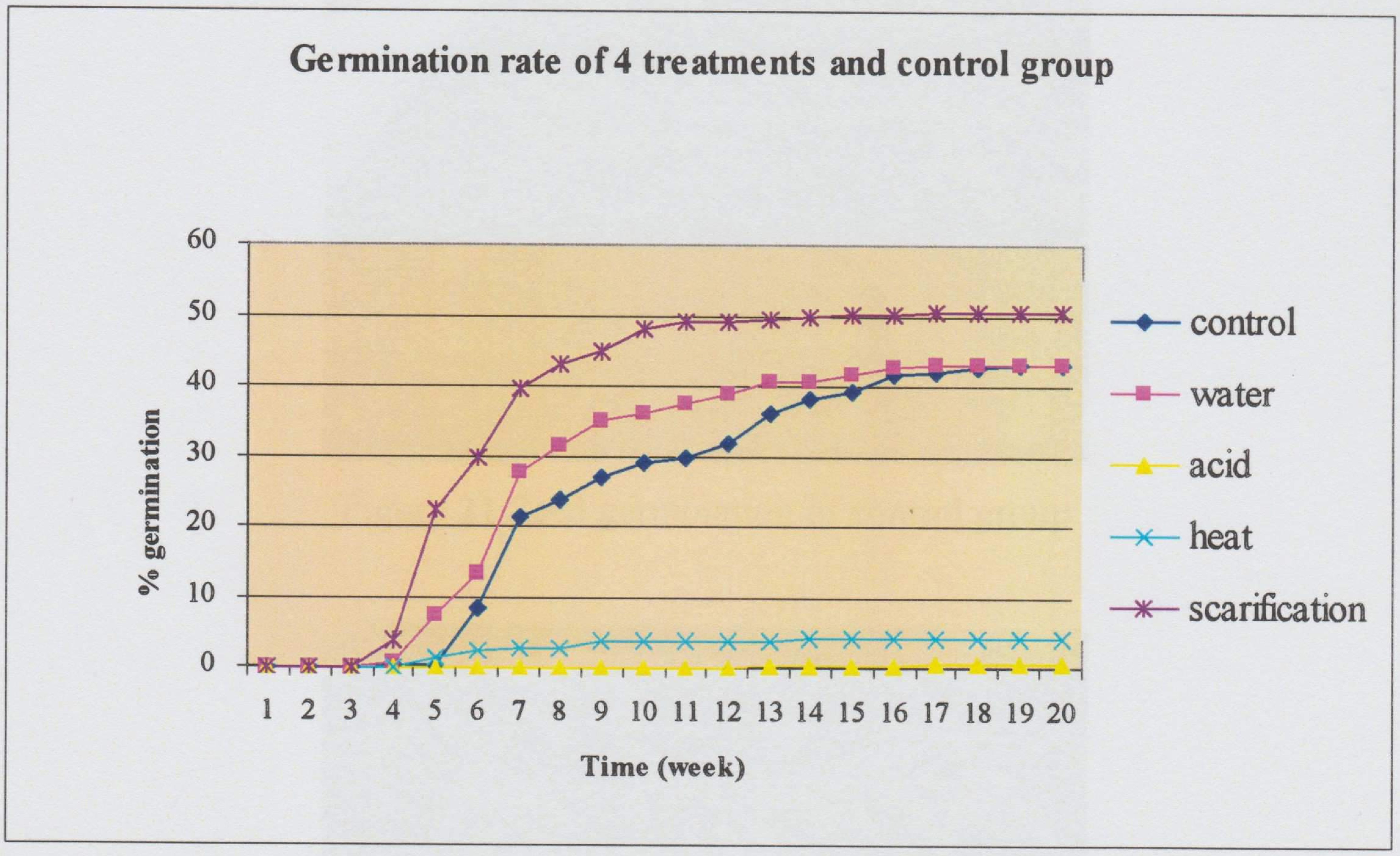

Figure 20 Percent seed germination of treatment
and control group of *Terminalia chebula*

Pair-wise t-tests (assuming equal variances) confirmed that soaking in water had (Figure 22) no significant effect on either germination percent (t value = 0.5, $p<0.05$) or MLD (t value =0.21, $p<0.05$) compared with the control group (Figure 21).

On the other hand, seeds dipped in sulphuric acid (Figure 23) had significantly lower germination percent (t value = 0.00, $p<0.05$) and significantly longer MLD (t value =0.02, $p<0.05$) than the controls.

Soaking seeds in hot water (Figure 24) significantly reduced germination percent (t value = 0.00, $p<0.05$) but had no effect on MLD (t value= 0.25, $p<0.05$).

Scarification by hand (Figure 25) had no significant effect on, percent seed germination (t value= 0.06, $p<0.05$) but significantly shortened MLD (t value= 0.01, $p<0.05$).

Figure 21 Seed germination of control group

Figure 22 Germination of pre-sowing with soaking water for 2 days

Figure 23 Seed germination of pre-sowing with acid

Figure 24 Seed germination of pre-sowing with hot water

Figure 25 Seed germination of pre-sowing with scarification

Chapter 5

Discussion

1. Seed dispersal of *Terminalia chebula* Retz.

During observations of 5 fruiting trees of *T. chebula* for 50 hours, *Callosciurus finlaysoni*, *Callosciurus erythaeus* and *Tamiops mcclellandi* were the most likely seed dispersers because of their feeding patterns in two ways.

Firstly, parts of the fruits, including the seeds, were thrown to the ground by these squirrels, immediately whilst they were foraging in the observed trees. This is primary dispersal, although the seeds did not travel far. The fate of these seeds depended on secondary dispersers on the ground to carry the seed away from the mother trees for example ground-dwelling rodents, such as rats and mice or, where they remain, wild or domestic cattle. Cattle are known to be attracted to *T. chebula* fruits (Villagers, pers.com, 2005).

Secondly, fruits and seeds were carried away from the mother trees by the squirrels and possibly stashed and forgotten. Large seeds are known to have a higher probability of survival, under such circumstances, since scatter-hoarding animals (small rodents) store higher-value food (e.g. large seeds) at lower densities to protect them (the squirrels or the seeds) (Stapanian and Smith, 1978 referred to by Xiao *et al*., 2004).

Since the fruit of *T. chebula* is a drupe of medium size, seed dispersal agents should include large mammals such as Barking Deer (*Mutiacus muntjac*), (Stanglmeier, 2001). Tannic acid in the fruit acts as a laxative. This encourages rapid passage of the fruit and seeds through the digestive tract, thus minimizing the chances that the embryo within the seed will be damaged by gastric acids (Tamhane *et al*., 1997).

Birds also pecked at the fruit bodies, sometimes dislodging them so they fell to the ground. This was a similar case of primary dispersal requiring secondary dispersal by ground-dwelling animals to move the seeds away from mother tree's canopy.

Interactions between animals (squirrels) and some of the observed *T. chebula* trees were made easier because of the short distance to neighboring trees. This was important to enable squirrels to reach the fruiting trees, since they prefer not to travel on the ground. Other trees observed with canopies that were far from neighboring trees attracted fewer squirrels.

The observed trees were located in places close to human activity. So some sensitive animal species, which may be seed-dispersal agents did not visit them. Therefore, more seed-dispersers may have been discovered if observations had been expanded to include more trees in non-disturbed forest.

2. Seed dispersal of *Gmelina arborea* Roxb.

Observations for 10 hours/tree with binoculars revealed a large number of visitors, including both birds and rodents (squirrels), interacting with *G. arborea*. However, the squirrels, *Callosciurus finlaysoni* and *Tamiops mcclellandi*, were the most likely seed dispersal agents of *G. arborea* because of their feeding patterns. They collected the fruit and gnawed at the body but dropped the seeds to the ground. From this pattern, the chances are that the seed travel only short distances from the mother tree. So although the 2 squirrel species were the primary seed dispersers, effective seed dispersal of *G. arborea* needs secondary dispersal agents on the ground that carry the seeds or the other fruits further away from the mother trees.

The birds, which interacted with *G. arborea*, were mostly insectivores and small frugivores. Firstly, the insectivores were in the family Dicruridae and *Acridotheres javanicus*. Sometimes they seemed attracted by the fruits, but this research found no clear evidence that they were involved in dispersal. Secondly, the small frugivores included Bulbuls in the family Pycnonotidae. The fruit of *G. arborea* is of medium size (22 mm in the diameter) and the characteristic of the fruit is a drupe with a toughened exocarp. So they could peck at the skin or swallow only the smaller immature fruits because the fruit odour interacted animals (Villagers, per.com, 2005). Bulbuls can swallow fruits or seeds up to 15 mm (Corlett, 1998).

Thus, in most cases, the birds observed were unlikely to be seed dispersal agents. Nevertheless, the wounds from pecking of the fruits by the birds could facilitate splitting of the fruits so that seeds could fall out and begin dispersal by other agents.

However, the two squirrel species did not often visit all observed trees and were not seen on every observation day. It is therefore likely that there are other seed dispersers of *G. arborea* besides these 2 species of squirrel. Other dispersers could include large mammals (including both wildlife and domestic animals). At present, forest has been invaded from the human activities. Therefore large wild animals have been extirpated or significantly reduced in population size.

I went to Doi Inthanon National Park, located Amper Mae Wang in Chiang Mai, where there are a lot of *G. arborea* trees. The villagers there said that domestic cows were dispersers (Villagers, per.com, 2005). The cows consumed the fruits but did not crush all of them in chewing, so some survived and could germinate in the cattle dung. In contrast, Calvino-Cancela (2004) reported that, if the seeds are eaten by frugivores and regurgitated, the regurgitated seed retained high viability than those which had pass through the digestive tracts of animals, suggesting that the seed embryo may be damaged by the acidic conditions within the gut.

Although the data showed that a few animals ate the fruits of *G. arborea*, this species was the habitat for many animals for feeding on insects or nectar, resting and nesting. *G. aborea* attracted a lot of wild life, so the planting of this species for forest restoration will encourage forest ecosystem recovery. This is one of the reasons why this species is recommended by FORRU as a framework species (Forest Restoration Research Unit, 2000).

In this research, observations of seed dispersal were made with binoculars during the daytime. Thus, if observations were extended to include the night-time, perhaps more nocturnal seed dispersers might have been found. Moreover, secondary dispersal or seeds dropped to the ground could not be observed because the dense ground flora obscured the view. Small mammal traps or sand traps could be used to confirm the presence of small secondary seed dispersers, whilst direct observations could be carried out, at night, with infrared to reveal the presence of larger mammalian seed dispersers (where they are still extant).

Future studies should also determine the fate the dispersed seeds and their viability after the dispersal process. Seed germination appears to be strongly dependent on the type of habitat where seeds are deposited by dispersers (Calvino-cancela, 2004), so it is important to monitor germination of seeds after dispersal (Xiao *et al.*, 2004).

3. Seed germination of *T. chebula*

This species belongs to the family Combretaceae. The fruit is an indehiscent drupe (Stanglmeier, 2002) 2-4 cm in diameter with a thick seed coat. *T. chebula* seed has the intermediate-dry syndrome (Garwood, 1983). Seeds were dispersed during the dry season and remained dormant until the beginning of the rainy season. Seeds are primarily dispersed 1-2 month before the beginning of the rainy season, which reduces the number of false germination cues encountered and decreases the length of time seeds are exposed to post-dispersal predation, while dormancy prevents germination during dry season rains. In this project, 4 treatments were tested

I) Soaking in the water, percent germination and MLD were similar with those of control group. Thus, this method was not suitable for producing seedlings, because the normal method is just as efficient and requires less effort.

II) Dipping in the acid. Singpetch (2001) recommended pretreating the seeds of *Terminalia alata* in acid to imitate the passage of seeds through the guts of dispersers, during which acid could break down seed coat.

However, percent germination (0.7±1.1) of *T. chebula* was the lowest with this treatment and 2 out of 3 replication had zero germination. MLD was 91 days. Thus, this treatment inhibited seed germination of this species. The most likely reason was that the acid not only perforated the seed coat, but also destroyed the embryo. Changing the acid to HCl, using a lower concentration or putting the seeds in the acid for a shorter time, might produce better results.

III) The heating treatment (to 70ºC with water as a buffer) was included because *T. chebula* is a deciduous species and is distributed in fire-prone areas. Seed germination was reduced by this treatment but it had no effect on MLD. In nature, seeds of *T. chebula* cannot resist high temperatures (70ºC). My suggestion, continuous research should vary temperature from low to high for treating seeds to maximize seed germination or limit tolerance.

IV) Scarification by hand, mechanical and chemical scarification of the seed can enhance seed germination by increasing permeability of the testa to water and gases or the perception of germination cues (Barnea *et al.*, 1990; Izhaki and Safriel, 1990; Sahai; 1995; Foster and Delay, 1998; referred to by Calvino-Cancela, 2004). Percent germination with this treatment was not significantly different compared with the control group, but MLD was shorter *T. chebula* seeds usually have a long dormant period (Stanglmeier, 2001). Therefore, using scarification could reduce the dormant period, and cause germination to occur more quickly thus accelerating seedling production. Some of the seedlings that germinated rapidly were attacked by insects and some of them died. So using of insecticides might be necessary to guarantee a healthy crop of the seedlings for planting out.

Since squirrels were observed to gnaw at the fruits and some part of seed coat of *T. chebula*, it seems likely that scarification may be occurring naturally for this species and that squirrels are needed, not only to help disperse the seeds but also to help accelerate their germination.

In forest restoration, production schedules are essential to guarantee production of a sufficient numbers of seedlings or good quality of each species at the optimal planting time. For *T. chebula* seeds are collected for sowing in late October. Optimal planting out time is the middle of June but seedlings of *T. chebula* do not grow fast enough for planting out in the first June after seed collection. They must be stored in the nursery a further year before planting out in the second June after seed collection. Although pre-sowing with scarification can reduce MLD by approximately ten days, it is not enough to have the saplings ready for planting within a year. Therefore, in the long run, scarification did not shorten the production schedule and is probably not necessary for this species. Using no treatment is the best choice for saving the budget and the seedlings have higher survival rate.

Corker (2003) reparted that seeds can be divided into two main types, orthodox and recalcitrant. Orthodox seeds can be dried and stored at temperatures of -20°C. Almost all species in a temperate flora can be stored in this way. Surprisingly, many tropical seeds are also orthodox. Recalcitrant seeds, in contrast, die when dried and frozen in this manner. Acorns of oaks are recalcitrant and it is believed that so are the seeds of most tropical rain forest trees. *T. chebula* seeds are orthodox and seedlings require 12-14 months for growth in the nursery. Therefore, *T. chebula* seeds could be stored dry and at low temperatures from late October and sown the following April-June.

Future experiments should concentrate on discovering treatments to increase germination above 50% and to shorten MLD to 10 days or less. Moreover, suitable growth factors (light, moisture, fertilizer etc.) for *T. chebula* seedling growth in the nursery require investigation.

Chapter 6

Conclusions

1. *Terminalia chebula* Retz. and *Gmelina arborea* Roxb. are animal-dispersed tree species.

2. Seed dispersal agents include squirrels (specifically the Variable Squirrel (*Callosciurus finlaysoni*), the Pallas's Squirrel (*Callosciurus erythaeus*) and the Burmese Striped Tree Squirrel (*Tamiops mcclellandi*)), but they disperse seeds a short distance from the mother trees. Thus, seed dispersal of these two tree species is also dependent on secondary dispersal agents on the ground.

3. Scarifying by hand reduced dormancy period of *Terminalia chebula* Retz. seeds. Therefore, the seed coat probably plays an important role in dormancy by prevent water and oxygen from reaching the embryo. Percent germination which resulted from soaking in water, scarification and the control group were similar.

4. Squirrel gnawing on the fruits and seeds could provide natural scarification, which facilitates rapid germination of *Terminalia chebula* Retz. in nature

5. Various bird and squirrel species were attracted to *Terminalia chebula* Retz. and *Gmelina arborea* Roxb. trees, confirming their conservation value and roles in accelerating biodiversity recovery if included in forest restoration plantings.

6. These two tree species are recommended for forest restoration because they i) provide animal food; ii) produce as dense shady canopy and iii) grow rapidly.

7. My recommendation is seed storage of *T. chebula* in dry and low temperature conditions from October for sowing in June.

8. Future research should aim to increase percent germination to more than 50% and reduced MLD to less than 10 days.

References

Bhumibamon, S., 1986. The environmental and socio-economic Aspects of Tropical Deforestation: a case study of Thailand. Department of Silviculture, Faculty Of Forestry, Kasetsart University.

Blakeley, D., Anusarnsunthorn, V., Kerby, J., Zangkum, S., Hardwick, K. and Elliott, S. 2000. Nursery technology and tree species selection for restoring forest biodiversity in northern Thailand pp. 207-222 in Eliott, S., Kerby, J., Blakesley, D., Hardwick, K., Wood, K. and Anusarnsunthorn, V. (eds.). Forest restoration for wildlife conservation. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University. Thailand.

Brown, G. 2001. Seed dispersal. [Online]. Available: http://www.users.csbsju.edu/~dgbrown/BIOL338/seeddisp.html [2005, April 28].

Calvino-Cancela, M. 2004. Ingestion and dispersal: direct and indirect effects of frugivores on seed viability and germination of *Corema album* (Empetraceae). *Acta Oecologica 26: 55-64.*

Corker, B. 2003. Biodiversity and conservation. [Online]. Available: http://www.countrysideinfo.co.uk/biodvy.htm [2005, May 22]

Corlett, R. T. 1998. Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. Biol. Rev. 73 : 413-448.

Corlett, R. T. and Hau, B. C. H. 2000. Seed dispersal and forest restoration pp.317-323 in Eliott, S., Kerby, J., Blakesley, D., Hardwick, K., Wood, K. and Anusarnsunthorn, V. (eds.). Forest restoration for wildlife conservation. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University. Thailand.

Duke, J.A. 1983. *Gmelina arborea* Roxb. [Online]. Available: http://www.hort.purdue.edu/newcrop/duke_energy/Gmelina_arborea.html#Uses [2005, April.20]

Elliott, S. 2000. Seed germination and dormancy, seed dispersal. Lecture of Tropical Ecology. Biology Department. Faculty of Science. Chiang Mai University. Thailand. Unpublication.

Emmons, L. H., 1991. Frugivory in treeshews. American Naturalist 138 : 642-649

FAO, 2001a. State of the World's Forest 2001. Food and Agriculture Organization of The Unitated Nation. Rome

FAO, 2001b. Global Forest Resource Assessment 2000 Main Report. Food and Agriculture Organization of the United Nation. Rome.

Forest Restoration Research Unit, 1998. Forest for the future: Growing and plantation native trees for restoring forest ecosystems. Biology Department, Faculty of Science, Chiang Mai University, Thailand.

Forest Restoration Research Unit, 2000. Tree Seeds and Seedling for Restoring Forest In Northern Thailand. Biology Department. Faculty of Science. Chiang Mai University. Thailand.

Garwood, N. C. 1983. Seed germination in a seasonal tropical forest in Panama: a community study. Ecological Monographs: 159-181.

Hardwick, K. And Elliott, 1992. Factor affecting germination of tree seeds from dry tropical forests in northern Thailand. Dhammannt Foundation and Biology Department, Chiang Mai University.

Ji-Qi, L. and Zhi-Bin, Z. 2004. Effects of habitat and season on removal and hoarding of seeds of wild apricot (*Prunus armeniaca*) by small rodents. Acta Oecologica 26: 247-254.

Kitamura, S., Yumoto, T., Poonsawad, P., Chuailua, P., Plongmai, K., Maruhashi, T. and Noma, N. 2002. Interaction between fleshy fruits and frugivores in a tropical seasonal forest in Thailand. Oecologia 133 : 559-572

Kitamura, S., Suzukit, S., Yumoto. T., Poonswad, P., Chuailua, p., Plonmai, K., Moma, N., Maruhashi, T. and Suckasam, C. 2004. Dispersal of *Aglaia spectabilis*, a large-seed tree species in a moist evergreen forest in Thailand. Journal of Tropical Ecology 20: 421-427.

Koning, R.1994. Seed germination. Plants physiology information wetsite. [Online]. Available: http://plantphys.info/index.html. [2005, May 1]

Lekagul, B. and McNeely, J.A. 1998. Mammals of Thailand. Kurusapha Ladprao. Bangkok. Thailand.

Lekagul, B. and Round, P.D. 1991. A guide to the birds of Thailand. Darnsutha Press. Bangkok. Thailand.

Parr, J.W.K. 2003. A guide to the Large Mammals of Thailand. Krungthep (Bangkok) Printing (1998). Bangkok. Thailand.

Prosea Foundation. 1994. Prosea Plant Resources of South-East Asia- Timber Trees Major Commercial Timber. Bogor, Indonesia.

Ramakrishanappa, K. 2002. Impact of cultivation and gathering of medicine plants on biodiversity case studied from India. Biodiversity and ecosystems approach in agriculture.

Rattanakul, A. 2003. Terminalia chebula. [Online]. Available: http://www.dnp.grg/ pattani_botany. [2005, February20].

Savithasuri. 2004. Haritaki. [Online]. Available: http://www.ayurhelp.com / plants/haritaki.html. [2004, May.1]

Sharp, A. 1995. Seed Dispersal and Predation in Primary Forest and Gap on Doi Suthep. M.S. Thesis. Biology Department, Faculty of Science, Chiang Mai University.

Singpetch, S. 2001. Propagation and Growth of Potential Framework Tree Species for Forest Festoration. M.S.Thesis. Biology Department, Faculty of Science, Chiang Mai University.

Stanglmeier, U. 2001. Saving the Last Old *Terminalia chebula* Trees. Ponadon Project.

Stanglmeier, U. 2002. Myrobalan –The Elixir of life. Vaidya-publication. Germany.

Tamhane, M.D., Thorat, S.P., Rege, N.N. and Dahanukar, S.A. 1997. Effect of oral administration of *Terminalia chebula* on gastric emptying: an experimental study. Ayurveda Research Centre. Department of Pharmacology. Seth GS Medical College.

Van der Pijl, L. 1972. Principle of Dispersal in Higher Plants. Springer-Verlag. Berlin.

Wenny, D.G and Levey, D. 1998. Directed seed dispersal by bellbirds in a tropical cloud forest. Proc. Natl. Acad. Sci. USA 95 : 6204-6207.

Whittaker, R.J. and Jones, S.H. 1994. The role of frugivorous bats and birds in the rebuilding of tropical forest ecosystem, Krakatau, Indonesia. J. Biogeograhy :254-258

Wunderle Jr., J.M. 1997. The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. Forest Ecology and Management 99 : 223-235.

Xiao, Z., Zhang, Z. and Wang, Y. 2004. Dispersal and germination of big and small nuts of *Quercus serrata* in a subtropical broad-leaved evergreen forest. Forest Ecology and Management 195 : 141-150.

Table 1 Percentage of seed germination between control group and soaking in water with statistic result of t-test (two-sample assuming equal variances)

	Control	*water*
Mean	43.00	43.00
Variance	12.00	97.00
Observations	3.00	3.00
Pearson Correlation	0.70	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	0.00	
P(T<=t) one-tail	0.50	
t Critical one-tail	2.92	
P(T<=t) two-tail	1.00	
t Critical two-tail	4.30	

Table 2 Percentage of seed germination between control group and dipping in acid with statistic result of t-test (two-sample assuming equal variances)

	Control	*acid*
Mean	43.00	0.67
Variance	12.00	1.33
Observations	3.00	3.00
Pearson Correlation	-1.00	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	15.88	
P(T<=t) one-tail	0.00	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.00	
t Critical two-tail	4.30	

Table 3 Percentage of seed germination between control group and soaking in hot water with statistic result of t-test (two-sample assuming equal variances)

	Control	*heat*
Mean	43.00	4.33
Variance	12.00	2.33
Observations	3.00	3.00
Pearson Correlation	0.76	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	26.61	
P(T<=t) one-tail	0.00	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.00	
t Critical two-tail	4.30	

Table 4 Percentage of seed germination between control group and soaking in hot water with statistic result of t-test (two-sample assuming equal variances)

	Control	*scarification*
Mean	43.00	50.67
Variance	12.00	30.33
Observations	3.00	3.00
Pearson Correlation	0.42	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	-2.59	
P(T<=t) one-tail	0.06	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.12	
t Critical two-tail	4.30	

Table 5 Median length of dormancy between control group and soaking in water with statistic result of t-test (two-sample assuming equal variances)

	Control	*water*
Mean	45.67	46.33
Variance	4.33	2.33
Observations	3.00	3.00
Pearson Correlation	0.84	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	-1.00	
P(T<=t) one-tail	0.21	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.42	
t Critical two-tail	4.30	

Table 6 Median length of dormancy between control group and dipping in acid with statistic result of t-test (two-sample assuming equal variances)

	Control	*acid*
Mean	45.67	123.67
Variance	4.33	800.33
Observations	3.00	3.00
Pearson Correlation	-0.97	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	-4.46	
P(T<=t) one-tail	0.02	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.05	
t Critical two-tail	4.30	

Table 7 Median length of dormancy between control group and soaking in hot water with statistic result of t-test (two-sample assuming equal variances)

	Control	*heat*
Mean	45.67	54.33
Variance	4.33	421.33
Observations	3.00	3.00
Pearson Correlation	1.00	
Hypothesized Mean Difference	0.00	
Df	2.00	
t Stat	-0.81	
P(T<=t) one-tail	0.25	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.50	
t Critical two-tail	4.30	

Table 8 Median length of dormancy between control group and scarification with statistic result of t-test (two-sample assuming equal variances)

	Control	*scarification*
Mean	45.67	38.00
Variance	4.33	13.00
Observations	3.00	3.00
Pearson Correlation	0.87	
Hypothesized Mean Difference	0.00	
df	2.00	
t Stat	6.38	
P(T<=t) one-tail	0.01	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.02	
t Critical two-tail	4.30	

Table 8 Data sheet for recording seed germination of *Terminalia chebula*

Date	Control				Water				Acid				Heat				Scarification			
	R1	R2	R3	M	R1	R2	R3	M	R1	R2	R3	M	R1	R2	R3	M	R1	R2	R3	M
19/10/2004	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0
26/10/2004	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0
5/11/2004	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0
12/11/2004	0	1	0	0.3	1	1	0	0.7	0	0	0	0.0	0	0	0	0.0	0	8	3	3.7
21/11/2004	3	7	6	0.3	8	9	5	7.3	0	0	0	0.0	1	2	1	1.3	22	26	19	22.3
26/11/2004	8	9	8	8.3	19	14	7	13.3	0	0	0	0.0	1	5	1	2.3	34	29	26	29.7
4/12/2004	20	22	22	21.3	39	24	20	27.7	0	0	0	0.0	2	5	1	2.7	43	41	35	39.7
10/12/2004	21	26	24	23.7	43	27	25	31.7	0	0	0	0.0	2	5	1	2.7	48	43	39	43.3
17/12/2004	25	27	29	27.0	44	36	25	35.0	0	0	0	0.0	4	6	1	3.7	52	43	40	45.0
24/12/2004	27	30	30	29.0	46	38	25	36.3	0	0	0	0.0	4	6	1	3.7	54	46	44	48.0
31/12/2004	29	30	31	30.0	48	40	25	37.7	0	0	0	0.0	4	6	2	4.0	55	47	45	49.0
7/1/2005	32	31	33	32.0	49	40	28	39.0	0	0	0	0.0	4	6	2	4.0	55	47	45	49.0
15/1/2005	37	38	34	36.3	52	40	30	40.7	0	0	1	0.3	4	6	2	4.0	56	47	45	49.3
21/1/2005	40	39	36	38.3	52	40	30	40.7	0	0	1	0.3	4	6	3	4.3	57	47	45	49.7
28/1/2005	42	40	36	39.3	53	40	32	41.7	0	0	1	0.3	4	6	3	4.3	57	47	47	50.3
5/2/2005	43	45	37	41.7	54	40	34	42.7	0	0	1	0.3	4	6	3	4.3	57	47	47	50.3
19/2/2005	44	45	37	42.0	54	40	35	43.0	0	0	2	0.7	4	6	3	4.3	57	47	48	50.7
26/2/2005	45	45	38	42.7	54	40	35	43.0	0	0	2	0.7	4	6	3	4.3	57	47	48	50.7
5/3/2005	45	45	39	43.0	54	40	35	43.0	0	0	2	0.7	4	6	3	4.3	57	47	48	50.7
12/3/2005	45	45	39	43.0	54	40	35	43	0	0	2	0.7	4	6	3	4.3	57	47	48	50.7

R1 = First replication
R2 = Second replication
R3 = Third replication
M = Mean

Curriculum vitae

Name	Khwankhao Sinhaseni
Date of Birth	October 25, 1982
Place of Birth	Chiang Mai, Thailand
Educational Background	
Primary	Prechanusart School, Chonburi, Thailand
Secondary	Dara Academy, Chiang Mai, Thailand
Communication	kimmim_s@hotmail.com Mobile phone 01-7835870 70/35 M.2 T.Chang Perk A.Muang Chiang Mai, Thailand