

THESIS

**SILVICULTURE OF *MANSONIA GAGEI* J.R.DRUMMOND
IN PRACHUAP KHIRI KHAN PROVINCE**

KONGSAK MEEKAEW

GRADUATE SCHOOL, KASETSART UNIVERSITY

2008



THESIS APPROVAL
GRADUATE SCHOOL, KASETSART UNIVERSITY

Doctor of Philosophy (Forestry)

DEGREE

Forestry

FIELD

Interdisciplinary Graduate Program

PROGRAM

TITLE: Silviculture of *Mansonia gagei* J. R. Drummond in Prachuap Khiri Khan Province

NAME: Mr. Kongsak Meekaew

THIS THESIS HAS BEEN ACCEPTED BY

Bunvong Thaiutsa

THESIS ADVISOR

(Assistant Professor Bunvong Thaiutsa, Ph. D.)

Ladawan Puangchit

COMMITTEE MEMBER

(Assistant Professor Ladawan Puangchit, D. Sc.)

Somkid Siripatanadilok

COMMITTEE MEMBER

(Associate Professor Somkid Siripatanadilok, Ph. D.)

Ladawan Puangchit

GRADUATE COMMITTEE
CHAIRMAN

(Assistant Professor Ladawan Puangchit, D. Sc.)

APPROVED BY THE GRADUATE SCHOOL ON

17 May 2008

Gunjana Theeragool

DEAN

(Associate Professor Gunjana Theeragool, D.Agr.)

THESIS

SILVICULTURE OF *MANSONIA GAGEI* J.R.DRUMMOND
IN PRACHUAP KHIRI KHAN PROVINCE

KONGSAK MEEKAEW


A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Philosophy (Forestry)
Graduate School, Kaestsart University
2008

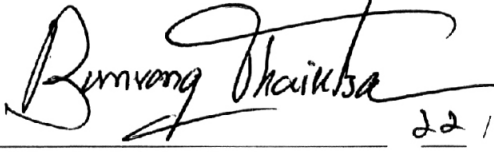
Kongsak Meekaew 2008: Silviculture of *Mansonia gagei* J.R.Drummond in Prachuap Khiri Khan Province. Doctor of Philosophy (Forestry), Major Field: Forestry, Interdisciplinary Graduate Program. Thesis Advisor: Assistant Professor Bunvong Thaitutsa, Ph.D. 111 pages.

The study on silviculture of *Mansonia gagei* J.R. Drummond was carried out in Prachuap Khiri Khan province with particular emphases on natural habitat and ecology as well as reproductive phenological phenomena in the natural stands and growth and yields in plantation. Three national parks were considered as study sites of natural stands, while a 10-year-old plantation was in an adjacent area.

The results showed that stand composition of the species varied among sites. In Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks, there were 28, 63 and 27 tree species, respectively; while *M. gagei* tree densities were 27, 32, and 35 trees per ha and the species diversity indices were 1.486, 2.767 and 2.014, respectively for those 3 national parks. The most richness of the species was found in Namtok Huai Yang National Park, while the least was found in Khao Sam Roi Yot National Park. IVI of *M. gagei* at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were 28.523, 13.270 and 13.108, respectively. Crown cover of *M. gagei* was in the upper layer in every study site. The natural existence of *M. gagei* in these national parks showed that the species tolerated various soil types. Soil pH, however, showed strong impact on tree growth.

Reproductive period of *M. gagei* from flower bud sprout to mature fruit took 6 months, from July to December. Every day there was 1 or 2 flowers opening in one inflorescence, up to 20 flowers in one twig. Flower opened around 7 am with its peak receptive period around 7-9 am. The flower then closed from 10 am to 5 pm and reopened from 5 to 7 pm. Only 25.79 % of flowers could develop to mature fruits. The fruit was samara and considered as a seed. Seed weight with wing and de-winged had the averages of 366.3 ± 92.8 and 272.9 ± 58.8 g per 1,000 seeds, respectively. Fruit color was found to be a good indicator for seed maturity. Mature seed was greenish brown in late December. Seed longevity was less than 90 days. The seedling growth was rather slow compared to other native species. Height, diameter at ground level and DBH of 10-year-old trees in plantation were 6.59 m, 11.67 cm and 9.16 cm, respectively. The estimation on stem, branch, leaf, and total aboveground biomass were of 25.023 t/ha, 11.473 t/ha, 3.568 t/ha and 40.065 t/ha, respectively with the stem volume of $31.125 \text{ m}^3/\text{ha}$.


Student's signature


Thesis Advisor's signature

22 / May / 2008

ACKNOWLEDGEMENTS

I would like to express my grateful thanks and am deeply indebted to Asst. Prof. Dr. Bunvong Thaiutsa, chairman of graduate committee for his continuous advices, encouragements and valuable suggestions to complete this thesis. Also, my sincerely thanks are conveyed to Asst. Prof. Dr. Ladawan Puangchit, and Assoc. Prof. Dr. Somkid Siripattanadilok as committee members, and Asst. Prof. Dr. Uthaiwan Sangwanit as a representative from the Graduate School for their valuable comments and suggestions.

Mr. Prasong Saguantam, Mr. Prasit – Ms. Chamnan Peananuruk, Mr. Porntep Muanpong, Mr. Pongtep – Ms. Ladawan Tongtapao, Mr. Sukum – Ms. Sarika Chantachot, Mr. Somporn Kaikaew, Mr. Varapong Limtin, Miss Tassanee Klinhual, Miss Aor Pranchai Ms. Kanyapa Staporn, Mr. Pongsakorn – Mr. Anusorn Chumpia and field staffs of Prachuap Khiri Khan Silvicultural Research Station cannot be avoided to accept my appreciations due to their assistances in data collection and analysis.

I especially appreciate to my parents, Mr. Sumon – Ms. Prapai Meekaew, my highly respective Prakhru Bunpot Pattanakol, Mr Chaloa Tunpiban, my sister and brothers, Ms. Supit – Manit Chumpia and Mr. Toardpong – Mr. Prasan Meekaew for their continuing encouragements. Finally, I deeply appreciate to Ms. Amporn Meekaew, my wife and also my sons, Mr. Vanawat, Vanut and Vasun Meekaew who always devote time, supports and give me their heartfull loves during my graduate study.

Kongsak Meekaew
May 2008

TABLE OF CONTENTS

| | Pages |
|--------------------------------|--------------|
| TABLE OF CONTENTS | i |
| LIST OF TABLES | ii |
| LIST OF FIGURES | iv |
| INTRODUCTION | 1 |
| OBJECTIVES | 3 |
| LITERATURE REVIEW | 4 |
| MATERIALS AND METHODS | 30 |
| RESULTS | 45 |
| CONCLUSION AND RECOMMENDATIONS | 99 |
| Conclusions | 99 |
| Recommendations | 101 |
| LITERATURE CITED | 103 |

LIST OF TABLES

| Table | Page |
|---|-------------|
| 1 Stand composition in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks, Prachuap Khiri Khan province. | 45 |
| 2 Species diversity, richness and evenness index of a sample plot at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks. | 53 |
| 3 Relative density, relative frequency, relative dominance and importance value index of trees (DBH > 4.5 cm) at Kuiburi National Park. | 55 |
| 4 Relative density, relative frequency and importance value index of saplings (DBH < 4.5 cm, height > 1.30 m) at Kuiburi National Park. | 56 |
| 5 Relative density, relative frequency and importance value index of seedlings (height < 1.30 m) at Kuiburi National Park. | 57 |
| 6 Relative density, relative frequency, relative dominance and importance value index of trees (DBH > 4.5 cm) at Namtok Huai Yang National Park. | 58 |
| 7 Relative density, relative frequency and importance value index of saplings (DBH < 4.5 cm, height > 1.30 m) at Namtok Huai Yang National Park. | 61 |
| 8 Relative density, relative frequency and importance value index of seedlings (height < 1.30 m) at Namtok Huai Yang National Park. | 63 |
| 9 Relative density, relative frequency, relative dominance and importance value index of trees (DBH > 4.5 cm) at Khao Sam Roi Yot National Park. | 65 |
| 10 Relative density, relative frequency and importance value index of saplings (DBH < 4.5 cm, height > 1.30 m) at Khao Sam Roi Yot National Park. | 66 |
| 11 Relative density, relative frequency and importance value index of seedlings (height < 1.30 m) at Khao Sam Roi Yot National Park. | 67 |

LIST OF TABLES (Continued)

| Table | | Page |
|-------|--|------|
| 12 | Basal area, relative density, relative frequency, relative dominance and IVI of <i>M. gagei</i> at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Park. | 68 |
| 13 | Soil chemical properties at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks and Kuiburi plantation. | 78 |
| 14 | Soil texture at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks and Kuiburi Plantation. | 80 |
| 15 | Number of inflorescence, flowers and fruits of <i>M. gagei</i> . | 81 |
| 16 | Among–twig variation in number of flowers per inflorescence, fruits per inflorescence and Fr/FI ratio of <i>M. gagei</i> . | 82 |
| 17 | Weight of wingd and de-winged seeds of <i>M. gagei</i> . | 85 |
| 18 | De-winged and winged seed sizes of <i>M. gagei</i> . | 86 |
| 19 | Growth of <i>M. gagei</i> seedlings at 1-12 months old. | 91 |
| 20 | Height growth of <i>M. gagei</i> plantation planted at Kuiburi Silvicultural Research Sub-station. | 93 |
| 21 | Diameter growth of <i>M. gagei</i> plantation aged 1-10 years at Kuiburi Silvicultural Research Sub-station. | 95 |
| 22 | Biomass and volume of <i>M. gagei</i> plantation, 3 to 10 years of age, at Kuiburi Silvicultural Research Sub-station. | 98 |

LIST OF FIGURES

| Figure | | Page |
|--------|---|------|
| 1 | Morphology of <i>M. gagei</i> J.R. Drummond, flowering shoot (a), flower (b) and fruit (c). | 27 |
| 2 | Sample plot locations for <i>M. gagei</i> natural stands survey in Khao Sam Roi Yot, Kuiburi and Namtok Huai Yang National Parks at Prachuap Khiri Khan province. | 31 |
| 3 | The primary sample plots of 100 X 100 m ² and 20 subplots of 10 X 10 m ² , 4 X 4 m ² and 1 X 1 m ² used in the current. | 34 |
| 4 | The seed coat color of <i>M. gagei</i> a) green b) greenish brown and c) brown. | 41 |
| 5 | DBH frequency distribution of trees (left) and <i>M. gagei</i> (right) at Kuiburi (a) Namtok Huai Yang (b) and Khao Sam Roi Yot (c) National Parks. | 50 |
| 6 | Height frequency distribution of trees (left) and <i>M. gagei</i> (right) Kuiburi (a) Namtok Huai Yang (b) and Khao Sam Roi Yot (c) National Parks. | 51 |
| 7 | Profile diagram and crown cover of trees (DBH > 4.5 cm) at Kuiburi National Park, trees with painted represent <i>M. gagei</i> . | 70 |
| 8 | Profile diagram and crown cover of trees (DBH > 4.5 cm) at Namtok Huai Yang National Park, trees with painted represent <i>M. gagei</i> . | 71 |
| 9 | Profile diagram and crown cover of trees (DBH > 4.5 cm) at Khao Sam Roi Yot National Park, trees with painted represent <i>M. gagei</i> . | 72 |
| 10 | Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Kuiburi National Park. | 74 |
| 11 | Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Namtok Huai Yang. | 75 |
| 12 | Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Khao Sam Roi Yot National Park. | 76 |

LIST OF FIGURES (Continued)

| Figure | | Page |
|---------------|---|-------------|
| 13 | Scanning electron micrographs (SEMs) of <i>M. gagei</i> flower, Anther (A), Tricolpate type pollen grain (B), Receptive stigma with germinated pollen (C), Post receptive stigma (D). | 84 |
| 14 | Seed coat color as a maturity index in relation to germination percentage of <i>M. gagei</i> . | 87 |
| 15 | Storage of greenish-brown and brown fruits processed by air-dry and sun-dry treatments of <i>M. gagei</i> . | 89 |
| 16 | Germination rates of <i>M. gagei</i> seeds in 3 different media | 90 |
| 17 | Diameter at breast height of <i>M. gagei</i> planted at Kuiburi Silvicultural Research Sub-station. | 96 |

SILVICULTURE OF *MANSONIA GAGEI* J.R. DRUMMOND IN PRACHUAP KHIRI KHAN PROVINCE

INTRODUCTION

Mansonia gagei J.R. Drummond is one of three species of the Sterculiaceae family found in Thailand. The distribution elsewhere occurs in Burma and India (Phengklai, 1990). The species is known on various names in different parts of the country. In Nakorn Ratchasima, the tree and its wood are called *Chankhao* or *Chanhom*. In Prachuap Khiri Khan and Surat Thani it is known as *Chanhamot*, *Chanpama* or *Chanhom* (Smitinand, 1977). “*Hom*” in Thai means good fragrance. The Burmese call the wood “*Kalumet*” which the Thai spoken people on the Burma side of the border call *Karama*, *Chanpama* or Burmese sandal wood (Kerr, 1970).

Due to its attractive fragrance, the wood is used in many occasions in the Thai ways of live. It is the only wood used to make the royal Thai coffin. The most recent use was at the HM the King’s Mother’s cremation on March 10, 1996 (Chanthawich, 1996). The species is the most important wood used in traditional Thai funeral ceremony for both royal family and common people. Peeled wood made into a flower shape is used as a special fuel for cremation called “*Dok Mai Chan*” (flower made of *Chan* wood). People place the flowers under the coffin to pay respect and memorial to the dead body. For the royal funeral, *Chanhom* wood is also used for a special coffin (*Kot-Mai-Chan*), special combs, firewood, etc. (Chanthawich, 1996). In general, the wood is used to make furniture, scented sticks, perfume, cosmetic and many kinds of medicines (Phengklai, 1990). Using the plant as traditional medicine is also reported to produce a cardiac stimulant, a vertigo, an antiemetic, antidepressant and a refreshment agent (Pongboonrod, 1976). Scientific researches confirm the medical properties of the species when some chemical substances, such as, mansorins, coumarins, mansonones and mansoxetane (Tiew *et al.*, 2002, 2003) could be extracted from its heartwood.

In spite of these useful properties and its special uses, very little information is available in Thailand. Since its Thai name, “*Chan* or *Chanhom*”, is referred to other species, such as, *Chan-in* (*Diospyros decendra*), *Chanchamot* (*Aglaia silvestris*), *Chandang* (*Myristica iners*), *Chan India* (*Santalum album*) and *Maihom* (*Aquilaria malaccensis*) it may lead to some confusions. Even though the description of the species is well documented (Phengkklai, 1990), there are still problems for users when information is transferred. Nowadays, this species is protected by law and only the royal family are allowed to use, while the commoners’ uses are very low.

The species is found in a small part of the country, particularly in the limestone mountains of the Southwest corner of Nakorn Ratchasima province and on the hills bordering Tanawsee ranges from Ratchaburi to Surat Thani provinces. Surprisingly, there is no plantation of this species to supply those uses. All woods are taken from natural forest which is making the plant become rare or extinct.

In order to sustain the use of *M. gagei*, planting the tree should be taken into consideration. Study on its silvicultural aspect, however, has never been conducted. Complete research on silviculture of this tree species from natural habitat and ecology, to the development from flower and fruit to seed, seed collection, nursery techniques and plantation establishment is, therefore, necessary. The results of this study will result to further planting extension.

OBJECTIVES

Since informations on *M. gagei*, a scented wood of eastern tropical Asia, especially in Thailand dealing with its indigenous status, characteristics, reproductive periodic phenomena, community structure in nature, nursery practices, plantation technology and monitoring of growth are very limited, the objectives of this study are as follows:

1. To study the natural stand and ecology of *M. gagei* .
2. To study the reproductive phenomena of *M. gagei*.
3. To study the seed characteristics and seedling growth of *M. gagei*
4. To study the growth and yield of *M. gagei* in plantations.

LITERATURE REVIEW

Silviculture

Silviculture, which is derived from the Latin word “*silva*” and “*culture*” is a process of growing trees. One of the most important of the many disciplines in forestry is silviculture. It is the agriculture of trees, *i.e.*, how to grow them, how to maximize growth and return, and how to manipulate tree species compositions to meet landowner objectives. To understand silviculture, one must firstly understand silvics. Silvics involves understanding how trees grow, reproduce, and respond to environmental changes. Silvics also is concerned with seedling requirements, elevation, and location. Different species will show up in different areas, on different soils, and at different elevations. If this sounds like ecology, then it can be stated accurately that silvics is the ecology of the forest. From a forestry point of view, silviculture is concerned with controlling the establishment, growth, composition, health and quality of forest vegetation (Thaiutsa and Puangchit, 2007).

1. Establishment

Establishment in silviculture is referred to regeneration. An International Symposium on Man-made Forests held in Canberra in 1967 classified forest regeneration into three groups, namely, natural regeneration, artificial regeneration, and mixed regeneration.

Forest regeneration is a technique of renewing tree covered by establishing young trees naturally and/or artificially, generally promptly after the previous stand or forest has been removed. The method, species, and density are chosen to meet the goal of the landowner. Forest regeneration includes such practices as changes in stand density through human-assisted natural regeneration, enrichment planting, reduced grazing of forested savannas, and changes in tree provenances/genetics or tree species.

For natural regeneration, seeds are naturally dispersed from the older trees. These seeds do not need any human support. Man may have an influence by preparing for the seed before hand. This is termed as “human-assisted natural regeneration”. Human-assisted natural regeneration means establishment of a forest from natural seeding or sprouting after harvesting through selection cutting, shelter (or seed-tree) harvest, soil preparation, or restricting the size of a clear cut stand to secure natural regeneration from surrounding trees. Another term, enrichment planting means increasing the planting density (*i.e.*, the numbers of plants per hectare) in an already growing forest stand.

Artificial regeneration is a regeneration from human influence. A person chooses an area to plant the seedlings and small trees. They, then, prepare the area in order to make it more fertile for the seed. This is called forestation and the area of forest is called a plantation or a man-made forest. If the area has never been covered by the forest, it would be called afforestation, but if it had been forest before the term reforestation is called.

The decision to use artificial means to regenerate forests is taken where as follows:

- 1) The natural regeneration cannot be reliably secured or is excessively dense of poor quality, diseased, or of undesirable species.
- 2) Prompt regeneration is needed with simultaneous control of species and density.
- 3) The benefits of tree breeding and tree improvement are available in improved nursery stock.
- 4) Matching species to site and/or planting an exotic species will result in significant gains in production.

Mixed regeneration is a combination of natural and artificial regenerations. An example of this is the King’s 50th Anniversary Reforestation Project where both methods were used.

1.1 Flowering

Flowering refers to the developmental process where by a vegetative bud, shoot, or entire plant becomes reproductive. Although only hardwoods produce true flowers, the term can also be used to describe the process of cone (strobili) production in conifer (Owens, *et al.*, 1991).

Tropical forest trees are extremely variable in frequency of flowering, many rarely being without flowers. They mostly often flower and many tropical forest trees exhibit indirect flowering in which there is a period of dormancy between floral initiation and pollination for other groups of tropical flowering where periodicities are recognized :

1) Everflowering species, such as, *Ficus* initiate flower through out the year and, therefore, flower, seed and fruits at various stages of development are always present.

2) Non seasonal flowering species exhibit flowering periodicity among plants and from branch to branch.

3) Gregarious flowering species initiate floral buds continuously but they remain closed for weeks or months until environmental conditions are favorable for anthesis, sometimes resulting in anthesis over a wide geographical area, as in coffee.

4) Seasonal in the species responds to subtle seasonal variations in day length or temperature, as has been proposed for certain Dipterocarps (Ashton *et al.*, 1988).

Phynology is the science concerned with the study of the relationship between natural phenomena that occur periodically and changes in seasons and climate. In this instance, phenology refers to the relationship between change in

seasons and climate and phenomena, such as, bud formation anthesis, pollination, fertilization, fruit ripening, *etc.* (Owens *et al.*, 1991).

1.2 Seed

A seed is a structure that is formed by the maturing ovule. Following fertilization the outer layer, the seed coat (testa), develops from the interments of the ovule. The seed coat usually consists of three layers : 1) an outer, thin often colored sarcotesta, 2) a middle, thick sclerotesta consisting of hard stone cells, and 3) a thin inner, endotesta. The scar, where the funniculus attaches, is the hilum. The seed coat is usually very hard and often is permeable to water. It may be covered by epidermal hairs or hairless according to the species.

Fruits occur only in flowering plants. A fruit is a mature, ripened ovary (or group of ovaries) that contains the seed. The wall of the ovary develops into the pericarp, which often thickens and differentiates into three layers : 1) an outer, exocarp, 2) a middle, often thick and fleshy mesocarp, and 3) an inner, endocarp. The mesocarp is often absent. Fruits can be dry and dehiscent, meaning that the pericarp splits opening when mature and releases the seeds, or it can be dry and indehiscent, meaning that the pericarp does not split opening and is not readily separable from the seed. Fruits can be frets, in which case the pericarp consists of a skin enclosing the frets mesocarp. Some frets are derived from the fusion of various floral parts. Others are derived from various parts of the pistil or receptacle (Coombe, 1976).

Trees in Sterculiaceae family have flowers with unisexual bisexual, 5-merous, regular ; petals alternate with the sepals or petals absent. Stamens and pistils are often on the gynandrophore. Stamens 5-many, free or united, anthers basifixed or dorsifixed, 2 locular, opening length-wise. Staminodes present or absent, ovary superior, 1-many locular ; locule 1-many ovules ; style subulate or branched, sigma lobed or pointed. Fruit, a capsule, winged or wingless, 1-many-seeded. Seed, winged or wingless.

The flowers of *M. gagei* have 5-merous bisexual in axillary or the end of wings. Sepals and petals are present. Petals are free. The ten stamens are united into a slender gynandrophore, surrounding the ovary. Staminodes in between stamens and ovary, ovary 5, free, alternate with staminodes; each locule with a curved and narrow style, the stigmas simple and narrow. The fruit and cilipsoid are samara (Phengkhai, 1990).

1.2.1 Seed coat colour

In the forest tree species, the changes in seed coat colour were a reliable index for seed maturity of *Pinus radiata*. Etejer *et al.*, (1982) reported that the reddish brown seed of *Parkia clapertoniana* germinated readily while dark brown seeds exhibited seed coat dormancy. Similarly, Tanasescu (1969) found the same results in *Robinia pseudoacasia* seeds. It was also found that the dark colored *Pinus sylvestris* seeds were more resistant to the damping-off fungi than the light ones (Grzywac and Rosochaka, 1980).

In leguminous tree species, Mishra (1991) reported that the blackish brown seed of *Dalbergia sissoo* gave better germination than the brick-brown and black seeds and found that the green seed of *Acacia mellifera* gave better germination and vigour than the greenish-brown and brown seeds.

1.2.2 Seed size

Characteristics important in the quality of the tree seed are the germinative capacity, the carrying size of the seedling it produces, and the degree to which it possesses desirable inheritable characteristics. The effect of the environment on vigorous vegetative development is the major factor in determining the germinative capacity and size of seed. Size in turn influences the carrying size of the seedling. On the other hand, plant environment plays, but an indirect, role in determining the inheritable qualities of the seed. Germinative capacity and size of seed are easy to measure, requiring only rather simple experimental methods. The germplasm of the

seed, however, is complex and must be investigated by more detailed methods over a long period of years. These three components of quality are interrelated and have not always been separated in examinations of the effect of origin on seed quality with a loss of desirable clarity.

1.2.3 Seed weight

The weight of 1,000 seeds in grams is sometimes useful in determining whether a lot of seed is up to standard. Seeds from different origins and different crops vary in weight considerably, but extremely light seeds often suggest low viability and undeveloped embryos. Under-weight seeds often occur in poor seed years or come from immature trees.

1.2.4 Seed germination

Germination is the resumption of growth by the embryo plant which has lain dormant in the seed. This being as soon as the resting seed begins to imbibe moisture. Germination in the commonly accepted botanical use of the term occurs when the radical begins to protrude beyond the seed coat (Toumey and Stevens, 1982). Of all the quality measurements on seeds, none is more important than how well they will germinate. This information is the deciding factor on the value of the seedlot. For the buyer, whether to purchase the seed; the grower, whether to use the seeds this year or store them for future use, and at time of use, what the sowing rate should be (Edwards and Wang, 1995).

Seed must be exposed to favorable environmental conditions before germinating. The favorable environmental conditions are an adequate supply of water, an adequate gas exchange, and suitable temperature and light. Temperature is one of the most important environmental factors affecting seed germination. It affects the germination percentage as well as the rate of germination, and varies with different species (Mayer and Poljakoff-Manber, 1982).

Generally, seeds of many temperate species require a low temperature to break dormancy (Edwards, 1973; Bonner *et al.*, 1974; Barton, 1982; Carl, 1983; Hopper *et al.*, 1985; ISTA, 1996). The requirement for different species or seedlots within species differs depending on depth of dormancy, the origin of the seeds and/or their maturity (Hellum and Dynock, 1986). Conversely, seeds of desert species require high temperature pretreatment to insure germination (Resce, 1961; Capon and Asdall, 1967).

Krugmen *et al.* (1974) indicated that the seed of many species germinated over a wide range of temperatures. Thompson (1973) found that *Gypsophila perfoliata* seeds germinated in a broad range of temperatures, 2 °C to over 24 °C, while *Allium porrum* was capable of germinating only in the range of 7-23 °C. Liengsiri (1987) found that the seeds of *Pterocarpus macrocarpus* should be germinated under 25-30 °C, day-night alternating temperatures to reach the highest total germination regardless of origins.

The basis for this test is that the higher vigour seed can tolerate the high temperature and high humidity treatment and thus retain their capability to produce normal seedlings in the germination test. The optimum temperature and time combinations for the accelerated aging technique can be used in predicting the storability of seeds (Delouche and Baskin, 1973).

Accelerated aging is a good vigor test for many agriculture species and for some forest tree species (Pitel, 1980; Bonner, 1984). A unique characteristics of accelerated aging is the increased germination of some species, often a short period of accelerated aging was observed in *Melia azedarach* (Boonchaleo, 1986). However, the extent of germination enhancement in response to accelerated aging is also influenced by initial seed quality including constant moisture (Mc Donald, Jr., 1977).

1.2.5 Seed storage

A seed is largely made up of living material and any injury that prevents later development of a normal seedling destroys the value of the seed for crop production. The life processes of a stored seed are very much reduced intensity in comparison with those of a growing plant. However, increase of seed moisture increases the life activity of the stored seed, even though the moisture content is far below that required for active growth or germination. Increase of temperature also increases this life activity. Not much is known about the actual processes leading to the death of seed, but it would appear that as these life activities take place in storage, the living material is gradually weakened and complete loss of viability finally results. These general considerations make it clear that increased moisture in the seed speeds the changes that finally lead to a loss of viability and that increased temperature finally leads to loss of viability. The increased temperature further increases the rate of these changes. Any exposure to high temperatures and high moisture reduces the potential duration of life of seeds, even before the percentage of germination is reduced. Weakening of seed may result from unfavorable conditions during ripening on the plant, during harvesting or during curing immediately after harvest, therefore, the age of seed from harvest may not be a measure of ability to withstand further storage.

Many temperate seeds and a few tropical ones such as *E. deglupta*, can be stored even more effectively for long periods at a temperature of 15-20°C. It has been reported that seed germinated after being dried to about 7% moisture content can normally be cold-stored for extended periods at that moisture content. Some species that accept or even require higher moisture content, about 35-40% are *Quercus* and *Castanea* for subtropical zones and *Hevea*, *Swietenia* and *Dipterocarpus* for the Tropics. (Briscoe, 1990).

1.3 Seedling

When seedlings are planted, they are often subjected to extreme environmental stresses, such as, high temperatures and drought. Root systems of newly planted seedlings have poor contact with soil; consequently, water and nutrient uptake is initially poor. Planting healthy and vigorous seedling ensures that the plants have the best chance to produce new roots quickly in order to establish good access to soil and cope with environmental stresses.

Seedling quality has been defined as those attributes necessary for a seedling to survive and grow after outplanting. There are several methods to assess seedling quality. However, the ideal stock quality test should be rapid, simple, accessible, reliable, non-destructive, quantitative and diagnostic. There is, however, no single test that can give a complete picture of seedling health. Some morphological and physiological characteristics that define a light quality tree seedling are as follows: the ability to rapidly produce new roots, the ability to quickly resume photosynthesis and continue growth, large fibrous root systems, sun adapted foliage, a large diameter, balanced root/shoot ratio and good optimum mineral nutrient content. With the aid of mycorrhizal or rhizobium, more complete seed are established.

Production of high quality seedlings in large scale operations presents a number of difficulties, one of which is the provision of a suitable growing medium. The properties of a potting mix which will produce healthy seedlings in a container are 1) slightly acidic pH, 2) high cation exchange capacity (CEC), 3) low inherent fertility, 4) adequate porosity and 5) freedom from pests and diseases (Landis *et al.*, 1989).

Morphological characteristics, such as, seedling size, have been used traditionally to rank seedling quality in the nursery and match seedlings to the environmental conditions on the outplanting site. These morphological indices fail to account for differences in seedling physiology. As an extreme example, rating a

seedling on morphological dimensions alone does not indicate whether the seedling is dead or alive.

Shoot height is the vertical distance from the ground line to the tip of the terminal leader. The ground line is obvious in the nursery bed but must be established on harvested stock by close observation. One physical indication of the original line is the point where the color of the inner bark changes from white to green when the outer bark is scraped aside. The technique is slow and destructive. The top of the seedling shoot can be difficult to ascertain, particularly when the seedling is actively growing. If there is no obvious terminal bud, the measurement should be taken from the slightly swollen part of the shoot tip, indicating the position of the terminal meristem.

Stem diameter, often called root collar diameter or caliper, is the diameter of the main stem of the seedling at ground line. Because the stem diameter can change significantly in this area, measurements should be made at a standardized location. Some nurseries specify that stem diameter should be measured at the cotyledon scar or 1 cm above the first lateral root.

2. Growth and Yield

Growth is the increase or increment over a given period of time. Yield is the total amount available for harvest at a given time or the summation of the annual increments. Therefore, information on forest growth and yield is important for forest managers to plan and manage their forest resources to provide for continuity of production in a long-term or sustainable way. Tree growth is a consequence of biochemical processes that result in increasing size for a number of common growth characteristics, namely, shoot elongation, root elongation, and diameter growth. Shoot and root growth are traceable to division and elongation of apical meristems at the terminal growing points, such as the tips of shoot and roots. Diameter growth of stems and branches is the result of division and expansion of cells of the cambium layer located between the bark and wood (Kozlowski, 1982).

Growth analysis is an approach to the analysis of yield influencing factors and plant development as net photosynthate accumulation naturally integrated over time. The basic concept and physiological implications in growth analysis are relatively simple and have been explained in the early classic approaches. Only the measurements, made at frequent intervals are required for growth analysis: leaf area and dry weight. The most common approaches include classic growth analysis. This involves measurements made at fairly long intervals (1-2 weeks) on a relatively large number of plants. The second approach involves measurements at more frequent intervals (2-3 days) on a small number of plants. Quantities used in growth analysis of plant communities include (1) leaf area index, (2) leaf area duration, (3) crop growth rate of total biomass and (4) net assimilation rate.

3. Composition

3.1 Structural characteristics

Structure means the composition of the biological community including species, numbers, biomass, life history and distribution in space of population. Kershaw (1964) defined the structure of vegetation using three components: (1) the vertical arrangement of species, *i.e.* the stratification; (2) the horizontal arrangement of species, *i.e.* the spatial distribution of individuals and (3) the abundance of each species.

3.1.1 Density

Density is the count of the number of individuals of a particular species per unit area (Goldsmith and Harrison, 1976; Barbour *et al.*, 1980). It is usually to count the number of individuals within a series of randomly distributed quadrats, calculating the average number of individuals relative to the quadrat used, from the total sample (Kershaw, 1964). It is equal to the number of square units of the total area divided by the individuals. Relative density is the density of one species as a percent of total plant density (Barbour *et al.*, 1980)

Sahunalu and Dhanmanonda (1995) studied the four community types of dry dipterocarp forest. They found that the density of trees ($DBH \geq 4.5$ cm) varied from 554 to 733 trees per hectare and the number of species ranged from 28 to 33 species.

3.1.2 Frequency

The frequency of a species is defined as the chance of finding a species in a particular trial sample. The measure is obtained very simply by noting whether a species is present or not in a series of randomly placed quadrats. It is obtained by using quadrats and expressed as the number thrown or, more often, as a percentage. Frequency relates to the number of times a species occurred in a given number of repeatedly placed small sample plots. Relative frequency is the frequency of one species as a percentage of total plant frequency (Goldsmith and Harrison, 1976).

3.1.3 Dominance

In several-layered tree and shrub communities the degree of dominance of a species is given by its share in the different layers of the vegetation. The relative abundance of the different species may indicate whether each single species has any influence on the system.

Relative dominance is the cover of a particular species as a percentage of total plant cover. Typically, however, canopy cover of trees is assumed to correlate with trunk cross-sectional area (basal area, BA) of with trunk diameter at breast height (DBH) (Barbour *et al.*, 1980).

3.2 Importance value index

Importance value index (IVI) of any species in a community can range between 0-300. It defines as the sum of relative dominance, relative density and

relative frequency (Curtis and McIntosh, 1951). This index presents ecological success of the abundant species. Importance value index will provide an indication of the dominant species.

Sahunalu and Dhanmanonda (1995) studied the IVI value of dry dipterocarp forest at Sakaerat. They found that, for the 1st stand, *Shorea floribunda* had the highest IVI followed by *Quercus kerrii*. For the 2nd and the 3rd stands, *Shorea obtusa* and *Shorea siamensis* were the highest. For the 4th stand, *Shorea siamensis* was the highest followed by *Shorea floribunda*.

3.3 Vertical stratification

The recognition of more or less continuous layers of vegetation on the basis of height differences is a structural approach to vegetation and is inherent in most life-form classification (Goldsmith and Harrison, 1976). On a more local scale, a structural approach can be used to simplify and describe the organization of complex vegetation types. Each layer is described in terms of height and in many instances floristic information is used to supplement this preliminary description (Goldsmith and Harrison, 1976). A technique pioneered in the Tropics by Davis and Richards (1933) involves a complete visual representation of the stratification of community in a profile diagram.

Plant height is used as a criterion in life-form classification. Therefore, the life-form spectra also give a certain idea of stratification or layering in communities (Mueller-Dombois and Ellenberg, 1974). In tropical forest the stratification of the vegetation has been long recognized as one of its characteristic features, though the variation of height within any one stratum has led to some argument as to distribution of the various strata recognized by different workers. Profile diagram can also be usefully employed in vegetation of lower stature to illustrate the relationship between topography and the distribution of individuals of a species. Moreover, profile diagrams can be used to illustrate details in vertical spacing of species (Mueller-Dombois and Ellenberg, 1974).

Davis and Richards (1933) constructed a method to describe of the stratification of forest vegetation using to scale, profile diagrams taken from narrow strips. The method consists of laying out a narrow rectangular sample plot of required length and width. All vegetation lower than a chosen arbitrary height is cleared away, the remaining trees and shrubs being carefully mapped and the diameters of the trunks noted. The total height, height to first living branch, lower limit of crown and width of crown are measured. From these measurements an accurate scaled profile diagram can be obtained, one showing the spatial relationship of the different species to each other, both in a horizontal sense and a vertical sense. Using a crown depth diagram, the stratum separation can be judged from three principle criteria: the minimum point of the vertical crown curve; the abrupt downward change in height curve; and the step-like distribution of tree groupings on the H- H_B diagram (Ogawa *et al.*, 1965). Ogawa's method was found to be convenient and sufficient, and need without complex calculations and graphical interpretations.

Vertical structure of forest stands is examined by the crown depth diagram, which is based on the measurement of total height (H) and height of the lowest living branch (H_B). The relationship between H and H_B is also used for supplementary analysis. It may be reasonably assumed that the height of the lowest living branch is nearly equal to that of the base of crown. The difference between H and H_B is then expected to give the crown depth of the height range in which leaves are distributed. Respectively plotting the height above the ground on the vertical axis and the number of trees bearing their leaves at respective height on the horizontal axis, the crown curve in the diagram is obtained. At the certain height level H^* the crown curve gives the number of trees for which the condition, $H \geq H^* H_B$, is satisfied. The height curve, on the other hand, represents the number of tree taller than a certain height level, or it is the cumulative curve of tree number are expressed as a rule in percentages of the total in both curves.

Trees belonging to a same stratum provide their curves situated in the same height level. When a stand is single-layer, crowns of all trees occur at one

height level; so that crown curve is then expected to reach 100% at the level. If the stand is composed of two completely segregated strata with no vertical overlap between the two crown layers, the crown curve would naturally fall to 0% at the intermediate height level. In the latter case, the tree tops of the lower stratum are always lower than the crown bases of upper layer trees, and therefore the members of the two strata are expected to form two separated groups on the H-H_B diagram, which do not overlap each other on both coordinates.

Any discontinuous change of gradient of the height curve indicates a change of density between upper and lower trees. Where the height curve runs parallel to the ordinate, trees of the correspondent height range do not exist in the stand. The lack of the trees belonging to the certain height class, and the sudden change of tree density at the certain level, may also indicate a kind of structural in the forest profile.

Similar way of structure analysis can be applied to any forest types. The principles of recognizing different strata are as follows:

- 1) A distinct minimum in the crown curve indicates the segregation of two well-defined strata.
- 2) Even where the crown curve lacks a minimum, the step-like distribution of tree groups on the H-H_B diagram suggests the differentiation of layers. The layers are not so well-defined, and more or less continuous with each other in this case.
- 3) A discontinuity of the gradient in the height curve, meaning the abrupt change of tree density at the corresponding height, is also considered as a structural change.

Sahunalu and Dhanmanonda (1995) studied the four community types of the dry dipterocarp forest at Sakaerat. They divided the tree stratum into 2-3 strata.

The top tree layers are above 10.5, 13.0, 10.5 and 14.0 m high in the four stands, respectively, while the second tree layers are lower and a third layer is found only in some parts of stands 2 and 4, below 10 m high. Such stratum separation is judged from three principle criteria: the minimum point of the vertical crown curve together with the abrupt downward change in height curve and the step-like distribution of tree grouping on the H-H_B diagram (Ogawa *et al.*, 1965)

3.4 Diversity indices

Diversity is basically a measure of variety in ecological communities. Species diversity for a community is a function of the number of different species present, the number of individuals per species, and the total number of individuals of all species in that communities (Southwick, 1976). Several indices have been proposed over the last four decades. Some indices that Ludwig and Reynolds (1988) compiled are as follows:

The Shannon-Wiener index of diversity, $H(S)$ sometimes called the Shannon-Weaver index (Shannon and Weaver, 1949), is used when the relative abundance of each species is logarithmically related to their significance to the whole system.

If the relative abundance was assumed to be linearly related to the significance for the system, a useful measure of diversity was proposed. The Simpson's index of diversity gives very little weight to rare species and is most sensitive to the number of abundant species recommended the reciprocal of this index as the "best" general index of diversity, because Shannon-Wiener index is more sensitive to rare species and this is where sampling error may be most pronounced (Barbour *et al.*, 1980).

Species diversity may be thought as being composed of two components. The first is the number of species in the community, which ecologists often refer to species richness. The second component is species evenness or equitability. Evenness

refers to how the species abundances (*e.g.*, the number of individuals, biomass, cover, *etc.*) are distributed among the species (Ludwig and Reynolds, 1988). Species richness is simply the number of species in a community.

Each species is not likely, however, to have the same number of individuals. The distribution of individuals among the species is called evenness or species equitability. Evenness is maximum when all species have the same number of individuals and decrease toward zero as the relative abundances of the species diverge away from evenness (Ludwig and Reynolds, 1988)

4. Wood Quality

Any factor that changes the growth pattern or form of a tree may result in a change in wood quality and properties. Silvicultural practice, site factors and the genetic quality of planting stock can affect tree growth patterns, and thus influence timber quality.

Silvicultural practices tend to act indirectly on wood quality through their effect on the growing environment from the tree's crown to roots divided silvicultural operations into two broad types as follows:

- 1) Those which act directly on individual trees, or on groups of trees, such as initial spacing, thinning and pruning.
- 2) Those which modify the site, and thus act on the crop as a whole, such as cultivation, weed suppression and fertilizer application.

The productivity of most forest plantations is less than their physiological potential as defined by the prevailing climate, because the supply or capture of light, water and nutrients is less than optimal. However, maximum growth does not equate to maximum wood value. The silvicultural challenge is to design and use management regimes that achieve target growth rates and wood quality by manipulating resource

supply, capture or use. It has been and remains possible to identify and ameliorate factors limiting growth, sometimes on a large scale, *e.g.* by soil cultivation, residue management, fertiliser, weed control, irrigation, coppice management, thinning and pruning.

4.1 Wood product

Wood of *M. gagei* is reported as being easy to furnish. The dead wood has a good smell and is used for making boxes, crafts, combs, *Dok-Mai-Chan* and jot sticks. Trading of its wood product is found only in Myanmar. The Forest Department in Myanmar counts the following NWFFP for trade purposes: bamboo, cane (rattan), catch, tanning bark, straw (bast), Kalumet (*M. gagei*), thanatkha, hpala, kanyin oil, roofing materials, honey, beeswax, batguano, thitsi, edible bird nests, lac, orchids, bomayaza and pine resin. The Forest Department in Myanmar reported that annual production of Kalumet in Myanmar from 1992 to 1995 were 55,500, 22,500 and 24,000 kg in the years 1992/93, 1993/94 and 1994/95 (provisional), respectively. Qiang Ma, (1999) reported on the production of NWFP (1988 to 1995) showed that Kalumet produced 49, 62, 11, 24, 85, 63 and 26 tons in 1988–89, 1989–90, 1990–91, 1991–92, 1992–93, 1993–94 and 1994–95, respectively. A majority of these were for domestic uses, only a small amount was exported. Khin (1995) reported on the export quantities, 7,500 kg of Kalumet among other NWFFP in the year 1992-1993, but there was none in the following year. Although NWFFP contributed revenue to the country and also provided income-generation opportunities for forest dwellers, they had a low economic profile (Khin, 1995).

4.2 Perfume and cosmetics

Scented woods, are including Kalumet (*M. gagei*), nanthani (*Pterocarpus santalinus*), santagu (*Santalum album*), taungtan-gyi (*Premna integrifolia*) and thithmwe (*Aquilaria agallocha*) used in fragrances, scented sticks and medicines. These species are rare in natural forests and consequently very expensive. (Khin, 1995).

4.3 Medicine

Using the plant as traditional medicine is also reported to make a cardiac stimulant, a vertigo, an antiemetic, antidepressant and a refreshment agent (Pongboonrod, 1976). Scientific researches confirm the medical properties of the species when some chemical substances such as coumarins, mansonones and mansoxetane (Tiew *et al.*, 2002, 2003) could be extracted from its heartwood. Eleven compounds isolated from the heartwood of *M. gagei* were tested for their antifungal activities against *Cladosporium cucumerinum* and *Candida albicans* as well as for their larvicidal activities against *Aedes aegypti* and radical scavenging properties in a DPPH assay. Mansonone C (4) was found to be the most interesting compound with antifungal activities against *Cladosporium cucumerinum* and *Candida albicans* as well as for its larvicidal properties against *Aedes aegypti*. Mansonone E (5) was active against *Cladosporium cucumerinum* and *Candida albicans*. Two coumarin derivatives, mansorin A (1) and mansorin B (2) were also found to be active against *Cladosporium cucumerinum*, while mansonone N (9) was the only isolated product to show radical scavenging properties (Tiew *et al.*, 2003). A group of researchers from Chulalongkorn University found that Mansonone extracted from *M. gagei* showed high toxicity against brine shrimp (*Artemia salina* Linn.). In cooperation with a group of Beijing University research they found that hexane dichloromethane and methanolic extracts from *M. gagei* toxic to a variety of cancer cell lines such as Human Colon Carcinoma (HCT-8), Human Leukemia Carcinoma (HL-60) and Human Gastric Carcinoma (BGC-823). The use of *M. gagei* as a mixer with other medicinal herbs in saunas to treat dermatitis in AIDS patients, was reported to soothe the pain and to refresh the patients.

4.4 Thai tradition

In Thailand, from the past the wood of *M. gagei* has been used when the tree are dead naturally, because it would have fragrance after standing death. The most important usage is to use in the funeral of the royal family, special coffin (as called “*Kot Mai Chan*”), wooden combs and firewood.

Common people use peeled wood to make wooden flowers and bring to the funeral. The people place the wooden flowers under the coffin to pay respect to the dead person. At last people put the wooden flowers in fire as fuel. Thai people believe the scented smell of the wood put in fire will bring the spirit of the dead person up to heaven. Nowadays, wood of *M. gagei* is difficult to find and it is protected by forest law. Thus, people make wooden flowers from wood of another species, such as, *Wrightia tomentosa* and *Astonia angostiloba*. Moreover, sometimes people make flowers from paper for the reasons of economy and forest conservation.

Silvicultural Characteristics of *Mansonia gagei*

1. Sandal Wood and Scented Wood

1.1 Sandal wood

Sandal wood and scented wood are two groups of plants with distinct fragrances and are used in fragrances, scented sticks and medicines. Each group has the same Thai name as “*Chan*” or “*Chandhana*” which have the Sanskrit root. This causes some confusions. In Thailand the word *Chan* is used in connection with a number of scented woods, and is also applied to the *Chan* or (nutmeg tree) which synonym name of *Myristica fragrans* Houit. (Kerr, 1970) such as *M. gagei* in the Sterculiaceae family (Thai name is *Chanhom* with local names *Chan*, *Chanhamot* *Chankhao* and *Chanpama*); *Diospyros decendra* Lour (Thai name is *Chan-in* or *Chan-O*); *Aglaia silvestris* Merr (Thai name is *Chanhamot*); *Myristica iners* (Thai name is *Chan-dang*); *Santalum album* Linn (Thai name is *Chan India*). *Aquilaria malaccensis* is another species known as *Mai-Hom Krisna* (scented wood) to be misunderstood (Smitinand, 1977). Kerr (1970) tried to clear up the obscurities in their nomenclature in Thailand but there was still a mix up in many places until now. The reasons for these errors are that the local names of the same tree often vary from district to district, while the same name may be applied to different species in different districts. To understand the differences between sandal wood and scented wood, it should be referred to Kerr (1970).

Kerr (1970) clarified sandal wood that the true sandal wood obtained from *Santalum album* Linn, a wood that is fragrant in the fresh state and does not occur in Thailand. It is often imported from India, being much used at cremations. It is known by Sanskrit name *Chan* or *Chandhana*. Under *Chan* in the Thai Plant Names, it appears the name *Diospyros decandra*, (Smitinand, 1977) which is a synonym of *Santalum album*. The sandal wood species which are valuable sources of fragrant timber and oils. The Australian species of *Santalum* described with greater details given for those studied at Curtin University are *S. album* and *S. spicatum* (Barrett and Fox, 1994)

Santalum album or Indian sandal wood is not naturalized in Thailand. The seeds were taken from Indonesia 10 years ago and planted in Prachuap Khiri Khan province (Meekaew, 2006). The heartwood of *Santalum album* is very valuable for its perfumed oil. The wood has similar oil content to *Santalum yasi* (about 6% on average) and considerable more than *Santalum spicatum* and *Santalum lanceolatum* (about 2% and 1% on average). The nuts of *Santalum album* contain oils which have been used as lubricants (Barrett and Fox, 1994).

The *Santalum album* is a tree form and may reach 15 m in height. Leaves opposite, bright green, sometimes yellowed; ovate to lanceolate elliptic, flat, 25-70 mm long and 15-40 mm wide. Flowers are grouped in small groups, has four triangular to ovate tepals about 2 mm long and turning from green through pink to dark red with age. Fruiting may commence from 2-3 years of age. Drupe is round with diameter of 7-8 mm which a dark purple-red to black epicarp. Fruit flesh mesocarp is creamy yellow. The endocarp nut is more or less spherical, up to about 6-8 mm in diameter and smooth. The kernel is firm and white (Barrett and Fox, 1994).

1.2 Scented wood

Scented wood is developed as the result of some kinds of diseases. It is only found in a small percentage of trees and in them, often only in quite a small quantity. Nor can it be ascertained with certainty that any tree has such wood, until it is felled and cut up. There are various theories about the cause of this disease, but most of them are mere speculations, with very little foundation on fact. The first one is of local informants at Chantabun saying that “The stem, when perfectly sound, does not furnish this valuable wood, or at least not the kind so much sought after in trade, but the birds, which come to peck at the fruits, break the branches and in these places a kind of blight thus originates, the plant begins to be sick and the sap is irregularly distributed, so that there is more in some places, hence it grows resinous. The tree dies, and the ants gnaw the loose much putrefied wood and build their nests in it. Most of the scented wood is obtained by falling living trees”. Another theory is that “This wood results from a molecular change in the heart-wood caused by a disease induced, as they say, by the decomposition of bird-droppings in the forks of the branches.” The authors of this theory go on to tell us that the name eagle-wood is derived from the plumage-like markings on the wood. A more probable view is that the appellation eagle-wood is ultimately derived from the Sanskrit *Agaru*.

Scented woods found in Thailand belong to these families, namely; Meliaceae, Thymelaeaceae, Ulmaceae, Agavaceae, Myrtaceae, Euphorbiaceae, Hymenocardiaceae, Lythraceae, Sapotaceae, and Rubiaceae. The species list is as follows: *Aglaia silvestris* Merr. (Meliaceae), *Aquilaria crassna* Hance. (Meliaceae), *Celtis cinnamomea* Lindl. (Ulmaceae), *Cinnamomum porrectum* Kosterm. (Lauraceae), *Dracaena loureiri* Gagnep. (Agavaceae), *Eugenia cumini* (Linn.) Druce. (Myrtaceae), *Euphorbia antiquorum* Linn. (Euphorbiaceae), *Hymenocardia wallichii* Tul. (Hymenocardiaceae), *Largerstroemia floribunda* Jack. (Lythraceae), and *M. gagei* (Sterculiaceae).

M. gagei was the most important commercially of Thai scented woods in 1941. The trade in scented woods had much less relative importance at that time than

in former days, but it still continues (Kerr, 1970). At present this species, however, is not of any value in trade in Thailand. But the continuation is evident in a neighboring country, Myanmar, at which the species called Kalumet has some value in trade, as one of the non-wood products from the forest (Khin, 1995). In Thailand, the importance of the species immersed when the urgent need for the wood to make *Kot Mai Chan* for the King's Mother's coffin in 1996 and the plant was hard to find. Then, the interest of the species began again.

2. *Mansonia gagei* J.R. Drummond

2.1 Taxonomy

The description of *M. gagei* is well documented as follows: Tree up to 20 m high; bark whitish, smooth; twigs sparsely hairy to glabrescent. Stipule Lanceolate, Caducous. Leaves are ovate to elliptic-oblong, 8-14 by 3-6 cm; acute apex; truncate, subcordate and minutely oblique base. Subcoriaceous, glabrescent. And olive-green when dry; 30-50 nerves at base; slightly serrate margin. Petiole 0.5-1 cm, blackish when dry. Inflorescences a short panicle at the end of twigs and axially, up to 15 cm long. Flowers, white sepals united at base, with 5 lanceolate lobes, hairy outside. Petals 5, free, spatulate or oblanceolate. Stamens 10 alternated with staminodes, united into a slender gynandrophore, surrounding the ovary; anther one-celled, with a short filament. Ovary 5, free, hairy; fertile locules with 5-9 ovules; style slender and curved outwards; stigma pointed. Fruit, an ellipsoid samara, usually in pairs, 10-15 by 5-7 mm; the apical wing curved, 2.5-3 by 1-1.5 cm and there is one seed in one fruit (Phengkhai, 1990) (Figure 1).

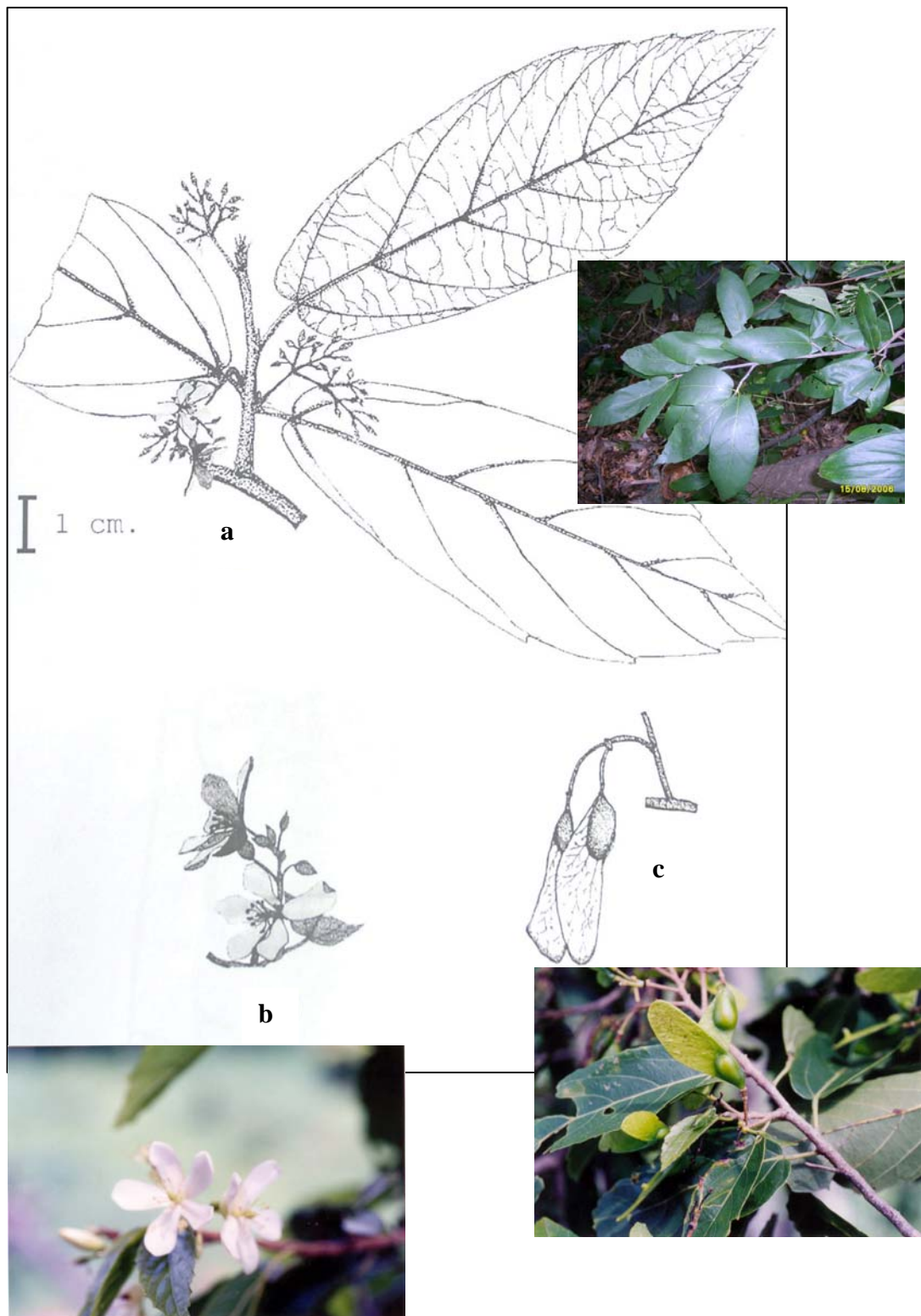


Figure 1 Morphology of *M. gagei* J.R. Drummond, Flowering shoot (a), Flower (b) and Fruit (c).

2.2 Natural habitat and ecology

The natural *M. gagei* stand is in dry evergreen and deciduous forests, on limestone hills; altitude ranging between 100-400 m MSL. Dry evergreen forest ecotype is commonly found over the country. The annual rainfall is between 1,000 – 2,000 mm. Aside from these regions, it is also present in the central region, and part of Nakhom Ratchasima province plateau in the Northeast. The forest canopy can be divided into 3 layers. The dominant layer consists of *Anisoptera*, *Dipterocarpus*, *Hopea*, *Shorea*, *Alstonia*, *Pterocymbium*, *Tetrameles*, *Azelia*, *Ailanthus*, *Ulmus*, *Lagerstroemia*, and *Acrocarpus*. The middle layer canopy ranges in height from 10 to 25 m. The dominant tree species in this layer are *Nephelium hypoleucum*, *Aglaia pirifera*, *A. pyramidata*, *Polyalthia viridis*, *Knema linifolia*, *Aphanamixis polystachya*, *Carallia brachiata*, *Diospyros ferrea*, *D. malabarica*, *D. variegata*, *Millettia atropurpurea*, *Walsura trichostemon*, *Vatica odorata*, *Memecylon ovatum*, *Pterospermum acerifolium*, *Picrasma javani*, *Garcinia merguensis*, *Hydnocarpus ilicifolius*, *H. antheleminthicus*, *Dalbergia cochinchinensis*, *Miliusa velutina*, *Mitrephora vandiflora* and *Suregada multiflorum*. It is difficult to separate this layer from the top canopy due to the climbers connecting the top layer to the bottom layer. (Smitinand, 1977).

The lower layer, shrub layer, is 5-10 m high, mostly at about 6 m. This layer is mixed with saplings of the top and middle canopy trees and also some shrub species, such as *Tarenna hoaensis*, *Melodorum fruticosum*, *Gonocaryum lobbianum*, *Antidesma* spp., *Aporusa villosa*, *Croton oblongifolius*, *Mallotus paniculata*, *Capparis micracantha*, *Memecylon scutellatum*, *Bridelia ovata*, *Ancistrocladus tectorius* and *Baccaurea ramiflora*. In the canopy gaps, species of Zingiberaceae occupies the forest floor along with *Achasma macro-cheilos*, *Amomum* spp., *Catimbium malaceense* and *Curcuma parviflora*. The ground surface is covered only by a thin layer of leaf litter. Rapid consumption of dead plant matter by bacterial action results to the absence of humus in the soil (Smitinand, 1977).

Khoo (2004) edited the Management Plan of the Pha Taem Protected Forest Complex which found that this area was covered with dry evergreen forest, mixed deciduous forest and deciduous dipterocarp forest. The diversity of tree species over 4.5 cm DBH is very abundant. The forest comprises of 45 families, 130 genera and 207 identified as tree species and *Chan Chamot* (*M. gagei*) is present in the dry evergreen forest, too.

Deciduous forest is influenced by the seasonal pattern of climate tending towards a water deficit in the long dry season, fire and drought susceptibility, precipitation around 1,000 mm mixed with deciduous broad leaves are dominant. Trees in deciduous formation shed or lose leaves during the dry season and develop an annual ring. The three main classification are recognized as mixed deciduous forest, dry deciduous dipterocarp forest, and savanna forest.

2.3 Natural distribution

Smitinand (1977) found *M. gagei* scattered in evergreen forest and mixed deciduous forest in Thailand except in the North. Some may be found on the limestone mountains in Nakorn Ratchasima, Saraburi, Ranong and Prachuap Khiri Khan. In other countries like Myanmar and India, the tree is also present. Kerr (1970) stated that the tree was found on some limestone hills in the Southwest corner of Nakorn Ratchasima province and more plentifully, on the hills bordering on Tanawsee range from Ratchaburi province to Surat Thani province.

MATERIALS AND METHODS

Materials

1. Measuring tape (20 m and 50 m long)
2. Hand compass
3. Diameter tape
4. Pole or Haga hypsometer
5. Data sheet
6. Seed collector tool (flexible saw, pruner, hook, *etc.*)
7. Plastic bags and seed containers
8. Temporary nursery
9. Seed bed and potting media
10. Balance
11. Tweezers
12. Camera

Natural Stands

1. Site Selection

The research was attempted to find existing status of *M. gagei* in natural conditions that included explanation in site, species association, its distribution, abundance, physiognomy, and size. Three National Parks in Prachuap Khiri Khan province were selected as study sites, which were Khao Sam Roi Yot National Park, Kuiburi National Park and Namtok Huai Yang National Park (Figure 2).

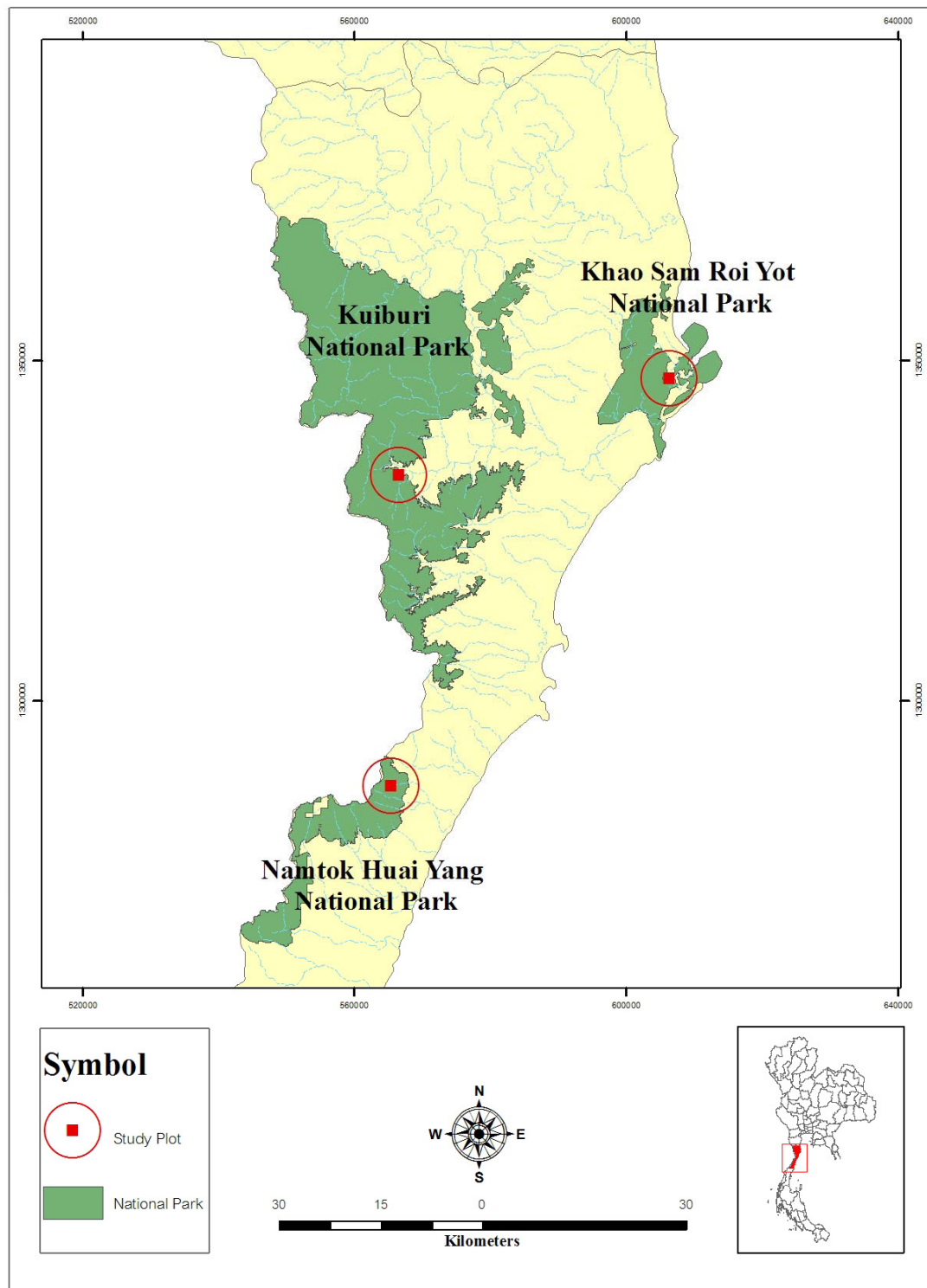


Figure 2 Locations of sample plots of *M. gagei* natural stands at Khao Sam Roi Yot , Kuiburi and Namtok Huai Yang National Parks in Prachuap Khiri Khan province.

1.1 Khao Sam Roi Yot National Park

Khao Sam Roi Yot National Park is situated in the bottom of the central part and in the North of the southern part of Thailand, beside the western site of the Gulf of Thailand, South of Amphoe Pranburi and in the North of Amphoe Kuiburi, Prachuap Khiri Khan province. It is located between $99^{\circ} 53' E$ to $100^{\circ} 02' E$ longitude and $12^{\circ} 05' N$ to $12^{\circ} 20' N$ latitude covering an area of about 98.08 km^2 . The limestone mountain range is the dominant topographic feature of the national park. The highest elevation is 605 m above mean sea level. The site encompasses the largest remaining freshwater, flowing streams, narrow fringe of mangrove along the riverine margin, open coastal flats, sandy beaches, mudflats, rocky cliffs, shallow sea along the 30 km coastline, and inter-tidal islands. The area of national park has two main habitats, terrestrial and wetland habitats. The terrestrial habitat does not have a particular diverse flora and fauna, since there is only dry woodland on steep limestone outcrops, which usually refers to mixed deciduous forest. The wetland habitat is very noteworthy in rare, endangered, and endemic species of plants and animals. (Forest and Land Resource Division, 1997).

The climate of this national park is under tropical monsoon influence with an average annual rainfall of 902 mm, mean annual temperature of $27.7^{\circ} C$, and average relative humidity of approximately 75.3%. The wind speed and wind direction during December and January is affected by the northeast monsoon. The average wind speeds is 1.9 km/hr and the maximum is 37.5 km/hr (Meteorological Department, 2002)

1.2 Kuiburi National Park

Kuiburi National Park is situated along the western site of Amphoe Pranburi, Amphoe Kuiburi and Amphoe Maung, Prachuap Khiri Khan province near the border of Myanmar. It is located between $99^{\circ} E$ to $99^{\circ} 45' E$ longitude and $11^{\circ} 50' N$ to $12^{\circ} 50' N$ latitude covering an area of about 969 km^2 . The natural forest eco-types are dry evergreen and moist evergreen forest. The important trees are

Dipterocarpus tuberculatus, *Hopea odorata*, *Terminalia chebula* and palms. The annual rainfall is of 902 mm. The average temperature is between 25.3-29.3 °C (Forest and Land Resource Division, 1997).

1.3 Namtok Huai Yang National Park

Namtok Huai Yang National Park is situated along the western side of Prachuap Khiri Khan province, South of Maung and Tapsakae districts. It is located between 99° 05' E to 99° 20' E longitude and 11° N to 11°50' N latitude covering an area about 198.88 km². The national park topography is steep mountainous on Tanawsee range at 200-800 m above mean sea level. It is valuable in watershed area which supply large amount of water in many rivers, and also demarcate as borderline between Thailand and Myanmar. The national park is covered by moist evergreen and dry evergreen forests. The important trees are *Hopea odorata*, *Lagerstroemia tomentosa*, *Dipterocarpus* spp, *Toona ciliata* and variety of bamboo. (Forest and Land Resource Division, 1997).

2. Sample Plots

Sample plots for this study were designed and applied in 1999. Structural compositions of *M. gagei* habitat were investigated in those plots layout distributed in 3 national parks mentioned. A sample plot of 100 X 100 m² (1 ha) was set up in each national park where *M. gagei* was present and natural regeneration was collected using 20 square sub-sample plots of 4 X 4 m² and 1 X 1 m² (Figure 3).

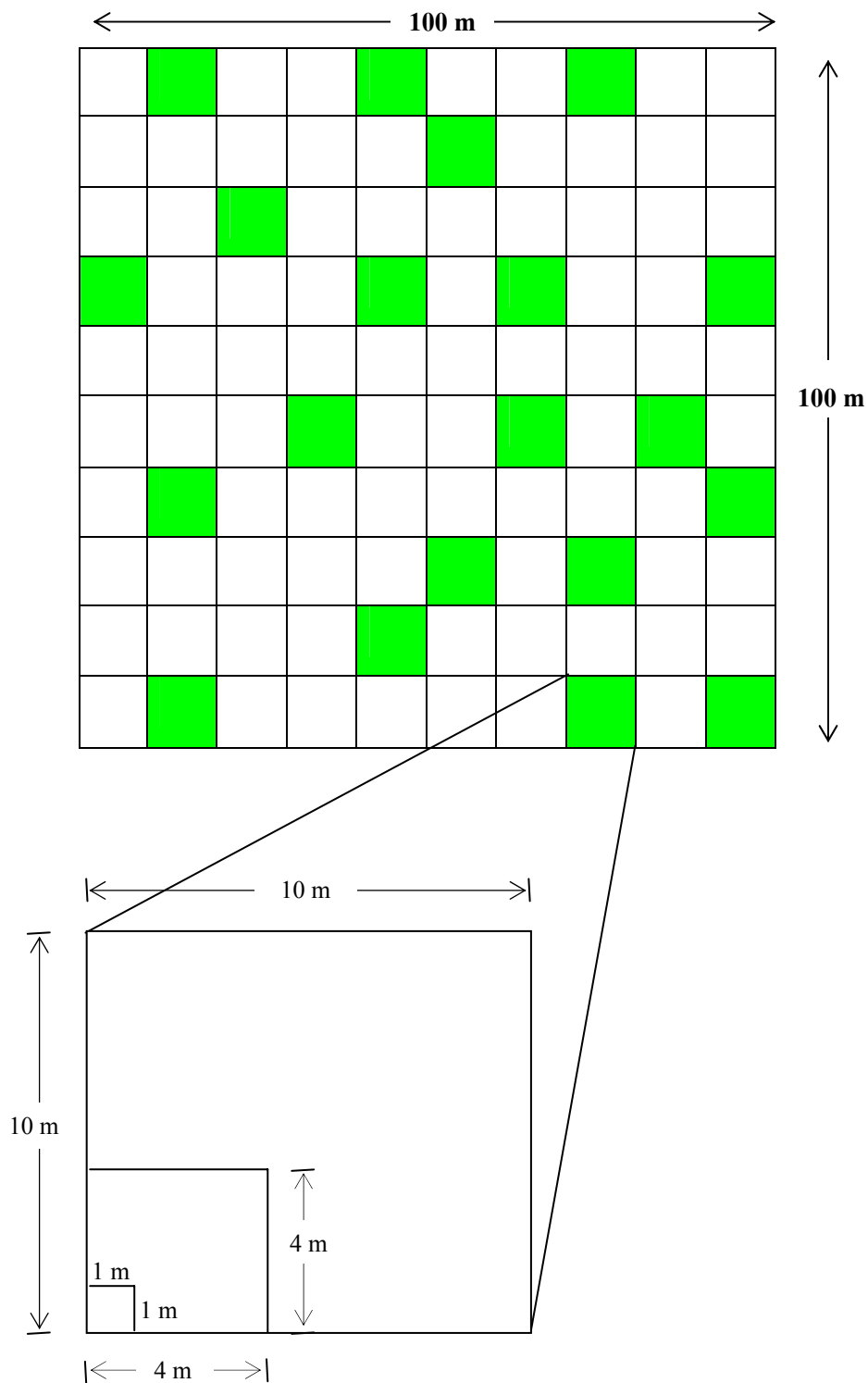


Figure 3 The primary sample plots of 100 X 100 m² and 20 subplots of 10 X 10 m², 4 X 4 m² and 1 X 1 m² used in the current study.

3. Data Collection

3.1 Each primary sample plot (100 X 100 m²) was divided into 100 sub-plots of 10 X 10 m². In each 10x10 m² plot, all trees with over 4.5 cm in DBH were identified for their species, measured their DBH (1.30 m above ground) by diameter tape, and measured tree height in two different figures *i.e.*, total height and height of the lowest living branch by Haga hypsometer. The crown length could be estimated by subtracting of those heights.

Tree positions along sample plot of X-Y coordinates were located carefully by two 50 m tapes. The crown diameters of each tree in 100 X 100 m² sample plot were also measured twice, perpendicular for illustration the vertical profile structure and crown projection diagram.

In this stage, species diversity, relative density, relative frequency, relative dominance, importance value index (IVI) could be calculated.

3.2 Twenty adjacent sub-plots of 4 X 4 m² and 1 X 1 m² were located for collecting data on saplings and seedlings, respectively. Saplings are trees with a DBH smaller than 4.5 cm, but taller than 130 cm. Seedlings are any plants shorter than 130 cm. In each subplot, saplings and seedlings were counted, height measured and identified by species. Sapling and seedling height were measured with a pole. The data were then calculated to ascertain, relative density, relative frequency and IVI.

3.3 A plot of 10 X 100 m² was set in each place to study tree profile diagram. Every tree in the plot was mapped by coordinates. Crown diameter measurements were made 2 times perpendicularly. Total height and persistent height was measured for every tree. The data was then sketched up for horizontal crown cover and vertical crown height level. Profile diameter was classified by the Davis and Richards (1933) technique.

3.4 Soil samples were collected in three sample plots, approximately 50 m apart in each study area as well as in a *M. gagei* plantation to investigate soil properties both chemical and physical properties. Each soil pit, soil samples were collected from two separated layers, according to soil profile, as top soil (0 – 15 cm) and subsoil (16 – 30 cm). Except for the Khao Sam Roi Yot National Park where only upper soil could be sampled due to the shallow soil depth. Analysis of chemical properties including soil reaction (pH), organic matter, phosphorus, potassium, calcium and magnesium were conducted at the Department of Soil Science Laboratory, Kasetsart University. Investigated physical soil properties were soil texture, which included the percentage of sand, silt and clay.

4. Data Analysis

The studies were carried out by adopting the quantitative ecological methods as follows:

4.1 The importance value index (IVI)

The importance value index (IVI) of each species in each plot was determined by Cattam (1949) as:

$$IVI = \% \text{ relative density} + \% \text{ relative frequency} + \% \text{ relative dominance}$$

$$\text{where, Relative Density (\%)} = \frac{\text{density of species } i}{\text{total density of all species}} \times 100$$

$$\text{Relative Frequency (\%)} = \frac{\text{frequency of species } i}{\text{total frequency of all species}} \times 100$$

$$\text{Relative Dominance (\%)} = \frac{\text{basal area of species } i}{\text{total basal area of all species}} \times 100$$

$$i = 1, 2, 3, 4, \dots, S$$

$$S = \text{total number of species}$$

The relative density was determined from all standing trees of DBH larger than 4.5 cm in the whole plot of 100 X 100 m². The relative frequency was determined for one hundred 10 X 10 m² subplots set by regularly subdividing the 100 X 100 m² plot. The relative dominance was obtained from the basal area at breast height, calculated as $\pi DBH^2/4$ of each tree in the whole plots.

The number of abundant species was also determined by the Ohsawa's formula (1984) as follows:

$$d = \frac{1}{S} \left[\sum_{i \in T} (X_i - X')^2 + \sum_{j \in U} X_j^2 \right]$$

where, X_i = actual percent share (IVI is adopted) of the top species (T),
i.e. in the top dominant in the one- dominant model, or the
 two top dominant in the two- dominant model and so on
 X' = ideal percent share (IVI is adopted) of the top species
 X_j = percent share of the remaining species (U)
 S = number of species
 D = deviation between actual IVI and the expected percent
 share of the corresponding co-dominant-number model

In addition, the percent similarity in each plot pair-wise was studied by Bray and Curtis's method. The formula was adopted as follows:

$$PS_{jk} = \left(\frac{2w}{A + B} \right) (100)$$

$$\text{Where, } w = \sum_{i=1}^s [\min(X_{ij}, X_{ik})]$$

$$A = \sum_{i=1}^s X_{ij}$$

$$B = \sum_{i=1}^s X_{ik}$$

PS_{jk} = percent similarity between stand j and stand k

X_{ij}, X_{ik} = number of individual of species i in stand j and stand k

S = total number of species in stand j and stand k

4.2 Species diversity indices

The Shannon-Wiener's index of species diversity, $H(s)$ (Shannon and Weaver, 1949) was adopted as follows:

$$H(s) = - \sum_{i=1}^s p_i \log_2 p_i$$

Where, p_i = proportion of the number of individuals of species i to the total number of individuals of all species ($i=1, 2, \dots, S$)

S = total number of species in the sample area

\log_2 = base 2 logarithm

The Simpson's index of species diversity (D) was calculated as follows:

$$D = 1 - \sum_{i=1}^N \frac{N_i(N_i-1)}{N(N-1)}$$

Where, N_i = total number of individuals of species i

N = total number of individuals of all species

D = Simpson's index of species diversity

The richness index, in forms of richness index 1 (R_1) and richness index 2 (R_2) of Menhinick's index were used:

$$R_1 = \frac{S-1}{\ln(N)}$$

$$R_2 = \frac{S}{\sqrt{N}}$$

Where, S = total number of species.

N = total number of individuals of all species

ln = natural logarithm

The evenness index, in form of evenness index (E) was used as follows:

$$E = \frac{H}{H_{\max}} = \frac{H}{\log_2 S}$$

where, E = species evenness

H = Shannon-Weiner index of species diversity

H_{max} = maximum of Shannon-Weiner index of species diversity

S = total number of species

Log₂ = base 2 logarithm

Reproductive Phenological Phenomena

1. Flower Phenology

The phenological characteristics were described by one randomly selected sample *M. gagei* tree for monitoring of flowering phenology, starting from development of flower buds until the dispersal of seeds.

To study the number of flowers and fruits per twig, 10 twigs with diameter of 0.5 cm were tagged in July 1999. The number of inflorescences per twigs were

counted. Flowers at all stages, young fruits and mature fruits were separately counted per twig. The number of flowers, young fruits and mature fruits were then calculated by dividing the total numbers per twig by the number of inflorescences.

Flowers of *M. gagei* were collected from one sample tree in July 1999. Specimens were scanned by scanning electron microscopy (SEM) by fixing in formalin-acetic acid-alcohol (FAA) and subjected to a dehydration series of 100% ethanol. They were then critical-point dried, mounted on aluminum stubs, sputter-coated with gold and observed using a JEOL JS M 35 SEM at 15 kv. Morphology of anther, pollen grain, pollen tube and stigma were observed and photographed.

Seed and Seedling

1. Seed

Fruits of *M. gagei* were collected from a natural forest at Kuiburi National Park in January 2000. Fruits were cleaned by removing twigs and leaves. The whole fruit without de-winging was used as seed in this study. Seed data including seed weight, seed and fruit sizes, seed maturity, seed processing, and seed germination were recorded.

1.1 Seed weight. Collected seeds were air dried in the shade for one week before weighing. Study of seed weight was done following the ISTA rules. Eight replications of one hundred bulked seeds were sampled and weighed in grams and a weight of 1,000 seeds was calculated (ISTA, 1996).

1.2 Seed size. Seeds were sampled and divided to four replications with fifty seeds per replication. Seed size including seed width, seed length, wing width and fruit length were measured. Mean and standard deviation of data were then calculated.

1.3 Seed maturity. Seed coat colors of the fruit were studied to indicate seed maturity. Seed coat color was identified and grouped into three colors, *i.e.* green, greenish brown and brown (Figure 4). Four replications of one hundred seeds from each group were then germinated in a sand seedbed. The relationships between fruit seed coat color and seed germination percentage were used to indicate seed maturity.

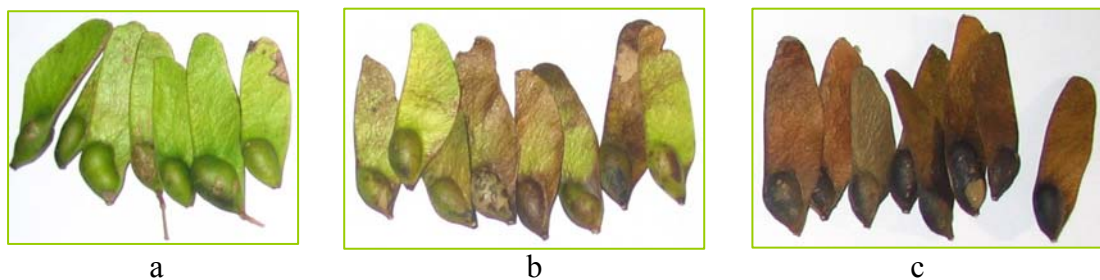


Figure 4 Seed coat color of *M. gagei* (a) green, (b) greenish brown and (c) brown.

1.4 Seed processing. Seed processing was studied in two colors of seeds, greenish-brown and brown. For both colors seeds were divided into two groups, sun drying and air drying. Seed with sun-dried treatment were spreaded on a mat under sunlight until dry. The seeds were then kept in room temperature before testing their longevity. Air-dried seeds were spreaded on a mat and kept in room temperature of about 25 °C. Four replications of 100 seeds were then taken from each treatment to test their viability by sowing in a sand seedbed on day 1, 7, 15, 22, 30, 45, 60, and 90 days after seed collection. Watering was done twice a day in the morning and in the evening. Total germination of seeds from every treatment was recorded. Comparisons between treatments were analyzed using the statistical program. The data were used to determine the seed longevity and proper seed processing.

1.5 Seed germination. The seeds used for germination testing were greenish-brown. Seeds had been kept in room temperature for one week prior to the testing. Seeds were randomly sampled for 12 replications. Each replication contained 100 seeds. Three sowing media, *i.e.* fine sand, soil and coconut husk were used as sowing media. Four replications were applied for each treatment. Media were contained in

seedbed size, 1 X 4 X 0.4 m³. One hundred seeds were then spreaded and sown in each bed before covering the seeds with the same media, about 0.5 cm thick.

Watering was done twice a day, in the morning and in the evening. Seed germination was observed and recorded every day. The data were then analyzed for germination rate in each media with the statistical program.

2. Seedling

Two factors in raising *M. gagei* seedlings were container size and media. Factorial design was used. The containers used in this study were black plastic bags with two different sized, 4 X 6 cm² and 5 X 8 cm². Three different media used were surface soil, coconut husk and a mixer of coconut husk and soil with 1:1 ratio by volume. Each container size and media was arranged in 10x10 rows for 4 replications. Two-week-old seedlings were then transplanted into the bags containing each media. Watering and maintenance were done as with other species. Height growth was measured every month, up to twelve months. Differences in growth due to the container sizes and media were analyzed by statistical program.

Growth in Plantation

The study on growth and yield of *M. gagei* plantation was carried out at Kuiburi Silvicultural Research Sub-station, Kuiburi district, Prachuap Khiri Khan province. The plantation was planted in 1998 with 2 X 2 m² spacing. The area is relatively flat and at altitude of just above mean sea level. The mean annual temperature of the study site is 27.4 °C, with the mean maximum and minimum temperatures of 23.5 – 31.7 °C. The mean annual rainfall is 850 mm. The soil is loamy sand with a soil reaction (pH) of 5.8 – 7.7.

1. Tree Growth

Four permanent sample plots of 10 X 10 m² were set up to measure the survival rate and tree growth. Each plot contained 5 X 5 trees. A month after

planting, the survival rate was checked and total height was measured. Replanting was done where trees died in the first year. Measurement of height and diameter at ground level had been carried out every year until the tenth year. Diameter at breast height (DBH) had been measured every year from the third year to the tenth year. Data were then used to formulate a relationship equation between age and height, age and diameter at ground level, and age and DBH as follows:

$$Y = a X + b$$

Where, Y = height (cm), diameter at ground level (cm), and diameter at breast height (cm)

X = age (years)

a, b = constant

2. Aboveground Biomass

The study on aboveground biomass was carried out from selected 10-year-old *M. gagei* in plantation. The tree sizes were ranked and grouped in several intervals then selected some sample trees representative of each size class to obtain the biomass derived from every diameter class. The aboveground biomass was studied by using stratified clip technique (Monsi and Saeki, 1953). The harvested tree was separated into different aboveground components or tree parts *i.e.*, leaf, branch, and stem. Stem and branch were cut into 1 m long. Fresh weight was recorded in the field. Weight of the samples of each component (leaf, branch and stem) was done after be oven dried at 80 °C until the constant weight was maintained. The total dry weight was calculated from its fresh weight and percent dry weight. To calculate percentage of moisture content by using the formula as follows:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{Ovendry weight}}{\text{Ovendry weight}} \times 100$$

Allometric relation of estimated component + dry matter on diameter at ground(Do), diameter at breast height (DBH) and total height (Ht) were developed from the harvested sample trees for each components separated by using the formula as follows:

$$y = ax^b$$

$$\text{Log}(y) = \log A + B \log x$$

Where, A and B = specific constant
 x = tree diameter or height (cm)
 y = tree biomass (kg)

The component biomass values of the plantation trees were obtained by applying DBH to the logarithmic regression equations developed for each components and multiplying by the number of trees in the diameter class. The component biomass values of each diameter class of the plantation stand were added and converted to stand biomass of *M. gagei* per hectare.

3. Stem Volume

The stem volume of the 10-year-old *M. gagei* planted at Kuiburi was calculated from the following formula:

$$V = \pi r^2 H$$

Where, V = volume (m³)
 r = radius (m)
 H = height (m)

RESULTS

Structure and Floristic Composition of *Mansonia gagei* Forest

1. Stand Composition

The stand composition in terms of tree (DBH>4.5 cm), sapling, and seedling associated with *M. gagei* in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were shown in Table 1.

Table 1 Stand composition in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks, Prachuap Khiri Khan province

| Stand composition | Kuiburi | Namtok Huai Yang | Khao Sam Roi Yot |
|---|---------|------------------|------------------|
| Number of species | | | |
| Total | 28 | 63 | 27 |
| Tree | 24 | 36 | 22 |
| Sapling | 16 | 18 | 13 |
| Seedling | 15 | 12 | 6 |
| Total density (trees / ha) | | | |
| Tree | 1,699 | 1,252 | 1,175 |
| Sapling | 8,438 | 9,969 | 406 |
| Seedling | 253,000 | 60,000 | 300 |
| Density of <i>M. gagei</i> (trees / ha) | | | |
| Tree | 27 | 32 | 35 |
| Sapling | 156 | 63 | 94 |
| Seedling | 105,500 | 10,500 | 0 |
| Basal area (m ² / ha) | | | |
| Total | 26.840 | 19.705 | 6.874 |
| <i>M. gagei</i> | 5.634 | 1.325 | 0.285 |

At Kuiburi National Park, there were 28 species of which 24 species were trees, 16 species were saplings and 15 species were seedlings. The densities of trees, saplings, and seedlings were 1,669, 8,438 and 253,000 individuals per hectare, respectively. The densities of *M. gagei* in tree form, saplings and seedlings were 27, 156 and 105,500 individuals per hectare, respectively.

At Namtok Huai Yang National Park, there were 63 species of which 36 species were trees, 18 species were saplings and 12 species were seedlings. The densities of trees, saplings, and seedlings were 1,252, 9,969 and 60,000 individuals per hectare, respectively. The densities of *M. gagei* in tree form, saplings and seedlings were 32, 63 and 10,500 individuals per hectare, respectively.

At Khao Sam Roi Yot National Park, there were 27 species of which 22 species were trees, 13 species were saplings and 6 species were seedlings. The densities of trees, saplings, and seedlings were 1,175, 406 and 300 trees per hectare, respectively. The densities of *M. gagei* trees and saplings were 35 and 94 individuals per hectare, respectively. There was no seedling at this study site.

Results in Table 1 showed that Namtok Huai Yang National Park had the most abundance of trees species, followed by Kuiburi National Park and Khao Sam Roi Yot National Park. The data showed that tree diversity at Namtok Huai Yang National Park is abundant twice as much as the diversity at Kuiburi and Khao Sam Roi Yot National Parks. The densities of *M.gagei* trees in three national parks were so close, *i.e.* 27, 32 , 35 trees per hectare. But saplings found in Kuiburi National Park were the most abundant at 156 trees per hectare where Khao Sam Roi Yot National Park had only 94 trees per hectare. The least was found in Namtok Huai Yang National Park with 63 trees per hectare. Seedlings of target species found so high in number, arranged in the order of 105,500 , 10,500 and none seedlings, respectively.

In comparison to secondary dry dipterocarp at Somdet, Kalasin province and the primary dry dipterocarp forest at Sakaerat , Nakhon Ratchasima province,

there were 22 and 31 ± 2 species per hectare (Sahunalu and Dhanmanonda, 1995), respectively. The dry dipterocarp forest in northern and northeastern regions of Thailand (*Shorea obtusa* type) was 37 species per hectare (Bunyavejchewin, 1983). Also, in comparison to the other forests in Thailand, dry evergreen forest at Sakaerat had 57 species per hectare (Visaratana, 1983). Yang stand at Pa Klang Ao, Prachuap Khiri Khan had 53 species per hectare (Wachrinrat *et al.*, 1999). Moist evergreen forest at Khao Chong and Khao Pra Taew had 150 ± 22 and 119 ± 22 species per hectare, respectively. Toh Daeng peat swamp forest, Narathiwat had 46 species per hectare. Hill evergreen forest at Haui Nam Dang, Chiang Mai had 56 species per hectare (Suksomut, 1987). Compared to other forests, number of species at Kuiburi and Khao Sam Roi Yot National Parks were lower. Number of species at Namtok Hui Yang National Park was higher than those of dry dipterocarp forest but lower than moist evergreen forest because soil moisture of dry dipterocarp forest was less than other forest. It means that moisture is one of the important factors controlling species composition. Number of species depends on soil moisture in the forest (Ogawa *et al.*, 1965). Number of species will therefore increase from dry dipterocarp forest to mixed deciduous forest, dry evergreen forest and moist evergreen forest.

The *M. gagei* seedling density was the highest at Kuiburi National Park, up to 105,500 seedlings per hectare or 10.55 seedlings per m^2 . Ten times less were found at Namtok Huai Yang National Park, with only 10,500 seedlings per hectare or 1.05 seedlings per m^2 . No seedling of *M. gagei* was found at Khao Sam Roi Yot National Park. One possible reason to explain this situation was juvenility of the stand since no flower could be observed in the past few years. The other reasons may due to the harsh environment such as high soil pH, limestone sites, steep slope, drought, strong wind, salt spray from the coast and low annual rainfall limiting their flowering ability.

1.1 DBH frequency distribution

The DBH class distributions of vegetation at all study sites were found to be L-shaped (Figure 5). The mode of data was present at 10-15 cm. The result showed

that there was a good frequency distribution of DBH levels. DBH class distribution of *M. gagei* at Kuiburi National Park was from 30-90 cm (Figure 5). Mode of data present ranged from 35-40 cm. Smaller sizes were found at Namtok Huai Yang National Park, where the *M. gagei* tree DBH distribution was from 5-45 cm. The majority appeared to be 10-25 cm. At Khao Sam Roi Yot National Park the *M. gagei* tree DBH was even smaller. The DBH class distribution ranged from 5-25 cm. The majority was found in the 10-15 cm class.

With an emphasis on *M. gagei* DBH size distribution, it revealed that larger size could be found in Kuiburi while the smaller size class was commonly found in Namtok Huai Yang and the smallest size was at Khao Sam Roi Yot National park. According to their distribution, it could be concluded that only 30-80 cm size class was dominant in Kuiburi but smaller size class was disappeared whenever removal of those mature stage without successive regeneration the extinction of *M. gagei* in this site should be considered. But stand at Namtok Huai Yang National Park was found consistent distribution in size class and even in number although it was rich in smaller size (< 5 to 40 cm DBH). This appearance ensures the continuous succession of *M. gagei* in future under well protection without any disturbance. The severe status occurred in Khao Sam Roi Yot National Park where only small size class of <5 to 25 cm DBH was found with small amount. The mature or seed tree was not exist, so that future young tree cannot regenerate in natural stand.

1.2 Height frequency distribution

Frequency distribution in height class of forest vegetation at Kuiburi and Namtok Huai Yang National Parks showed similar characteristics. The majority of the tree height appeared in the class of 5-10 m. While at Khao Sam Roi Yot National Park, it appeared at 0.5-5 m. It could be observed that trees grown at Khao Sam Roi Yot National Park were smaller and shorter. The limestone site was a limiting factor for tree growth. The patterns of height distribution in all places were L-shaped

(Figure 6). Height class frequency distribution of *M. gagei* in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks mode appeared at 5-10 m.

In conclusion, the DBH class distribution of *M. gagei* at Kuiburi National Park was from 30-90 cm; Namtok Huai Yang National Park, full of *M. gagei* tree DBH distribution in smaller size ranging from 5-45 cm; and the smallest size of 10-25 cm found in Khao Sam Roi Yot National Park. The height of *M. gagei* at Kuiburi and Namtok Huai Yang National Parks were distributed from 0.5-20 m, but at Khao Sam Roi Yot National Park were distributed from 0.5-15 m.

The DBH and height frequency distributions of *M. gagei* at Kuiburi and Namtok Huai Yang National Parks showed similar characteristics, while those at Khao Sam Roi Yot National Park could be observed that tree growth were relatively low in both stem diameter and height, because of the limestone mountains.

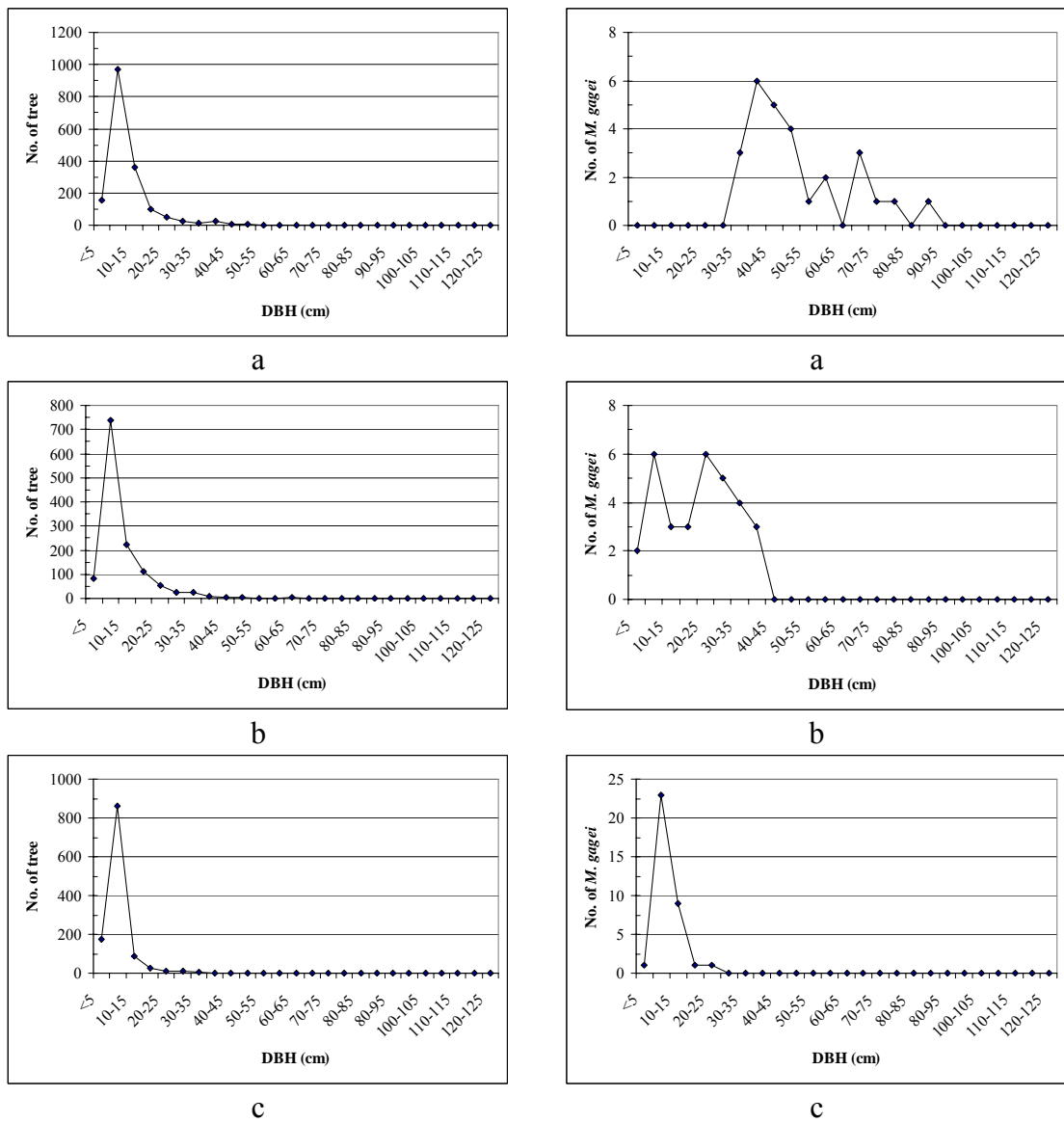


Figure 5 DBH frequency distribution of trees (left) and *M. gagei* (right) at Kuiburi (a) Namtok Huai Yang (b) and Khao Sam Roi Yot (c) National Parks.

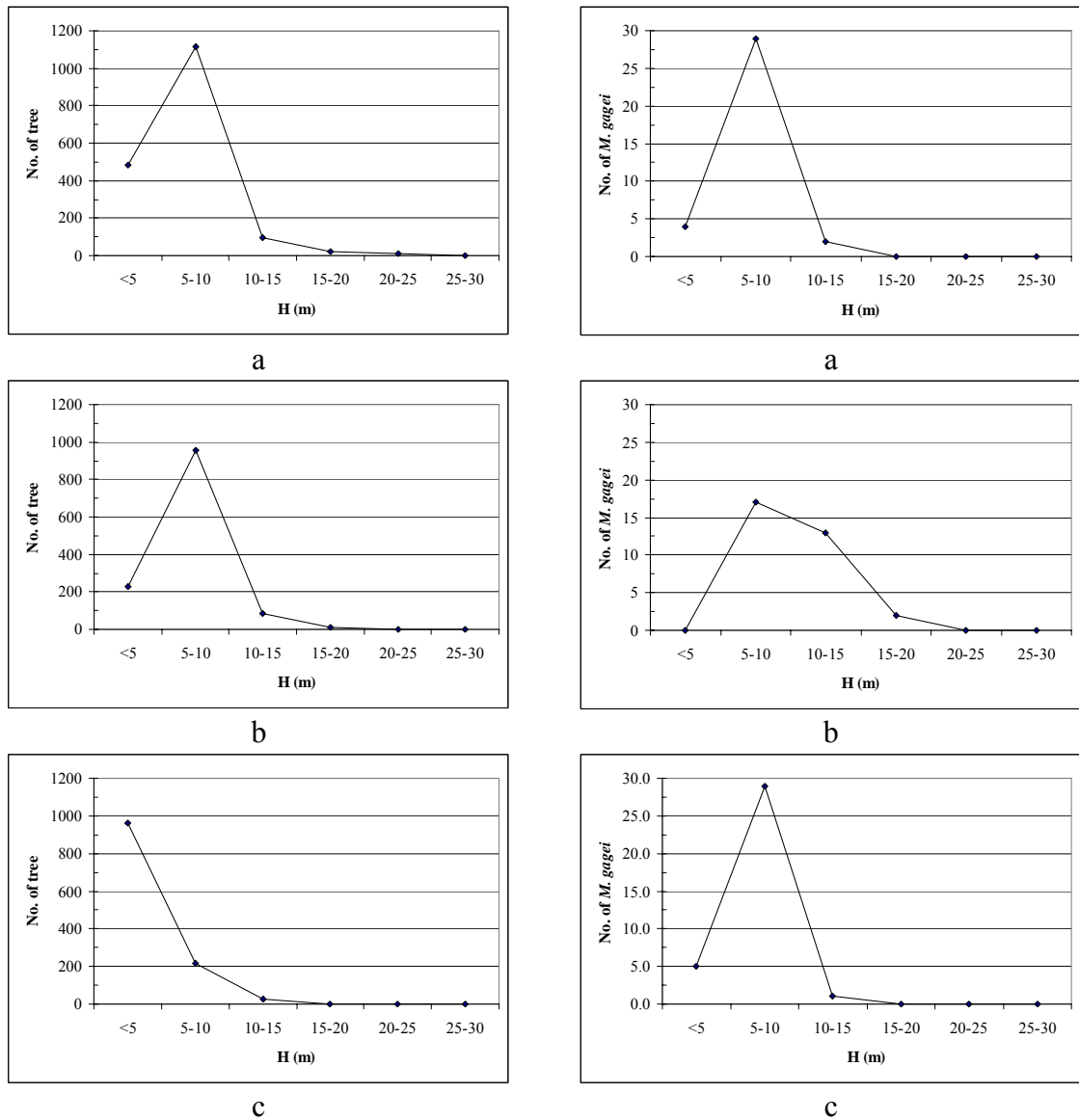


Figure 6 Height frequency distribution of trees (left) and *M. gagei* (right) at Kuiburi (a) Namtok Huai Yang (b) and Khao Sam Roi Yot (c) National Parks.

2. Species Diversity Index

The species diversity index was calculated to follow the Shannon-Wiener index. At Kuiburi, Namtok Huai Yang, and Khao Sam Roi Yot National Parks, the species diversity indices were equal to 1.486, 2.767 and 2.014, respectively. In comparison to other forest types, it was found that the index was lower than those of hill evergreen forest (4.280) and moist evergreen forest (4.491), but higher than those of dry deciduous forest (1.916). This result indicated that species diversity of study areas were very low. The species diversity index calculated by Simpson's index, MC1 and MC2 also showed the same trend. Species diversity index calculated by Simpson's index, MC1 and MC2 of Kuiburi National Park were 0.661, 0.428 and 0.417, respectively. At Namtok Huai Yang National Park they were 0.904, 0.709 and 0.683; while at Khao Sam Roi Yot National Park they were 0.783, 0.549 and 0.533, respectively. Richness of the species (R1, R2) and evenness (E) at Kuiburi National Park were 3.099, 0.587 and 0.467, respectively; at Namtok Huai Yang National Park they were 7.003, 1.436, and 0.703, respectively; and at Khao Sam Roi Yot National Park they were 2.970, 0.641 and 0.651, respectively (Table 2).

Table 2 Species diversity, richness and evenness index of the sample plots at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks

| Parameter | Kuiburi | Namtok Huai Yang | Khao Sam Roi Yot | MEF.* | HEF.* | DEF.* | DDF.* |
|-----------------------------------|---------|---------------------|---------------------|-------|-------|-------|-------|
| Species diversity index | | | | | | | |
| Shannon- Wiener's Index (H) | 1.486 | 2.767 | 2.014 | 4.491 | 4.280 | 4.833 | 1.916 |
| Simpson's | | | | | | | |
| Index (D) | 0.661 | 0.904 | 0.783 | - | 0.959 | 0.961 | 0.597 |
| MC1 | 0.428 | 0.709 | 0.549 | - | - | - | - |
| MC2 | 0.417 | 0.683 | 0.533 | - | - | - | - |
| Richness index | | | | | | | |
| R1 | 3.099 | 7.003 | 2.970 | - | 5.940 | 8.529 | 2.195 |
| R2 | 0.587 | 1.436 | 0.641 | - | 1.688 | 3.411 | 0.980 |
| Evenness | | | | | | | |
| E | 0.467 | 0.703 | 0.651 | - | 0.815 | 0.659 | 0.792 |

Remarks : MEF. = Moist evergreen forest

HEF. = Hill evergreen forest

DEF. = Dry evergreen forest

DDF. = Dry dipterocarp forest

From : Wachrinrat *et al.*, 1999.

In comparison to other forest types, it was found that the richness index at Namtok Huai Yang National Park was higher than those of Kuiburi and Khao Sam Roi Yot National Parks, hill evergreen forest (5.940) and dry dipterocarp forest (2.195), but was lesser richness than dry evergreen forest (8.529). Kuiburi and Khao Sam Roi Yot National Parks showed lesser richness than hill evergreen forest and dry evergreen forest in similar to dry dipterocarp forest.

3. Importance Value Index (IVI)

The IVI is an index used to determine dominant trees in the stands. The index is a sum of relative density, relative frequency and relative dominance. The results of this investigation are as follows:

At Kuiburi National Park, highest relative density was the *Chionanthus microstigma*, having the relative density of 47.334 %, followed by *Blachia siamensis* and *Antheroporum glacum*, with the relative density of 33.074 % and 5.153 %, respectively. *Chionanthus microstigma* showed the highest relative frequency of 23.650 while *Blachia siamensis* and *Antheroporum glacum*, the second and the third highest with the values of 22.879 % and 10.797 %, respectively. The species with highest relative dominance was *Blachia siamensis* (28.496 %), followed by *M. gagei* (20.993 %) and *Chionanthus microstigma* (16.554 %). Results from calculation revealed that the first three species of the highest IVI were *Chionanthus microstigma* (87.538), *Blachia siamensis* (84.449) and *M. gagei* (28.523). *M. gagei* in this area was bigger resulting to high relative dominance leading to high importance value index as mentioned (Table 3).

For sapling, *Blachia siamensis* was the species with the highest relative density of 40.370 %. The next species were *Chionanthus microstigma* (28.148 %) and *Mitrephora keithii* (10.370 %). The highest relative frequency species were *Blachia siamensis*, *Chionanthus microstigma* and *Mitrephora keithii* with the values of 21.250 %, 20.000 % and 15.00 %, respectively. The highest importance value index was *Blachia siamensis* (61.62) followed by *Chionanthus microstigma* (48.148) and *Mitrephora keithii* (25.37). The relative density, relative frequency and importance value index of *M.gagei* saplings in this area were 1.852 %, 3.75 % and 5.602, respectively.

Table 3 Relative density, relative frequency, relative dominance and importance value index of trees (DBH \geq 4.5 cm) at Kuiburi National Park

| No. | Species | Thai name | Basal area (m ² /ha) | Relative (%) | | | IVI |
|-------|--------------------------------|------------------|------------------------------------|--------------|--------------|---------------|---------------|
| | | | | Density | Frequency | Dominance | |
| 1 | <i>Chionanthus microstigma</i> | กระโดงแดง | 4.443 | 47.334 | 23.650 | 16.554 | 87.538 |
| 2 | <i>Blachia siamensis</i> | กระชืด | 7.648 | 33.074 | 22.879 | 28.496 | 84.449 |
| 3 | <i>Mansonia gagei</i> | จันทน์หอม | 5.634 | 1.618 | 5.913 | 20.993 | 28.523 |
| 4 | <i>Antheroporum glaucum</i> | ทลายเขา | 1.279 | 5.153 | 10.797 | 4.764 | 20.714 |
| 5 | <i>Cleidion spiciflorum</i> | ดีหมี | 1.655 | 3.655 | 10.026 | 6.166 | 19.847 |
| 6 | <i>Diospyros ehretioides</i> | ตับเต่าตัน | 0.616 | 2.756 | 6.684 | 2.296 | 11.736 |
| 7 | <i>Grewia eriocarpa</i> | ปอแก่นเทา | 2.632 | 0.359 | 0.771 | 9.807 | 10.938 |
| 8 | <i>Ailanthus triphysa</i> | มะยมป่า | 0.455 | 1.797 | 4.884 | 1.697 | 8.379 |
| 9 | <i>Hydnocarpus ilicifolia</i> | กระเบากลัก | 0.286 | 1.019 | 3.342 | 1.064 | 5.425 |
| 10 | <i>Ficus</i> sp. | ไทร | 1.287 | 0.060 | 0.257 | 4.797 | 5.114 |
| 11 | <i>Nephelium hypoleucum</i> | คอแลน | 0.129 | 0.779 | 2.571 | 0.480 | 3.830 |
| 12 | <i>Acronychia pedunculata</i> | กระเบื้องถ้วย | 0.308 | 0.419 | 1.799 | 1.147 | 3.366 |
| 13 | <i>Murraya paniculata</i> | แก้ว | 0.092 | 0.479 | 1.799 | 0.344 | 2.623 |
| 14 | <i>Memecylon caeruleum</i> | พลองชี่ควาย | 0.037 | 0.240 | 1.028 | 0.139 | 1.407 |
| 15 | <i>Baliospermum</i> spp. | ตองแตก | 0.018 | 0.300 | 0.514 | 0.068 | 0.882 |
| 16 | <i>Lagerstroemia cuspidate</i> | ตะแบก | 0.149 | 0.060 | 0.257 | 0.554 | 0.871 |
| 17 | <i>Microcos tomentosa</i> | พลับพลา | 0.028 | 0.180 | 0.514 | 0.103 | 0.797 |
| 18 | <i>Champereia manillana</i> | ผักหวานป่า | 0.004 | 0.120 | 0.514 | 0.015 | 0.649 |
| 19 | <i>Capparis micracantha</i> | ชิงชี่ | 0.004 | 0.120 | 0.514 | 0.013 | 0.647 |
| 20 | <i>Dialium cochinchinense</i> | เขลง | 0.056 | 0.120 | 0.257 | 0.210 | 0.587 |
| 21 | <i>Vitex gamosepala</i> | หมากเล็กหมากน้อย | 0.057 | 0.060 | 0.257 | 0.213 | 0.530 |
| 22 | <i>Ixora cibdela</i> | เข็มป่า | 0.008 | 0.120 | 0.257 | 0.028 | 0.405 |
| 23 | <i>Gardenia collinsae</i> | พุดผา | 0.005 | 0.120 | 0.257 | 0.020 | 0.397 |
| 24 | <i>Flacourtia indica</i> | ตะขบป่า | 0.008 | 0.060 | 0.257 | 0.030 | 0.347 |
| Total | | | 26.84 | 100 | 100 | 100 | 300 |

Table 4 Relative density, relative frequency and importance value index of saplings (DBH < 4.5 cm, height >1.30 m) at Kuiburi National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|----------|----------------------------------|------------------|--------------|--------------|--------------|
| | | | Density | Frequency | |
| 1 | <i>Blachia siamensis</i> | กระชืด | 40.370 | 21.250 | 61.620 |
| 2 | <i>Chionanthus microstigma</i> | กระโดงแดง | 28.148 | 20.000 | 48.148 |
| 3 | <i>Mitrephora keithii</i> | มหาพรม | 10.370 | 15.000 | 25.370 |
| 4 | <i>Champereia manillana</i> | ผักหวานป่า | 6.296 | 12.500 | 18.796 |
| 5 | <i>Antheroporum glaucum</i> | ทลายเขา | 4.444 | 8.750 | 13.194 |
| 6 | <i>Mansonia gagei</i> | จันทน์หอม | 1.852 | 3.750 | 5.602 |
| 7 | <i>Diospyros ehretioides</i> | ต๊อบเต่าตัน | 1.852 | 3.750 | 5.602 |
| 8 | <i>Hydnocarpus ilicifolia</i> | กระเบาเกล็ด | 1.481 | 2.500 | 3.981 |
| 9 | <i>Cladogynos orientalis</i> | เปล้าน้ำเงิน | 1.111 | 2.500 | 3.611 |
| 10 | <i>Cleidion spiciflorum</i> | ดีหมี | 0.741 | 2.500 | 3.241 |
| 11 | <i>Acronychia pedunculata</i> | กระอวม | 0.741 | 1.250 | 1.991 |
| 12 | <i>Gardenia collinsae</i> | พุดผา | 0.741 | 1.250 | 1.991 |
| 13 | <i>Ixora cibdela</i> | เข็มป่า | 0.741 | 1.250 | 1.991 |
| 14 | <i>Murraya paniculata</i> | แก้ว | 0.370 | 1.250 | 1.620 |
| 15 | <i>Prismatomeris filamentosa</i> | พุดป่า | 0.370 | 1.250 | 1.620 |
| 16 | <i>Vitex gamosepala</i> | หมากเล็กหมากน้อย | 0.370 | 1.250 | 1.620 |
| Total | | | 100 | 100 | 200 |

For *M. gagei* seedling, it was found to have the highest relative density of 41.700 %, followed by *Chionanthus microstigma* (30.237 %) and *Blachia siamensis* (14.032 %). For relative frequency, *M. gagei* seedling was the highest followed by *Blachia siamensis* and *Chionanthus microstigma* with the values of 27.835 %, 15.464 % and 12.371 %, respectively. The importance value index of *M. gagei* was the highest (69.535) followed by *Chionanthus microstigma* (42.608) and *Blachia siamensis* (29.496) (Table 5).

Table 5 Relative density, relative frequency and importance value index of seedlings (height \leq 1.30 m) at Kuiburi National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|-------|--------------------------------|--------------|--------------|-----------|--------|
| | | | Density | Frequency | |
| 1 | <i>Mansonia gagei</i> | จันทน์หอม | 41.700 | 27.835 | 69.535 |
| 2 | <i>Chionanthus microstigma</i> | กระโดงแดง | 30.237 | 12.371 | 42.608 |
| 3 | <i>Blachia siamensis</i> | กระชิด | 14.032 | 15.464 | 29.496 |
| 4 | <i>Cladogynos orientalis</i> | เปล้าน้ำเงิน | 2.767 | 8.247 | 11.014 |
| 5 | <i>Cleidion spiciflorum</i> | ดีหมี | 2.964 | 5.155 | 8.119 |
| 6 | <i>Murraya paniculata</i> | แก้ว | 1.581 | 5.155 | 6.736 |
| 7 | <i>Hydnocarpus ilicifolia</i> | กระเบากลัก | 1.186 | 5.155 | 6.340 |
| 8 | <i>Ixora cibdela</i> | เข็มป่า | 0.988 | 5.155 | 6.143 |
| 9 | <i>Mitrephora keithii</i> | มหาพรหม | 0.988 | 5.155 | 6.143 |
| 10 | <i>Diospyros ehrettioides</i> | ดัดเต่าตัน | 0.593 | 3.093 | 3.686 |
| 11 | <i>Champereia manillana</i> | ผักหวานป่า | 0.988 | 2.062 | 3.050 |
| 12 | <i>Antheroporum glaucum</i> | ทลายเขา | 0.395 | 2.062 | 2.457 |
| 13 | <i>Ailanthus triphysa</i> | มะยมป่า | 1.186 | 1.031 | 2.217 |
| 14 | <i>Grewia eriocarpa</i> | ปอแก่นเทา | 0.198 | 1.031 | 1.229 |
| 15 | <i>Atalantia monophylla</i> | มะนาวผี | 0.198 | 1.031 | 1.229 |
| Total | | | 100 | 100 | 200 |

At Namtok Huai Yang National Park, the tree with the highest relative density was *Helicteres elongata* followed by *Antheroporum glaucum* and *Grewia eriocarpa*. The relative density figures were 18.540 %, 16.054 % and 10.463 %, respectively. The relative frequency of *Helicteres elongata*, *Antheroporum glaucum* and *Grewia eriocarpa* were 11.503 %, 9.969 % and 8.896 %, respectively. Relative dominance of *Helicteres elongata* was the highest at 11.672 % followed by *Grewia eriocarpa* and *Pterospermum diversifolium* at 10.209 % and 9.555 %, respectively. *Helicteres elongata* therefore, had the highest importance value index of 41.626. The next species were *Antheroporum glaucum* and *Grewia eriocarpa* with the values of 35.373 and 29.568, respectively. Relative density, relative frequency, relative dominance and importance value index of *M. gagei* in this study area were rather low having the figures of 2.556 %, 3.988 %, 6.726 % and 13.270, respectively (Table 6).

Table 6 Relative density, relative frequency, relative dominance and importance value index of trees (DBH \geq 4.5 cm) at Namtok Huai Yang National Park

| No. | Species | Thai name | Basal area (m ² /ha) | Relative (%) | | | IVI |
|-----|-----------------------------------|------------|------------------------------------|--------------|--------------|--------------|---------------|
| | | | | Density | Frequency | Dominance | |
| 1 | <i>Helicteres elongata</i> | ขี้อิน | 2.299 | 18.450 | 11.503 | 11.672 | 41.626 |
| 2 | <i>Antheroporum glaucum</i> | ทลายเขา | 1.842 | 16.054 | 9.969 | 9.350 | 35.373 |
| 3 | <i>Grewia eriocarpa</i> | ปอแก่นเทา | 2.011 | 10.463 | 8.896 | 10.209 | 29.568 |
| 4 | <i>Pterospermum diversifolium</i> | ขนาน | 1.882 | 9.585 | 8.282 | 9.555 | 27.422 |
| 5 | <i>Nephelium hypoleucum</i> | คอแลน | 0.557 | 8.866 | 9.202 | 2.826 | 20.894 |
| 6 | <i>Pterocymbium malayanum</i> | ปออีแก้ง | 0.947 | 5.112 | 6.442 | 4.806 | 16.359 |
| 7 | <i>Mansonia gagei</i> | จันทน์หอม | 1.325 | 2.556 | 3.988 | 6.726 | 13.270 |
| 8 | <i>Terminalia nigrovenulosa</i> | ขี้ยาย | 0.644 | 3.994 | 5.521 | 3.268 | 12.783 |
| 9 | <i>Phyllanthus collinsae</i> | แขนงพริ้ว | 0.192 | 5.431 | 5.521 | 0.975 | 11.928 |
| 10 | <i>Hydnocarpus ilicifolia</i> | กระเบากลัก | 1.077 | 2.077 | 2.914 | 5.464 | 10.455 |
| 11 | <i>Lagerstroemia cuspidata</i> | ตะแบก | 0.800 | 1.917 | 2.607 | 4.060 | 8.585 |

Table 6 (Continued)

| No. | Species | Thai name | Basal area (m ² /ha) | Relative (%) | | | IVI |
|-----|-----------------------------------|------------------|------------------------------------|--------------|-----------|-----------|-------|
| | | | | Density | Frequency | Dominance | |
| 12 | <i>Vitex gamosepala</i> | หมากเล็กหมากน้อย | 0.957 | 1.278 | 1.840 | 4.857 | 7.976 |
| 13 | <i>Ficus spp.</i> | ไทร | 1.254 | 0.319 | 0.613 | 6.365 | 7.298 |
| 14 | <i>Pterospermum diversifolium</i> | ขนาน | 0.221 | 2.077 | 1.994 | 1.121 | 5.191 |
| 15 | <i>Murraya paniculata</i> | แก้ว | 0.245 | 1.438 | 2.301 | 1.245 | 4.983 |
| 16 | <i>Mitrephora keithii</i> | มหาพรหม | 0.302 | 1.038 | 1.840 | 1.531 | 4.409 |
| 17 | <i>Millettia leucantha</i> | ชะเง้อ | 0.186 | 0.799 | 1.380 | 0.943 | 3.122 |
| 18 | <i>Proiphys serratum</i> | มะแฟน | 0.067 | 1.038 | 1.687 | 0.338 | 3.064 |
| 19 | <i>Bombax valetonii</i> | จิวป่า | 0.229 | 0.000 | 1.840 | 1.165 | 3.005 |
| 20 | <i>Flemingia sootepensis</i> | กาสามปีก | 0.445 | 0.240 | 0.460 | 2.259 | 2.958 |
| 21 | <i>Garuga pinnata</i> | ตะคล้า | 0.304 | 0.719 | 0.613 | 1.541 | 2.873 |
| 22 | <i>Nephelium hypoleucum</i> | คอแลน | 0.400 | 0.160 | 0.307 | 2.030 | 2.497 |
| 23 | <i>Phoebe cathia</i> | ทัน | 0.102 | 1.038 | 0.920 | 0.516 | 2.475 |
| 24 | <i>Paranephelium xestophullum</i> | ลำไยป่า | 0.153 | 0.559 | 1.074 | 0.779 | 2.411 |
| 25 | <i>Grewia hirsuta</i> | ข้าวตาก | 0.301 | 0.399 | 0.307 | 1.528 | 2.234 |
| 26 | <i>Mitrephora winitii</i> | มหาพรหม | 0.092 | 0.559 | 1.074 | 0.468 | 2.100 |
| 27 | <i>Clausena harmandiana</i> | ส่องฟ้า | 0.019 | 0.639 | 1.074 | 0.099 | 1.811 |
| 28 | <i>Mallotus peltatus</i> | ขี้เต่า | 0.193 | 0.240 | 0.460 | 0.979 | 1.679 |
| 29 | <i>Diospyros pubicalyx</i> | ดำดง | 0.087 | 0.319 | 0.613 | 0.443 | 1.376 |
| 30 | <i>Syzygium cerasiforme</i> | กลางนาง | 0.129 | 0.240 | 0.460 | 0.656 | 1.356 |
| 31 | <i>Diospyros ehretioides</i> | ตับเต่าตัน | 0.052 | 0.399 | 0.613 | 0.263 | 1.275 |
| 32 | <i>Oxyspora spp.</i> | มังเระ | 0.084 | 0.160 | 0.307 | 0.425 | 0.892 |
| 33 | <i>Litsea glutinosa</i> | หมี่เหม็น | 0.040 | 0.240 | 0.307 | 0.201 | 0.747 |
| 34 | <i>Symplocos impressa</i> | เหมือดตาไหม | 0.036 | 0.160 | 0.307 | 0.183 | 0.650 |
| 35 | <i>Sterculia foetida</i> | ลำโรง | 0.019 | 0.160 | 0.307 | 0.096 | 0.563 |
| 36 | <i>Anogeissus acuminata</i> | ตะเคียนหนู | 0.047 | 0.080 | 0.153 | 0.239 | 0.473 |

Table 6 (Continued)

| No. | Species | Thai name | Basal area (m ² /ha) | Relative (%) | | | IVI |
|-------|-------------------------------|------------|------------------------------------|--------------|-----------|-----------|-------|
| | | | | Density | Frequency | Dominance | |
| 37 | <i>Hopea odorata</i> | ตะเคียนทอง | 0.039 | 0.080 | 0.153 | 0.200 | 0.433 |
| 38 | <i>Memecylon caeruleum</i> | พลอง | 0.035 | 0.080 | 0.153 | 0.176 | 0.409 |
| 39 | <i>Hymenodictyon orixense</i> | ส้มกบ | 0.003 | 0.080 | 0.307 | 0.013 | 0.400 |
| 40 | <i>Vatica cinerrea</i> | สะเดาปีก | 0.031 | 0.080 | 0.153 | 0.156 | 0.390 |
| 41 | <i>Amtidesma neurocarpum</i> | พลองขาว | 0.006 | 0.160 | 0.153 | 0.031 | 0.344 |
| 42 | <i>Ficus hispida</i> | มะเดื่อ | 0.019 | 0.080 | 0.153 | 0.097 | 0.330 |
| 43 | <i>Syzygium chavarana</i> | หว่านขก | 0.017 | 0.080 | 0.153 | 0.084 | 0.317 |
| 44 | <i>Cleidion spiciflorum</i> | ดีหมี | 0.003 | 0.080 | 0.153 | 0.017 | 0.250 |
| 45 | <i>Diospyros montana</i> | ถ่านไฟผี | 0.003 | 0.080 | 0.153 | 0.014 | 0.248 |
| 46 | <i>Litsea cubeba</i> | ตะไคร้ต้น | 0.002 | 0.080 | 0.153 | 0.012 | 0.246 |
| 47 | <i>Anogeissus acuminata</i> | เบ็น | 0.002 | 0.080 | 0.153 | 0.012 | 0.245 |
| 48 | <i>Dacryodes costata</i> | มะเลื่อม | 0.002 | 0.080 | 0.153 | 0.012 | 0.245 |
| 49 | <i>Mallotus oblongifolius</i> | หลอดเถื่อน | 0.002 | 0.080 | 0.153 | 0.010 | 0.244 |
| 50 | <i>Xantolis siamensis</i> | ตานเลี้ยง | 0.002 | 0.080 | 0.153 | 0.008 | 0.242 |
| Total | | | 19.705 | 100 | 100 | 100 | 300 |

For saplings, the highest relative density was *Helicteres elongata* followed by *Mallotus oblongifolius* and *Pterospermum diversifolium* at 19.122 %, 17.555 % and 14.107 %, respectively. The first four species with the highest relative frequency were *Pterospermum diversifolium*, *Helicteres elongata*, *Mallotus oblongifolius* and *Antheroporum glacum* at 13.571 %, 10.000 %, 10.000 % and 9.286 %. *Helicteres elongata* was found to have the highest IVI (29.122), followed by *Pterospermum diversifolium* (27.678) and *Mallotus oblongifolius* (27.555). Relative density, relative frequency and the importance value index of *M. gagei* in this experimental plot were 0.627 %, 0.714 % and 1.341, respectively (Table 7).

Table 7 Relative density, relative frequency and importance value index of saplings (DBH <4.5 cm, height > 1.30 m) at Namtok Huai Yang National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|-----------|-----------------------------------|------------------|--------------|--------------|--------------|
| | | | Density | Frequency | |
| 1 | <i>Helicteres elongata</i> | ขี้ตุน | 19.122 | 10.000 | 29.122 |
| 2 | <i>Pterospermum diversifolium</i> | ขนาน | 14.107 | 13.571 | 27.678 |
| 3 | <i>Mallotus oblongifolius</i> | หลอดเดือน | 17.555 | 10.000 | 27.555 |
| 4 | <i>Antheroporum glaucum</i> | ทลายเขา | 7.837 | 9.286 | 17.123 |
| 5 | <i>Phyllanthus emdlicia</i> | มะขามป้อม | 9.404 | 7.143 | 16.547 |
| 6 | <i>Cladogynos orientalis</i> | เจตพังดี | 5.643 | 10.000 | 15.643 |
| 7 | <i>Sympocos impressa</i> | เหมือดตาไหม | 2.821 | 4.286 | 7.107 |
| 8 | <i>Syzygium chavaran</i> | หว่านแขก | 3.448 | 2.857 | 6.305 |
| 9 | <i>Grewia eriocarpa</i> | ปอแก่นเทา | 2.508 | 3.571 | 6.079 |
| 10 | <i>Clausena harmandiana</i> | ส่องฟ้า | 2.194 | 2.857 | 5.052 |
| 11 | <i>Vatica cinerrea</i> | สะเดาบัก | 2.508 | 2.143 | 4.651 |
| 12 | <i>Milliletia leucanta</i> | ขะเจี๊ยะ | 1.567 | 2.143 | 3.710 |
| 13 | <i>Mitrephora winitii</i> | มหาพรม | 1.567 | 1.429 | 2.996 |
| 14 | <i>Holoptelea integrifolia</i> | กระเขา | 0.627 | 1.429 | 2.056 |
| 15 | <i>Gardenia collinsae</i> | พุดผา | 0.627 | 1.429 | 2.056 |
| 16 | <i>Terminalia nigrovenulosa</i> | ขี้ฮ้าย | 0.627 | 1.429 | 2.056 |
| 17 | <i>Phyllanthus collinsae</i> | แขนงพริ้ว | 0.627 | 1.429 | 2.056 |
| 18 | <i>Vitex pinnata</i> | ตีนนก | 0.627 | 1.429 | 2.056 |
| 19 | <i>Pterocymbium malayanum</i> | ปออีแก้ง | 0.627 | 1.429 | 2.056 |
| 20 | <i>Mitrephora keithii</i> | มหาพรม | 0.627 | 1.429 | 2.056 |
| 21 | <i>Paranepheleum xestophullum</i> | ลำไยป่า | 0.627 | 1.429 | 2.056 |
| 22 | <i>Murraya paniculata</i> | แก้ว | 0.627 | 0.714 | 1.341 |
| 23 | <i>Mansonia gagei</i> | จันทน์หอม | 0.627 | 0.714 | 1.341 |

Table 7 (Continued)

| No. | Species | Thai name | Relative (%) | | IVI |
|-------|-----------------------------------|------------|--------------|-----------|-------|
| | | | Density | Frequency | |
| 24 | <i>Hydnocarpus ilicifolia</i> | กระเบาหลัก | 0.313 | 0.714 | 1.028 |
| 25 | <i>Polyalthia suberosa</i> | กลิ้งกล่อม | 0.313 | 0.714 | 1.028 |
| 26 | <i>Grewia hirsuta</i> | ข้าวตอก | 0.313 | 0.714 | 1.028 |
| 27 | <i>Bombax ceiba</i> | จิ้ง | 0.313 | 0.714 | 1.028 |
| 28 | <i>Syzygium aqueum</i> | ชมพู่ป่า | 0.313 | 0.714 | 1.028 |
| 29 | <i>Capparis micracantha</i> | ชิงชี่ | 0.313 | 0.714 | 1.028 |
| 30 | <i>Garuga pinnata</i> | ตะคล้า | 0.313 | 0.714 | 1.028 |
| 31 | <i>Diospyros montana</i> | ถ่านไฟผี | 0.313 | 0.714 | 1.028 |
| 32 | <i>Anogeissus acuminata</i> | ตะเคียนหนู | 0.313 | 0.714 | 1.028 |
| 33 | <i>Chukrasia tubularis</i> | ยมหิน | 0.313 | 0.714 | 1.028 |
| 34 | <i>Pterospermum diversifolium</i> | ขนาน | 0.313 | 0.714 | 1.028 |
| Total | | | 100 | 100 | 200 |

M. gagei seedling was found to have the highest relative density (17.500%), followed by *Cladogynos orientalis* 15.000 % and *Mallotus oblongifolius* (10.000 %). Five species with the highest relative frequency were *Cladogynos orientalis* (14.706 %), *M. gagei* and *Hydnocarpus ilicifolia* (10.294 %) *Mallotus oblongifolius* (8.824 %) and *Antheroporum glacum* (8.824 %). *Cladogynos orientalis* seedling was found to have the highest importance value index (29.706), followed by *M. gagei* (27.794), *Hydnocarpus ilicifolia* (19.461) and *Mallotus oblongifolius* (18.824) (Table 8).

Table 8 Relative density, relative frequency and importance value index of seedlings (height \leq 1.30 m) at Namtok Huai Yang National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|-------|-----------------------------------|-------------|---------------|---------------|---------------|
| | | | Density | Frequency | |
| 1 | <i>Cladogynos orientalis</i> | เจดพิงตี | 15.000 | 14.706 | 29.706 |
| 2 | <i>Mansonia gagei</i> | จันทน์หอม | 17.500 | 10.294 | 27.794 |
| 3 | <i>Hydnocarpus ilicifolia</i> | กระเบาเกล็ด | 9.167 | 10.294 | 19.461 |
| 4 | <i>Mallotus oblongifolius</i> | หลอดเดือน | 10.000 | 8.824 | 18.824 |
| 5 | <i>Antheroporum glaucum</i> | ทลายเขา | 7.500 | 8.824 | 16.324 |
| 6 | <i>Phoebe cathia</i> | ทิ้น | 8.333 | 7.353 | 15.686 |
| 7 | <i>Pterospermum diversifolium</i> | ขนาน | 5.833 | 5.882 | 11.716 |
| 8 | <i>Murraya paniculata</i> | แก้ว | 4.167 | 5.882 | 10.049 |
| 9 | <i>Grewia hirsuta</i> | ข้าวตาก | 5.000 | 4.412 | 9.412 |
| 10 | <i>Clausena harmandiana</i> | สองฟ้า | 3.333 | 2.941 | 6.275 |
| 11 | <i>Helicteres elongata</i> | ซี่อิน | 2.500 | 2.941 | 5.441 |
| 12 | <i>Mitrephora winitii</i> | มหาพรหม | 2.500 | 2.941 | 5.441 |
| 13 | <i>Mitrephora keithii</i> | มหาพรหม | 1.667 | 1.471 | 3.137 |
| 14 | <i>Ixora cibdela</i> | เข็มป่า | 0.833 | 1.471 | 2.304 |
| 15 | <i>Phyllanthus collinsae</i> | แขนงพริ้ว | 0.833 | 1.471 | 2.304 |
| 16 | <i>Grewia eriocarpa</i> | ปอแก่นเทา | 0.833 | 1.471 | 2.304 |
| 17 | <i>Atalantia monophylla</i> | มะนาวผี | 0.833 | 1.471 | 2.304 |
| 18 | <i>Protium serratum</i> | มะแฟน | 0.833 | 1.471 | 2.304 |
| 19 | <i>Syzygium chavarana</i> | หว่านแขก | 0.833 | 1.471 | 2.304 |
| 20 | <i>Paranephelym xestophullum</i> | ลำไยป่า | 0.833 | 1.471 | 2.304 |
| 21 | <i>Symplocos impressa</i> | เหมือดตาไหม | 0.833 | 1.471 | 2.304 |
| Total | | | 100 | 100 | 200 |

Trees with DBH over 4.5 cm at Khao Sam Roi Yot National Park were *Euonymus javanicus* having the highest relative density of 36.0 %, followed by *Drypetes perreticulata* and *Ficus sp.* at 27.319 % and 5.277 %, respectively. *Euonymus javanicus* also had the highest relative frequency followed by *Drypetes perreticulata* and *Cleidion spiciflorum* with the values of 22.010 %, 18.900 %, and 8.134 %, respectively. For relative dominance it was also found that *Euonymus javanicus* was the highest followed by *Ficus sp.* and *Drypetes perreticulata* at 18.394 %, 17.941 % and 17.177 %, respectively. The top three importance value index, *Euonymus javanicus*, *Drypetes perreticulata* and *Ficus sp.* were 76.403, 63.396 and 30.873, respectively. *M. gagei* in this forest had relative density, relative frequency, relative dominance and importance value index of 2.979 %, 5.981 %, 4.148 % and 13.108, respectively (Table 9).

Table 9 Relative density, relative frequency, relative dominance and importance value index of trees (DBH \geq 4.5 cm) at Khao Sam Roi Yot National Park

| No. | Species | Thai name | Basal area (m ² /ha) | Relative (%) | | | IVI |
|----------|--------------------------------|------------------|------------------------------------|--------------|--------------|--------------|---------------|
| | | | | Density | Frequency | Dominance | |
| 1 | <i>Euonymus javanicus</i> | กระดุกไม้ | 1.264 | 36.000 | 22.010 | 18.394 | 76.403 |
| 2 | <i>Drypetes perreticulata</i> | มันหมู | 1.181 | 27.319 | 18.900 | 17.177 | 63.396 |
| 3 | <i>Cleidion spiciflorum</i> | ดีหมี | 0.200 | 4.851 | 8.134 | 2.913 | 15.898 |
| 4 | <i>Ficus sp.</i> | ไทร | 1.233 | 5.277 | 7.656 | 17.941 | 30.873 |
| 5 | <i>Knema globularia</i> | สมิง | 0.733 | 4.766 | 7.416 | 10.668 | 22.851 |
| 6 | <i>Mansonia gagei</i> | จันทน์หอม | 0.285 | 2.979 | 5.981 | 4.148 | 13.108 |
| 7 | <i>Antheroporum glaucum</i> | ทลายเขา | 0.147 | 4.255 | 4.785 | 2.143 | 11.183 |
| 8 | <i>Bridelia ovata</i> | มะกา | 0.194 | 3.830 | 4.785 | 2.816 | 11.430 |
| 9 | <i>Lenner coromandulica</i> | กุ่ม | 0.901 | 2.213 | 4.784 | 13.109 | 20.107 |
| 10 | <i>Psydrax dicocca</i> | ตะกริม | 0.075 | 2.128 | 4.306 | 1.084 | 7.518 |
| 11 | <i>Sterculia balanghas</i> | ปอขนุน | 0.231 | 1.106 | 2.632 | 3.355 | 7.093 |
| 12 | <i>Capparis rudura</i> | หางนกกะลิง | 0.119 | 0.936 | 2.153 | 1.735 | 4.825 |
| 13 | <i>Pterocymbium malayanum</i> | ปออีแห้ง | 0.136 | 1.362 | 1.675 | 1.974 | 5.011 |
| 14 | <i>Pentace triptera</i> | เลื้อยดง | 0.027 | 0.766 | 1.435 | 0.396 | 2.598 |
| 15 | <i>Streblus ilicifolius</i> | ขี้แรด | 0.016 | 0.596 | 1.196 | 0.226 | 2.018 |
| 16 | <i>Lagerstroemia tomentosa</i> | เสลา | 0.043 | 0.681 | 0.718 | 0.624 | 2.023 |
| 17 | <i>Millettia leucantha</i> | กระพี้เขาควาย | 0.035 | 0.255 | 0.478 | 0.503 | 1.237 |
| 18 | <i>Morinda coreia</i> | ยอป่า | 0.028 | 0.085 | 0.239 | 0.404 | 0.728 |
| 19 | <i>Diospyros ehretioides</i> | ตับเต่าดิน | 0.007 | 0.170 | 0.239 | 0.095 | 0.505 |
| 20 | <i>Diospyros montana</i> | ถ่านไฟผี้ | 0.002 | 0.085 | 0.239 | 0.032 | 0.356 |
| 21 | <i>Atalantia monophylla</i> | มะนาวผี้ | 0.018 | 0.340 | 0.239 | 0.260 | 0.839 |
| Total | | | 6.874 | 100 | 100 | 100 | 300 |

The results in Table 10 revealed that *Euonymus javanicus*, *Drypetes perreticulata* and *Knema globularia* saplings had relative density of 46.087 %, 16.522 % and 13.043 %; while their importance value index were 85.742, 30.315 and 25.112, respectively. Sapling of *M. gagei* had relative density, relative frequency and importance value index of 2.609 %, 1.724 % and 4.333, respectively.

Table 10 Relative density, relative frequency and importance value index of saplings (DBH <4.5 cm, height > 1.30 m) at Khao Sam Roi Yot National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|----------|-------------------------------|------------------|--------------|--------------|--------------|
| | | | Density | Frequency | |
| 1 | <i>Euonymus javanicus</i> | กระดุกไก่อ | 46.087 | 39.656 | 85.742 |
| 2 | <i>Drypetes perreticulata</i> | มันหมู | 16.522 | 13.793 | 30.315 |
| 3 | <i>Knema globularia</i> | ส้มิง | 13.043 | 12.069 | 25.112 |
| 4 | <i>Psydrax dicocca</i> | ตะกริม | 8.696 | 13.793 | 22.489 |
| 5 | <i>Clausena harmandiana</i> | สองฟ้า | 5.217 | 5.172 | 10.390 |
| 6 | <i>Glycosmis chlorosterma</i> | น้ำข้าวเขา | 2.609 | 3.448 | 6.057 |
| 7 | <i>Lenner coromandulica</i> | กุ่ม | 1.739 | 3.448 | 5.187 |
| 8 | <i>Mansonia gagei</i> | จันทน์หอม | 2.609 | 1.724 | 4.333 |
| 9 | <i>Cleidion spiciflorum</i> | ดีหมี | 0.870 | 1.724 | 2.594 |
| 10 | <i>Antheroporum glaucum</i> | ทลายเขา | 0.870 | 1.724 | 2.594 |
| 11 | <i>Ficus spp.</i> | ไทร | 0.870 | 1.724 | 2.594 |
| 12 | <i>Champerea manillana</i> | ผักหวานป่า | 0.870 | 1.724 | 2.594 |
| Total | | | 100 | 100 | 200 |

The importance value index of *M. gagei* trees at Kuyburi National Park and Namtok Huai Yang National Park were in the 3rd and the 7th ranks, respectively. Saplings were ranked at the 6th and the 23rd while seedlings were at the 1st and the 2nd. Such results indicated some obstacles for the trees during their development from seedlings to trees. At Khao Sam Roi Yot National Park the importance value index of

trees and saplings were ranked the at the 6th and the 8th, respectively. There was no seedling at all due to the harsh environment for seed germination.

The results in Table 11 revealed that there were only six seedling species. *Antidesma neurocarpum* had the highest relative density and relative frequency of 30.769 % and 25.000 %, respectively. The next species were *Clausena harmandiana*, *Psydrax dicocca*, *Atalantia monophylla* and *Drypetes perreticulata* with the relative density and relative frequency of 15.385 % and 16.667 %, respectively. The importance value index of *Antidesma neurocarpum* and the remaining five species were 55.769 and 32.052, respectively. *M. gagei* seedlings had the least importance value index in this forest. Limestone site and drought could be the main causes of such phenomena.

Table 11 Relative density, relative frequency and importance value index of seedlings (height \leq 1.30 m) at Khao Sam Roi Yot National Park

| No. | Species | Thai name | Relative (%) | | IVI |
|-------|-------------------------------|-----------|--------------|-----------|--------|
| | | | Density | Frequency | |
| 1 | <i>Antidesma neurocarpum</i> | พลองขาว | 30.769 | 25.000 | 55.769 |
| 2 | <i>Clausena harmandiana</i> | สองฟ้า | 15.385 | 16.667 | 32.052 |
| 3 | <i>Psydrax dicocca</i> | ตะกริม | 15.385 | 16.667 | 32.052 |
| 4 | <i>Atalantia monophylla</i> | มะนาวผี | 15.385 | 16.667 | 32.052 |
| 5 | <i>Drypetes perreticulata</i> | มันหมู | 15.385 | 16.667 | 32.052 |
| 6 | <i>Euonymus javanicus</i> | กระตุกใต้ | 7.692 | 8.333 | 16.026 |
| Total | | | 100 | 100 | 200 |

The IVI has been used to consider the species dominant. The species dominant of Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were *Chionanthus microstigma* and *Blachia siamensis*, *Helicteres elongata* and *Antheroporum glaucum* and *Euonymus javanicus* and *Drypetes perreticulata*. Sahunalu and Dhanmanonda (1995) studied the IVI value of dry dipterocarp forest at

Sakaerat and found that the highest and the second IVI for each stand were *Shorea floribunda* and *Quercus kerrii*, *Shorea obtusa* and *Shorea siamensis*, *Shorea obtusa* and *Pterocarpus macrocarpus*, and *Shorea siamensis* and *Shorea floribunda* for stand No. 1, 2, 3 and 4, respectively.

In conclusion, the IVI of *M. gagei* at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were 28.523, 13.270 and 13.108, respectively (Table 12). The basal area of *M. gagei* at Kuiburi National Park was the greatest (5.634m²/ha) while basal areas of *M. gagei* at Namtok Huai Yang and Khao Sam Roi Yot National Parks were 1.325 m² ha and 0.285 m²/ha, respectively. The relative density of *M. gagei* at Kuiburi National Park was 1.618% less than those at Namtok Huai Yang (2.556%) and Khao Sam Roi Yot National Parks (2.979%). The relative frequency and relative dominance of *M. gagei* tree at Kuiburi National Park (5.913%, 20.993%) were larger than those at Namtok Huai Yang (3.988%, 6.276 %) and Khao Sam Roi Yot National Parks (5.981%, 4.148%). The IVI of *M. gagei* at Kuiburi National Park was larger than at Namtok Huai Yang and Khao Sam Roi Yot National Parks. They are 28.523 and 13.108, respectively (Table 12).

Table 12 Basal area, relative density, relative frequency, relative dominance and IVI of *M. gagei* at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks

| Site | Basal Area (m ² /ha) | Relative (%) | | | IVI |
|--------------------------------|------------------------------------|--------------|-----------|-----------|--------|
| | | Density | Frequency | Dominance | |
| Kuiburi National Park | 5.634 | 1.618 | 5.913 | 20.993 | 28.523 |
| Namtok Huai Yang National Park | 1.325 | 2.556 | 3.988 | 6.726 | 13.270 |
| Khao Sam Roi Yot National Park | 0.285 | 2.979 | 5.981 | 4.148 | 13.108 |

4. Vertical Profile Classification

The vertical classification by profile diagram according to Davis and Richards (1933) revealed that for forest at Kuiburi National Park, crown strata could be divided into 2 levels, *i.e.* upper layer ranging between 6.87-18.09 m and lower layer between 1.30-6.87 m (Figure 7). The total height of the overall stand was averaged at 6.87 m. *M. gagei* crown was in the upper class with a height up to 18.09 m. The environment of Kuiburi National Park was suitable for its growth and distribution. Good natural regeneration could be expected since abundance of seedlings was present.

At Namtok Huai Yang National Park, the crown vertical structure could be divided into 2 levels, *i.e.*, the upper layer ranging between 6.00-9.00 m and the lower layer between 1.30-6.00 m (Figure 8). The total stand height was averaged at 6.00 m. The *M. gagei* crown was in the upper class with a height up to 9.00 m, the same class with *Pterospermum diversifolium* and *Grewia eriocarpa*. Trees appeared in lower class were *Antheroporum glaucum*, *Mitrephora keithi*, *Nephelium hypoleucum*, and *Hydnocarpus ilicifolia*. The crown was massively dispersed.

At Khao Sam Roi Yot National Park, crown could be found at one layer ranging between 1.3-6.3 m with stand height average of 4.7 m. *M. gagei* crown was in the upper class with a height up to 6.3 m. The density of crown cover was less than those at Namtok Huai Yang and Kuiburi National Parks. It was the result of limestone mountain and many small trees were affected by drought (Figure 9).

M. gagei in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Park were in the upper class with the height up to 18.09 m, 9.00 m and 6.30 m, respectively. Such outstanding differences in total height of *M. gagei* are expected to be the results of environments affecting tree growth and development of each site. The *M. gagei* were associated as the dominant tree and intercept full sunlight by nature.

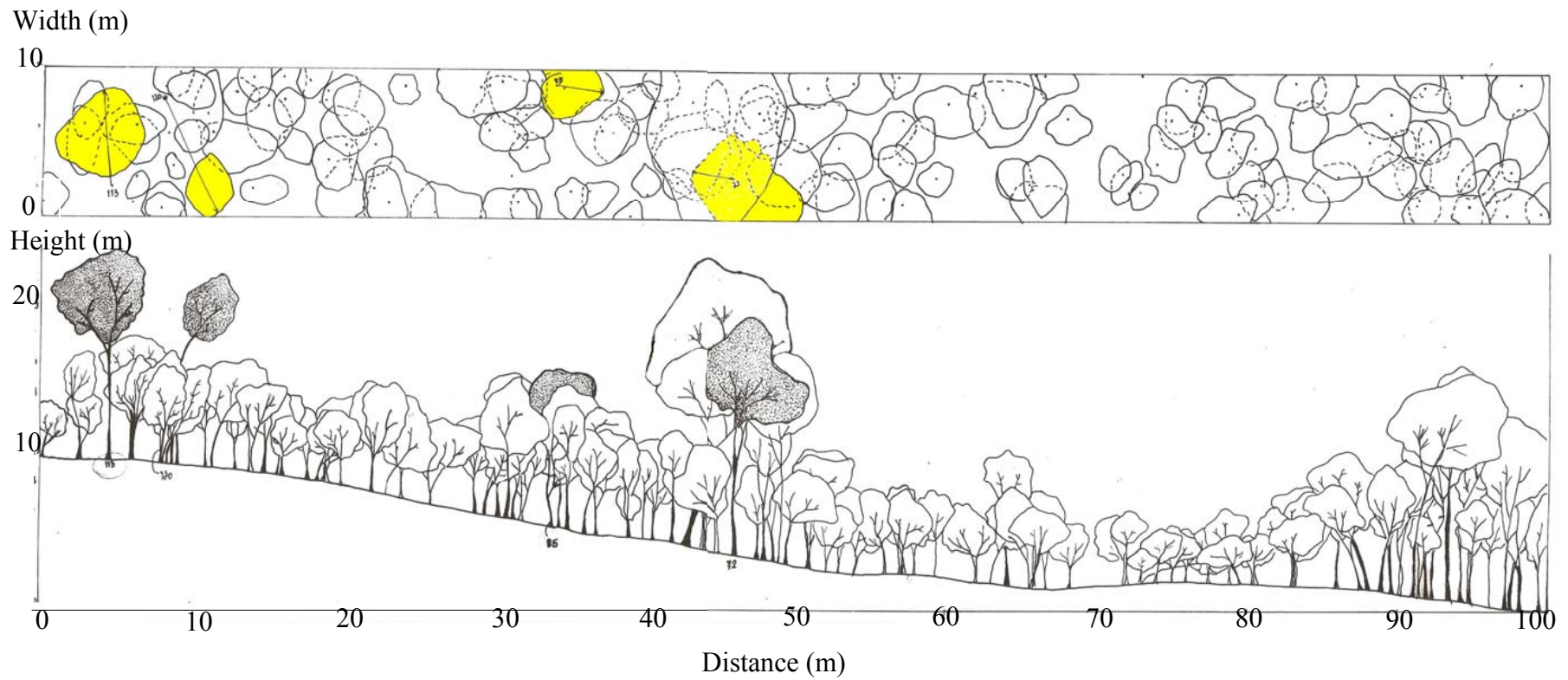


Figure 7 Profile diagram and crown cover of trees (DBH > 4.5 cm) at Kuiburi National Park, trees with shadow represented *M. gagei*.

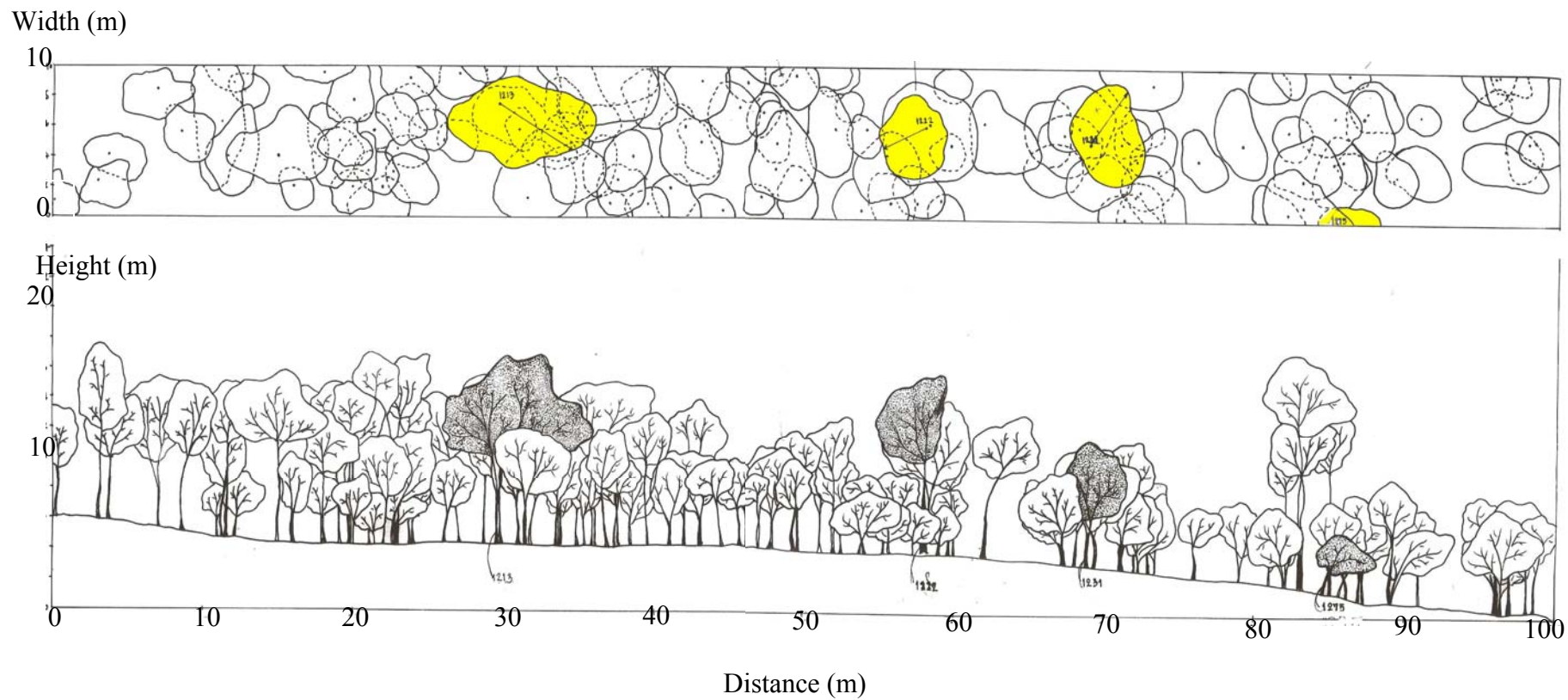


Figure 8 Profile diagram and crown cover of trees (DBH > 4.5 cm) at Namtok Huai Yang National Park, trees with shadow represented *M. gagei*.

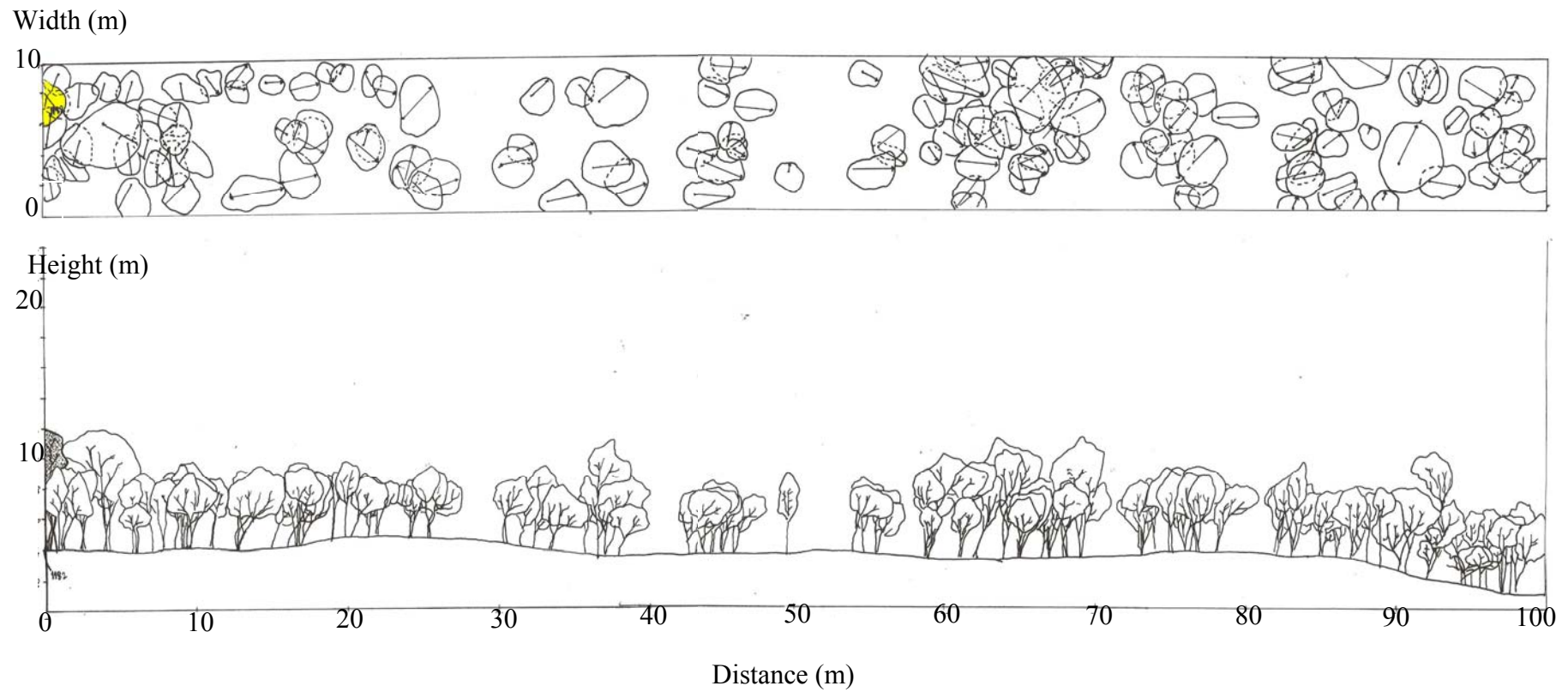


Figure 9 Profile diagram and crown cover of trees (DBH > 4.5 cm) at Khao Sam Roi Yot National Park, trees with shadow represented *M. gagei*.

5. Crown Cover

Crown cover of forest vegetation at Kuiburi National Park was 73.17 % (Figure 10). At Namtok Huai Yang National Park the covered area was 76.44 % (Figure 11) and at Khao Sam Roi Yot National Park it was 34.35 % (Figure 12). The *M. gagei* crown covered area was 14.5 %, 13% and 4.5% at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks, respectively. Moreover, it was found that crown cover percentage of *M. gagei* in relation to those of total crown cover was highest at Kuiburi (19.8 %) , followed by Namtok Huai Yang (17.00 %), while there was no crown cover of *M. gagei* at Khao Sam Roi Yot's sample plot. This great variation was also due to different site quality of those three stands. Kuiburi and Namtok Huai Yang could be considered as proper site for *M. gagei* in comparison to Khao Sam Roi Yot National Park.

Soil Properties

1. Soil Chemical Properties

At Kuiburi National Park, soil pH was in the range that plant can uptake nutrients in both soil depth, 5.9 and 5.7 for the upper and the lower soil, respectively. Organic matter was classified as medium in the upper soil (3.1 %), while as low in the lower soil (1.1 %). Most of chemical compositions were considered as high and very high, especially K in both soil depths. Only P was low (6 ppm and 3 ppm) in the upper and the lower soil depths (Table 13).

At Namtok Huai Yang National Park, soil pH was 6.1 and 5.6 in the upper and the lower layers, respectively (Table 13). Organic matter and other chemical compositions in the upper soil were more abundant than those in the lower soil. To compare with other two national parks, Namtok Huai Yang had organic matter, P and Ca in the second rank while K and Mg were in the last.

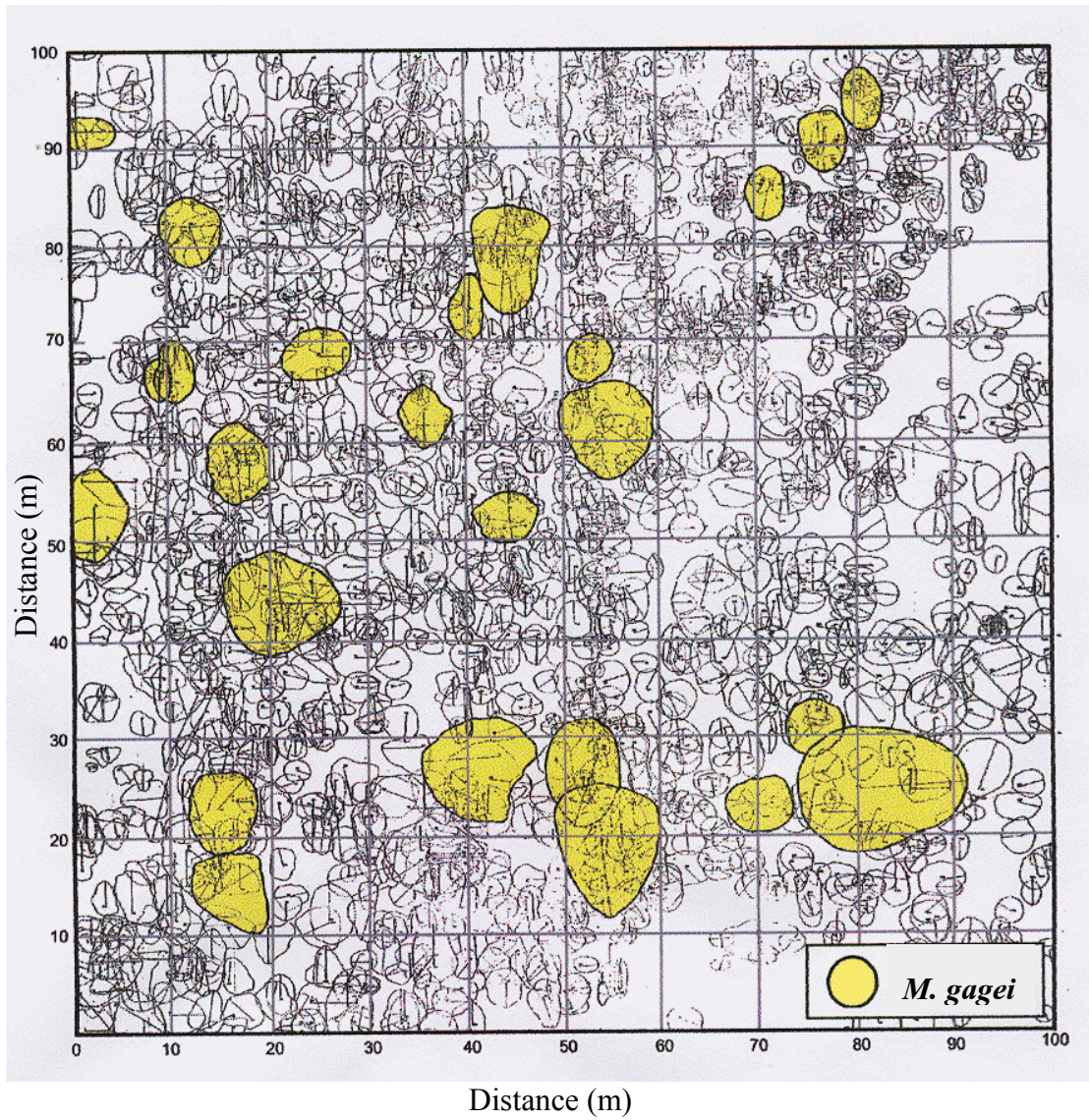


Figure 10 Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Kuiburi National Park.

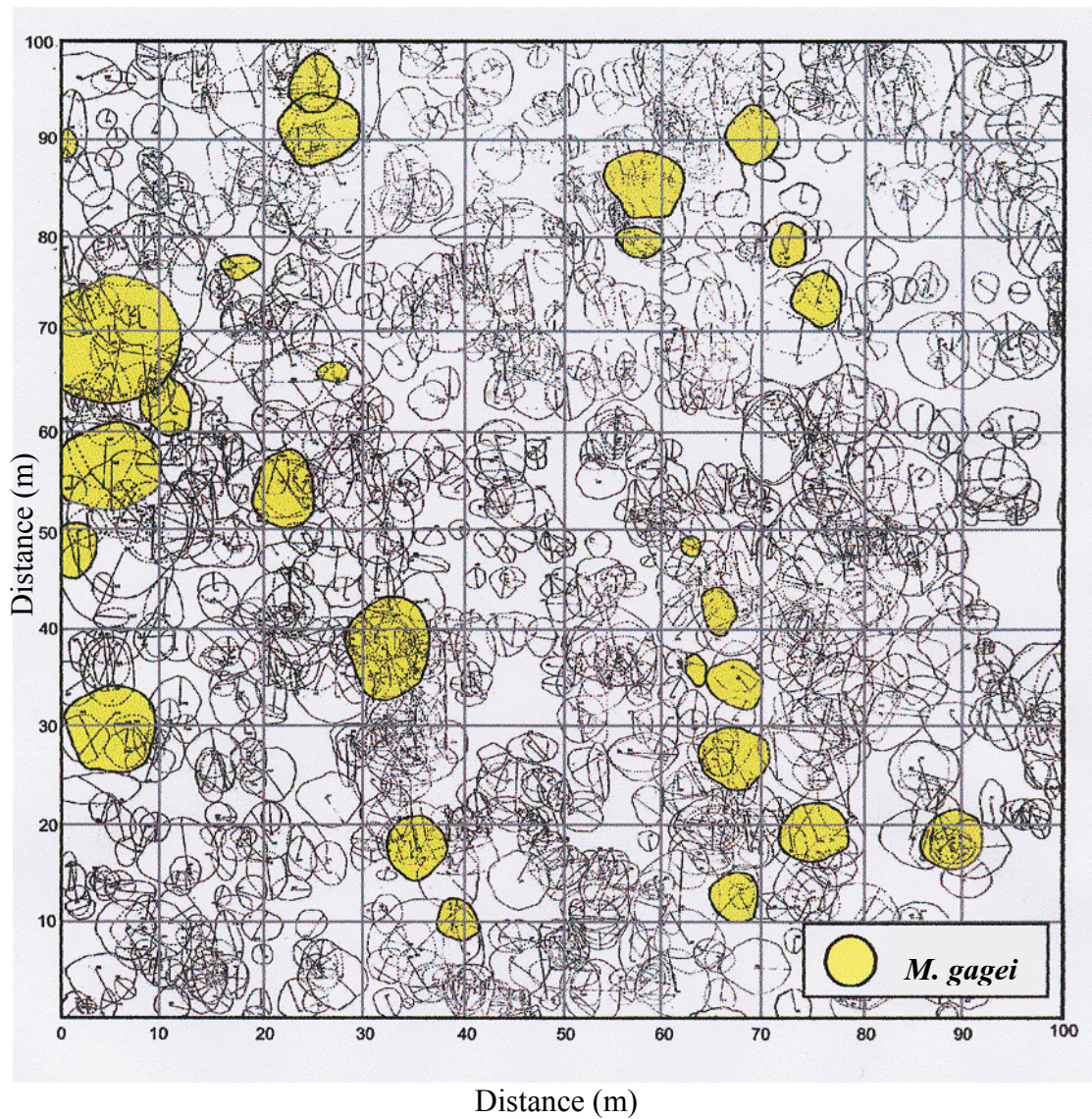


Figure 11 Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Namtok Huai Yang National Park.

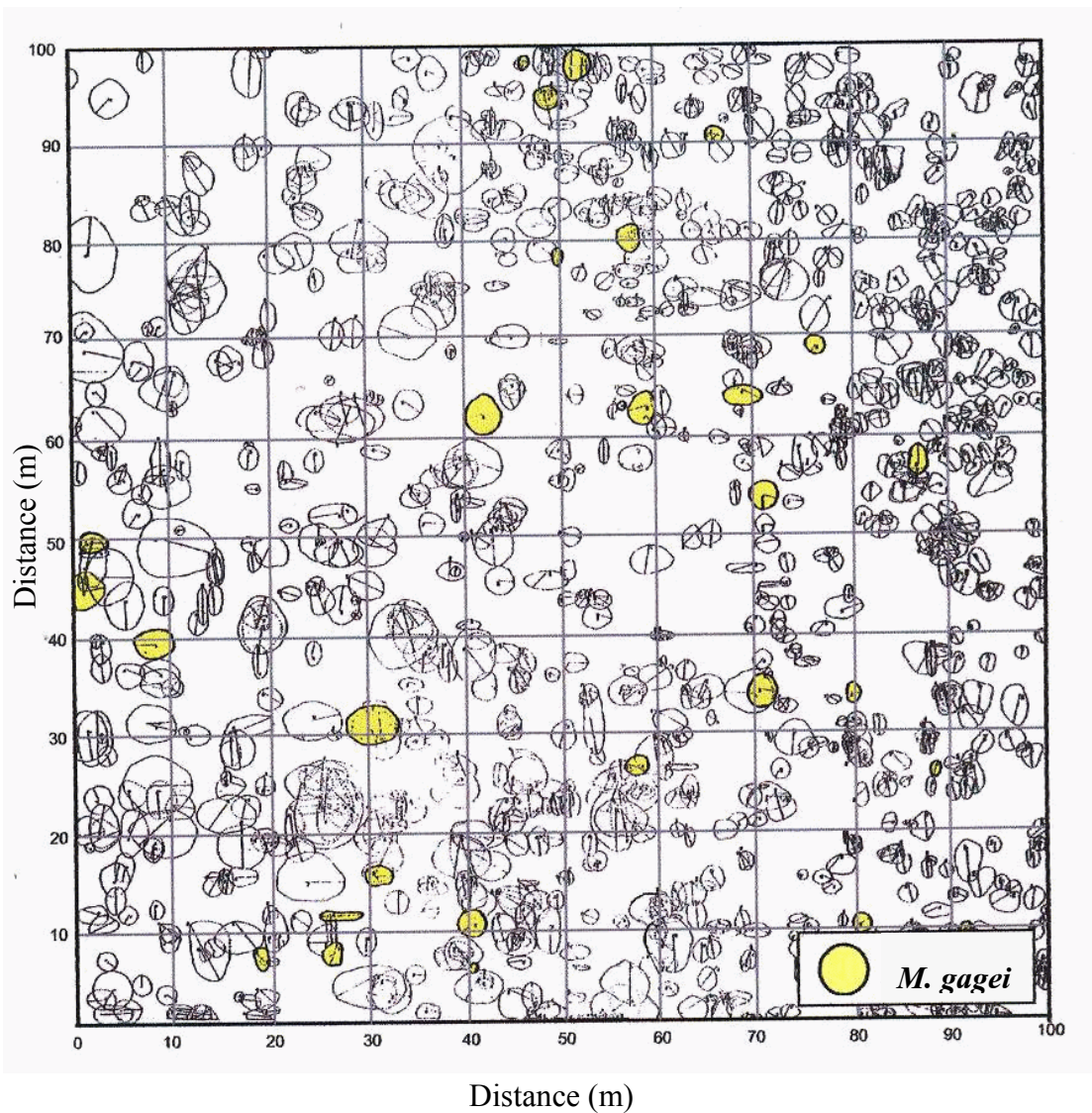


Figure 12 Crown projection diagram of trees (DBH > 4.5 cm) within a one hectare sample plot at Khao Sam Roi Yot National Park.

At Khao Sam Roi Yot National Park, the chemical compositions of soil in this site were considerably higher than the other sites. Because of parent material of the site was limestone, soil was relatively alkaline (pH 7.1). Soil with high pH over 6.5 might reduce availability of all macro-nutrients to plants. Although there were very high organic matter, P and K of 10.8 %, 69 ppm and 290 ppm and high Ca and Mg of 3,183 ppm and 867 ppm, respectively, growth of trees at this national park was poor. The lower soil sample in this site could not be collected due to the shallow profile. Soil lower than 15 cm was full of stones which responsible to the poor growth of trees as well. Roots of the trees could not penetrate through these stone layers, only grew through cracks leading to the lack of soil nutrients.

Soil type at Kuiburi plantation was similar to those of *M. gagei* natural stand in Kuiburi National Park, since the distance between those two sites was not so far. Kuiburi plantation site was, therefore, selected for this study. Soil properties at Kuiburi plantation were also similar to those at Namtok Huai Yang National Park. The soil pH was slightly higher than Kuiburi and Namtok Huai Yang National Parks, but still in a range which nutrients were available to plants. Organic matters, however, were considerably low in the upper soil and very low in the lower soil. P was also low in both soil depths. The other three mineral elements, K, Ca and Mg were high in the upper soil and slightly lower in the lower soil layer.

Table 13 Soil chemical properties at Kuiburi, Namtok Huai Yang , Khao Sam Roi Yot National Parks and the Kuiburi plantation

| Location | Soil depth (cm) | Chemical properties | | | | | |
|-----------------------|-----------------|--|--------------------|------------------|-----------------|---------------|-----------------|
| | | pH | Organic matter (%) | Phosphorus (ppm) | Potassium (ppm) | Calcium (ppm) | Magnesium (ppm) |
| Kuiburi | 0-15 | 5.9 | 3.1 M | 6 L | 213 VH | 1,887 H | 210 H |
| | 15-30 | 5.7 | 1.1 L | 3 L | 130 VH | 733 H | 180 H |
| Namtok Huai Yang | 0-15 | 6.1 | 4.3 H | 14 M | 157 VH | 2,027 H | 123 H |
| | 15-30 | 5.6 | 1.2 L | 5 L | 113 H | 453 L | 64 H |
| Khao Sam Roi Yot | 0-15 | 7.1 | 10.8 H | 69 VH | 290 VH | 3,183 H | 867 H |
| | 15-30 | (Soil sample not available due to rocky layer) | | | | | |
| Kuiburi Plantation | 0-15 | 6.5 | 1.3 L | 14 M | 113 H | 1,160 H | 110 H |
| | 15-30 | 6.6 | 0.77 VL | 3 L | 100 M | 760 H | 77 M |

Remarks : Letters L, M, H and VH ranked soil chemical properties:

L = Low, M = Medium, H = High, VH = Very high

Variation in soil chemical properties of these sites and of *M. gagei* plantation (Table 13) indicated that the species tolerate various soil types. Soil pH, however, showed very high impact on the growth of the species. Although there were very rich in nutrients at Khao Sam Roi Yot National Park, at least two times of the other sites, growth of *M. gagei* trees was very poor. Soil pH above 6.5 might reduce availability of all macro-nutrients to plants.

2. Soil Texture

Soil texture was the only physical property to be investigated here. In all places soil texture in both soil depths were similar, even though the percentages of

sand, silt and clay were slightly different (Table 14). Soil texture at Kuiburi National Park was sandy clay loam (SCL). The percentages of sand, silt and clay were 48, 26 and 26 in the upper soil and 60, 20 and 20 in the lower soil, respectively. Soil had more sand at Namtok Huai Yang National Park. Soil texture was classified as sandy loam (SL). The percentages of sand, silt and clay were 74, 12 and 14 in the upper soil and 83, 8 and 9 in the lower soil, respectively. Soil texture at Khao Sam Roi Yot National Park was more clayey and classified as clayey loam (CL). Clay composition in this site was higher than other study areas. The percentages of sand, silt and clay were 43, 22 and 35 in the upper soil, respectively. The lower soil data could not be obtained because soil profile was shallower than 15 cm.

The natural existence of *M.gagei* in these three national parks showed that the species could be grown in various types of soil, *i.e.* clay loam, sandy clay loam and sandy loam. Due to poor performance in growth of *M. gagei* at Khao Sam Roi Yot National Park, both chemical and physical properties should be taken in consideration if *M. gagei* is planned to be planted in future.

In the plantation, soil texture in both soil depths were classified as sandy loam (SL). The percentages of sand, silt and clay were 65, 19 and 16 in the upper soil and 65, 20 and 15 in the lower soil, respectively. Soil texture in this site should not be a problem for *M. gagei* growth, since its fertility and texture were similar to the natural site at Namtok Huai Yang National Park.

Table 14 Soil texture at Kuiburi, Namtok Huai Yang , Khao Sam Roi Yot National Parks and Kuiburi Plantation

| Location | Soil Depth (cm) | % Soil Component | | | Texture |
|--------------------|--------------------|------------------|------|------|---------|
| | | Sand | Silt | Clay | |
| Kuiburi | 0-15 | 48 | 26 | 26 | SCL |
| | 15-30 | 60 | 20 | 20 | SCL |
| Namtok Huai Yang | 0-15 | 74 | 12 | 14 | SL |
| | 15-30 | 83 | 8 | 9 | SL |
| Khao Sam Roi Yot | 0-15 | 43 | 22 | 35 | CL |
| | 15-30 | - | - | - | - |
| Kuiburi Plantation | 0-15 | 65 | 19 | 16 | SL |
| | 15-30 | 65 | 20 | 15 | SL |

Reproductive Phenomena

1. Floral Phenology

Leaves of *M. gagei* started shedding in January and finished in March. New buds rapidly sprouted about 1-2 weeks later. New shoots and leaves fully developed, the tree then full of leaves. In July flower bud formation occurred at leaf axil. The bud then developed into a small inflorescence and flowers on inflorescence started to bloom in September. Every day there was 1 or 2 flowers blooming in one inflorescence and up to 20 flowers in one twig. Flower opened around 7 am and continued until 9-10 am. The flower then closed from 10 am to 5 pm and reopened from 5 to 7 pm. One flower bloomed 1-2 days before falling. Fertilized flowers developed into small young fruits. The flowering period lasted about 1 month. After fertilization young small fruits developed to full size fruits in October. About 45-60

days after fully develop, fruits mature in the late December to early January. Flowering period of *M. gagei*, from flower bud sprout to mature fruit, took about 6 months. It was observed that good seed year of *M. gagei* would occur once every 3 years.

1.1 Number of flowers and fruits per twig

The number of inflorescence per twig varied from 7 to 33 inflorescences with an average of 13.6 inflorescences per twig. The number of flowers also varied widely from 24 flowers to 148 flowers per twig with an average of 60.1. Calculation then revealed that there were 8.3 flowers per inflorescence on average. These flowers would develop to be young fruits. An average of young fruits was 15.5 fruits per twig and 1.17 fruits per inflorescence. Data showed that only 25.79 % of flowers could develop to fruits while the rest were failed. There were also mature fruits present at an average of 7.6 fruits per twig and averaged less than 1 fruit per inflorescence (Table 15). There was no fruit left in some inflorescences. During the development from young to mature fruits there were so many fruits getting failed. There were only 12.64 % and 49.03 % of flowers and of young fruits, respectively, could develop to mature.

Table 15 Number of inflorescences, flowers and fruits of *M. gagei*

| Twig No. | Number /Twig | | | | Number / Inflorescence | | |
|----------|---------------|--------|-------------|--------------|------------------------|-------------|--------------|
| | Inflorescence | Flower | Young fruit | Mature fruit | Flower | Young fruit | Mature fruit |
| 1 | 13 | 74 | 23 | 12 | 5.69 | 1.77 | 0.92 |
| 2 | 15 | 97 | 46 | 21 | 6.46 | 3.06 | 1.40 |
| 3 | 7 | 51 | 12 | 8 | 7.28 | 1.71 | 1.14 |
| 4 | 7 | 24 | 7 | 3 | 3.42 | 1.00 | 0.43 |
| 5 | 7 | 49 | 4 | 0 | 7.00 | 0.57 | 0.00 |
| 6 | 14 | 28 | 22 | 12 | 2.00 | 1.57 | 0.86 |
| 7 | 9 | 27 | 2 | 1 | 3.00 | 0.22 | 0.11 |
| 8 | 33 | 148 | 21 | 11 | 4.48 | .64 | 0.33 |
| 9 | 15 | 51 | 6 | 3 | 3.40 | 0.40 | 0.20 |
| 10 | 16 | 52 | 12 | 5 | 3.25 | 0.75 | 0.31 |
| Average | 13.6 | 60.1 | 15.5 | 7.6 | 4.42 | 1.169 | 0.56 |

Data from Table 16 could be estimated Fr/FI ratio of *M. gagei* which varied from 0 to 0.43 in different twigs and averaged as low as 0.13. Owens (1994) explained that low Fr/FI ratio could occur during prezygotic period as well as during postzygotic period. In the first period, there were flower abortion due to unpollinated or unfertilized. While the later period, there were fertilized flowers and developing fruits dropped because there were limited available resources.

Table 16 Among–twig variation in number of flowers per inflorescence, fruits per inflorescence , and Fr/FI ratio of *M. gagei*

| Twig No. | Number of Flower per Inflorescence (FI) | Number of Fruits per Inflorescence (Fr) | Fr/FI ratio |
|----------|--|--|----------------|
| 1 | 5.69 | 0.92 | 0.16 |
| 2 | 6.46 | 1.40 | 0.22 |
| 3 | 7.28 | 1.14 | 0.16 |
| 4 | 3.42 | 0.43 | 0.13 |
| 5 | 7.00 | 0.00 | 0.00 |
| 6 | 2.00 | 0.86 | 0.43 |
| 7 | 3.00 | 0.11 | 0.04 |
| 8 | 4.48 | 0.33 | 0.07 |
| 9 | 3.40 | 0.20 | 0.06 |
| 10 | 3.25 | 0.31 | 0.10 |
| Average | 4.42 | 0.56 | 0.13 |

Floral Morphology

M. gagei flowers were arranged in a small inflorescence. Inflorescence is a short panicle at the end of twigs and axillary branches up to 15 cm long. Petiole is 0.5 – 1 cm long. Sepals united at the base with 5 free spatulate or oblanceolate white petals. Ten stamens alternated with staminodes, united into a slender gynandrophore, surrounding the ovary. Scanning Electron Microscopy (SEM) revealed that one

anther has two microsporangia, each bearing two chambers (Figure 13 A). The pollen grain is tricolpate type and round shape (Figure 13 B). Receptive stigma collected around 8 am showed swell cells, four germinating pollens protruded their tubes into 1 stigma (Figure 13 C). Unpollinated stigma collected at around 10 am showed collapsing cells (Figure 13 D).

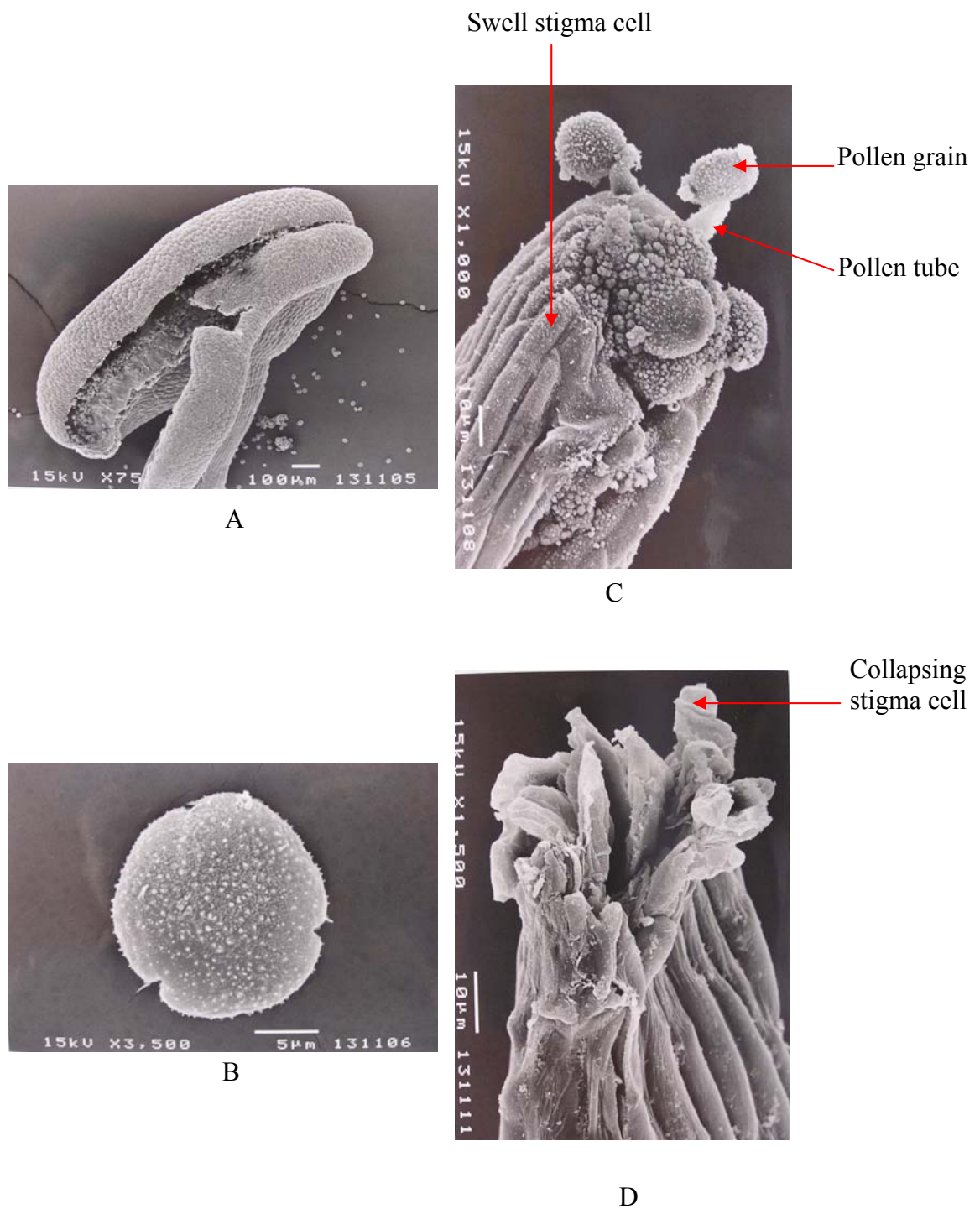


Figure 13 Scanning electron micrographs (SEMs) of *M. gagei* flower, Anther (A), Tricolpate type pollen grain (B), Receptive stigma with germinated pollen (C), and Post receptive stigma (D).

Seed and Seedling

1. Seed Weight

Seed orders are given by weight. Seed weight together with purity and germination percentage is important when calculating seed demand for a given planting programme. Seed with wing and de-wing are different in seed weight. In *Swietenia macrophylla*, weight of winged seed was about 2,100 seeds per kg, while for de-winged seeds it was about 2,300 seeds per kg. There were other factors influencing seed weight, such as, moisture content (m.c.). Seed weight of *S. macrophylla* roughly increased from above 2,400 per kg at 5% m.c. to 2,300 seeds per kg at 9% m.c (Schmidt, 2000).

Weighting of *M. gagei* seeds with wing and de-winging fruits showed that 8 replications of 100 seeds had an averaged weight of 36.63 ± 9.28 g and 27.29 ± 5.88 g, respectively (Table 17). When calculated to 1,000 seeds, there were the on averaged weight of 366.3 ± 92.8 g and 272.9 ± 58.8 g for wing and de-winging fruits, respectively. Removing wing reduced seed weight down to about 95.4 g per 1,000 seeds.

Table 17 Weights of winged and de-winged seeds of *M. gagei*

| Replication | Weight (g)/100 winged seeds | Weight (g)/100 de-winged seeds |
|-------------|-----------------------------|--------------------------------|
| 1 | 28.09 | 22.98 |
| 2 | 25.38 | 19.53 |
| 3 | 43.86 | 26.15 |
| 4 | 42.25 | 29.15 |
| 5 | 30.30 | 29.88 |
| 6 | 52.50 | 38.46 |
| 7 | 32.68 | 22.57 |
| 8 | 37.74 | 29.50 |
| Average | 36.63 | 27.29 |
| SD | 9.28 | 5.88 |

Such data could be converted to number of seeds per kg as $2,861 \pm 720$ seeds per kg when the whole fruits were used and as $3,936 \pm 790$ seeds per kg for de-winged seeds. SD value indicated that there were high variation in seed weight. Removing wings could increase number of seeds per kg about 1,075 seeds. Seed de-winging reduced storage space and weight to be carried. In terms of seed germination, however, seed de-winging is unnecessary. The study showed that winged and de-winged seed germination was not significantly different at 80.5% and 85%, respectively (Meekaew, 2006).

2. Seed Size

Seed size varies in different species. Size of seed can determine volume, weight and quality of seed for the same species. A given species with larger seeds tend to produce more vigor and healthier seedlings. Measurement of seed sizes showed that *M. gagei* winged seed length, winged seed width, de-winged seed length and de-winged seed width were the average of 3.52 ± 0.46 , 1.12 ± 0.15 , 1.18 ± 0.173 and 0.65 ± 0.08 cm, respectively (Table 18).

Table 18 De-winged and winged seed sizes of *M. gagei*

| Replication. | De-winged seed size (cm) | | Winged seed size (cm) | |
|--------------|--------------------------|-------|-----------------------|-------|
| | Length | Width | Length | Width |
| 1 | 3.48 | 1.07 | 1.21 | 0.65 |
| 2 | 3.41 | 1.11 | 1.21 | 0.67 |
| 3 | 3.29 | 1.07 | 1.10 | 0.62 |
| 4 | 3.89 | 1.21 | 1.30 | 0.68 |
| Average | 3.52 | 1.12 | 1.22 | 0.65 |
| SD | 0.46 | 0.15 | 0.17 | 0.08 |

3. Seed Maturity

Seeds were considered as mature when they were fully germinable after extraction from their fruits and possible breakage of dormancy (Schmidt, 1999). Maturation of fruits and seeds were usually synchronous, so that maturity of fruit and seed was attained at approximately the same time except for some species (Schmidt, 2000). Determination of the best collection time should be based on maturity indices for the given species. Changes of fruit and seed appearance indicated maturity, *e.g.* change of colour, drying, dehiscence, softening of fruit pulp, odour and hardening of the seed coat and endosperm. Maturity indices were used to schedule of seed collection (Schmidt, 1999). Maturity indices varied with fruit types and species and should be learned particular species to be collected (Schmidt, 2000). Changes in color, moisture content and development of abscission zones occurred in most types. Changing in fruit color was the easiest index to determine. For this study, therefore *M. gagei* fruit colors in relation to their ability to germinate were used to indicate seed maturity. Seed colors used in the study were green, greenish brown and brown having average germination of 40.75 %, 85.25 % and 82.50 %, respectively (Figure 14).

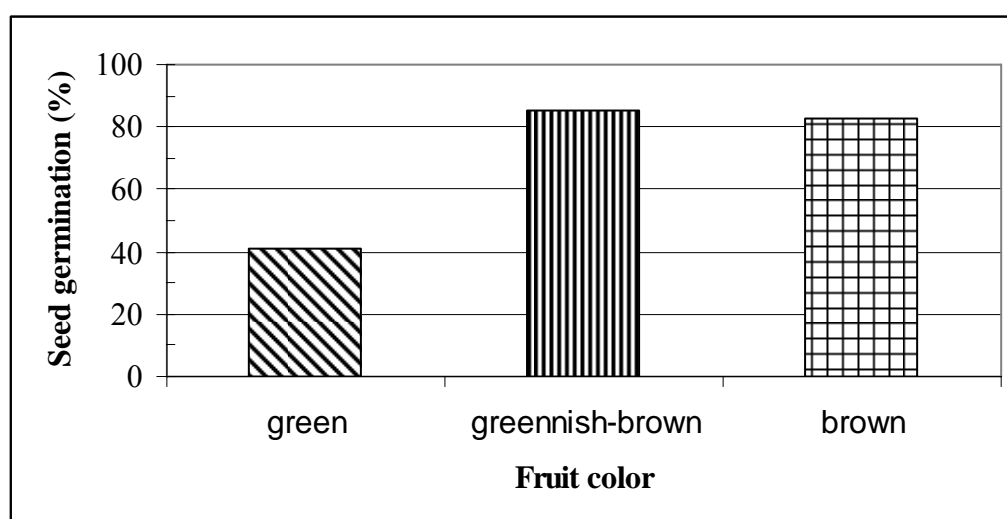


Figure 14 Seed coat color as a maturity index in relation to germination percentage of *M. gagei*.

Statistical analysis indicated that greenish-brown and brown seeds germinated significantly better than the green seeds at $\alpha = 0.05$. Fruit color was a good indicator for seed maturity of *M. gagei*. Green fruit showed low germination due to its juvenility. Greenish-brown fruit showed the highest total germination indicated its maturity. Total germination of the brown fruit tended to be less indicating its late maturity. The best time to collect seeds of *M. gagei* was found when the fruit was greenish brown which occurred in late December, the latest should not be later than when the fruit was brown *i.e.* early January.

4. Seed Processing and Longevity

The objective of fruit or seed processing is to achieve clean and, pure seeds of high physiological quality (germinability) which can be stored and easily handled during succeeding processes, such as pretreatment, transport and sowing. Processing includes a number of handling procedures, where applicability differs depending on fruit and seed types, condition of the fruits or seeds at collection and potential storage periods. Processing could be grouped into 7 procedures, namely, pre-cleaning, pre-curing, extraction, de-winging, cleaning, grading, and adjustment of moisture content (Schmidt, 2000).

After cleaning, both greenish-brown and brown winged seeds of *M. gagai* were processed by air-dry and sun-dry treatments for 1 week to adjust moisture content. The seeds were then stored in hessian bags under shade and shelter. Longevity of seeds was tested by germination testing at 1, 7, 15, 22, 30, 45, 60, and 90 days after collection. The germination percentage of each treatment was shown in Figure 15. The figure showed that greenish-brown fruit germinated significantly better in both processing treatments than brown fruit. Longevity of greenish-brown fruit was also significantly longer in both processing treatments than brown fruit. For both fruit colors, the air-dry method was significantly better than the sun-dry method. Sun drying the seeds significantly reduced both germination and longevity of seeds due to heat damage. Longevity of *M. gagei* seeds was shorter than 90 days. Seeds could be grouped to recalcitrant seeds (Robert, 1973). Direct sun drying for *M. gagai*

seeds therefore should be avoided because seeds with high moisture content or recalcitrant seeds were more prone to heat damage (Schmidt, 2000).

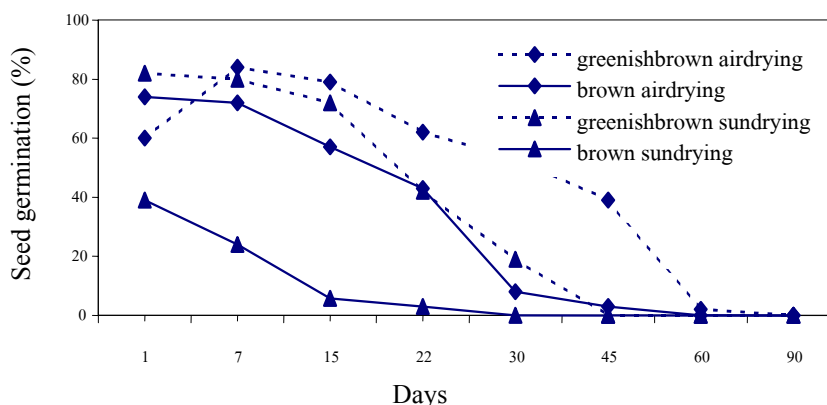


Figure 15 Storage of greenish-brown and brown fruits processed by air-dry and sun-dry treatments of *M. gagei*.

5. Seed Germination

Germination is the transition from a seed to a plant or a process that induces seed to grow again. It demarcates the transition from the seed being dependent on food sources from the mother plant to an independent plant capable of taking up nutrients and growing independently (Schmidt, 2000).

Seed germination rate of *M. gagei* in 3 different media was shown in Figure 16. The figure showed that seed germination started within 5 days in all tested media. At day 5, germinated seeds of about 7, 10 and 13 % emerged with 1 pair of cotyledon when sown in soil, coconut husk and sand, respectively. Mode of germination and seedling development was epigeal. The first appearance of seedling part was the loop of the elongated hypocotyl above the ground. As the hypocotyl straightens, the seed was lifted. The cotyledons normally separated from each other and become the first photosynthetic leaves. The germination rate increased rapidly 7 days later, up to 45, 47 and 74 % and reached the peak at day 9 up to 58, 65 and 81 % when sown in soil, coconut husk and sand, respectively. Some remaining seeds were slowly germinated

and finished within 13 days. Total germination was 60, 72 and 85 percent when sown in soil, coconut husk and sand, respectively. Statistical analysis showed that *M. gagei* seeds sown in sands germinated significantly better than those in coconut husk and soil. The latter two media were not significantly different.

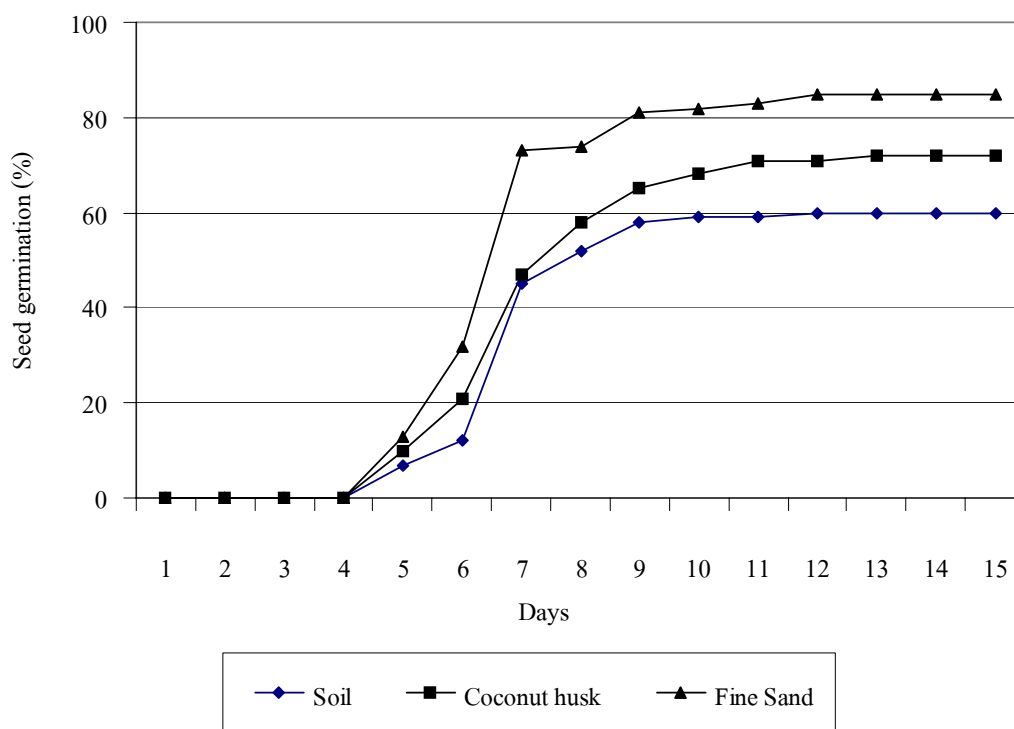


Figure 16 Germination rates of *M. gagei* seeds in 3 different media.

6. Seedling Growth

M. gagei seedling growth was rather slow compared to other species. Six month-old seedlings were too small to be transplanted to the field. Height of seedlings grown in 4 X 6 inch plastic bags were 18.53, 7.94 and 15.52 cm when planted in surface soil, coconut husk, and the mixer of soil and coconut husk, respectively. In 5 X 8 inch bags, seedling height were 17.34, 7.43 and 15.37 cm when planted in those media, respectively (Table 19).

Height of the 12-month seedlings planted in 4 X 6 inch plastic bags were 24.75, 11.72 and 20.16 cm when planted in surface soil, coconut husk, and the mixer of soil and coconut husk, respectively. In 5 X 8 inch bags, seedling height were 24.52, 10.03 and 21.14 cm when planted in surface soil, coconut husk, and the mixer of soil and coconut husk, respectively (Table 19). The highest of seedling height was planted in surface soil in plastic bags of 4 X 6 inches in size.

Table 19 Growth of *M. gagei* seedlings at 1-12 months old

| Age (month) | Height (cm) | | | | | |
|----------------|---------------------------|-----------------|--------------------------|---------------------------|-----------------|--------------------------|
| | Plastic bags 4 X 6 inches | | | Plastic bags 5 X 8 inches | | |
| | Surface Soil | Coconut husk | Coconut mixer of soil | Surface Soil | Coconut husk | Coconut mixer of soil |
| 1 | 3.64 | 2.39 | 2.61 | 3.24 | 2.68 | 2.80 |
| 2 | 5.38 | 3.28 | 4.22 | 5.23 | 3.38 | 4.19 |
| 3 | 7.81 | 4.09 | 5.49 | 7.55 | 4.56 | 5.94 |
| 4 | 11.63 | 5.38 | 9.06 | 10.57 | 6.00 | 9.17 |
| 5 | 14.57 | 6.88 | 12.03 | 13.12 | 6.77 | 12.33 |
| 6 | 18.53 | 7.94 | 15.52 | 17.34 | 7.43 | 15.37 |
| 7 | 21.22 | 9.78 | 17.25 | 19.90 | 8.11 | 17.24 |
| 8 | 22.55 | 9.97 | 18.88 | 21.22 | 8.41 | 18.52 |
| 9 | 23.98 | 10.72 | 19.53 | 23.00 | 8.83 | 20.21 |
| 10 | 24.26 | 11.13 | 19.76 | 23.36 | 9.15 | 20.60 |
| 11 | 24.69 | 11.46 | 19.94 | 24.17 | 9.59 | 21.07 |
| 12 | 24.75 | 11.72 | 20.16 | 24.52 | 10.03 | 21.14 |

Growth of *Mansonia gagei* in Plantation

1. Growth Characteristics

Tree growth refers to expanding in size, increasing of volume or tree biomass. Growth rate varies among tree species and in the same specie at different ages. Tree growth can be illustrated in form of relation equation between age and size, volume and weight. The relation will be sigmoid curve. The curve can be divided into 4 parts according to phases of growth as follows: 1) Exponential phase: slow growing; 2) Linear phase: rather steady growing; 3) Declining phase: growing decline; and 4) Steady state. Growth could be measured in terms of height, diameter, volume and dry weight (Puangchit, 2007). Growths of *M. gagei* were measured when the trees were 1-10 years old. *M. gagei* plantation was established in 1996 at Kuiburi Silvicultural Research Sub-station. Annual rainfall at planting site was averaged at 850 mm. Trees were planted at 2 X 2 m² spacing. Four 10 X 10 m² permanent plots were set up including 5 X 5 trees to be measured. Growth parameters to be measured were diameter at ground level, diameter at breast height and total height. Survival percentages were recorded from 1 year old up to 10 years old. Dead trees were replanted within the first year after planting.

1.1 Height growth

Average height of the planted *M. gagei* was estimated from the first year up to 10 years old. Data on height growth together with its annual increment were shown in Table 20. Height increments varied from 0.29 m/year to 1.09 m/year with the maximum of 1.09 m/year during year 8 to year 9. An average increment in height growth was found at 0.659 m/year.

Table 20 Height growth of *M. gagei* plantation planted at Kuiburi Silvicultural Research Sub-station

| Age (year) | Height (m) | Height increment (m/year) |
|------------|-------------|---------------------------|
| 1 | 0.66 ± 0.23 | |
| 2 | 0.95 ± 0.31 | 0.29 |
| 3 | 1.47 ± 0.49 | 0.52 |
| 4 | 2.23 ± 0.56 | 0.76 |
| 5 | 2.82 ± 0.66 | 0.59 |
| 6 | 3.56 ± 0.79 | 0.74 |
| 7 | 4.29 ± 0.88 | 0.73 |
| 8 | 4.96 ± 1.04 | 0.67 |
| 9 | 6.05 ± 1.08 | 1.09 |
| 10 | 6.59 ± 1.15 | 0.54 |
| Average | | 0.66 |

The increases of height according to ages after planting from Table 20 could be formulated a relationship between height and age. The gradual increasing slope of the graph indicated the continuing of height growth. Such relationship equation could be formulated as follows:

$$Ht=8.4825779/1+15.249081(\exp(-0.396372)(age))$$

$$R^2 = 0.9967$$

Where, Ht= height (m)

exp=exponential (2.71828)

age= age (years)

1.2 Diameter at ground level

The average diameter at ground level of *M. gagei* in plantation measured at 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 years after planting were 1.45, 2.46, 3.74, 4.41, 5.58, 6.73, 7.89, 9.06, 10.75 and 11.67 cm, respectively. The annual increment of diameter

at ground level were 1.01, 1.28, 0.67, 1.17, 1.15, 1.16, 1.17, 1.69 and 0.92 cm at 1st to 2nd, 2nd to 3rd, 3rd to 4th, 4th to 5th, 5th to 6th, 6th to 7th, 7th to 8th, 8th to 9th, and 9th to 10th year, respectively. The average annual increment of diameter at ground level was 1.17 cm/year. The highest increment of diameter at ground level was found during the 8th to 9th year equaled to 1.69 cm/year. The lowest increment of diameter at ground level found during the 3rd to 4th year was 0.67 cm/year (Table 21).

Data from Table 21 could be formulated the linear regression relationship between diameter at ground level and age. The slope of the graph indicated the continuous diameter growth at ground level. The relationship equation could be formulated in linear regression as follows:

$$D_0 = 22.687227(\exp^{(-\exp(1.0966985 - 0.15089809(\text{age})))})$$

$$R^2 = 0.9970$$

Where, D_0 = diameter growth at ground level (cm)

exp=exponential (2.71828)

age= age (years)

1.2 Diameter at breast height

The average diameter at 130 cm above ground level (DBH) of *M. gagei* in plantation measured at 3, 4, 5, 6, 7, 8, 9 and 10 years after plantation were 0.94, 1.32, 2.51, 3.64, 4.82, 5.98, 8.07 and 9.16 cm, respectively. The DBH annual increment were 0.38, 1.19, 1.13, 1.18, 1.16, 2.09 and 1.09 cm at 3rd to 4th, 4th to 5th, 5th to 6th, 6th to 7th, 7th to 8th, 8th to 9th, and 9th to 10th year, respectively. The average annual increment of DBH was 0.92 cm/year. The highest increment of DBH was found during the 8th to 9th year equivalent to 2.09 cm/year. The lowest increment of DBH occurred during the 3rd to 4th year was 0.38 cm/year (Table 21).

Table 21 Diameter growth of *M. gagei* planted at Kuiburi Silvicultural Research Sub-station

| Age (year) | Diameter at ground level | | Diameter at breast height | |
|------------|--------------------------|---------------------|---------------------------|---------------------|
| | Do (cm) | Increment (cm/year) | DBH(cm) | Increment (cm/year) |
| 1 | 1.45 ± 0.45 | | - | - |
| 2 | 2.46 ± 0.86 | 1.01 | - | - |
| 3 | 3.74 ± 1.53 | 1.28 | 0.94 ± 0.56 | - |
| 4 | 4.41 ± 1.74 | 0.67 | 1.32 ± 0.67 | 0.38 |
| 5 | 5.58 ± 1.98 | 1.17 | 2.51 ± 1.25 | 1.19 |
| 6 | 6.73 ± 2.75 | 1.15 | 3.64 ± 1.57 | 1.13 |
| 7 | 7.89 ± 2.30 | 1.16 | 4.82 ± 1.52 | 1.18 |
| 8 | 9.06 ± 2.48 | 1.17 | 5.98 ± 1.75 | 1.16 |
| 9 | 10.75 ± 2.63 | 1.69 | 8.07 ± 1.68 | 2.09 |
| 10 | 11.67 ± 2.16 | 0.92 | 9.16 ± 2.14 | 1.09 |
| Average | | 1.17 | | 0.92 |

The data from Table 21 could be illustrated as the relationship between diameter at breast height and age. The relationship equation could be formulated as follows:

$$\text{DBH} = 21.011181(\exp^{(-\exp(1.7450093-0.19437608(\text{age})))})$$

$$R^2 = 0.9960$$

Where, DBH = diameter at breast height (cm)

exp = exponential (2.71828)

age = age (years)

Based on the above formulated DBH equation, a sigmoid curve could be drawn (Figure 17). The slope of the graph indicated the continuing of diameter growth. Little slope during years 1-5, tree growth was classified as the exponential phase. Steep slope during years 5-10, tree growth was classified as linear phase.

From the curve, growth of the trees after 10 years could be predicted with $r = 0.998$. Tree growth in declining phase would occur during 15-20 years old, while the steady state would occur after 20 years. The estimated information could be used in silvicultural practice planning for *M. gagei*.

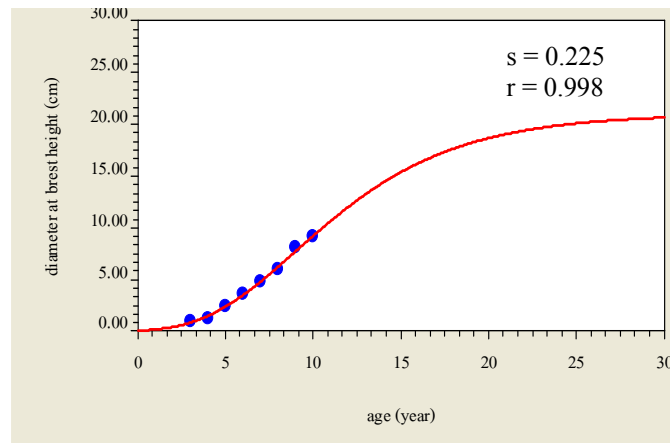


Figure 17 Diameter at breast height of *M. gagei* planted at Kuiburi Silvicultural Research Sub-station.

The Royal Forest Department classified forest trees into 5 categories according to their growth rates per year: 1) Very fast growing species when DBH increment exceed 5 cm per year, 2) Fast growing species when DBH increment between 1.5-5 cm per year; 3) Ordinary growing species when DBH between 0.8-1.5 cm per year; 4) Rather slow growing species when DBH between 0.3-0.8 cm per year; and 5) Slow growing species when DBH between < 0.3 cm per year.

Ten years old *M. gagei* in plantation at Kuiburi Silvicultural Research Sub-station with a DBH increment of 0.92 cm per year was, therefore, classified as ordinary growing group. Other important tree species in this category are teak and local pines. Utilization of tree in this group can be done when the trees are about 15-20 years old.

2. Biomass and Volume

The study on stem, branch, and leaf biomass as well as volume of *M. gagei* in plantation at Kuiburi Silvicultural Research Sub-station was carried out when the trees was 10 years old. The plantation density were 2,075 tree/ha (survival rate = 83%). The range of diameter at breast height was between 1.5-17.7 cm. Five trees were selected and harvested as sample represented DBH of 3.2, 5.4, 7.2, 10.8 and 12.3 cm. Data were calculated to biomass and volume. It was found that the relationship, in terms of allometric equation, DBH^2 , total height (Ht), stem biomass (Ws), branch biomass (Wb), leaf biomass (Wl) and total aboveground biomass (Wt) as well as stem volume (Vs) could be derived for the estimation of growth and yield of the planted *M. gagei*. The estimated formula were as follows:

$$\begin{array}{ll} W_s = 0.0531x^{0.894} & R^2 = 0.9600 \\ W_b = 0.0143x^{0.9785} & R^2 = 0.9411 \\ W_l = 0.0372x^{0.6386} & R^2 = 0.8721 \\ W_t = 0.0883x^{0.8883} & R^2 = 0.9522 \\ V = 0.001x^{0.7178} & R^2 = 0.9614 \end{array}$$

Where,

$$\begin{array}{l} W_s = \text{stem biomass (kg)} \\ W_b = \text{branch biomass (kg)} \\ W_l = \text{leaf biomass (kg)} \\ W_t = \text{total aboveground biomass (kg)} \\ V = \text{Volume (m}^3\text{)} \\ X = DBH^2 \text{ (cm)} \text{ Ht (m)} \end{array}$$

The equations of stem biomass, branch biomass, leaf biomass and total aboveground biomass were applied to growth and yield of *M. gagei* planted at 10 years old. The estimation was found that 10-year-old *M. gagei* had stem, branch, leaf, and total aboveground biomass were 12.06 kg, 5.53 kg, 1.72 kg and 19.31 kg per tree,

respectively. The biomass of *M. gagei* per hectare of those parts were 25.023 t, 11.473 t, 3.568 t and 40.065 t, respectively.

Table 22 Biomass and volume of *M. gagei* plantation, 3 to 10 years of age, at Kuiburi Silvicultural Research Sub station

| Age (year) | Height (m) | DBH (cm) | Biomass (t/ha) | | | | Volume (m ³ /ha) |
|---------------|---------------|-------------|----------------|--------|-------|--------|--------------------------------|
| | | | Stem | Branch | Leaf | Total | |
| 3 | 1.47 | 0.94 | 0.272 | 0.084 | 0.135 | 0.491 | 0.800 |
| 4 | 2.23 | 1.32 | 0.490 | 0.159 | 0.208 | 0.806 | 1.298 |
| 5 | 2.82 | 2.51 | 2.057 | 0.755 | 0.583 | 3.396 | 4.128 |
| 6 | 3.56 | 3.64 | 4.162 | 1.552 | 1.089 | 6.770 | 6.582 |
| 7 | 4.29 | 4.82 | 8.123 | 3.228 | 1.757 | 13.159 | 11.854 |
| 8 | 4.96 | 5.98 | 12.067 | 5.170 | 2.112 | 19.449 | 17.400 |
| 9 | 6.05 | 8.07 | 15.893 | 6.951 | 2.612 | 25.456 | 21.964 |
| 10 | 6.59 | 9.16 | 25.023 | 11.473 | 3.568 | 40.065 | 31.125 |

Based on the earlier formulated volume equation ($V=0.001x^{0.7878}$), volume of *M. gagei* in plantation at 3-10 years old could be estimated as follows: 0.800, 1.298, 4.128, 6.582, 11.854, 17.400, 21.964 and 31.125 m³/ha, respectively (Table 22).

The biomass and volume of *M. gagei* plantation at 9 years old were 25.456 t/ha and 21.964 m³/ha, respectively. It seemed lesser than biomass and volume of *Peterocarpus macrocarpus* plantation at the same ages of which the total aboveground biomass was 31.66 t/ha and volume of 50.90 m³/ha.

Wood density of *M. gagei* at 10 years old could be estimated by dividing stem biomass by volume which equal to 803.95 kg/m³. This value, however, slightly lower than wood density of this species reported by RFD (940 kg/m³). The differences may due to variation in wood sample age. Another reason was the fact that wood samples for this study were included the whole tree trunk and bark portion.

CONCLUSION AND RECOMMENDATIONS

Conclusions

Although few previous reports revealed some natural distributions of *M. gagei* on limestone hills in Nakorn Ratchasima province and along Tanawsee range from Ratchaburi to Surat Thani provinces, the most abundance was found in Prachuap Khiri Khan province. The current study was found that stand composition of the species varied among different sites. There were 28, 63 and 27 trees species in Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks, respectively. Densities of *M. gagei* trees, saplings and seedlings in Kuiburi National Park were 27, 156 and 105,500 plants per hectare, respectively. DBH class distribution was from 30-90 cm. The majority of tree height appeared in the class of 35-40 m. Densities of *M. gagei* trees, saplings and seedlings in Namtok Huai Yang National Park were 32, 63 and 10,500 plants per hectare, respectively. Smaller DBHs were found from 5 to 45 cm while the height was found similar to those of Kuiburi National Park. Densities of *M. gagei* trees and saplings in Khao Sam Roi Yot National Park were 35 and 94 plants per hectare, respectively; but there was no seedling in this study area. The smallest DBH were found in 5-25 cm class with height appeared at 0.5-5 m.

Concerning with species diversity index, Kuiburi National Park, Namtok Huai Yang and Khao Sam Roi Yot National Parks, had the figures of 1.486, 2.767 and 2.014, respectively. The most Richness index of the species was found at Namtok Huai Yang National Park, while the least was found at Khao Sam Roi Yot National Park. The importance value index of *M. gagei* at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were 28.523, 13.270 and 13.108, respectively. Crown cover of *M. gagei* was found in the upper layer in every site. Tree crown covers at Kuiburi, Namtok Huai Yang and Khao Sam Roi Yot National Parks were of 73.17 %, 76.44 % and 34.35 %, respectively. The natural existence of *M. gagei* in these national parks showed that this species tolerate various soil types. Soil pH, however, showed high impact on the growth of this species. Although there were very rich in soil nutrients, pH of over 6.5 might reduce nutrient availability to plants

leading to poor growth. Due to poor growth of the trees at Khao Sam Roi Yot National Park, both chemical and physical properties should be taken into account.

Regarding to reproductive phenology of *M. gagei*, its initiation was found when new buds rapidly sprout about 1-2 weeks after leaf shedding in March. Flower bud formation occurred in July and started opening in September. Every day there was 1 or 2 flowers opening in one inflorescence and up to 20 flowers in one twig. Flowers opened around 7 am with a peak receptive period during 7-9 am. The flowers then closed from 10 am to 5 pm and reopened from 5 to 7 pm. After fertilization, flowers became young fruits and developed to full-size fruits in October. About 45-60 days after fully developed, fruits would be mature in late December to early January. Reproductive period of *M. gagei* from flower bud sprout to mature fruit took about 6 months. Good seed year of *M. gagei* occurred once every 3 years. The number of inflorescences and flowers per twig varied with the averages of 13.6 and 60.1, respectively. There were only 25.79 % of flowers could develop to fruits. *M.gagei* flower morphology was arranged in a small inflorescence. Petiole was 0.5 – 1 cm long. Sepals united at the base with 5 free spatulate or oblanceolate white petals. Ten stamens alternated with staminodes, united into a slender gynandrophore, surrounding the ovary.

M. gagei fruit was classified as samara and considered as a seed. Seed weight with wing and de-winged had averages of 366.3 ± 92.8 and 272.9 ± 58.8 g per 1,000 seeds, respectively. Fruit color is a good indicator for seed maturity. Seed maturity occurred when color turned to greenish brown in late December; while green in early December was juvenile and brown in early January considered as over mature. The later two phenomena produced less germination percentages. Longevity of seeds could be prolonged if greenish-brown seeds were collected and processed by air-dry and stored under shade and shelter. The longevity, however, is no longer than 90 days. *M. gagei* seeds started to germinate within 5 days after sowing and reached its peak at day 9. Germination percentages could be as high as 80 % if sand was used as media. Mode of germination and seedling development was epigeal. *M. gagei* seedling growth was rather slow compared to other tropical species. The species

needed at least 18 months to reach the RFD standard of plantable size if they were raised in 4 X 6 inch plastic bags having surface soil as media.

At tenth year, the average height of *M. gagei* trees in plantation was 6.59 m, diameter at ground level was 11.67 cm and diameter at breast height was 9.16 cm. Annual increments in height, diameter at ground level and DBH were 0.659 m/year, 1.17 cm/yr and 0.92 cm/year, respectively. The estimation on stem, branch, leaf, and total aboveground biomass of 10-year-old *M. gagei* per hectare were 25.023 tons, 11.473 tons, 3.568 tons and 40.065 tons, respectively with the stem volume of 31.125 m³/ha.

Recommendations

Based on knowledges and experiences gained from the study on silviculture of *M. gagei*, some recommendations could be made as follows:

1. The variation in tree, sapling and seedling densities of *M. gagei* in the study sites suggested that some silvicultural practices should be carried out in order to increase survival rates and development of seedlings into saplings and trees in Kuiburi and Namtok Huai Yang National Parks. At Khao Sam Roi Yot National Park, on the other hand, reproductive induction might be managed to increase number of seedlings in the area. Low IVI of *M. gagei* at the study sites suggested that the species needed to be conserved at some aspects, such as, *in situ* or *ex situ* gene conservation.

2. Technical informations in reproductive phenological phenomena of *M. gagei* could be used for tree improvement plans in future.

3. Since seed longevity was no longer than 90 days, appropriate seed management should be seriously considered. Seed collection should be done during the late December right after the fruit color getting greenish brown, then, processed by air-dry and stored under shade and shelter. To prolong seed longevity study on

seed storage in various conditions including cold storage might be kept in consideration.

4. As a result of slow-growing seedlings compared to other tropical species, studies on different potting media and fertilizer application should be investigated.

5. In plantation, the trees grew relatively slow, therefore, proper plantation management and silvicultural practices, such as, tree improvement, nursery techniques, weeding, fertilization, thinning and pruning, should be carried out to promote growth and yields of the planted *Mansonia gagei*.

LITERATURE CITED

- Ashton, P.S., T.J. Givnish, and S. Appanah. 1988. Staggered flowering in the Dipterocarpaceae : New insights into floral induction and the evolution of most fruiting in the seasonal Tropics. **Am. Nat.** 132 : 44-66.
- Barbour, M.G., J.H. Burk, and W.D. Pitts. 1980. **Terrestrial Plant Ecology**. The Benjamin/Cummings Publishing Co., Inc., Menlo Park.
- Barrett, D.R. and J.E.D. Fox. 1994. Early growth of *Santalum album* in relation to shade. **Australian J. Bot.** 42: 83-93.
- Barton, L.V. 1982. Hastening the germination of southern pine seeds. **J. For.** 26 : 774-785.
- Bonner, F.T. 1984. New forests from better seeds : The rule of seed physiology. pp. 37-59. In M.L. Duryea and G.N. Brown (eds.). **Seedling Physiology and Reforestation Success**. London.
- Bonner, F.T., B.F. Melemore and J.P. Barnett. 1974. Presowing treatment of seed to seed germination. pp.126-135. In C.S. Schopmeyer (ed.). **Seeds of Woody Plants in the United States**. USDA. Agr. Handbook No. 450, Washington, D.C.
- Boonchaleo, H. 1986. **Effect of accelerated aging and osmoconditioning on germination of *Melia azedarach* Linn. Seeds**. M.S. Thesis, Kasetsart University. (In Thai Language).
- Brazier, J.D. 1977. The effect of forest practices on the quality of the harvested crop. **For.** 50: 50 -56.

- Briscoe, C. B. 1990. **Field Trails Manual for Multipurpose Tree Species**. MPTS Manual No 3. Winrock International Institute for Agricultural Development.
- Bunyavejchewin, S. 1983. Canopy structure of dry deciduous forest of Thailand. **Thai For. Bull.** 14 : 1-132.
- Capon, B. and W.V. Asdall .1967. Heat pre-treatment as a mean of increasing germination or desert annual seeds. **Ecol.** 48 : 305-306.
- Carl, C.M., Jr. 1983. Stratification of sugar maple seeds. **Tree Planters'Notes**. 34 : 25-27.
- Chanthawich, N. 1996. **Photos of Memory: An album to Commemorate the Cremation of H.M. the King's Mother**. Office of the Prime Minister, Bangkok. (In Thai Language).
- Coombe, B.G. 1976. The development of freshy fruits. **Rev. Plant. Physiol.** 27 : 207-228.
- Cattam, C. 1949. The phytosociology of an oak woods in south-western Wisconsin. **Ecol.** 30 : 271-287.
- Curtis, J.T. and R.P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. **Ecol.** 32: 476-498.
- Davis, T.A.W. and P.W. Richards. 1933. The vegetation of Moraballi Creek, British Guiana: An ecological study of a limited area of tropical rain forest, Part II. **Ecol.** 21: 350-384.
- Delouche, J.C. and C.C. Baskin. 1973. Accelerated aging technique for predicting the relative storability of seed lots. **Seed Sci. and Technol.** 1 : 427-452.

- Edwards, D.G.W. 1973. Effects of stratification on western hemlock germination. **Can. J. For. Res.** 3 : 522-527.
- Edwards, D.G.W. and B.S.P. Wang. 1995. A training guide for laboratory analysis of forest tree seeds. **Pacific Forestry Centre Canadian Forest Service Natural Resources Canada.** p. 64
- Etejer, E.O., M.O. Fawole and A. Sani. 1982. Studies on the seed germination of *Parkia clappertoniana* (*P. clappertoniana*). **Turrialba** 32 : 181-185.
- Forest and Land Resource Division. 1997. **Master Plan of Khao Sam Roi Yod National Park, Changwat Prachuap Khiri Khan, National Resource Conservation Bureau.** Royal Forest Department, Bangkok. (In Thai Language).
- Goldsmith, F.B. and C.M. Harrison. 1976. Description and analysis of vegetation. pp. 85-155. *In* S.B. Chapman (ed.) **Methods in Plant Ecology.** Blackwell Scientific Publications, Oxford.
- Grzywac, A.P. and J. Rosochaka. 1980. The colour of *Pinus sylvestris* L. seed and their susceptibility to damping-off. I. The colour and quality of seeds and fatly acids content of the seed coat. **European. J. For. Path.** 10 : 138-144.
- Hellum, A.K. and I. Dynock. 1986. Cold stratification for lodgepole pine seed. pp. 107-111. *In* **Proc. Conifer Tree Seed in the Inland Mountain West Symp.** USDA For. Serv. Gen. Tech. Rep. INT-203. Missoula.
- Hopper, G.M., D.W. Smith and D.J. Parrish. 1985. Germination and seedling growth of northern red oak : Effects of stratification and pericarp removal. **For. Sci.** 31 : 31-39.

- ISTA. 1996. International rules for seed testing. **Seed Sci. and Technol.** 24, Supplement, Rules.
- Kerr, W. B. 1970. **Maritime Provinces of British North America and the American.** Russell and Russell, New York.
- Kershaw, K.A. 1964. **Quantitative and Dynamic Ecology.** Arnold, London.
- Kershaw, K.A. and J.H.M. Looney. 1985. **Quantitative and Dynamic Plant Ecology.** Edward Arnold, London.
- Khin, M. L. 1995. **Myanmar in Beyond Timber : Social, Economic and Cultural Dimension of Non-wood Forest Products in Asia and the Pacific.** RAP publication 1995/13 Bangkok, FAO Regional Office for Asia and the Pacific.
- Khoo, K. C. 2004. **Forest Ecology Study.** Forestry Research Center, Faculty of Forestry Kasetsart University, Bangkok.
- Kozlowski, T.T. 1982. Water supply and tree growth. Part II. **Flooding For. Abst.** 43 : 145-161.
- Krugmen, S.L., W.I. Stein and D.M. Schmitt. 1974. Seed biology, pp. 5-33. *In* CS. Schopmeyer (ed.). **Seeds of Woody Plants in the United States.** USDA Agr. Handbook No. 450, Washington, D.C.
- Landis, T.D., R.W. Tinus, S.E. McDonald and J.P. Barnett. 1989. **Seedling Nutrition and Irrigation. Vol. 4 : The Container Tree Nursery Manual.** USDA Agr. Handbook No. 674. Washington, D.C.
- Liengsiri, C. 1987. **Effects of temperature on seed germination in *Pterocarpus macrocarpus* Kurz.** M.Sc. Thesis, University of Alberta, Edmonton.

- Ludwig, J.A. and J.F. Reynolds. 1988. **Statistical Ecology**. John Wiley & Sons Inc., Toronto.
- Mayer, A.M. and A. Poljakoff-Mayber. 1982. **The Germination of Seeds**. Pergamon Press Ltd., Oxford.
- McDonald, M.B., Jr. 1977. The influence of seed moisture on the accelerated aging seed vigor test. **J. Seed Technol.** 2 : 18-28.
- Meekaew, P. 2006. **Research Progress Report**. Silvicultural Research, Royal Forest Department, Bangkok. (In Thai Language).
- Meteorological Department. 2002. Climatological data for the year 1992-2001. **J. Trop. For. Sci.** :233-244.
- Mishra, N.C. 1991. Genetics and molecular biology of *Neurospora crassa*. **Adv. in Genet.** 29 : 1-62.
- Monsi, M. and T. Saeki. 1953. Uber den Lichtfaktor inden Pflanzengase llschaten and seine Bedeutung fur die Stoff production. **Jap. J. Bot.** 14 : 22-25.
- Mueller-Dombois, D. and H. Ellenberg. 1974. **Aims and Methods of Vegetation Ecology**. John Wiley & Son Inc., Toronto.
- Ogawa, H., K. Yoda. and T. Kira. 1965. Comparative ecological study on three main types of forest vegetation in Thailand. II Plant biomass. **Nature and Life in Southeast Asia.** 4 : 49-80.
- Ohsawa, M. 1984. Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji. **Vegetation.** 57 : 15-52.

- Owens, J.N., P. Sornsathapornkul, and S. Tangmitcharoen. 1991. **Studying Flowering and Seed Ontogeny in Tropical Forest Trees**. Centre for Forest Biology, University of Victoria, British Columbia.
- Owens, J.N. 1994. Constraints to seed production in tropical forest trees. pp. 40-51. **In Proc. Inter. Symp. on Genetic Conservation and Production of Tropical Forest Tree Seeds**. Chiangmai.
- Phengkklai, C. 1990. **Sterculiaceae**. Royal Forest Department, Bangkok.
- Pitel, J.A. 1980. Accelerated aging studies of seeds of Jack pine (*Pinus banksiana* Lamb.) and oak (*Quercus rubra* L.). pp. 40-54. **In** B.S.P. Wang and J.A. Pitel (eds.) **Proc. of Inter. Symp. on Forest Tree Seed Storage**. Petawawa National Forestry Institute, Chalk River.
- Pongboonrod, S. 1976. **Exotic Plants in Thailand**. Bangkok.(Mimeographed, Thai language).
- Puangchit, L. 2007. Growth and development of trees. pp.50-79. **In** L. Puangchit (ed.) **Silviculture : Foundation of Forest Planting**. Aksorn Siam Printing. Bangkok. (In Thai language).
- Qiang Ma. 1999. **Asia-Pacific Forestry Sector Outlook Study : Volume I – Socio-economic, Resources and Non-wood Products Statistics, Asia-Pacific Forestry towards 2010**. FAO Working Paper No APFSOS/WP/43. Bangkok.
- Resce, A.R. 1961. Effect of high-temperature pretreatment on the germination of oil palm seed. **Nature**. 189 : 74-75.
- Roberts, E.H. 1973. **Storage, Environment and the Control of Viability: Viability of Seed**. Syracuse Univ. Press, Syracuse.

- Sahunalu, P. and P. Dhanmanonda. 1995. Structure and dynamic of dry dipterocarp forest, Sakaerat, northeastern Thailand. pp. 165-494. *In* E.O. Box *et al.* (eds.) **Vegetation Science in Forestry**. Kluwer Academic Publisher, Amsterdam.
- Schmidt, L. 1999. **Glossary of Seed Biology and Technology**. Indochina Tree Seed Project, Indochina Central Forest Seed Company, DANIDA.
- Schmidt, L. 2000. **Guide to Handling of Tropical and Sub-tropical Forest Seed**. Danida Forest Seed Center, Humleback.
- Shannon, C.E. and W. Weaver. 1949. **The Mathematical Theory of Communication**. University of Illinois Press, Urbana.
- Sounthwick. C.H. 1976. **Ecology and the Quality of Our Environment**. Litton Educational Publishing Inc., New York.
- Smittinand, T. 1977. **Vegetation and Ground Cover of Thailand**. Faculty of Forestry, Kasetsart University, Bangkok.
- Suksomut, P. 1987. **Community dynamics of hill evergreen forest at Huay Nam Dung Watershed Station, Chaing Mai Province**. M.S. Thesis, Kasetsart University.
- Tanasescu, S. 1969. The colour of *Robinia* seed (In Romanian with English summary). **Padurilor**. 84 : 6-7.
- Thaiutsa, B. and L. Puangchit. 2007. Silvics and silviculture. pp. 1-15. *In* L. Puangchit (ed.) **Silviculture : Foundation of Forest Planting**. Aksorn Siam Printing. Bangkok. (In Thai language).
- Thompson, P.A. 1973. Geographical adaptation of seed. pp. 31-38. *In* W. Heydecker (ed.). **Seed Ecology**. Butterworths, London.

- Tiew, P., A. Puntumchai, U. Kokpol and W. Chavasiri. 2002. Coumarines from heartwoods of *Mansonia gagei* Drumm. **Phytochem.** 60: 773-776.
- Tiew, P., H. Takayama, M. Kitajima, N. Aimi, U. Kokpol and W. Chavisiri. 2003. A novel neolignan, mansoxetane, and two new sesquiterpens, mansonones R and S, from *Mansonia gagei*. **Tetrahedron Letters** 44: 6759-6761.
- Toumey, J.W. & C.L. Stevens. 1982. **The Testing of Coniferous Tree Seeds at Yale University 1906-1926.** Yale Univ. School For. Bull. 21.
- Visaratana, T. 1983. **Structural characteristics and canopy gap regeneration of dry evergreen forest at Sakaerat Environmental Station.** M.S. Thesis, Kasetsart University.
- Wachrinrat, C., P. Dhanmanonda, W. Eiadthong, B. Boonthawee, and P. Meekaew. 1999. **Structural characteristics of Yang stand in Pa Klang Ao, Changwat Prachuap Khiri Khan.** pp. 16-36. *In Proc. on Dipterocarpus alatus Roxb. and Dipterocarpaceae Vol.2.* Kasetsart University, Bangkok.

CIRRICULUMVITAE

NAME : Mr. Kongsak Meekaew

BIRTH DATE : June 25, 1962

BIRTH PLACE : Phangnga, Thailand

| EDUCATION | : <u>YEAR</u> | <u>INSTITUTE</u> | <u>DEGREE/DIPLOMA</u> |
|------------------|----------------------|-------------------------|------------------------------|
| | 1985 | Kasetsart Univ. | B. Sc. (Forestry) |
| | 1992 | Kasetsart Univ. | M. S. (Forestry) |

POSITION/TITLE : Silvicultural Research Officer

WORK PLACE : Royal Forest Department

SCHOLARSHIP/AWARDS : -