THE REPRODUCTIVE ECOLOGY OF TREES IN DRY DIPTEROCARP FOREST AT NONG RAWIANG, NAKHON RATCHASIMA

Mr. Surasak Ratree

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environmental Biology
Suranaree University of Technology
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นิเวศวิทยาการสืบพันธุ์ของไม้ยืนต้นในป่าเต็งรัง
ที่หนองระเวียง นครราชสีมา

นายสุรศักดิ์ ราตรี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

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การศึกษาดำเนินการระหว่างปี 2543–2545 โดยมีวัตถุประสงค์เพื่อทำบัญชีรายชื่อพรรณไม้ ศึกษาพฤติกรรมการออกดอก ความสัมพันธ์ของการออกดอกกับสภาพแวดล้อมและพาหะถ่ายเรณู ศึกษาคุณภาพเรณู ผลผลิตเมล็ด การแพร่กระจายของเมล็ด คุณภาพเมล็ดพันธุ์ และรวบรวมข้อมูลทางสัณฐานวิทยาของผลและเมล็ด

สำรวจพบไม้ยืนต้น 38 ชนิดใน 33 สกุล และ 22 วงศ์ มีค่าดัชนีความหลากชนิดของพรรณไม้เท่ากับ 2.09 มีพันธุ์ไม้เด่นในพื้นที่ 4 ชนิดได้แก่ รัง แดง คำรอก และมะค่าแต้ ตามลำดับ ปัจจัยที่มีผลต่อการออกดอกของพืชมากที่สุดคือ ความเข้มแสงและการคายระเหย แมลงที่สำคัญในการถ่ายละอองเรณูและผสมเกสรของพันธุ์ไม้เด่นคือ แมลงภู่และชันโรง เรณูของพันธุ์ไม้เด่นทั้ง 4 ชนิดมีความงอกต่ำกว่า 32 % เมล็ดพันธุ์รัง แดง และมะค่าแต้ มีความงอกมากกว่า 80 % ยกเว้นคำรอกมีความงอกเพียง 16.25 % ผลแก่รัง สามารถแพร่กระจายด้วยลมได้ไกลกว่า 30 เมตร

สาขาวิชาชีววิทยา ลายมือชื่อนักศึกษา ____________

ปีการศึกษา 2546 ลายมือชื่ออาจารย์ที่ปรึกษา ____________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ____________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ____________

SURASAK RATREE : THE REPRODUCTIVE ECOLOGY OF TREES IN DRY DIPTEROCARP FOREST AT NONG RAWIANG, NAKHON RATCHASIMA. THESIS ADVISOR : ASSOC. PROF. SOMPONG THAMMATHAWORN Ph.D. 371 PP. ISBN 974-533-275-5

DRY DIPTEROCARP FOREST, FLOWER, POLLEN, FRUIT, SEED

The study was carried out during the year 2000 to 2002. The objectives of the research were to make a plant species list, to observe flowering phenomena and pollinators, to test pollen efficiency, to study seed production, seed dispersal, seed quality and to collect database of fruits and seeds morphology.

The trees of this forest comprised 38 species, 33 genera and 22 families. The value of Shannon-Wiener index of diversity was 2.09. *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus* and *Sindora siamensis* are the 4 dominant tree species, respectively. The light intensity and evaporation were the most effective factors affecting the flowering. *Xylocopa* sp. and *Trigona apicalis* were the most frequent dominant flower pollinators. The pollen germination of 4 dominant tree species was less than 32 %. *Sh. siamensis, X. xylocarpa* and *Si. siamensis* had seed germination more than 80 %, except *E. tomentosus* had 16.25 %. The dispersal radius of mature fruit of *Sh. siamensis* was longer than 30 meters.

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Surasak Ratree

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CHAPTER I

INTRODUCTION

1.1 General introduction

Dry dipterocarp forest (DDF) is an important ecosystem which has habitat diversity, species diversity and genetic diversity. These properties promote human use such as medicine and food supply, timbers, and natural equilibrium. It is a kind of tropical forest that occurs in Southeast Asia which includes Thailand, Vietnam, Lao, Cambodia, Mynmar, and Northeastern region of India (อัจฉรา ธรรมถาวร, 2530).

As for Thailand a survey in 1982 found that DDF area constituted about 31.25 % of the total country forest area, with a distribution in various regions except Southern region (กรมป่าไม้, 2542). DDF is a kind of important forest in Thailand because there are many valuable timbers and natural resources. These lead to economics and life style of rural communities. However, the rate of deforestation and forest fragmentation in Thailand tends to become higher every year. According to an official estimate, current forests cover is 26 % of the country, down from 53 % in 1961 (Bhumibhamon, 1986). DDF areas also decrease rapidly especially in the plains, due to invading, occupying forest, or illegal logging of local people. As a result, most of DDF of the country has been degraded. So it is necessary to accelerate reforestation.

However, the main problem for reforestation is lack of seeds for producing seedlings because factors of flowering and pollination of parent trees in DDF are high variable. In some years there is flowering, in other years there is not any flower. Sometimes parent trees have fallen flowers before fertilization, less fruit sets or incomplete fruiting. These bring about variability in numbers of seed production (Owens, Sornsathapornkul and Tangmitcharoen, 1991). Many times it was found that forest tree seeds have the problems about seed quality such as low percentage of seed germination. Some seed species cannot keep seed viability for a long time. Some tree species produce many fruit sets for reproduction in each year, but very few saplings survive. As a result, they become problems of the regeneration. Consequently studying on reproductive ecology of trees in DDF is necessary.

Tree reproductive study encompasses pollination, seed production and seed predation, as well as fruit dispersal and post-dispersal establishment. This field of research is critical to the successful management of forest habitats, either as conservation area or as sustainable sources of forest products (Hartshorn, 1995). Thus, the current studies will be described on six topics which are (1) plant community description and analysis, (2) flowering phenomena and pollinator observation, (3) pollen efficiency, (4) seed production and seed dispersal, (5) seed quality and (6) morphological database of fruits and seeds.

1.2 Plant community description and analysis

In nature, different kinds of organisms grow in association with each other. A group of several plants species living together with mutual tolerance and beneficial interactions in a natural area is known as a community. In a community, organisms share the same habitat growing in an uniform environment. Most communities include mixtures of members from most kingdoms.

A community necessarily implies some form of organization. All communities exhibit some form of spatial arrangement both vertically and horizontally, and are influenced by the growth form and structure of vegetation, from trees to mosses. Spatial distribution of species is influenced by variations in environmental conditions such as soil, moisture, light, and nutrients and by relationships among the species. For this reason species composition or membership varies greatly among communi - ties (Smith, 1992). For terrestrial communities, the form and structure can be characterized by the nature of the vegetation.

Variation of structural elements within and between stands of forest is due to differences in floristic, architectural features and biochemical structure. These differences are associated with difference of site condition, dynamics of regeneration, growth and succession and of biotic impacts (Brunig, 1970).

In order to understand plant community certainly, it will be interpreted as the detail of plants species involve structure and composition. The result can be applied for the prediction of environmental impacts, for the development of environmental conservation and management programmes.

The purposes of this study are to analyse soil properties, to give the ecology data on the community structure, to investigate dominant tree species and to describe tree species of DDF.

1.3 Flowering phenomena and pollinator observation

Flowers are the reproductive structure that serve to attract pollinators, which help pollination, and therefore fertilization for seeds. So flower is an important function of vegetation regeneration and needs to be closely studied. One of the most frequent causes of reduced seed production is the failure of trees to flower. Almost all forest trees show variation in flowering periodicity (Owens and Blake, 1985). For example, the dipterocarp species are the kinds of dominant tree species in DDF which have problems in regeneration such as the irregular time of flowering, fruiting and the short viability period of seed (Cacanindin, 1983).

There are wide differences of flowering in each kind of vegetation depending on plant competition, plant species, flowering periodicity and relative environmental factors such as light, temperature, moisture and soil fertility. A study of flower morphology is expected to understand the reproductive mechanism for instance, compatibility patterns and pollination mechanism of the vegetation. Flower morphological characteristics could be used to indicate the types and characteristics of pollinators (Siripatanadilok and Likitrammanit, 1991).

A basic understanding of flowering and pollination is essential background information for reproductive and breeding system. Previous studies mostly emphasized on economic crops and few studies on forest trees.

The objectives of this study have been to determine which environmental factors might be responsible for triggering flowering, to understand the reproductive mechanism, to indicate the types of pollinators and observe the peak visitation period. All this in order to provide guide lines for management forest tree seed production.

1.4 Pollen efficiency

In seed plants, pollen grains are the male partners in sexual reproduction and develop in anthers. Pollen grains are transferred to the stigma by biotic or abiotic agents. After pollination, pollen grains issue pollen tubes, which grow through the pistil and discharge the male gametes in the vicinity of the egg cell for fertilization and eventual development of embryo and seed. Pollen biology thus encompasses pollen production, its transfer to the stigma, and details of pollen-pistil interaction leading to fertilization and seed set. (Knox, Williams and Dumas, 1986).

Pollen development is not always normal and not all pollen is viable. Pollen development is very sensitive to temperature. Abnormalities, abortion and inviability are common in species grown outside their natural range. Pollen samples will usually contain some abnormal, dead, or nonvigorous pollen. Pollen can appear normal externally but be dead or lack vigor and therefore not function in fertilization. In other cases, dead pollen will be obvious because it is small, abnormal in shape, or the grains may have failed to separate (Philipson, Owens and O'Donnell, 1990). In order to know the quality of pollen produced, tests for pollen germination have been studied in this topic.

1.5 Seed production and seed dispersal

The constancy of plant community in the nature depends on the reproductive success of new regeneration beneath the parent plant or within the gap of the canopy which to be a result of seed production, seed dispersal, seed germination and seedling establishment.

Seed production in forest trees is the culmination of a series of developmental events, usually occurring over a long time. It begins with floral initiation and is followed by floral development, which may be interrupted by a dormant period, Pollination then occurs, which is followed by fertilization and embryo, seed and fruit development. Many things can go wrong during development. Indeed, the longer the period of development, the more likely it is that something will occur to reduce the amount of seed, or fruit produced. To understand and possibly regulate seed production, should have knowledge of the entire reproductive process (Owens, Sornsathapornkul and Tangmitcharoen, 1991).

There is thus an immense variety among angiosperm fruits. Much of it is related to the need for seed dispersal. Survival and growth of young seedlings under the parent tree is often difficult, because of lack of light and intense root competition. Dispersal over a wide area can ensure that some seeds find conditions suitable for germination and survival, even though the vast majority will perish from the effects of harsh site conditions, competition or destruction by animals or disease (Willan, 1985). To understand dispersal mechanisms should have knowledge of seed dispersal ability.

The aims of this topic are to study seed production, reproductive success, seed dispersal and seed predator of dominant tree species, to study climate factors affecting seed germination at natural site, and to observe growth rate and development of dominant tree species seedlings.

1.6 Seed quality

Reforestation programmes depend on the successful establishment of plantations. The quality and vigor of seedlings used for planting are among the most important factors in determining the success of plantation establishment. The loss of substantial areas of forest in Thailand has reduced the availability of high quality parent trees from which seed can be collected for reforestation. It is essential, therefore, that seed collection should be conducted in the most efficient and effective manner possible in order to provide seed of the highest quality for vital reforestation.

Seed quality is tested to evaluate the germination potential of seedlots; calculate sowing rates; and detect dormancy, fungal infections, and other weaknesses of the seedlots. The physical characteristics of seeds which are tested include purity, weight, and moisture content; physiological characteristics are measured by viability or germination tests. In seed quality evaluation, it is important to follow the prescriptions of the international rules for seed testing because they are based on sound biological principles and statistics (Wang, 1990). In response to know the quality of tree seeds in DDF, tests for seed germination and seed vigor have been studied in this topic.

1.7 Morphological database of fruits and seeds

Trees are the main important structure of the forest. Without trees, the forest can not be exuberate, it is only a degraded forest or savanna. One problem of some kinds of trees is they are often limited by inadequate seed dispersal. Uncontrolled hunting has eliminated many large bird and mammal species from the forest. Many kinds of trees which depended on large animals for seed dispersal may be unable to disperse their seeds into gaps, even though some of them may be able to grow under gap conditions. Fruit and seed characteristics (e.g. color, type, dimensions, wet and dry mass etc.) are being entered into a database that will act as an identification guide for the tree species which may be affected with seed dispersal. Furthermore, since most floras identify plant species on the basis of flower characteristics, fruit and seed morphology also can be used at the beginning of identification before further distinguish in laboratory. Database output of this kind can have considerable value for research in forest conservation and related field.

The objectives of this study are to have fruits and seeds morphological database for tree species identification, to reveal relationships between seed/fruit morphology and phenology in Nong Rawiang DDF.

1.8 Research objectives

1. To study and survey tree species diversity in Nong Rawiang DDF.

2. To observe flowering phenomena and pollinators, and to investigate environmental factors affecting the tree flowering.

3. To test pollen efficiency and seed quality of selected tree species.

4. To study seed production and seed dispersal of dominant tree species.

5. To collect database of fruits and seeds morphology.

1.9 Study site and period of study

Field study and laboratory experiment were carried out during 2000 to 2002 in;

1. DDF at Nong Rawiang, Muang District, Nakhon Ratchasima province.

2. Farm Mechanics division, Rajamangala Institute of Technology, Northeastern campus, Nakhon Ratchasima.

3. The Center for Scientific and Technology Equipment, Suranaree University of Technology.

4. Silviculture Research Division, Forest Research Office, Royal Forest Department.

1.10 Expected results

1. To know tree species diversity in dry dipterocarp forest.

2. To know the method for management forest tree seed production.

3. To understand and assist natural regeneration processes in degraded DDF.

4. To gain morphological database of tree fruits and seeds for identification of tree species.

CHAPTER II

LITERATURE REVIEW

2.1 General introduction

2.1.1 The forest types of Thailand

Thailand is located in Southeast Asia with an area of 513,115 km^2. At present, it is estimated that the 33.96 % of the land is under forest cover, including forest plantations (กรมป่าไม้, 2543). The country lies within two major biogeographical regions viz. the Indo-Himalayan Chinese region (including the Eastern Himalaya, Myanmar, south China, Indo-China) and the Malesian region. Thus, Thailand is a crossroad of the two major floristic elements (The Forest Herbarium, 2002). WCMC (1994) and RAFI (1996) classified Thailand as one of the countries with high levels of 'hot spots' in biological diversity due to the richness of vascular plant species.

The forests of Thailand can be broadly divided into two categories: deciduous forest consist of forest trees which shed their leaves during the dry season and they will produce new leaves together when rainy season comes, it distributes in dry climate area that has certain long-continuous period of dry season; evergreen forest that most of plants do not shed their leaves together but they will gradually fall through out the year and produce new leaves instantly, so their crowns always look evergreen (Maxwell, 2001).

Werner and Santisuk (1993) distinguish deciduous forests into three categories: dry deciduous dipterocarp, mixed deciduous, and pine-deciduous dipterocarp forests. Ashton (1990) recognizes three basic forest types for Thailand which are seasonal evergreen-dipterocarp (dry evergreen), dry deciduous (dipterocarp), and moist deciduous forest. IUCN (1986) described vegetation types in Thailand into the following categories : tropical lowland evergreen rain forest once covered much of central and southern Thailand, but is now reduced to fragments in the peninsular Thailand; seasonal rain forest or dry evergreen forest or semi-evergreen forest dominated by Dipterocarpaceae in central and northern Thailand below 1,000 m; lower montane forest or hill evergreen forest with oak species above 700 m, much disturb ed by shifting cultivation; deciduous dry dipterocarp forest and mixed deciduous forest with teak and non-teak are the most extensive forest types; lower montane pine forest in the north and northeast; mangrove and beach forests extensive on the west coast and Chao Phraya delta; and fresh water swamp forest which is rather irregular in the central northeastern and southern regions.

However, อุทิศ กุฎอินทร์ (2541) described forest types of Thailand base on Smitinand (1977), where evergreen and deciduous forests are distinguished. Evergreen forests include mangrove forest, beach forest, swamp forest, hill evergreen forest, coniferous or pine forest, dry evergreen forest and tropical rain forest which divides into lower tropical rain forest and upper tropical rain forest. Deciduous forests consist of savanna, tropical grassland, deciduous dipterocarp forest and mixed deciduous forest which are further divided into three categories, viz. moist upper mixed deciduous forest, dry upper mixed deciduous forest and lower mixed deciduous forest.

2.1.2 Distribution of dry dipterocarp forest (DDF)

A survey in 1982 found that DDF of Thailand has an area of 48,930 km^2 or about 31.25 % of the total country forest area. Its distribution is in the Northern, Northeastern, Central, and Eastern region about 34,318, 13,819, 540, and 253 km^2, respectively. In the Northeastern region, especially, DDF occurs and covers an area 53.38 % of the total region forest area (กรมป่าไม้, 2542).

A characteristic of DDF is its low forest density. It is mostly constituted by medium and small trees, and fewer understory species and vines. The ground forest usually is covered with *Vietnamosasa pusilla* and *Cycas siamensis*. Herbs did not develop on the forest floor, except for scattered fired-tolerant cycad, which is a characteristic type of floor vegetation in DDF of Thailand. In general, grasses will be dried and desiccated during the dry season. Dead grasses and litter are regularly swept by ground fire in the dry season, which plays an important role in the maintenance of this forest type (สมนึก ผ่องอำไพ, 2518). DDF can distribute well on areas which have average rainfall 1,000-2,000 mm/year, usually growing on sandy or laterite or gravelly soil (Nalumphun, Santisuk and Smitinand, 1969). Khemnark, Wacharakitti, Aksornkoae and Kaewlaiad (1972) found that DDF is a plant community that is controlled by soil factors, seasonal changes, and microclimate.

Sukwong (1982) described DDF, and it is a forest with a wide distribution in various regions of Thailand except in the Southern region. It is a low density forest, where tree species of the Dipterocarpaceae family are the most abundant. It is usually found on laterite soil, hill or rocky mount. Bunyavejchewin (1983) reported that the largest DDF area in Thailand is found on the plateau and hills at about 150-1,000 m elevation. Climate conditions of DDF have a dry period of 5-6 months, average rainfall 1,000-1,500 mm per year, and relative humidity 60-80 %. It usually favors sandy and laterite soil. Soil fertility is lower than in another forest types.

2.1.3 Deforestation in Thailand

Thailand's rapidly expanding economy and over population has placed immense pressure on its remaining natural resources. Deforestation remains the most serious threat to biodiversity throughout Thailand, despite a ban on commercial logging since 1989. It also plays a significant role in exacerbating rural poverty and degrading watersheds. The official estimate of current forest cover in 1993 is 134,910 km^2 or 26.02 % of the country, down from 53.33, 43.21, 38.67 and 34.15 % in 1961, 1973, 1976 and 1978, respectively (Bhumibhamon, 1986, Royal Forest Department, 1993). However, unofficial estimates put Thailand's natural forest cover at less than 20 % (Leungaramsri and Rajesh, 1992). For Northeastern of Thailand, estimation of current forest cover in 1993 is 12.72 % of the region, down from 41.99, 30.01, 18.49 and 15.33 % in 1961, 1973, 1978 and 1982, respectively (Sono, 1982, Royal Forest Department, 1993).

Fifty five to 65 % of forest has been cleared for permanent and shifting agriculture and tree plantations, often following logging (IUCN, 1986). Between 1981-1990 the annual deforestation rate was 3.3 %, the highest rate in Southeast Asia. After the logging ban, the deforestation rate dropped by an estimated 84 % to about 40,000 hectares per year. Illegal logging remains a serious cause of deforestation, although clearance of forest for agriculture, establishment of fast-growing tree plantation, tourism and infrastructure development are also significant causes (Leungaramsri and Rajesh, 1992).

2.2 Plant community description and analysis

2.2.1 Plant community

An ecological community is a dynamic collection of species populations occurring together in space and time within some common environment, they are integrated or interacted so as to influence other component members. Communities are defined either by the habitat or by the dominant life-forms and occupy a variety of scales (Jones, 1997). The composition of any community is determined in part by the species that happen to be distributed on the area and can survive its environmental conditions (Smith, 1992).

2.2.1.1 Characters used in community structure

Sharma (1979) described the various characters used in community structure. These are broadly classified into two major categories :

(1) Analytical characters. There are two types consist of :

1.1 Quantitative characters. These include such characters as frequency, abundance, density, cover and basal area and dominance.

1.2. Qualitative characters. These include physiognomy, phenology, vitality, stratification, abundance, sociability and life-form.

(2) Synthetic characters. For comparing the vegetation of different areas, community comparison needs the calculation of their synthetic characters. These are determined in terms of : presence and constancy, fidelity, importance value index, interspecific association and association index, index of similarity, dominance index, species diversity and diversity index.

Forests may be described qualitatively or in quantitative terms. Qualitative descriptions have been concerned mainly with the stratification or the patterning of trees in the vertical and horizontal dimension. Floristic descriptions of the forest can be included here (Golley, 1983).

In quantitative term, frequency is the number of sampling units in which a particular species occurs. Density represents the numerical strength of a species in the community. Abundance is the number of individuals of any species per sampling unit of occurrence. Dominance is the index that shows each species performance in community. It accepts to measure in 3 values that is cover, basal area and biomass (Sharma, 1979).

These parameters may not be expressed generally in every aspect of plant community characters. For example density mentions only number of species but cannot image for tree size. Dominance relates with tree size but does not relate with distribution. Frequency indicates only distribution. Although many species have the frequency of 100 %. However, it does not mean that these species distribute throughout the forest, since the sampling sites are selected for only those species. Using individual parameter, it does not give correct idea. There has been proposed the idea of the importance value index (IVI). IVI of a species in the community gives the idea of its relative importance. Values of relative density, relative frequency and relative dominance are obtained and added for IVI. The high IVI species indicate that these species perform better than low IVI species in the community (Curtis, 1959). Kimmins (1987) suggested that the community with few species will have high relative IVI, whereas the community which consist of many species will normally have low values.

Features of tree architecture relevant to the theme are leaf anatomy, shape, color, orientation, crown architecture, the ratios of tree height/stem diameter, size of live crown to tree height and stem diameter (Brunig, 1970). The diameter and basal area of a tree stem at DBH are easy to measure and basal area is a convenient indicator of a tree's share in the phytomass of the stand and, more reliably, of its contribution to stand productivity. The specific relationship between basal area and volume or phytomass of trees is ideally straight linear (Ovington, 1965).

Species diversity, simply defined, is the number of species in a community, the greater the number, the greater the diversity of species (Smith, 1992). Ecologists try to propose several indexes for measure species diversity. Each index has both distinctive and weak point. The interest indexes are index of Simpson (Simpson, 1949), index of Shannon-Wiener (Shannon and Weaver, 1949) and Fisher's index (Fisher, Corbet and Williams, 1943). The Shannon index of diversity is only one of a number of diversity indexes. Based on information theory, it measures the degree of uncertainty. If diversity is low, then the certainty of picking a particular species at random is high. If diversity is high, then it is difficult to predict the identity of a randomly picked individual. High diversity means high uncertainty (Smith, 1992).

Shannon-Wiener function should use data by random which collect from large community, it connects with species number and species evenness (อุทิศ กุฏอินทร์, 2541). Species richness and species evenness are two parameters that are useful in measuring species diversity. A community that contains a few individuals of many species will have a higher diversity than a community containing the same number of individuals but with most of them confined to a few species (Smith, 1992). Huebert (1971) emphasized that a comparative study of species diversity between communi-ties will use equal sampling area.

2.2.1.2 Methods of study of communities

Sharma (1979) described various methods of study of plant communities. These are broadly grouped into three major categories :

(1) Floristic methods. The flora is studied by listing various genera and species present in the community. These are rather obsolete methods.

(2) Physiognomic methods. The various species of the community are studied chiefly in terms of their life-forms, general stature, spread etc. This method has two parts : record of different life-forms and biological spectrum.

(3) Phytosociological methods. This method provides detailed information on the growth, structure, composition, species diversity, trends of succession and other characteristics of the community. On the basis of the nature of sampling units, there are three popular methods of study of communities :

3.1 Quadrat method, where the definite area is the sampling unit, and it is taken in the form of a square, a rectangle, or a circle. Study of community by quadrat method involved three steps:

1. To determine the minimum size of quadrat by Species-Area-Curve
2. To determine the minimum number of quadrats to be laid down.
3. Record of the species : Their listing and counting of the individuals of each species. After the record of various species, the values of frequency, density, and abundance are determined for each species of the community.

3.2 Transect method. A transect is a sampling strip extending across a stand or several stands of vegetation where a line is the sampling unit.

3.3 Point method, where the sampling unit is a point.

2.2.2 Structural characteristics of dry dipterocarp forest

2.2.2.1 Type of dry dipterocarp forest

Ogawa, Yoda and Kira (1961) divided DDF into 3 community types which are

(1) *Shorea obtusa-S. siamensis* community type is the driest forest that distributes in a hillside. Mostly soil is initiate from sandstone, granite, gneiss or basalt. It is usually found on laterite soil. *S. obtusa* and *S. siamensis* are the dominant species. Ground cover generally distributes with grass and *Cycas siamensis*. In more arid zones, there are *Zyzyphus* and *Cratoxylon*.

(2) *Dipterocarpus tuberculatus-D. obtusifolius* community type distributes in low land level, rather plain and at 700 m level. It usually grows on sandy loam, deep soil and there is not lateritic characteristics. *D. tuberculatus* and *D. obtusifolius* are dominant species. If general conditions are more moist, this forest will have higher tree species numbers.

(3) Mixed dry dipterocarp community type usually has more moisture and grows on sandy clay loam as in a valley. There is not dominant species in this forest. It is mixed with *D. tuberculatus*, *D. obtusifolius*, *S. obtusa* and *S. siamensis*.

Sukwong (1974) classified 4 community types of DDF by addition 1 community type from Ogawa, Yoda and Kira (1961), that is Pine dipterocarp. This forest occurs on mountain ridges from sea level above 750-1,100 m, but sometimes this forest can be found from 100-400 m near low plain land. *Pinus merkusii* is the dominant species and mixed with *D. tuberculatus*, *D. obtusifolius*, *S. obtusa*, *S. siamensis* and *Quercus spp.* William (1965) reported that there are 2 sub-types of DDF comprising Deciduous dipterocarp forest which occurs in deep soil and has soil moisture content enough in growth season, and Dry dipterocarp forest which distributes in shallow soil. Ogawa et al. (1965a) suggested that DDF in Northern region of Thailand was Savana forest.

Kutintara (1975) described DDF at Hod district, Chiangmai into 6 community types consisting of *Shorea obtusa-S. siamensis, Dipterocarpus tuberculatus-S. obtusa, D. tuberculatus-Pinus merkusii, D. tuberculatus-D. obtusifolius, D. obtusifo lius-S. obtusa* and *D. obtusifolius-P. merkusii* community type. Poulwongsa (1975) divided 4 community types of DDF at Ngao district, Lampang base on dominant species including *S. siamensis, D. tuberculatus, D. obtusifolius* and *Pinus merkusii* community type. Wacharakitti et al. (1979) mentioned DDF at Nam Pong basin of Northeastern region into 2 categories : DDF medium-high stem type, and DDF scrub type.

Bunyavejchewin (1983) classified DDF from 52 stands throughout the country into 5 community types as follows :

(1) *Pentacme suavis* community type :

1.1 *P. suavis* xeric sub-community type,

1.2 *P. suavis* mesic sub-community type

(2) *Shorea obtusa* community type :

2.1 *S. obtusa* xeric sub-community type,

2.2 *S. obtusa* mesic sub-community type

(3) *Dipterocarpus obtusifolius-Shorea obtusa* community type

(4) *Dipterocarpus tuberculatus* community type

(5) Pine-Dipterocarpus community type

5.1 *Dipterocarpus obtusifoliu-Pinus merkusii* sub-community type

5.2 *Pinus merkusii-Dipterocarpus tuberculatus* sub-community type

5.3 *Dipterocarpus tuberculatus-Pinus kesiya* sub-community type

5.4 *Dipterocarpus obtusifolius-Shorea obtusa-Pinus merkusii* sub-commu nity type

2.2.2.2 Quantitative characters of dry dipterocarp forest

A study on species diversity in Huay Tak aboretum, Ngao district, Lampang shown that percentage of basal area was 0.30 with DBH > 4.5 cm. The most important tree species was determined by IVI which was *Dipterocarpus tuberculatus* with relative frequency, density, dominance and IVI of 15.45, 24.20, 45.40 and 28.35 %, respectively (ศิลป์ชัย พิพิธวิทยา, 2539).

Investigation on the forest growth cycle in DDF at Sakaerat, Nakhon Ratchasima found that the mean basal area was 14.42 m^2/ha with DBH larger than 4.5 cm. The dominant tree species was *Shorea floribunda* with relative frequency, density, dominance and IVI of 12.72, 14.44, 18.49 and 45.65 %, respectively. The vertical arrangement of trees in the stand shown 2 layers including top layer and lower layer (Dhammanonda, 1992).

The analysis of community structure of DDF at Hod district, Chiangmai indicated that the species-area curves of tree species was 40 x 40 m of quadrat size in 11 plots of minimal number of quadrats. The tree species higher than 1.3 m were recorded. The mean basal area was 13.63 m^2/ha. *Shorea siamensis* was the dominant species in the forest with 100 % of frequency, 62.18 % of abundance, 48.93 % of relative density, 51.83 % of relative dominance and 27.52 % of relative IVI. The stratification had 2 layers consisting of the upper crown layer and lower crown layer (Khamyong, 1995).

Studying the structural characteristics of the secondary DDF at Nongteng-Jakkarat forest, Nakhon Ratchasima, it was found that the total basal area was 23.57 m^2/ha with DBH larger than 4.5 cm. *Dipterocarpus tuberculatus* was the only one dominant species with relative frequency, density, dominance and IVI of 20.17, 60.52, 80.73 and 53.80 %, respectively. The vertical stratification of the stand had only one layer with 9 m high (จรัส ช่วยนะ, 2540).

Sahunalu (1995) studied variations and dynamics of species diversity of trees (DBH ≥ 4.5 cm) in 4 sub-types of DDF. It was found that various indices of species diversity, evenness and richness were significantly correlated with the species diversity index (Shannon-Wiener index) and enabling the indirect estimation of each index by using Shannon-Wiener index : H(S) as an independent variable.

Based on Sahunalu (1994), sub-types of DDF in Thailand were classified, density of tree species and H(S) were investigated from relatable literature as follows

Table 2.1 All tree species found in each sub-type of dry dipterocarp forest

Sub type	**Location**	**Plot size (ha)**	**No. of stands**	**Tree size**	**Number species**	**Number individuals/ha**	**H(S)**
1.	Doi Inthanon, Chiengmai	0.25	1	D≥ 4.5 cm	33	1,576	3.460
2.	Tak-Sukhothai Highway	0.10	1	"	25	1,340	3.972
3.	N, W, NE, Thailand	0.20	4	D≥ 10 cm	42	376	2.607*
4.	N, W, NE, Thailand	0.20	8	"	61	708	3.335*
5.	N, W, NE, Thailand	0.20	12	"	82	1,145	2.910*
6.	N, W, NE, Thailand	0.20	13	"	42	1,091	1.908*
7.	N, W, NE, Thailand	0.20	14	"	41	1,291	2.420*
8.	Sakaerat, Nakhon Ratchasima	1.00	1	D≥ 4.5 cm	36	554	4.258
9.	Sakaerat, "	1.00	1	"	32	667	2.959
10.	Sakaerat, "	1.00	1	"	28	733	2.370
11.	Sakaerat, "	1.00	1	"	33	701	3.524

Table 2.1 (cont.)

Sub type	Location	Plot size (ha)	No. of stands	Tree size	Number species	Number individuals/ha	H(S)
12.	Nongteng-Jakkarat, "	1.00	1	"	33	1,740	2.322
13.	Huay Tak aboretum, Lampang	1.00	1	"	48	628	4.584
14.	Doi Inthanon, Chiengmai	0.16	1	D≥ 3.0 cm	30	769	2.943
15.	Doi Inthanon, Chiengmai	0.16	1	"	31	1,281	3.150
16.	Doi Inthanon, Chiengmai	0.16	1	"	28	450	3.372
17.	Doi Inthanon, Chiengmai	0.16	1	"	27	669	3.674
18.	Namphrom, Chaiyaphoom	0.16	1	D≥ 4.5 cm	12	938	1.926
19.	Pingkong, Chiengmai	0.16	1	"	28	906	3.673
20.	Pingkong, Chiengmai	0.16	1	"	22	1,488	3.676
21.	Somdet, Kalasin	0.16	1	"	15	1,444	2.357
22.	Somdet, Kalasin	0.32	1	"	23	316	3.248
23.	Huay Hin Dam, Chiengmai	0.16	1	D≥ 1.9 cm	41	813	-

Sub-type :

1. = Dipterocarp savanna
2. = Mixed savanna
3. = *Dipterocarpus tuberculatus-Shorea obtusa*
4. = *Dipterocarpus obtusifolius-Shorea obtusa*
5. = *Shorea siamensis*
6. = *Shorea obtusa*
7. = Pine-dipterocarp
8. = *Shorea floribunda-Quercus kerrii*
9. = *Shorea obtusa-Shorea siamensis*
10. = *Shorea obtusa-Pterocarpus macrocarpus*
11. = *Shorea siamensis-Shorea floribunda*
12. = Secondary dry dipterocarp
13. = Mesopentacmetum suavis
14. = *Shorea obtusa*
15. = *Shorea siamensis*
16. = *Dipterocarpus obtusifolius*
17. = *Dipterocarpus tuberculatus*
18. = *Shorea obtusa-Shorea siamensis*
19. = Monsoon-savanna
20. = Dipterocarp savanna
21. = Secondary dry dipterocarp
22. = Primary dry dipterocarp (shrine forest)
23. = *Shorea siamensis*

H(S) = Shannon-Wiener index of diversity

* Average for 4, 8, 12, 13, 14 stands, respectively

Data source : Sub-type 1-2 : Ogawa, Yoda and Kira (1961)
Sub-type 3-7 : Sukwong et al (1976,77,78) and Bunyavejchewin (1983)
Sub-type 8-11 : Sahunalu and Dhammanonda (1991)
Sub-type 12 : จรัส ช่วยนะ (2540)
Sub-type 13 : ศิลปชัย พิพิธวิทยา (2539)
Sub-type 14-17 : Khamyong (1996)

Sub-type 18	:	Sahunalu et al (1979)
Sub-type 19-20	:	Ogawa et al (1965 a)
Sub-type 21-22	:	Kanzaki et al (1991)
Sub-type 23	:	Khamyong (1995)

2.2.2.3 Tree species list of dry dipterocarp forest

The important component of plant community description is what plant species are present in the community. The study area normally has large size so plant species list is usually compiled from sampling plots such as quadrat method. Data from species list can indicate species number in each plant community. This data also calculates similarity index between two plant sources or two periods of time. This index can calculate from coefficient of community in form of presence and absence data (อุทิศ กุฎอินทร์, 2541). Sahunalu et al. (1979) explored structural characteristics of DDF at Namprom basin, Chaiyaphoom. The tree number was 12 species consisting of : *Pentacme suavis, Buchanania reticulata, Shorea obtusa, Terminalia alata, Eugenia cumini, Dalbergia dongnaiensis, Anthocephalus cadamba, Quercus kerrii, Diperocarpus intricatus, Heterophragma adenophyllum, Gardenia coronaria* and 1 unidentified species.

Bunyavejchewin (1979) classified DDF throughout the country into 5 community types and shown the dominant tree species in the study area based on their important values as follows :

(1) *Pentacme suavis* community type : *Pentacme suavis, Shorea obtusa, Dipterocarpus obtusifolius, S. talura, Eugenia cumini, Canarium kerrii, Mitragyna brunosis, Aporosa villosa, Vitex peduncularis, Terminalia tomentosa, T. mucronata.*

(2) *Shorea obtusa* community type : *Shorea obtusa, Pentacme suavis, P. suavis* var. *siamensis. Dipterocarpus tuberculatus*, *Melanorrhoea usitata, Terminalia tomentosa, Quercus kerrii, Dalbergia cultrata, Pterocarpus macrocarpus,*

(3) *Dipterocarpus obtusifolius-Shorea obtusa* community type : *Dipterocarpus obtusifolius, D. tuberculatus*, *Shorea obtusa, Pentacme suavis, Quercus kerrii, Terminalia tomentosa, Aporosa villosa, Melanorrhoea usitata.*

(4) *Dipterocarpus tuberculatus* community type : *Dipterocarpus tuberculatus D. obtusifolius, Shorea obtusa*, *Pentacme suavis, Aporosa villosa, Quercus kerrii, Vitex peduncularis*, *Terminalia tomentosa, Anneslea fragrans, Parinaria annmense.*

(5) Pine-Dipterocarpus community type

5.1 *Dipterocarpus obtusifolius-Pinus merkusii* sub-community type : *Dipterocarpus obtusifolius, D. tuberculatus, Pinus merkusii, Shorea obtusa, Quercus kerrii, Aporosa villosa, Melanorrhoea usitata.*

5.2 *Pinus merkusii-Dipterocarpus tuberculatus* sub-community type : *Pinus merkusii, Dipterocarpus tuberculatus, D. obtusifolius, Melanorrhoea usitata, Tristania burmanica, Shorea obtusa, Dillenia obovata.*

5.3 *Dipterocarpus tuberculatus-Pinus kesiya* sub-community type : *Dipterocarpus tuberculatus, Pinus kesiya, Shorea obtusa, Quercus kerrii, Tristania burmanica, Melanorrhoea usitata, Lithocarpus polystachyus.*

5.4 *Dipterocarpus obtusifolius-Shorea obtusa-Pinus merkusii* sub-community type : *Dipterocarpus obtusifolius, Shorea obtusa, S. thorelii, Pinus merkusii, Melanorrhoea usitata, Tristania burmanica, Solenospermum duperreanum, Dalbergia glomerata.*

Dhamanitayakul (1984) investigated tree phenology of DDF at Paktong chai, Nakhon Ratchasima. Fourty one species were recorded including *Albizia odoratissima, Antidesma diandrum, Aporusa villosa, Bauhinia variegate, Canarium subulatum, Careya arborea, Cratoxylum formosum, Dalbergia cultrata, D. dongnaiensis, D. oliveri, Dillenia obovata, Diospyros ehretioides, D. montana, Dipterocarpus intricatus, D. tuberculatus, Erythrophloeum succirubrum, Eugenia cumini, Gardenia erythroclada, G. sootepensis, Irvingia malayana, Lithocarpus polystachyus, Mangifera duperreana, Mitragyna brunosis, Morinda coreia, Ochna wallichii, Parinari anamense, Phyllanthus emblica, Pterocarpus parvifolius, Quercus kerrii, Randia tomentosa, Schleichera oleosa, Shorea siamensis, S. talura, Sindora maritina, Lophopetalum duperreanum, Stereospermun neuranthum, Terminalia chebula, Vitex peducularis, Xylia kerii, Zizyphus rugosa* and *Ixora* sp.

Dhammanonda (1992) studied forest growth cycle in a relative long protected area with less human disturbance of the DDF in the southeast section of Sakaerat, Nakhon Ratchasima. Thirty six tree species were found comprising *Albizia odoratissima, Antiaris toxicaria, Antidesma laurifolium, Aporusa villosa, Bombax anceps, Careya sphaerica, Dalbergia cultrata, D. oliveri, Dillenia obovata, Desmodium renifolium, Diospyros ehretioides, D. mollis, Dipterocarpus intricatus, Gardenia sootepensis, Eugenia cumini,* Hybrid of *Dipterocarpus intricatus, Irvingia malayana, Kydia calycina, Lannea coromandelica, Mangifera caloneura, Mitragyna brunosis, Morinda coreia, Nauclea brunnea, Parinari anamense, Phyllanthus emblica, Pterocarpus macrocarpus, Quercus kerrii, Sindora siamensis, Shorea floribunda, S. obtusa, S. siamensis, Terminalia chebula, Vatica odorata, Vitex pinnata, Xylia xylocarpa* and 1 unidentified species.

Khamyong (1995) analyzed community structure of DDF at Huay Hin Dam village, Hod district, Chiangmai. There were totally 41 tree species which were as follows : *Shorea siamensis, S. obtusa, Dipterocarpus obtusifolius, D. tuberculatus, Terminalia alata, T. chebula, Melanorrhoea usitata, Holigarna kurzii, Anneslea frangrans, Quercus kerrii, Lannea grandis, Canarium kerrii, Randia dasycarpa, Gardenia erythroclada, Morinda coreia, Bridelia pierre, B. affins, Bombax anceps, Dillenia obovata, Croton longissimus, Afzelia xylocarpa, Xylia kerrii, Helicia nilagirica, Blumea balsamifera, Lagerstroemia balansae, Colona flagrocarpa, Eugenia cumini, Melientha suavis, Adina cordifolia, Phyllanthus emblica, Strichnos nux-vomica, Buchanania latifolia, Mellettia leucantha, Dalbergia assamica, D. oliveri, D. dongnaiensis, Pterocarpus macrocarpus, Cassia fistula, Castanopsis fissa, Vitex pinnata* and 1 unidentified species.

ศิลปชัย พิพิธวิทยา (2539) studied species diversity of trees in Huay Tak aboretum, Ngao district, Lampang. This aboretum was Mesopentacmetum suavis forest with mixed between DDF and mixed deciduous forest composed of 48 species, these are *Dipterocarpus tuberculatus, Shorea obtusa, S. siamensis, Terminalia alata, T. mucronata, T. triptera, T. chebula, Canarium subulatum, Xylia xylocarpa, Lagerstroemia duperreana, Tectona grandis, Vitex canescens, Pterocarpus macro-carpus, Symplocos longifolia, Kydia calycina, Zizyphus mauritiana, Lagerstroemia macrocarpa, Diospyrosehr etiodes, Strychnos nux-vomica, Lannea coromandelica, Grewia eriocarpa, Gmelina arborea, Bridelia retusu, Berrya ammonilla, Miliusa velutina, Barringtonia acutangula, Wrightia tomentosa, Mitragyna brunonis, Dalber -gia assamica, Schlcichera oleosa, Stereospermum cylindricum, Lagerstroemia* *loudonii, L. venusta, Eugenia grandis, Artocapus lakoocha, Calophyllum inophyllum, Irvingia malayana, Dalbergia cana, Morinda coreia, Garuga pinnata, Bombax valetonii, Spondias pinnata, Melanorrhoea glabra, Albizia odoratissima, Careya sphaerica, Alangium salviifolium, Wrightia viridiflora* and *Dillenia obovata.*

จรัส ช่วยนะ (2540) studied structural characteristics of secondary DDF at Nongteng-Jakkarat forest, Nakhon Ratchasima. The results revealed that the forest consisted of 33 tree species including *Alangium salviifolium, Aporusa villosa, Bauhinia saccocalyx, Bridelia retusa, Buchanania latifolia, Butea superba, Canarium subulatum, Colona siamica, Dalbergia cultrata, D. dongaiensis, Dillenia obovata, Dyospyros ehretioides, Xylia xylocarpa, Dipterocarpus tuberculatus, Flacourtia indica, Gardenia obtusifolia, Irvingia malayana, Lagerstroemia macrocarpa, Lophopetalum duperreanum, L. wallichii, Mitragyna rotundifolia, Mangifera sp., Morinda elliptica, M. pubescens, Ochna integerrima, Pavetta tomentosa, Phyllanthus emblica, Shorea obtusa, S. siamensis, Strychnos nux-vomica, Syzygium cumini, Terminalia alata* and *T. chebula.*

Dhammanonda (1996) indicated that tree species in DDF were normally *Shorea obtusa, S. siamensis, S. floribunda, Dipterocarpus tuberculatus, D. obtusifolius Sindora siamensis, Terminalia alata, Melanorrhoea uistata, Buchanania latifolia, Irvingia malayana, Bridelia retusa, Strychnos nux-blanda, S. nux-vomica, Phyllanthus emblica, Cassia garettiana, Morinda coreia, Gardenia erythroclada, Dillenia spp. Pterocarpus macrocarpus, Xylia xylocarpa, Vitex peduncularis, Mitragyna brunonis, Wrightia tomentosa, Cratoxylum formosum, C. maingayi, Eugenia cumini, Lannea grandis* and *Parinari anamense.* The undergrowth which means shrub and shrubby tree were *Memecylon scutellatum, Bauhinia acuminata, Randia dasycarpa, Melientha suavis, Crotalaria alata, C. bracteata, Desmodium gangeticum, D. motorium, D. pulchellum, Indigofera caloneura, I. elliptica, I. spicata, I. hirsuta, I. lacei, I. siamensis, I. sootepensis, I. trifoliata, I. zollingeriana, Uraria macrostachya, Helicteres isora, Holarrhena densiflora, Ellipeiopsis cherrevensis, Clausena excavata, Barleria siamensis, Abelmoschus esculentus, Decaschistia harmandii, D. intermedia, D. parviflora, D. siamensis, Leea indica, L. guineensis* and *L. macrophylla.*

อุทิศ กุฏอินทร์ (2541) described floristic composition of DDF base on stratification of community types :

(1) Deciduous DDF accomplished type. The vertical stratification of the stand has 3 layers.

1.1 Top layer. The trees are 20-35 m high. Dominant tree species include *Shorea obtusa, S. siamensis, Dipterocarpus obtusifolius, D. tuberculatus, D. intricatus, Quercus kerrii, Lithocarpus dealbatus, Pterocarpus macrocarpus, Xylia xylocarpa, Schleichera oleosa, Canarium subulatum, Albizia procera, Xyzygium* sp. and *Mangifera* sp.

1.2 Secondary layer. The trees are not over 20 m high. Dominant tree species include *Lagerstroemia* sp., *Diospyros ehretioides, Phyllanthus emblica, Morinda elliptica, M. coria, Cratoxylon formosum, Melanorrhoea usitata, Millettia brandisiana, Terminalia chebula, Buchanania latifolia, Mitragyna brunonis* and *Careya arborea.*

1.3 Lower layer. Height of trees is not over 7 m. Dominant tree species includes *Strychnos nux-vomica, S. nux-blanda, Aporusa villosa, A. wallichii, Memecylon scutellatum,* and *Cycas siamensis.*

(2). Deciduous DDF scrub type. The vertical arrangement of trees in the stand shown 2 layers.

2.1 Top layer. The trees are not over 15 m high. Dominant tree species include *Lagerstroemia* sp., *Diospyros ehretioides, Phyllanthus emblica, Morinda elliptica, Cratoxylon formosum, Melanorrhoea usitata, Millettia brandisiana, Terminalia chebula, Buchanania latifolia, Mitragyna brunonis* and *Careya arborea.*

2.2 Secondary layer. The trees are not over 7 m high. Dominant tree species includes *Strychnos nux-vomica, S. nux-blanda, Aporusa villosa, A. wallichii, Memecylon scutellatum* and *Cycas siamensis.*

2.2.3 Soil analysis

Soil is one of the most important ecological factors. Plants depend on plants nutrients, water supply, and anchorage upon the soil. Soil system is very c omplex and dynamic, undergoing continuous changes, and the rates of such changes being influenced by a number of other factors of the environment. Soil affects plants by affecting seed germination, size and erectness of the plant, vigour of the vegetative organs, woodiness of stem, depth of the root system, susceptibility to drought, frost and parasites, number of flowers per plant, and the time of flowering etc. (Marsden-Jones and Turrill, 1945).

Sharma (1979) described that soil is thus not merely a group of mineral particles. It has also a biological system of living organisms as well as some other components. It is thus preferred to call it a soil complex. The various components of the soil complex are (1) mineral matter, (2) soil air, (3) soil water, (4) soil solution, (5) soil organic matter or humus and (6) soil organisms.

There are differences about the role of environmental factors to plant community structure. Kutintara (1975) studied in dry dipterocarp forest found that the degree of slope, altitude, amount of rock, silt, Potassium and Phosphate in soil are the most important environmental factors. While a study of Bunyavejchewin (1983) reported that the most important environmental factors are altitude, amount of Potassium and exchangeable Sodium.

2.3 Flowering phenomena and pollinator observation

2.3.1 The flowering stage

Flowers are distinguished from other kinds of reproductive organs by having seeds in containers, which become fruits (Ghazoul, 1997). Flora displays are subject to selection pressures from several different factors, including pollinator attraction, competition for mates, time available for flowering and seed maturation, seed dispersal and predation (Janzen, 1969, Stebbins, 1974). Thus, a basic understanding of floral structure and phenology is essential background information for any pollination study.

2.3.1.1 What is flowering ?

Flowering refers to the developmental process whereby a vegetative bud, shoot, or entire plant becomes reproductive. The time in the life of a tree when flowering first occurs is referred to as maturation, phase change, or ripeness to flower. (Ng, 1966).

(1) Flowering periodicity

Trees, and woody plants in general, pass through a juvenile stage of 1-40 years during which they do not flower. The mature, reproductive stage is call "ripen-ess to flower" and the transition to this stage is call "phase change". Once plants are able to flower they can usually continue to do so, but the periodicity varies among and within species (Owens, 1990).

Tropical forest trees are extremely variable in frequency of flowering, many rarely being without flowers (Janzen, 1978). Most temperate and many tropical forest trees exhibit indirect flowering in which there is a period of dormancy between floral initiation and pollination. Four other groups of tropical flowering periodicities are recognized : (1) everflowering species such as *Ficus* initiate flowers throughout the year and, therefore, flowers, seeds, and fruits at various stages of development are always present; (2) nonseasonal-flowering species exhibit flowering periodicity among plants and from branch to branch; (3) gregarious-flowering species initiate floral buds continuously but these remain closed for weeks or months until environmental conditions are favorable for anthesis, sometimes resulting in anthesis over a wide geographical area, as in *Coffea*; (4) seasonal-flowering species flower in response to alternating rainy or dry seasons or subtle seasonal variations in dry length or temperature, as has been proposed for certain Dipterocarps (Ashton, Givnish and Appanah, 1988).

(2) Reproductive cycles

Many tropical hardwoods appear to exhibit continuous development over a period of several months from floral initiation to seed release. In the Dipterocar-paceae (Smitinand, Santisuk and Phengklai, 1980), for example, the entire process can occur in as little as 2-3 months or more than 6 months, but is most commonly intermediate in duration. The onset of the process is uncertain in most tropical hardwoods.

There is much variation in the phenology of floral development owing to the generally long reproductive cycles of most trees, although the sequence of development remains unchanged. The longer the process, the greater the possibility for fruit or seed failures to occur. It is not surprising, therefore, that many trees have low seed yields. To identify the cause of poor seed yield it is necessary to determine at what stage of development fruit or seed loss occurs. At this time there is limited information available and on relatively few tree species (Owens and Blake, 1985).

(3) Floral initiation

Floral initiation, which is the first step in all reproductive cycles, describes a process rather than specific structures. The classical view of floral initiation in herbaceous plants is that the flowering stimulus originates in various plant parts and is transmitted over a period of hours or days to the apex, where a transition occurs from a vegetative to a floral apex (Bernier, 1988). It has also been assumed that most plants flower in response to specific environmental changes, e.g., photoperiod and temperature. The classical view has never been accepted in the case of woody perennials, whose flowering appears to result from a series of developmental stages each sequentially determined by the hormone or substrate balance at the initiation site and modulated by different environmental factors acting on various plant organs (Jackson and Sweet, 1972).

2.3.1.2 Floral structure

Given the basic structure of the flower, there are many variations. The majority of flowers contain both stamens and carpels. Such flowers are called perfect, whereas if either is missing, the flower is called imperfect, these flowers are either staminate or carpellate. If both stamenate and carpellate flowers occur on the same plant, the plant is monoecious, if they are found on separate plants, the plants are dioecious. Hardwood flowers can be bisexual, as in most species of *Acer*, unisexual, as in *Quercus, Populus* and *Betula*, or polygamous, having both unisexual and bisexual flowers, as in some species of *Acer* (Davis, 1966).

(1) Flower morphology

Ghazoul (1997) described that flower structure has evolved to suit two primary purposes, advertisement and fertilization. As an approximation, the androecium and gynoecium are directly involved in pollen production, reception, and fertilization, while the calyx and corolla are involved in advertisement. Floral advertisement is expressed through a combination of color, size, shape, and scent. The 'reward', may be pollen or nectar, may also have a role in advertisement. Totland (2001) found that pollinators discriminate between flowers in response to flower size, shape, color, number, and nectar production rates, because flower size often is positively correlated with expected reward return or because large flowers are more easily recognized than small flowers.

(1.1) Flower colors

The visual cues of flowers serve to attract particular pollinating species, as well as provide information on the flowers' receptive stage (Waser and Price, 1981). Color preferences of pollinators are listed as follows.

Table 2.2 Color preferences of pollinators

Pollinator	Preference
Bees	Yellow, bright blue
Wasps	Dull brown
Beetles	Cream, dull green
Butterflies	Red, yellow, blue, bright pink
Moths : Nocturnal	White, pale pink
Diurnal	Red, purple, bright pink
Flies : Carrion, dung	Brown, dull purple
Others	Cream, white
Bats	Cream, purple, dull green
Birds	Bright red

(Adapted from Scogin, 1983)

(1.2) Flower shape and size

The size and morphology of floral parts, particularly the androecium and gynoecium, has great relevance to the pollination mechanism and breeding system. Information on the size and position of the anthers and the stigma, combined with overall floral size and shape, can restrict even further the search for the most effective pollinators. A large tubular flower, such as that of *Dipterocarpus obtusifolius* might be visited by large and long-tongued bees or moths, yet the position of the stigma at the corolla mouth and well beyond the anthers effectively rules out bees as pollinators. These insects land on the margins of the corolla and crawl down the tube thus bypassing the stigma. Large moths remain at the corolla mouth and probe for nectar at the base of the flower using their long proboscis. In this way pollen is deposited on their ventral thorax which is pressed against the stigma during flower visits (Ghazoul, 1997).

Table 2.3 Main flower shapes, functional characteristics, and pollinator syndromes

	Bowl	Funnel	Brush	Flag	Gullet	Tube	Traps
Visual advertisement	Corolla	Corolla	Stamens	Standard	Lips	Corolla	Perianth
Pollen presentation	Exposed	Partially hidden	Exposed	Hidden	Hidden	Hidden	Hidden
Reward	Pollen	Pollen Nectar	Nectar	Pollen Nectar	Pollen Nectar	Nectar	None
Examples	*Ochnaceae Dilleniaceae*	*Dipterocarpus*	*Pachira Gardenia*	*Fabaceae Polygalaceae*	*Strelitzia Mimetes*	*Malvaviscus Oxalis*	*Rafflesia Aristolochia*
Pollinators	(1)	(2)	(3)	(4)	(5)	(6)	(7)

Note :

(1) = Beetles, flies, unspecialized bees, Lepidoptera

(2) = Short-tongued bees, wasps, flies, moths, birds, bats

(3) = Butterflies, beetles, mammals, birds

(4) = Long-tongued bees, birds

(5) = Long-tongued bees, birds, hawkmoths, butterflies

(6) = Moths, butterflies, birds

(7) = Flies, beetles, bees (orchids)

(Adapted from Faegri and van der Pijl, 1979)

(2) Floral rewards

Flower color, shape, and scent serve as an advertisement to insects for the rewards that can be obtained. Insects and animals visit flowers to obtain a resource and, in the process, serve the plant by acting as a pollen transfer mechanism. Floral resources can be the pollen itself, or may be some other product produced by the plant, usually nectar. Other rewards include plant tissues, stigmatic fluid, and fatty oils upon which animals feed, and non-nutritional rewards such as warmth and shelter (Simpson and Neff, 1983).

Table 2.4 Floral rewards and some ecological implications

The reward	Main users	Ecological implications
Nectar	Almost all pollinators	Nectar volume, concentration, and secretion patterns are broadly related to the pollinator type and floral morphology.
Pollen	Bees, flies, beetles, thrips	Convenient and nutritious. Can be used by almost all insects with minimal structural modification of mouthparts.
Stigmatic exudates	Flies	The primary reward in very few plants eg. *Aristolochia* spp.
Floral tissues	Beetles, bees, bats	Special food structures or unspecialized tissues.
Oils	Some melittid and anthophorid bees	Produced in elaiophores specific to some tropical plants. Collection requires use of specialized bee structures.
Perfume	Male euglossine bees	Produced by some Orchidaceae, and possibly used by male bees to attract females.
Resin and gums	Some female bees	Produced by a few trees in tropical regions. Material used by bees for nest construction.
Brood sites	Insects, general and specialized	Oviposition and development in the flower. The adults may be the most important or only pollinator eg. *Yucca, Ficus.*
Shelter and heating	Bees, flies, beetles	Insects may raise body temperature to maintain activity by basking in flowers.
Mating site	Insects	Males searching for females at flowers effect pollination.

(Adapted from Dafni, 1992)

(2.1) Pollen as a reward

Although pollen is highly nutritious and widely available, relatively few taxa are adapted to digest it (mainly bees, flies, and thrips) due to the difficulty of penetrat ing the pollen wall or exine (Simpson and Neff, 1983). Insects that feed on pollen are often the pollinators of flowers that lack nectar and produce only pollen as a reward. These flowers typically have big colorful flowers with a mass of stamens that produce pollen profusely, eg. poppies *Papaver* spp. and rockroses *Helianthus* spp. Bees also visit flowers for pollen, which is the primary food source for their larvae.

(2.2) Nectar as reward

Nectar is the primary reward secreted by most flowers and is sought after by the majority of flower visitors. It is a sugary solution that is secreted by nectaries located usually at the base of the flower, though it may also occur on other parts of the plant (extra-floral nectaries). The primary constituents of nectar are sugars with small amounts of proteins and amino acids. The quantity and concentration of nectar is closely correlated to the demands of the pollinators, though it is important to recognize that nectar is produced not to sustain insect activity, but to promote pollen movement. Thus nectar will be distributed in flowers such that pollinators are forced to visit many flowers to satisfy their energetic demands. (Ott, Real and Silverfine, 1985).

2.3.1.3 Environmental factors affecting floral initiation

Owens (1990) reported that potential reproductive apices undergo several weeks of undetermined growth during which their development is very malleable. During this period, environmental and endogenous factors interact to control bud development. Many studies have tried to demonstrate a relationship between environmental factors and flowering in geographic regions, forest stands, and on individual trees, but it is difficult to identify causal mechanisms.

(1) Periodicity. Long-term fluctuations of periodicities in the production of seed and fruit crops have been demonstrated. These represent the climax of long reproductive cycles and can be influenced by many factors. Although periodicity is generally well documented, the causes are poorly understood because of the complex interactions of many endogenous and exogenous factors.

(2) Temperature. It has been demonstrated that in several temperate genera high summer temperatures favor increased flowering. High temperatures during floral initiation can affect metabolic processes but, unfortunately, there are little knowledge about these processes in reproductively mature trees (Owens, 1990). However, inhibitory effects of high temperature on floral development have been reported in a number of species (Saini, Sedgley and Aspinall, 1983) and specific effects on meiosis have been report in wheat (Saini, Sedgley and Aspinall, 1984). Transfer of plants to a cooler environment resulted in a continuation of normal development in some inflorescence buds through to anthesis. The face that fewer inflorescences flowered later and for a shorter period suggests that the more advanced buds were irreversibly inhibited whereas the less developed buds were able to continue differentiation under the cooler conditions (Sedgley, 1985).

(3) Light intensity. Most studies indicate that the effects of light intensity on flowering are indirect, involving crown exposure, slope, shading, and floral distribution within the crown. Generally, branches exposed to high light intensity flower more abundantly than shaded branches, as has been shown in *Tectona* (Nanda, 1962). Thinning has enhanced flowering and shading of individual branches has reduced flowering in conifers and certain fruit trees (Jackson and Sweet, 1972). Crown closure modifies light intensity and affects the proportion of male and female flowers in *Acer* (Hibbs and Fischer, 1979).

(4) Photoperiod. Photoperiod has not clearly been demonstrated to have a direct effect on flowering in trees as it has in many herbaceous plants (Bernier, 1988). In temperate hardwoods and conifers, photoperiod appears to control cessation of shoot elongation, which in many species coincides with floral differentiation (Jackson and Sweet, 1972). Photoperiod, therefore, could indirectly affect flowering and sex determination of buds, especially in species whose male and female floral structures do not differentiate at the same time. Photoperiod, which varies little in tropical regions, is likely to have little or no effect on tropical hardwoods under natural conditions.

(5) Moisture. Low moisture is frequently associated with increased flowering, but in nature it is difficult to separate its effects from those of high temperature and light intensity. In *Fagus*, dry summers were found to correlate with increased seed production over a 100-year period (Homsgaard and Olson, 1961). Subsequent experiments have shown that low moisture, separate from high temperature, affects flowering in *Fagus*. Many experiments, although showing the promotive effect of withholding water, have not quantified moisture stress levels or carefully related time of moisture stress to time of floral initiation.

(6) Mineral nutrients. All other factors being equal, trees growing on fertile sites produce more seed than those growing on less fertile sites (Mathews, 1963). There are many studies of hardwoods and conifers demonstrating how various fertilizer treatments, especially nitrogen and phosphorus, enhance flowering and seed production (Owens and Blake, 1985).

(7) Other factors. In general, any injury that results in stress on the tree will enhance flowering, these include : frost damage, resin tapping, defoliation, and root damage (Owens and Blake, 1985). These are commonly called stress crops and many stress treatments are used in floral induction and enhancement.

A study on floral initiation and development in *Acacia pycnantha* at Australia during 1982-1984 shown that low light intensity and high temperature can block different steps in the process of floral development and anthesis is prevented (Sedgley, 1985). Siripatanadilok and Likitrammanit (1991) studied on flowering and flower morphology of plants in the dry-evergreen forest at Sakaerat Environmental Research Station It was found that a large number of species produced flowers during February and April when temperature was rising up from low temperature in the winter and rain has just started. More than 50 % of flowering plant species belonged to shrub and climber. Elliott, Promkutkaew and Maxwell (1994) indicated that at the community level, in the dry tropical forest of Doi Suthep-Pui National Park in northern Thailand, trees flowering occurred in every month, peaking sharply in March, when 74 % of the species flowered, and reaching its lowest levels over the period July-September. The research on reproductive ecology of forest plants in the disturbed mixed deciduous forest at Mae Klong Watershed Research Station, Kanchanaburi, showed that the flowering time of most plants started flowering from November to March. Herbs showed the highest correlation between flowering and climatic factors. The light intensity was the most effective factors affecting the flowering of new species with a correlation value of 55.05 % (เชิดศักดิ์ ทัพไหญ่, 2539).

The association of intensified flowering activity with hot, dry weather is a commonly reported phenomenon in tropical forests. Even in rain forests, it has been reported for Singapore (Holttum,1931, Corlett, 1990), Nigeria (Njoku, 1963), Brazil (Ducke and Black, 1953), and Malaysia (Medway, 1972). In drier tropical forest, flowering during the dry season seems to be normal. It has been reported for Costa Rica (Fournier and Salas, 1966, Daubenmire, 1972, Frankie, Baker and Opler, 1974, Reich and Borchert, 1984), Sri Lanka (Koelmeyer, 1959), India (Newton, 1988), Nepal (Dinerstein, 1979), Tanzania (Boaler, 1966), and Thailand (Sukwong, Dhamanitayakul and Pongumphai, 1975). The only one study in a dry tropical forest that failed to show dry season flowering, that of Lieberman (1982), who reported a significant positive correlation between the number of species in flower and rainfall in a dry tropical forest in Ghana.

2.3.1.4 Flowering phenology

Phenology, the seasonal timing of life history events such as germination or reproduction, comprises a set of traits that may critically affect reproductive success (Rathcke and Lacey, 1985) yet whose optima are likely to a widely across colonizable habitats. Flowering phenology is particularly important because it determines reproductive synchrony with potential mates (Marquis, 1988), synchrony with or attractiveness to pollinators (Augspurger, 1981), and utilization of seasonally available resources such as light or water (Walker, Ingersoll and Webber, 1995). Flowering time may also strongly affect reproductive success by determining synchrony with, and thus vulnerability to, floral herbivores and seed predators (Pettersson, 1991).

Flowering phenology has ecological significance to pollinators, which may be dependent on flowers as resources, and to other plants in the community through competitive and mutualistic interactions for pollinators. The progress of flower anthesis can be a mechanism for the prevention of self-pollination, and the sequence of flowering among sympatric species is often closely related to pollinator or seed-predator population dynamics. The phenology of flowering may be studied on several scales, from the single flower to the whole community, and the main parameters are the timing, duration, sequence, intensity, and frequency of flowering, which may be dependent on aspects of both the physical and biological environment. (Ghazoul, 1997).

2.3.2 Pollinator biology

Ghazoul (1997) reported that flowering plants have evolved several strategies that promote gene exchange through pollen transfer. Indeed, flowers evolved, diverged, and specialized in response to the wide variety of insect and animal vectors that could serve as mechanisms for pollen transfer. While some plants have secondarity returned to wind pollination typical of the gymnosperms, the angio-sperms in general have radiated into thousands of species expressing a wide range of reproductive strategies based on animal effected cross-fertilization. Insects form the most important pollinator group, among which bees, butterflies and moths, beetles, and flies are predominant. Vertebrate pollinators, almost exclusively birds and bats, pollinate many tropical plants, but are less important in higher latitudes.

2.3.2.1 Major pollination groups

Ghazoul (1997) described the major pollinator groups as follows :

(1) Hymenoptera : bees

Bees are probably the most important pollinators of flowering plants world-wide. The adults feed on nectar and collect pollen on which the larvae feed. They are active fliers and visit large numbers of flowers, spending just enough time at each to feed and collect pollen. Although collected pollen is stored in specialized structures on the bodies of most bees, pollen grains can easily be found adhering to hairs on the head and thorax of foraging bees. A wide variety of plants are visited by Hymenoptera, and these plants advertise themselves with bright yellow and blue flowers. Bees preferentially visit objects that have longer outlines, but are apparently unable to distinguish shapes. The bees could be classified into four groups base on evolution : honey bee (*Apis* sp.), stingless bee (*Trigona* sp.), bumble bee (*Bombus* sp.) and wild bee eg. *Braunsapis* sp., *Megachile* spp., *Xylocopa* spp. (สมนึก บุญเกิด และ ธนานิธ เสือวรรณศรี, 2544).

(2) Lepidoptera : moths and butterflies

Moths and butterflies are well-known pollinators of many plants. These active insects have high energy demands and therefore need to visit many flowers to obtain the resources they require. As such, they are highly effective pollinators. Coevolutionary development linking floral structure to specialist lepidopteran pollination has arisen in several plant groups. Flowers that attract butterflies are usually red or blue and have strong, sweet smells. Moths, which are mostly active at night, visit strong-smelling, pale-colored flowers.

(3) Coleoptera : beetles

Many beetle groups feed on pollen and flower parts and, as such, pollinate a wide range of plants. The families Scarabeidae and Chrysomelidae are perhaps the most important pollinator groups, but other families also have members that are pollinators (Whitehead, Giliomee and Rebelo, 1987). Generally beetles are less efficient pollinators than bees, butterflies, or moths, as they are slow moving and generally spend prolonged periods within a single flower. The sense of smell plays an important part in flower location by beetles (Grant, 1950), and beetles have been shown to respond preferentially to red colors (Dafni et al., 1990).

(4) Diptera : flies

A wide variety of flies visit flowers and feed on pollen, though they are inefficient pollinators, except where they are specialist pollinators of some plant species. In many habitats, flies are by far the most abundant insects seen at flowers, and their inefficiency at pollination might be offset by their numbers. Flies are commonly attracted to pale colors. Sweet odors also attract them, while some plants attract carrion flies by emitting a 'rotting-flesh' odor eg. *Rafflesia* spp. (Endress, 1994)

(5) Thysanoptera : thrips

These small insects (< 2 mm) are found in many flowers where they feed on pollen grains and petal tissue. Although often thought of as pests, they do carry pollen on their bodies and are the pollinators of some plants. These tiny insects have been implicated in the pollination of some huge forest trees, most notably in Malaysia (Appanah and Chan, 1981). Flower-visiting thrips respond preferentially to the colors white, yellow, and blue-green (Kirk, 1984).

(6) Vertebrates : birds and bats

Insects are undoubtedly the most widespread and important pollinators, but a significant number of plants is pollinated by vertebrates, particularly the birds and bats. Vertebrate pollination is primarily found in the tropics and subtropics, although in North America bird pollination does occur as far north as Alaska. As with insects, the resources offered to birds and bats are nectar and pollen, though there is great diversity in the quantity of resources offered by different species. In the neotropics, hummingbirds are the principal flower visitors among birds, while sunbirds fill this role in the old-world tropics. Bird-pollinated flowers are bright red and tubular, with abundant nectar and lack of scent. They generally open in the early morning and are often considerably larger than butterfly-pollinated flowers.

Most bat-pollinated plants are trees or woody climbers, and the flowers tend to be exposed and easily accessible. Bat-pollinated flowers open at night and emit a strong fruity or musty scent unlike that of insect-pollinated flowers. The large robust flowers are white or cream colored, have abundant pollen and nectar, and are usually of the 'brush' form where the protruding stigma is surrounded by many exposed anthers.

2.3.2.2 Pollinator behavior

It is necessary to record insect behavior at flower simply to distinguish between pollinators and other flower visitors that may take resources but fail to pollinate the plant. Other studies, such as floral advertisement or plant competition for pollinators, need to be gauged in terms of flowers' effectiveness at attracting pollinators, while pollinator behavior and effectiveness in relation to environmental variables such as weather or habitat structure are frequently of interest to forest managers. Pollinator activity may be recorded at particular flowers or in the habitat more generally, depending on the nature of the question that is being asked.

Observations at a particular group of flowers, inflorescences, or plants may be carried out over a fixed period of time. Insect behavior and activity at flowers can be quantified either by the times spent at flowers, number of flowers visited, number of pollinators present, or some combination of these (Ghazoul, 1997).

Failure of a species to produce seed can be traced to the absence of pollinators or lack of synchronization between pollinators and floral receptivity. If a hardwood species has many pollinators, there may always be adequate vectors for seed production, whereas species that rely on a single pollinator may frequently have low seed production. *Tectona* is an example of a tropical hardwood that usually has low seed set thought to result from the frequent absence or scarcity of a single group of pollinating insects (Hedegart, 1973).

At Hisar, India, *Xylocopa fenestrata* visited several cucurbit crops and faced wide seasonal variations in temperature ranges. The daily foraging activity of the bee changed from unimodal to bimodal as the ambient temperature increased. This activity coincided with the flower opening times of the cucurbit crops and had a significantly higher foraging rate than *Apis florea* (Sihag, 1993). Jyothi, Atluri and Reddi (1990) found that *Xylocopa latipes* and *X. pubescens* were the major pollinators (57 % of bee visits) of *Moriga oleifera*, a tree indigenous to northwestern India. เชิดศักดิ์ ทัพใหญ่ (2539) studied the pollinators of dominated plant species at Mae Klong Watershed Research Station, found that the most visitors and efficient pollinators were *Trigona apicalis*, *Apis cerana* and *A. florae* respectively. The peak visitation period were during 8.00-11.00 h. A Study on diversity and abundance of insect flower visitors and the pollination ecology of teak in natural and plantation forest near Mae Ga Forest Tree Seed Production Station, Payao, stingless bee was found to be the main pollinator of teak flowers (Tangmitcharoen et al., 1999). While the main pollinators which visited *Orthosiphon aristatus* in medicinal plants garden, Kao Hin Sorn, Chachoengsao, were *Apis mellifera*, butterflies, *Trigona apicalis* and *A. florae*. Pollinators activity was highest between 9.00-10.00 h (จันทร์เพ็ญ ลิมปพยอม, 2542).

2.4 Pollen efficiency

2.4.1 Pollen structure and development

Pollen is the small, male gametophyte that consists of two or more cells enclosed by a thick protective wall with two layers. The outer wall (exine) is very resistant and may be sculptured. The thin inner wall (intine) forms the pollen tube. Hardwood pollen usually has distinct pores. Some tropical hardwoods such as *Acacia* have polyads that consist of 16 fused pollen grains (Kenrick and Knox, 1979).

Pollen development begins with pollen sacs which produce many pollen mother cells that undergo meiosis to produce four haploid microspores in a tetrad. The microspores separate and often undergo a long period of development during which cell divisions occur internally and the pollen wall differentiates. In hardwoods, each microspore divides to form a large vegetative cell and a small generative cell. The pollen can be shed at the two-cell stage or after the generative cell has divided to form two male gametes. The male gametes are simply nuclei, not motile sperm (Gifford and Foster, 1989).

2.4.2 Pollination

The second most important deterrent to successful reproduction, following failure to initiate flowers, is the failure of flowers to be pollinated. Most tropical hardwoods are pollinated by biotic agents, usually insects, but birds, bats, and other small mammals can also serve as vectors. Compared to wind pollination, insect pollination is largely incidental to nectar collection, quantities of pollen generally being low and the time of anthesis less tuned to environmental cues. Also, there may not be a leafless season and trees may be very widely spaced in dense and varied vegetation (Whitehead, 1983). Once pollen germinates it must often grow several millimeters to centimeters through the stigma, style, ovary, and nucellus before fertilization can occur. Growth is rapid, usually taking place within hours or days. In most conifers, pollen tubes need to grow only a few millimeters through the nucellus. Growth is often slow, taking days to weeks, or may be interrupted by a dormant period, as in pines, and occur over several months to 1 year (Owens and Blake, 1985). During this time many factors can intervene to stop or slow pollen tube growth and prevent fertilization.

2.4.3 Fertilization

In hardwood, each ovary can contain several ovules, each with 1 or 2 integuments and a thin nucellus. The embryo sac within the nucellus is quite variable among plant groups but usually has 1 egg cell and 2 adjacent synergids with a filiform apparatus, 3 nonfunctional antipodal cells and a large vacuolate central cell with 2 free polar nuclei. One pollen tube will usually enter each ovule through the filiform apparatus then a synergid, where the 2 male gametes are released. One male gamete then enters and fuses with the egg and the second fuses with the 2 central cell nuclei to form the primary endosperm nucleus. This process is called double fertilization. The endosperm may have several structural forms and it supplies nutrients for the embryo and stimulates embryo development. In most trees, the endosperm is used up during embryo development and seed storage products are contained within the cotyledons of the embryo (Schopmeyer, 1974). In general, the brief period of fertilization does not appear to be a major cause of seed loss in hardwoods.

2.4.4 Pollen testing

Webber (1991) described that pollen test is its fertility potential, i.e., its ability to fertilize and form a seed. Pollen viability and pollen vigor are important in vitro measures of pollen quality. Three techniques are commonly used to estimate in vitro pollen viability :

(1) Oxygen uptake has consistently produced the best estimates of fertility potential. The loss of oxygen in the solution in which pollen is suspended is measured. Vigorous pollen respires more rapidly and uses oxygen more rapidly than less vigorous pollen.

(2) Electrical conductivity measures the pollen electrolytes leached into an aqueous solution. Live pollen retains its electrolytes whereas the cell membrane in dead pollen allows electrolytes to flow into the aqueous medium.

(3) Percent germination. Viability is measured by percent of pollen germinated after a given time and vigor is measured by the rate of pollen tube growth. Pollen is dusted onto Brewbaker's medium usually containing 0.5 % agar (Brewba ker and Kwack, 1963), either in a small petri dish or on a microscope slide, and left at 20-25°C for up to 48 hours. Pollen is then scored as to whether it has germinated or not. Pollen is considered germinated if the pollen tube is twice the diameter of the pollen. Using a compound microscope, the length of pollen tubes can also be measured on sample pollen grains to determine the rate of tube elongation as a measure of pollen vigor.

In *Picea glauca*, pollen test is done by sprinkling the pollen in an open petri dish and placing this dish over water in a large closed container for 4 h at 25°C. Pollen tested in this manner has been ranked with regard to germination percentage and actual seed set. A germination rate >80 % gives good seed yield, 50-80 % moderate seed yield, 30-50 % low seed yield, and <30 % a seed set too low to be useful. These categories may not apply to other species because the amount of pollen present and the pollination mechanism are also important factors in determining final seed yield. (Webber, 1991).

Pollen germination and pollen tube growth are prerequisites for fertilization and seed development. Besides the carbohydrate source, boron and calcium play important roles in pollen germination and pollen tube growth (Steer and Steer, 1989). Lack of boron and/or calcium drastically affects pollen germination in many systems. In the absence of boron and calcium, pollen tubes often show abnormalities such as coiling and swelling of the tip, or they may even burst (Shivanna and Rangaswamy, 1992). The pollen population effect is overcome completely by a growth factor obtained in water extracts of many plant tissue. This factor is shown to be the calcium ion, and its action confirmed in 86 species representing 39 plant families. (Brewbaker and Kwack, 1963).

In *Silene alba,* pollen germination declined significantly with stigma age, but there was no significant effect of stigma age at pollination on the number or mass of resulting seeds. Thus, the decreased pollination success of bees is not due to a decrease in stigmatic receptivity but is most likely a result of pollinator (Young and Gravitz, 2002). Imani and Talaic (1998) found that the factors effect on pollen germination in vitro are pollen age, culture medium type and environment. The optimum temperature of pollen germination for mung bean are 25-30°C (Khattak, Raziuddin and Ahmed, 1997, Singh, 1998). The best condition in vitro for pollen germination of *Crotalaria juncea* (พิทักษ์ ใจคง, 2542) and *Cosmos sulphureus* (พิมพ์วดี พรพงศ์รุ่งเรือง, 2542) are temperature 25°C and the optimal concentration of sucrose in media agar are 6 % and 10 %, respectively.

2.5 Seed production and seed dispersal

Seed results from the fertilization and maturation of an ovule. It consists of the embryo plant, which develops into the seedling during germination, often of a nutritive tissue, and a protective coat, the testa, which encloses both.

2.5.1 Seed production

2.5.1.1 Measuring fruiting success

Fruit production can, in some cases, be assessed from the ground. Relative measures of fruit set can be obtained by scanning tree canopies with binoculars and scoring numbers of fruit set per inforescence. Counts of old flowers, aborted fruit, and mature fruit will provide a measure of seed production and fruit abortion as a proportion of fruit set. The flower and fruit harvest can be collected on a daily basis, thereby providing information on flower and fruit phenology, time of peak abortion, and rate of growth. From these data, reproductive success can be calculated (Ghazoul, 1997).

Production o f g ravity-dispersed s eeds can be assessed by collecting falling flowers and seeds throughout the reproductive period into trays or traps of equal area placed under tree canopies prior to flowering. Seed traps have been widely used and range in size and construction (Jackson, 1981, Andersen, 1989).

2.5.1.2 Reproductive success

Reproductive success of a species is divided into 2 phases: (1) preemergent, which refers to the number of viable seeds released into the environment, and (2) postemergent, which refers to the percentage of progeny from those seeds that survive to reproduce. Determining preemergent reproductive success are concerned. This is calculated as the product of the fruit to flower ratio (Fr/Fl) and seed to ovule ratio (S/O). In general, outcrossing species have a low preemergent reproductive success, often below 30 %, whereas inbreeding species have a high preemergent reproductive success, often greater than 90 % (Weins et al., 1987).

The proportion of flowers that develops into mature fruits (Fr/Fl) varies greatly among species, populations within a species, breeding system, and from year to year (Sutherland, 1986). In some species, 1,000 or more flowers can be produced for each fruit. In *Tectona*, only 2 % and in *Pterocarpus*, 7 % of flowers mature (Bawa and Webb, 1984). In the tropical legume *Cassia,* which is more typical, 30-60 % of flowers may produce fruits (Stephenson, 1981).

2.5.1.3 Factors affecting seed development

During the relatively long reproductive cycles in hardwoods, several factors can be responsible for the failure of sexual reproduction. The relative importance of each of these factors varies with the species and from year to year. The failure of sexual reproduction can result from failure at floral initiation or pollination or from bud, flower, embryo, or seed abortion. In many species, flowering and seed set can be increased through an understanding of these processes and by identifying the factors responsible (Owens, Sornsathapornkul and Tangmitcharoen, 1991).

One of the most frequent causes of reduces seed production is the failure of trees to flower. Almost all forest trees show variation in flowering periodicity. This is particularly true of trees with indirect flowering, in which floral initiation usually occurs at the same time as fruits from the previous flowering season are maturing. The maturing fruits preferentially use available nutrients, reducing or totally inhibiting floral initiation (Owens and Blake, 1985). Even when floral initiation occurs, there may be a considerable loss of floral structures as a result of abortion at various stages of development.

Unsuccessful pollination is usually the second most important factor in poor seed production. Most tropical forest trees are pollinated by animals, usually insects. The pollinator must be present and active when flowers are receptive. Not only must the time of flowering among trees be synchronized for cross-pollination, it must also be synchronized with the pollinator. The reproductive biology and phenology of each tropical forest tree must be understood, as well as the life cycle and behavior of the various pollinating species (Bawa, Bullock, Perry, Coville and Grayum, 1985).

Incompatibility, which prevents inbreeding is common in tropical hardwoods. Incompatibility is beneficial in that it reduces homozygosity, however, it also reduces seed production. Incompatibility can occur at different stages of the reproductive cycle. It reactions may prevent pollen from adhering to the stigma, prevent pollen hydration or germination, or inhibit pollen tube growth in the stigma, style, or nucellus (Gifford and Foster, 1989). Any of the these reasons will prevent fertilization by incompatible pollen and reduce seed production, although they may improve seed quality. These are all prefertilization events.

The number of ovules produced per flower usually far exceeds the number of seeds that mature. Losses occur throughout ovule and seed development, at prefertilization and postfertilization stages (Willson and Burley, 1983). Ovules may abort, even when abundant pollen is available, because of low pollen viability or vigor, incompatibility, or compatibility for resources (Owens and Blake, 1985). Woody species tend to be outcrossers and have lower seed : ovule and fruit : flower ratios than inbreeders (Weins et al., 1987). Woody perennials must allocate resources between vegetative and reproductive growth and store reserves for the next growing season. This often reduces flower, fruit, and seed numbers, lowering the percentage of fertile ovules that develop into viable seed (Charlesworth, 1989). Another factor involved in seed loss in outcrossers is high genetic load, which results in abortions of ovules, embryos, or seeds.

Hardwood flowers have varying numbers of ovules, depending on the species. In *Quercus*, six ovules form but only one matures into a seed (Mogensen, 1975). In *Betula*, only one of four ovules develops into a seed. Although ovule abortion decreases seed production, it can be an important means of selection or ensure the survival of remaining ovules (Shaanker, Ganeshaiah and Bawa, 1988). The number of ovules that develop into seeds may be limited by five main factors : (1) the number of ovules produced, (2) the quantity and quality of pollen transferred, (3) the amount of nutrients and photosynthate available for fruit and seed development, (4) damage to and predation of fruit and seeds, and (5) the physical environment (Ghazoul, 1997).

Aside from the quantity and quality of pollen received, fruit development and maturation may be limited by the availability of resources. Fruit located close to sources of photosynthate and nutrients often develop larger seeds or are less likely to abort than fruit further away (Wyatt, 1980). Similarly, flowers that are fertilized early in the season have higher survival than flowers pollinated later when stored resources are diminished (Lovett-Doust, 1980) and, within inflorescences, early formed basal fruits have the highest probability of maturation (Tayo, 1986).

2.5.2 Seed dispersal

Seed dispersal promotes survival by increasing the chance of landing in a favorable microsite, and decreasing the probability of predation. In the absence of dispersal, high densities of mature seeds beneath the parent plant would suffer intense parental and sibling competition for light and nutrients, and their spatial predictability makes them highly vulnerable to seed predation and herbivory. For example, in Costa Rica, seed predators attracted to high seed densities beneath parent trees of *Sterculia apetala* cause 100 % predation (Janzen, 1972). Thus, avoidance of natural enemies (Janzen, 1971), competition between siblings (Harper, Lovell and Moore, 1970), and the probability of finding a physically suitable establishment site (Connell, 1978) favor the evolution of seed dispersal. The spatial distribution of seeds around their source is termed the 'seed shadow', and the extent of tree seed shadows has important implications for the reproductive success of the parent plants, and the genetic structure of the population.

2.5.2.1 Dispersal mechanisms

The transport of mature seeds from the parent plant often involves an agent such as wind, water, or animals, although some plants scatter their own seeds by means of an exploding pod (Willson, 1992) Much of the variety in seed shape, size, and morphology is related to dispersal, and the dispersal mode is often easily identified from a brief examination of these features. Many seeds have no evident morphological specialization, but may be transported by wind if very small, or transported in mud adhering to the feet of animals. Others use a combination of dispersal strategies, such as explosion and ant dispersal (Ghazoul, 1997). Some common dispersal mechanisms and morphological characters relating to each are listed below.

Table 2.5 Dispersal modes of plants

Dispersal agent	**Morphological structure**	**Plant types**	**Dispersal potential**	**Examples**
Wind	Plumed, feathered, small seeds	Pioneers, lianas, canopy trees	Good	*Eucalyptus* spp. Compositae
Gravity	Winged	Canopy trees	Poor	Dipterocarpaceae
Exploding	None	Small trees, shrubs	Poor	*Xylia kerii*
Animal-Internal	Fleshy pericarp, tough endocarp	Large and small trees	Good	Ficaceae, Palmae, Lauraceae
Animal-External	Hooks, sticky	Undergrowth, shrubs	Good	*Arctium* spp., *Xanthium* spp.
Ants	Nutritious appendage	Small trees, shrubs	Poor	Australian Acacia spp.
Water	Flotation structure	Riparian, coastal	Good	*Cocos nucifera*

(Ghazoul, 1997)

Dispersal by wind is assisted when the seeds are very light and small (e.g. Eucalyptus), or when either the seedcoat (e.g. *Salix, Ceiba, Dyera*) or the pericarp (e.g. *Triplochiton, Pterocarpus, Koompassia, Casuarina, Fraxinus*) possesses wings or hairs which serve to prolong flight. Fruits may also be winged by the enlargement of persistent sepals (most Dipterocarps) or persistent petals (e.g. *Gluta, Swintonia*) (Krugman, Stein and Schmitt, 1974, Ng, 1981).

The distance of seed or fruit dispersal by wind depends not only on the weight and type of dispersal unit but also on the local wind conditions and the exposure and isolation of the mother trees, Studies of the winged fruits of *Shorea contorta* in the Philippines indicated that 90 % of the fruits travelled 20 m or less from the stem of the mother tree, and summary of other dipterocarp studies compiled by the same authors shows that most fruits landed within 30 m or, at most, 40 m. This compares with a dispersal distance within 2-3 m of the crown perimeter for a heavy, wingless seed such as *Quercus crispula* in Japan and a distance of over 60-90 m for 5 % of the light, winged seeds of *Betula ermannii* downwind from a belt of mother trees left in a logged over area (Tamari and Jacalne, 1984). A study on seed dispersal of *Dipterocarpus alatus* and *D. turbinatus* in the mixed deciduous forest at Kanchanaburi found that wind was the most important dispersal mechanism. The dispersal radius of mature fruits of *D. alatus and D. turbinatus* were longer than 50 and 60 m, respectively. The average fruit's size and wing's size found at various distance from the mother trees were not clearly different (พรพิทักษ์ ปัญญารัตน์, 2539).

2.5.2.2 Densities of dispersed seed and seedlings

Most seeds are not dispersed far, resulting in high seed densities close to the parent plant. However, the distribution pattern of adult plants in the habitat is not always clumped, but may appear random or even uniform (Hubbell, 1980). Seed density may or may not be an important variable. Density-related mortality factors can either decrease (Webb and Willson, 1985) or increase (Nilsson and Wastljung, 1987) the probability of individual survival at high densities, which might negate or enhance the fitness of plants with high seed production. Conversely, seedling establishment and survival might be independent of density, for example when only a limited number of micro-sites suitable for establishment exist. Thus seed and seedling density should be an important consideration in evaluating plant reproductive success and population dynamics (Ghazoul, 1997).

2.5.3 Seed predation

Large quantities of forest seed are required for plantation purposes. In some years flowers and seeds are abundant but in other years crops are light. Poor crops may be the result of a number of different factors including insects. Seed insects destroy seed by feeding on the seed endosperm and/or embryo thus destroying the seed or reducing viability. It is well documented that many native tree species suffer considerable loss of seed due to insect pests. Beeson (1941), Mathur, Singh and Lal (1958) in India have recorded that a large number of insects damage flowers, fruits and seeds of a wide range of tree species. The latter reported 558 insect species affecting 363 species of host plants. According to Chaiglom (1975) at least 61 of these insect species cause damage to flowers, seeds and fruits of forest trees in Thailand.

The factors which cause an insect to become harmful are very diverse. Many are climatic, and act either by inducing a state of stress which makes trees less resistant to attacks, or by increasing the reproductive potential of insects (increased fertility, increased survival rate). Considered interference by man, such as inappropriate forestry methods or the introduction of alien species, may have similar effects (Dajoz, 2000).

Fruit and seeds are predated by a wide variety of organisms, from very small insects to large mammals, and fruit and seed morphology or chemistry are often adapted to minimize predation. Thus, hard husks, irritating hairs, resins, toxic chemicals, and constrictions separating seeds are defense mechanisms that serve to reduce seed predation. Seed predators are divided into two groups according to the stage at which they attack the seed or fruit. Pre-dispersal predators are usually small, sedentary, specialist feeders, belonging to the insect orders Diptera, Lepidoptera, Coleoptera, and Hymenoptera. Post-dispersal predators tend to be large, more mobile generalists like rodents and birds, but can also be insects. These two groups differ in another important respect pre-dispersal predators attack fruit and seeds while they are still aggregated on the plant, and are thus spatially and temporally predictable; post-dispersal foragers must search for scattered, inconspicuous items at usually low densities and against a cryptic background (Ghazoul, 1997).

Table 2.6 Insect caused seed losses in some trees in Thailand, on the year 1983.

Tree species	Insect	Period	% damaged
Albizia procera	Coleoptera, Bruchidae, *Bruchus bilineatopygus*	Feb. – Mar.	30 – 40
Bauhinia saccocalyx	Coleoptera, Bruchidae, *Caryedon serratus*	Apr. – May	80 – 95
Cassia siamea	Coleoptera, Bruchidae, *Caryedon lineaticollis*	Mar. – Apr.	
Dipterocarpus intricatus	Coleoptera, Apionidae, *Nanophyes* sp.	Mar. – Apr.	50 – 90
	Hymenoptera, Torymidae, *Microdontomerus* sp.	Apr.	
Shorea roxburghii	Coleoptera, Curculionidae, *Alcidodes dipterocarpi*	Apr. – May	
Shorea siamensis	Coleoptera, Curculionidae, *Alcidodes dipterocarpi*	Apr. – May	

(Adapted from Eungwijarnpanya and Hedlin, 1983)

2.5.4 Seedling establishment

Ultimately, plant recruitment might be limited by the availability of suitable sites for seed germination and seedling establishment, and not viable seed availability. In most seeds the radicle of the embryo exerts pressure on the seedcoat which commonly splits first at the micropyte point. This gives rise to the primary root which grows down into the soil and soon produces lateral roots. Subsequent stages depend on whether the species exhibits epigeal germination (e.g. *Pinus*), or hypogeal germination (e.g. *Quercus*). In epigeal germination anchoring of the young plant by the radicle is followed by rapid elongation of the hypocotyl which arches upwards above the soil surface and then straightens; simultaneously the cotyledons and plumule are exposed, to which the seedcoat may or may not still be attached. The plumule then develops into the primary shoot and photosynthetic leaves. In hypogeal germination, the cotyledons remain in underground or on the ground while elongation takes place in the plumule (Ng, 1978).

Seedling emergence and establishment are critical at early plant life cycle stages. Attributes of newborn seedling such as size, function, position of cotyledons, and amount of maternal seed reserves may be crucial to capture resources, and to cope with mortality agents. This suite of attributes constitutes the so-called intitial seedling morphology or seedling type (Fenner, 1985).

In tropical forests, the adaptive value of different seedling types has been explored analyzing seedling performance under environment conditions that characterize open and closed-canopy forest patches. Seedlings of different types have different light requirements. Seedlings that establish under shaded conditions often possess large amounts of seed reserves, which increase the probability of survival under light-limited conditions (Foster, 1986). In contrast, seedlings of secondary forest species, which do not survive under the shade, have small seed reserves and photosynthetic cotyledons that enable them to grow fast in light-rich environments (Garwood, 1996). In initial morphology of seedlings is associated with seed size and dispersal capacity. For example, establishment of seedlings depends on interactions between forest environmental heterogeneity, seed dispersal, seed bank dynamics, and functional traits of seedlings (Augspurger, 1984). At Los Tuxtlas, Mexico, seedlings of tree species differing in initial morphology exhibited differential growth between gaps and mature forest. Although all species showed increasing growth with light, species with epigeal seedlings and small, widely dispersed seeds have higher relative growth rates and grew faster in biomass than hypogeal seedlings of large-seeded but poorly dispersed species (Popma and Bongers, 1988).

2.6 Seed quality

Efficiency and success in raising plants in their subsequent establishment in forest plantations depend to a great extent on the quality of the seeds used. It follows that foresters need accurate estimates of the quality of the seeds in which they deal or which form the basis of their afforestation projects. For the practising forester, the most important object of seed testing is the provision of an accurate estimate of the capacity of a given seedlot to produce healthy, vigorous plants suitable and to determine the value of seed for field planting. (Willan, 1985).

Seed is a living biological product and its behaviour cannot be predicted with the certainty that characterises the testing of inert or non-biological material. The methods used must be based on scientific knowledge of seed and on the accumulated experience of seed analysists (Turnbull, 1975). The physical characteristics of seeds which are tested include purity, weight, and moisture content; physiological characteristics are measured by germination tests, viability and vigor.

Seed vigor is the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence. Seeds which perform well are termed high vigor seeds and those which perform poorly are called low vigor seeds. The causes of variations in vigor are several and diverse and the commonly known factors which influence vigor level were listed to clarify the concept further. They are: genetic constitution, environment and nutrition of the mother plant, stage of maturity at harvest, seed size, weight or specific gravity, deterioration and ageing, and pathogens (Perry, 1978).

A seed vigor test is a laboratory method to evaluate seed vigor. Seed vigor is highly complex. At the biochemical level, it involves biosynthesis of energy and metabolic compounds. At the germination level, it involves speed and totality of germination, mechanical rupture force of seedlings, tolerance of seedlings to environmental stress and disease resistance. A vigor test can be a measurement of one or more of these events. Nearly all major vigor tests can be grouped into three general categories : (1) seedling growth and evaluation tests, (2) stress tests, and (3) biochemical tests. Tests falling in the first category include the seedling vigor classification, seedling growth rate tests and speed of germination. Stress tests include the accelerated aging test, cold test, cool germination test, brick grit test, and osmotic stress. Biochemical tests include the tetrazolium test, conductivity tests, respiration test, GADA test and ATP content (AOSA, 1983).

2.6.1 The moisture content

The moisture content of a sample is the loss in weight when it is dried in accordance by methods suitable for routine use. It is expressed as a percentage of the weight of the original sample.

Forest tree seed handlers are vitally concerned with the moisture content of stocks. Moisture content can influence or serve as an indicator of seed maturity, viability during storage, and pretreatment required. Seed moisture is the most important factor determining viability and it is essential that it be measured accurately. For each species, the appropriate drying temperature and drying period have to be determined experimentally and adhered to strictly in routine tests. Ideally, drying temperature and period should be such that : only free water is driven off, and no chemical changes take place (Krishnapillay, 1992). Owing to the different morpho logical and physiological characteristics of tree seed, optimal moisture content for successful storage varies greatly with species storage conditions. For most of coniferous and small-seeded hardwood seed that are tolerant to drying, Wang (1974) recommends a moisture content of 8 % (fresh weight).

2.6.2 The germination test

The most significant part of seed testing is the germination test, and its most important feature is evaluating the seedling, i.e. deciding which seedlings are normal and which are abnormal. Normal germination has been defined as "the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further into a satisfactory plant under favourable conditions in soil" (ISTA, 1996). The seed analyst must be alert to abnormal germination because it usually represents an intermediate stage between viability and death, and thus indicates weakness in the seedlot. Seeds of all species should have their own established criteria for germination. ISTA (1996) defined the criteria for germination as follows :

1. Normal seedlings show the potential for continued development into satisfactory plants when grown in good quality soil and under favourable conditions of moisture, temperature and light. To be classified as normal a seedling must conform with one of the following categories :

(1) intact seedlings : seedlings with all their essential structures well developed, complete, in proportion and healthy.

(2) seedlings with slight defects : seedlings showing certain slight defects of their essential structures, provided they show an otherwise satisfactory and balanced development comparable to that of intact seedlings of the same test.

(3) seedlings with secondary infection : seedlings which it is evident would have conformed with 1 or 2 above, but which have been affected by fungi or bacteria from sources other than the parent seed.

50 % rule : Seedlings are considered as normal if half or more of the total cotyledon tissue is functional, but abnormal when more than half of the cotyledon tissue is not functioning, e.g. missing, necrotic, discoloured or decayed. The 50 % rule does not apply when the tissue around the attachment of the cotyledons to the hypocotyl are affected, i.e. show signs of damage or decay (Hill, 1994).

2. Abnormal seedlings as defined by the ISTA rules is one which does not have the capacity to develop into a normal plant when grown in soil under favourable conditions of moisture, temperature and light. The following seedlings are classified as abnormal :

(1) Damaged seedlings: seedlings with any of the essential structures missing or so badly and irreparably damaged that balanced development cannot be expected.

(2) Deformed or unbalanced seedlings : seedlings with weak development or physiological disturbances or in which essential structures are deformed or out of proportion.

(3) Decayed seedlings : seedlings with any of their essential structures so diseased or decayed as a result of primary (i.e. from the parent seed) infection that normal development is prevented.

3. Ungerminated seeds : Seeds which have not germinated by the end of the test period when tested under the conditions given in ISTA rules, are classified as follows:

(1) Hard seeds : seeds which remain hard at the end of the test period, because they have not absorbed water.

(2) Fresh seeds : seeds, other than hard seeds, which have failed to germinate under the conditions of the germination test, but which remain clean and firm and have the potential to develop into a normal seedling.

(3) Dead seeds : seeds which at the end of the test period are neither hard nor fresh nor have produced any part of a seedling.

In seed germination tests, good progress has been made on effective pretreatments for overcoming seedcoat dormancy. The seeds of most legumes such as *Acacia* spp. and *Albizia falcataria* are hard-coated and require scarification before maximum uniform germination can be obtained. Manual scarification as well as acid scarification for 15 minutes were effective in breaking seedcoat dormancy in *Cassia siamea* and *Peltophorum dasyrachis* (Kobmoo, 1990), whereas seed cutting resulted in improved germination of *Leucaena leucocephala* (Ponoy, Bhumibhamon and Kobmoo, 1984).

2.6.3 Seedling vigor classification

This vigor test is to evaluate the stage of development of germinated seeds and classify them into a number of development or vigor classes. It is similar to the standard germination test. The only difference between the two tests is that normal seedlings are further classified as "strong" and "weak". For example, normal seedlings showing one or more of the following symptoms in the soybean germination test are classified as "weak" : primary root missing, one cotyledon missing, hypocotyl with breaks, lesions, necrosis, twisting, or curling. Other normal seedlings are classified as "strong". The basis for this test is that the "strong" and "weak" classification provides a means of separating seedlings free of deficiencies from those with deficiencies which are symptomatic of low vigor or reduced quality. A loss of a portion of the cotyledon could result in a decrease in growth inhibitor and a promotion in hypocotyl elongation (Burris and Knittle, 1975).

The advantage of this test is that very little work in addition to the standard germination test is required. However, careless handling of the test, variations in the judgment of seedling classification and microorganism infection may affect the counts of "weak" and "strong" seedlings. Indeed significant variation of testing results among laboratories was observed in two vigor "referee" programs for all crops tested (McDonald, 1977). This test was proposed for use in the vigor assessment of soybean, cotton, peanut, and garden bean (Woodstock, 1976). Significant correlations between testing results and field emergence were observed in the 1977 referee (McDonald, 1977) for corn, but no significant correlation was observed for corn in the 1978 referee (Tao, 1978).

2.6.4 Germination index

Generally, the use of total germination, by itself, is not a measurement that meets the needs of seed analysts; it is an absolute value that tends to be misleading. For example, a seed lot of a given species with 95 % germination in 15 days, obviously has a higher proportion of vigorous seeds than a seed lot of the same species that requires 45 days for 95 % germination. What is required is a formula that includes speed of germination as well as total germination. The emphasis has to be germination energy. This is what is meant by "germination index" or "speed of germination" (Krishnapillay, 1992).

Germination energy has been defined in more than one way : (1) The percent, by number, of seeds in a given sample which germinate within a given period e.g. in 7 or 14 days, under optimum or stated conditions or (2) The percent, by number, of seeds in a given sample which germinate up to the time of peak germination, generally taken as the highest number of germinations in a 24 hour period. (Ford-Robertson, 1971). Using these methods, it is found that the higher the number, the higher the seed vigor. Germinative energy is a measure of the speed of germination and hence, it is assumed, of the vigor of the seed and of the seedling which it produces. The interest in germinative energy is based on a theory that only those seeds which germinate rapidly and vigorously under the favourable conditions of the laboratory are likely to be capable of producing vigorous seedlings in field conditions, where weak or delayed germination is often fatal (Aldhous, 1972).

In the standard germination test, a first count and a final count are normally performed. The number of normal seedlings recorded in the first count represents the population of fast germinating seeds and thus functions as a vigor measurement. This test is similar to the seedling vigor classification test with the exception that the strong normal seedlings in the second count are excluded. In soybean studies, the first count (4 days) was found to provide an estimate of seedling vigor (Burris, Edje and Wahab, 1969) and has been used as a component of a vigor index (TeKrony and Egli, 1977). It has been reported that foliage development, dry matter accumulation, and seed yield from rapidly germination soybean seeds exceeded those from slowly germinating seeds in greenhouse and field conditions (Pinthus and Kimel, 1979). The advantage of the speed of germination test is that very little work is required when compared to the standard germination test. Variations in temperature or moisture in the test chamber and substrata, however, may affect test results.

2.6.5 The X-ray test

Usually, viability tests are faster than germination tests. At present, it is recognised that X-radiography is the quickest method for viability testing and is widely used in North America and Europe for forest tree seed research. Kamra (1976) indicated that for tropical forest trees X- radiography could be reliably used to rapidly detect the content of fruit, and the degree of seed development, mechanical damage, insect attack, disease, viability of seed, empty and filled seed, etc.

Techniques for X-radiography at ASEAN region have been reported by Kobmoo and Skeates (1986). The procedure can be used in determining seed quality. However, the test is not a direct test. It involves the use of X-radiography for studying the anatomical development of embryo and cotyledons in various kinds of seed. The technique has been tried on the fruits or seeds of 60 tropical forestry species and the results show that it can be reliably applied in processing such seeds (Kamra, 1980). Kamra and Simak (1965) found that the dosage level used in this technique had no ill-effect on germination percentage. Results can be used to evaluate seed quality by comparing with the standard germination test (Copeland, 1976). However, Saelim, Pukittayacamee, Bhodthipuks and Wang, (1996) reported that the x-ray tests generally overestimate viability. For example, the x-ray test of *Dalbergia cochinchinensis*, seeds stored for 2 years, was unreliable because it estimated that 94 % of the seeds were viable, whereas the actual germination percentage was 49 %.

The x-ray radiographs of seed are evaluated for seed viability according to their appearance on the film. Seed may be classified into 2 simple categories, viable and nonviable (Saelim, Pukittayacamee, Bhodthipuks and Wang, 1996).

Viable seed : Seed is considered viable when full development can be seen in both the embryo and endosperm or when insect damage is less than 33 % of cotyledons. Although insect-damaged seed can be considered viable, their germinants may have low vigor.

Nonviable seed : Seed is considered nonviable if it shows any of the following :

- absence of embryo, cotyledons
- fully developed cotyledons without embryo
- fully developed cotyledons with one or more underdeveloped embryos, none of which occupies more than 25 % of the embryo cavity
- shrunken cotyledons with underdeveloped embryo, which occupies less than 50 % of the embryo cavity
- underdeveloped cotyledons less than 50 % of seed content
- shattered cotyledons
- insect damage to the embryo or more than 33 % of cotyledons

2.7 Morphological database of fruits and seeds

2.7.1 Seed development

A seed is a structure formed by the maturation of the ovule following fertilization. Development of the fertilized ovule into the mature seed involves several different parts. From the outside inwards these are as follows :

(1) The integuments of the ovule become the seedcoat of the mature seed. The seed coat usually consists of 3 layers: 1) an outer, thin, often colored sacotesta, 2) a middle, thick sclerotesta consisting of hard stone cells, and 3) a thin, inner endo-testa. The scar, where the funiculus attaches, is the hilum. The seed coat is usually very hard and often impermeable to water. It protects the seed contents from drying out, mechanical injury, or attacks fungi, bacteria and insects, until it is split at germination. It may be covered by epidermal hairs or bear wings of various types (Gifford and Foster, 1989).

(2) The nucellus may persist in some genera as a thin layer, the perisperm, lying inside the seedcoat and supplying food reserves to the embryo. In most angiosperms, however, it soon disappears.

(3) The endosperm commonly grows more rapidly than the embryo during the period immediately after fertilization. It accumulates reserves of food and at its fullest development is rich in carbohydrates, fats, proteins and grow hormones

(4) The embryo occupies the central part of the seed. Its degree of development at the time the seed is ripe varies greatly according to species. The radicle which at germination will give rise to the primary root, the seed leaves or cotyledons, the plumule from which will develop the primary shoot, and the hypocotyl which connects the cotyledons with the radicle (Kozlowski, 1971).

In some species the embryo is still small and undeveloped when the seed is ready for dispersal, and an additional period under suitable environmental conditions is needed for maturation of the embryo after seed shed, before the seed can become capable of germination, e.g. *Fraxinus excelsior* (Willan, 1985).

2.7.2 Fruit development

A fruit is a mature, ripened ovary that contains the seeds. 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. There are several types of fruits, which differ as a result of variations in the structure or arrangement of the flowers from which they formed. The four basic types of fruits are listed below (Berg, 1997).

(1) **Simple fruit** : develops from a flower with a single pistil.

a. Fleshy : 1) Berry : soft and fleshy throughout, usually has many seeds.

2) Drupe : has a hard, stony pit, has a single seed.

b. Dry, splits open to release seeds : 1) Follicle : splits open along one side.

2) Legume : splits along two sides. 3) Capsule : splits along many sides or pores.

c. Dry, does not splits open : 1) Grain : single-seeded, seed fully fused to fruit wall. 2) Achene : single-seeded, seed attached to fruit wall at base only.

3) Nut : single-seeded, has a hard, thick fruit wall.

(2) **Aggregate fruit** : develops from a flower with many separate ovaries.

(3) **Multiple fruit** : develops from an inflorescence, that is from many flowers borne on a common floral stalk, the ovaries of these flowers fuse together to form a single fruit.

(4) **Accessory fruit** : develops from a flower in which the receptacle or floral tube enlarges and becomes part of the mature fruit.

Willan (1985) described the types of fruits as follows :

(1) Dehiscent, splitting open when ripe to release the enclosed seeds; examples are the **capsule** (e.g. *Eucalyptus*), a multilocular fruit derived from a syncarpous ovary, and the leguminous **pod** (e.g. *Cassia*), which is derived from a single carpel and splits along two sutures. The pericarp may be dry, semi-fleshy or fleshy at the time of dehiscence. Semi-fleshy to fleshy capsules are common in the humid tropics (e.g. *Baccaurea, Durio, Dysoxylum, Myristica*) and are often associated with the development of variously coloured, tasty or smelly pulp (aril or sarcotesta) around the seed.

(2) Indehiscent or dry, closely fused with the seed; example are the **achene**, a small hard one-seeded fruit with membranous pericarp, the **samara**, similar to the achene but with pericarp extended to form a wing (e.g. *Triplochiton*) and the **nut**, a rater large one-seeded fruit with woody or leathery pericarp (e.g. *Shorea, Quercus*).

(3) Indehiscent and fleshy, often distinguished by colour, smell and taste to attract fruit-eating birds and animals. Two types are distinguished. The **berry** has an outer skin and inner fleshy mass, containing seeds that have a hardened seedcoat (e.g. *Diospyros, Pouteria*). The **drupe** has the inner layer of the pericarp hardened to protect the seeds (e.g. *Prunus, Gmelina, Azadirachta, Mangifera*); the seedcoat, having no protective function in a drupe, is usually papery or membraneous. The different pericarp layers in a typical drupe are known as exocarp (the skin), mesocarp (the flesh) and endocarp (the stone).

2.7.3 The study about fruits and seeds

A study on fruits and seeds morphology from 140 of tree species in Doi Suthep-Pui National Park reported that fleshy fruits were found all year round, but dry fruits were found primarily between September to November. Large fruits (>2 cm length) were also found throughout the year, whereas the peak fruiting period for small fruits occurred between August to November (เกริก ผักกาด, 2540).

Color and size of seeds are indicators of seed viability, but they are not as accurate as other indicators because they are affected by environmental factors. Color can be used to determine the maturity of seeds of *Pinus insularis* and other *Dipterocarpus* spp. According to Lapitan (1991) seeds of *Trema orientalis* are mature when they turn from green to black. Seeds of *Pinus kesiya* are mature when the scales of cones turn brown. Seeds of *Dryobalanops aromatica*, *Anisoptera*, and *Shorea* spp. should be collected when their seed coats and cups are green. Veracion (1966) reported that larger and heavier seeds of *P. kesiya* had higher germination rates, and resulted in bigger and more vigorous seedlings with higher survival rates, than smaller, lighter seeds. Basada (1979) showed that the germination rate of big seeds of *Shorea contorta* was significantly higher than the germination rate of medium and large seeds. In Malasia, Yap (1981) documented that seeds of dipterocarps are ripe when their wings change from pink to brown and that pods of *Parkia javanica* are fully mature when they turn black. Mohammad and Ibrahim (1980) reported that seeds of *Gmelina arborea* collected from fruits with yellow pericarps have the highest germination rate. Yap (1980) indicated that dehiscent fruits such as *Dyera costulata* and *Shorea macrophylla* can be harvested when fruit walls begin to split.

The effect of seed weight on seedling growth of *Pterocarpus macrocarpus* was studied in 72 open-pollinated families from 7 populations, indicated that families with heavier seeds tended to produce taller seedlings at 2 months of age (Whuang-plong, Liengsiri, Piewluang and Boyle, 1994). It is known from work on other species that seed characters such as weigh and ripeness influence early grow and survival of seedlings (Barnett, 1985). The work of Piewluang, Liengsiri and Boyle (1994) has demonstrated that seed weight is related to fruit size, so the collection of heavier seed is feasible, and therefore has the potential to improve the efficiency of seed collection.

CHAPTER III

STUDY SITE AND METHODS

3.1 General description of the study site

3.1.1 Location

The field study area was conducted in Nong Rawiang forest, Muang District, Nakhon Ratchasima Province, at latitude 14° 56′ 53.1″ N to 14° 57′ 44.6″ N and longitude 102° 10′ 07.6″ E to 102° 11′ 27.4″ E, approximately 12 km from the city of Nakhon Ratchasima, or 6 km east from the Nakhon Ratchasima-Chok Chai road (Figure 3.1). Total area is 400 hectares. Most area is a level plain with an average altitude of 198 m above mean sea level (Figure 3.2). The northern, southern, and western edges are adjacent to public roads, while the east border is public land. Nong Rawiang in the past was public land, local peoples used for logging and agricultural activities. But since 1969 it has been belonging to Rajamangala Institute of Technology, Northeastern campus, Nakhon Ratchasima (RIT-NEC), for the objectives of field study and management for future expansion. Currently, the area is divided into 4 parts, namely (1) the Royal Garden of Queen Sirikit, (2) the area for buildings, (3) the area for field studies and cultivated plants, and (4) the plant preservation area. These land divisions are approximately 32, 32, 176, and 160 hectares, respectively (สุรศักดิ์ ราศรี, 2540). As for the last one, the preserved area is the part of the Plant Genetic Conservation Project Under The Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn.

3.1.2 Physical soil properties

According to surveying of the 3rd Regional Department of Land Development Nakhon Ratchasima it was found that soil properties of Nong Rawiang forest consist of two soil series. The eastern site of the area is Warin series with soil depth interval 0-66 cm is loamy sand, pH 6.0-6.5, and interval 66-200 cm is sandy loam, pH 4.5-5.0 (Table 3.1). The western site of the area is Chumpuang series with soil depth interval 0-33 cm is loamy sand, pH 5.5-6.5, and interval 33-160 cm is sandy loam, pH 4.5-5.0 (Table 3.2).

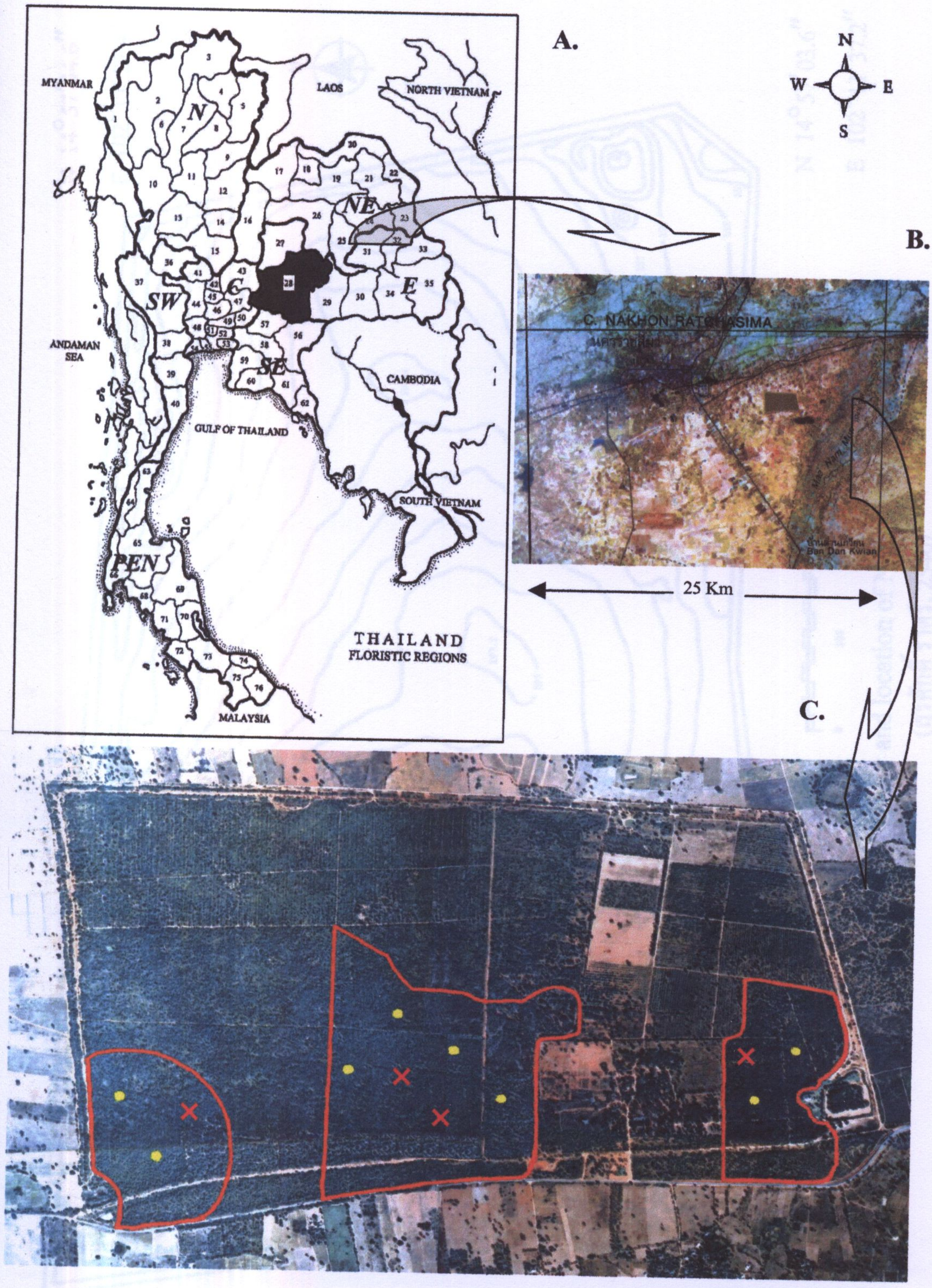


Figure 3.1 A. Map of Thailand. (Source : Flora of Thailand); B. Map of Nakhon Ratchasima province show Nong Rawiang forest area. (Ministry of Science Technology and Energy, 1991); C. Map of Nong Rawiang forest. (Ministry of Interior, 1994): area within the lines are dry dipterocarp forest, the eight round points are location of the study sites, the four x points are location of the cancel-sites

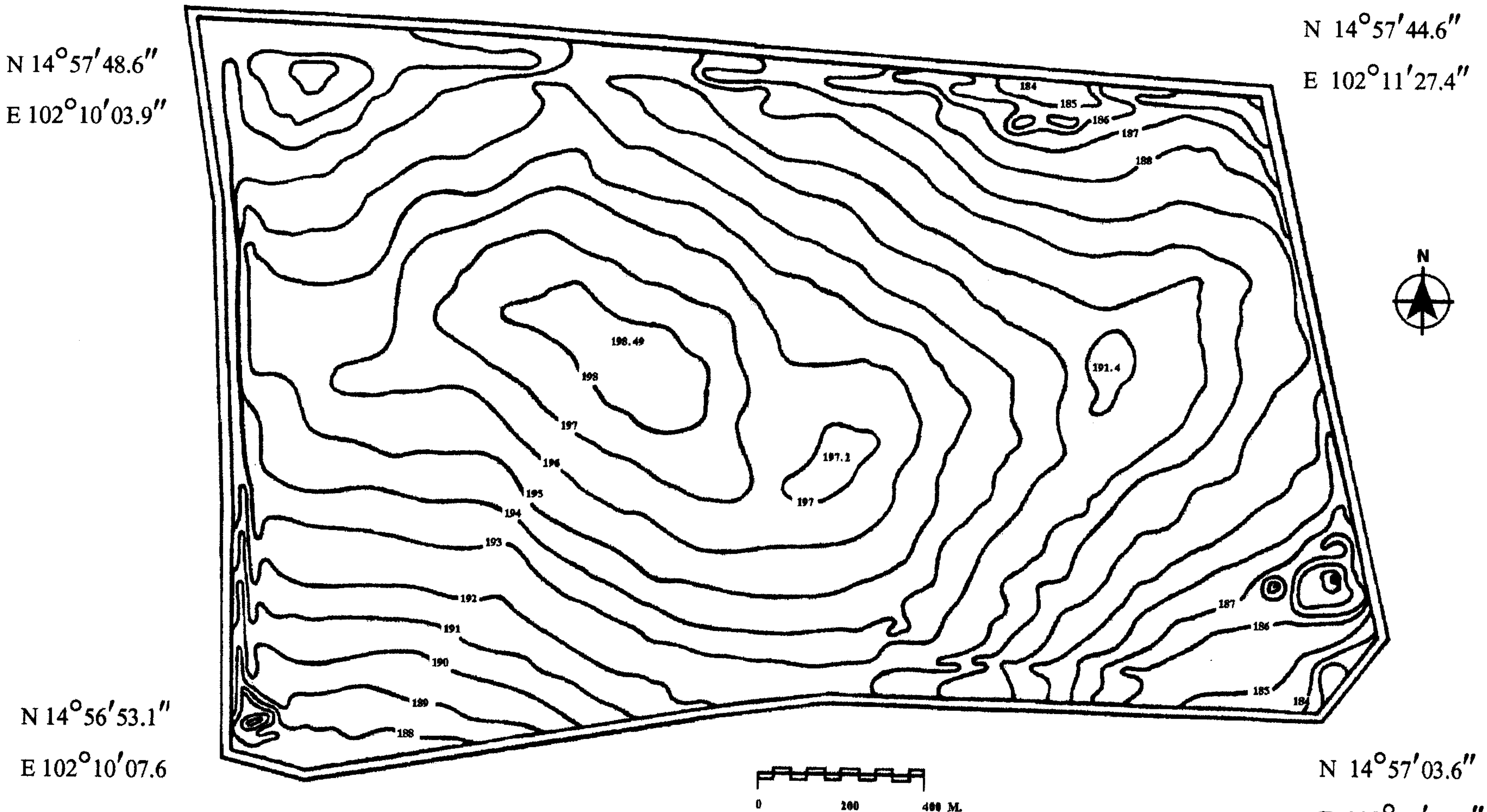


Figure 3.2 Contour and location of Nong Rawiang forest area
(สุรศักดิ์ ราตรี, 2540)

Table 3.1 Soil profile description in the eastern site of Nong Rawiang forest.

Depth (cm)	Description
0 - 8	Loamy sand, dark brown, slightly acid (pH 6.5)
8 - 18	Loamy sand, strong brown, strongly acid (pH 6.5)
18 - 66	Loamy sand, strong brown, medium acid (pH 6.0)
66 - 83	Sandy loam, yellowish red, very strongly acid (pH 4.5)
83 - 113	Sandy loam, yellowish red, very strongly acid (pH 4.5)
113 - 200	Sandy loam, yellowish red, very strongly acid (pH 5.0)

Type of soil : Warin coarse loamy (June 1996)

Table 3.2 Soil profile description in the western site of Nong Rawiang forest.

Depth (cm.)	Description
0 – 5	Loamy sand, dark reddish brown, slightly acid (pH 6.5)
5 – 33	Loamy sand, dark red, strongly acid (pH 5.5)
33 – 78	Sandy loam, reddish brown, very strongly acid (pH 4.5)
78 – 119	Sandy loam, red, very strongly acid (pH 5.0)
119 – 160	Sandy loam, red, very strongly acid (pH 5.0)

Type of soil : Chumpuang coarse loamy (July 1997)

(Classified by 3 rd Regional Department of Land Development Nakhon Ratchasima)

3.1.3 Floristic characteristics

Nong Rawiang forest area is classified into 2 different sites according to the density of trees. The higher density site has 46 species of woody trees and an average density of 173 individuals/hectare. Dominant species are *Lannea coromandelica, Cratoxylum formosum*, and *Urobotrya siamensis*. Sixty species of shrubs and herbs are found, and the average is around 1,262 individuals/hectare. Dominant understory species are *Arundinaria pusilla, Murdannia loureirii*, and *Erythroxylum oblanceolatum*. The averages of total height, the height of lowest limbs, and the diameter at breast height of the woody trees are 4.3 m, 1.5 m, and 5.7 cm, respectively. In the lower density site, there are 35 species of woody trees and the average density is around 72 individuals/hectare. Dominant species are *Lannea coromandelica, Erythrophleum succirubrum*, and *Litsea glutinosa*. Shrubs and herbs comprise more than 37 species and the average is around 4,159 individuals/hectare. The dominant understory species is *Vietnamosasa pusilla*. The averages of total height, the height of lowest limbs, and the diameter at breast height of the woody trees are 2.6 m, 0.9 m, and 4.6 cm, respectively (สุรศักดิ์ ราตรี, 2537).

The forest types covering the preserved area are dry mixed deciduous forest and dry dipterocarp forest (DDF) with an age of the native plants at around 25-30 years. They are secondary forest. Dry mixed deciduous forest has a greater diversity in tree species per area than DDF, 9 and 7 species/hectare, respectively. The dominant species of dry mixed deciduous forest are *Lannea coromandelica, Acacia comosa, Erythrophleum succirubrum, Aporosa villosa, Sindora siamensis*, and *Phyllanthus emblica*, and of dry dipterocarp forest are *Shorea siamensis, Sindora* *siamensis, Lannea coromandelica, Erythrophleum succirubrum,* and *Xylia xylocarpa* (สุรศักดิ์ ราตรี, 2540). A survey in present study found that there are 3 patches of dry dipterocarp forest located in the eastern, central and western areas of Nong Rawiang. Total DDF area is about 112 hectares (Figure 3.1).

3.1.4 Climate

The climate of Nakhon Ratchasima Province is affected by easterly, north-westerly, and southwesterly winds. According to the meteorological data for 40 years (1961-2000), the climate can be separated into 3 seasons with a marked hot season from February to May, followed by a rainy season from May to October, which peaked in September about 219.62 mm of rainfall, 19.45 rainy days, and 80.01 % relative humidity. There is a winter season from November to January, during which minimum temperature was 17.82°C in December, after which temperature and evaporation rise sharply, peaking at 36.42°C and 6.08 mm in April, respectively (Figure 3.3).

As for meteorological data during the period 1991-2000. The maximum highest mean wind speed was 34.6 km/h in April and the minimum highest mean wind speed was 22.5 km/h in January (Meteorological Station of Nakhon Ratchasima, 2001; 16 km from the study site). April and December were the months of maximum and minimum mean radiation at 476.97 and 401.67 cal/cm^2/day, respectively (Meteorological Station of Huay Ban Yang Agricultural Irrigation Research Station, 2001; 25 km from the study site) (Figure 3.4).

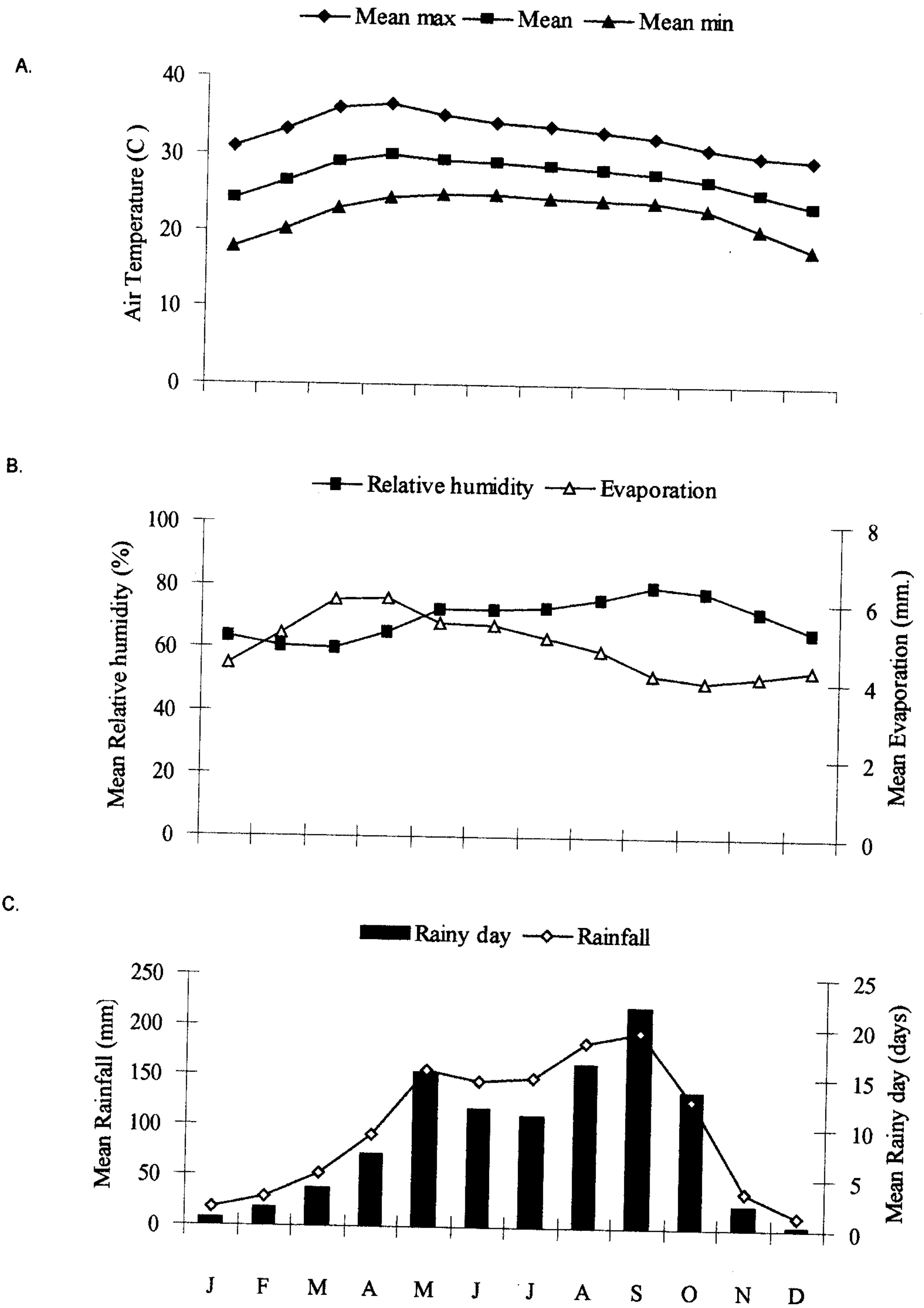


Figure 3.3 Diagram of the climatological data of Nakhon Ratchasima province during the period 1961-2000 : A. Mean air temperature; B. Mean relative humidity and mean evaporation; C. Mean rainfall and mean rainy day (Meteorological Station of Nakhon Ratchasima, 2001).

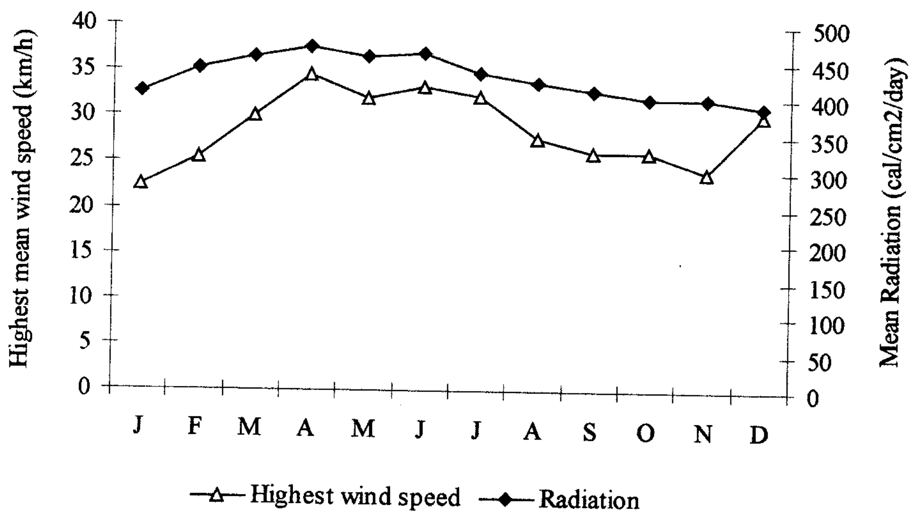


Figure 3.4 Diagram of the climatological data of Nakhon Ratchasima province during the period 1991-2000: Highest mean wind speed (Meteorological Station of Nakhon Ratchasima, 2001) and Mean radiation (Meteorological Station of Huay Ban Yang Agricultural Irrigation Research Station, 2001).

3.2 Materials

3.2.1 Plant community description and analysis

1. Equipment for sampling plots

   - Map of Nong Rawiang (scale 1 : 15,000)

   - Compass, cosine desimals, poles, measuring tape and plastic strings

   - Aluminium plates, hammer and nails

2. Equipment and chemicals for plant collection and description

   - Binoculars, camera, plastic bags, bottles, vernier, ruler and label tacks

   - Plant presses, cutter mounted on a long pole and pruning shears

   - FAA solution, 70 % ethyl alcohol, mercuric chloride and hot air oven

   - Stereoscopic microscope, magnifying lens, forceps, pin and scalpel

3. Equipment for collecting soil sample

   - Auger, plastic bags, mortar, pestle and sieve plate 2 mm mesh sized

3.2.2 Flowering phenomena and pollinator observation

1. Equipment and chemical for collecting flower data

   similar 3.2.1 (2)

2. Equipment and chemical for collecting pollinator data

   - Binocular, camera and watch
   - Hand-net, ethyl acetate, killing bottle, insect pins and insect box
   - Stereoscopic microscope and hot air oven

3.2.3 Pollen efficiency

Equipment and chemical for study pollen efficiency

- Pruning shears, scissors, plastic bags, beaker, petri dish, slide, cover glass, pin, forceps, and painting brush and distilled water.
- Cabinet germinator, compound microscope with attached camera
- Brewbaker's pollen germination medium (Brewbaker and Kwack, 1963).

3.2.4 Seed production and seed dispersal

1. Equipment for study seed dispersal

   - Binocular, cosine desimals, measuring tape, plastic net and seed trap

2. Equipment for study seed predator : similar 3.2.2 (2)

3. Equipment and chemical for study development of seedling

   - Plastic germination box, sand, fungicide and water

3.2.5 Seed quality

1. Equipment for seed moisture content test

   - Aluminium can, digital balance, hot air oven, and desicator

2. Equipment and chemical for seed germination test

   - Plastic germination box, sand, fungicide, water and hot air oven

3. Equipment and chemical for seed X-ray test

   - X-ray machine : Softex model SV-125A, film Kodak industrex AA 400.

   - Developer and fixer solution, cellotape, frames, tanks, trays, beaker, clips hangers, forceps, gloves, lamp, magnifying viewer, fluorescent screen.

3.2.6 Morphological database of fruits and seeds

Equipment and chemical for study fruit and seed morphology similar 3.2.1 (2)

3.3 Methods

3.3.1 Plant community description and analysis

(1.) Method for determining the study plots

The study was carried out in 3 patches of Nong Rawiang DDF on December, 1999. The method for determining the study plots as described by Greig-Smith (1983). The minimal size and number of quadrat were decided before sampling was carried out.

(1.1) Minimal area of quadrat

The size of quadrat was increased from 5 x 5, 10 x 10, 15 x 15.......to 60 x 60 m. In each size, number and name of tree species ≥ 3 cm in stem diameter at 1.3 m height above the ground (DBH) were recorded. The number of tree species with aluminium plate was marked and hold at tree stem. The replications of quadrat size were stratified by random sampling base on 3 patches of DDF. A species-area curve was obtained, and the minimal area of quadrat was decided at the asymtotic point which the number of tree species stable or does not increase more than 10 %.

(1.2) Minimal number of quadrat

Similar to the minimal area of quadrat, the definite quadrats size at random in 3 patches of DDF was laid down. List the different species which present in each quadrat. The species-number of quadrat curve was obtained. The asymtote implied to the minimal number of quadrat.

(2.) Method for description plant community characteristics

All trees with 3 cm in DBH and over existing in each quadrat were mapped, species recorded and measured their DBH. The study was carried out by adopting quantitative ecological method as follows : The importance value index (IVI) was determined by the method of Cottam (1949). Specific diversity was determined by the Shannon-Wiener index of diversity (Krebs, 1998). Stratification was studied adopting the method described by Ogawa et al. (1965b). Species were separated into each layer and listed with number and relative dominance.

(3.) Method for collecting and description tree species

Specimens of tree leaves of every different species were taken from each quadrat and were brought to distinguish in laboratory. Flower specimens collected in FAA solution consist of ethyl alcohol 70 % : 90 ml, glacial acetic acid 5 ml and formaldehyde 40 % : 5 ml (ฎวดถ บุศรรัตน์, 2528). Also fresh fruit and seed specimens were collected in 70 % ethyl alcohol. Dry fruit specimens dried by hot air oven and soaked with mercuric chloride.

For identification of tree species, the key of relative documents were used, for example Flora of Thailand (Smitinand and Larsen, 1970, 1972, 1981, 1984, 1985), Gardner, Sidisunthorn and Anusarnsunthorn (2000), Smitinand (2001), compared with specimens of Forest Herbarium, Bangkok, and by checking with experts such as Assoc. Prof. Dr. Sompong Thammathaworn and Dr. Paul J. Grote. Description of tree morphology base on the basis of plant taxonomy, and the measuring were determined from 20 specimens. Key to tree species were displayed.

(4.) Method for soil analysis

The study was carried out at Nong Rawiang DDF and Farm Mechanics division, RIT-NEC in 3 periods on April, September, and December 2000. In order to study general characteristics of soil, three pits were collected by random. Samples were taken from each quadrat at the depth of about 15 cm. Soil samples from each quadrat were mixed together and exposed to the wind at ambient conditions until they dried. The air-dry soil was grounded using mortar and pestle and sieved through a 2 mm mesh sized sieve. Soil was brought to the 5th Regional Department of Land Development Khon Kaen for analysis. Soil properties that was : Hydrogen ion concentration (pH), find out the pH of suspension of 1:1 w/v dilution by pH meter. Electrical conductivity (EC), measured the EC of suspension of 1:5 w/v dilution by EC meter. Find out organic matter (O.M.) by Walkey & Black method; total Nitrogen by Kjeldahl method; available Phosphorus by Bray no. II method; cation exchange capacity (C.E.C.) by ammonium saturation method; available Sulfer by turbidimetry method; exchangable Potassium, Calcium and Magnesium by ammonium acetate extraction (Jackson, 1973).

3.3.2 Flowering phenomena and pollinator observation

(1.) Method of studying flowering phenomena

The study was carried out at Nong Rawiang DDF from January to December 2000. Flowering of tree species list from 3.3.1 (3) were observed throughout DDF area every week in one year period. The flower were collected and preserved in 70 % alcohol. Flower morphological features were studied. A classified number of flowering tree species on inflorescence type, flower shape, petal color, flower position, flower diameter, level of anther and stigma within flower and ovary type were recorded, separated in each month and calculated in percentage. Relational values between flowering tree species and environmental factors including temperature, radiation, evaporation, rainfall, relative humidity, soil temperature and soil moisture content in each month were analysed by simple regression and multiple regression.

(2.) Method for pollinator observation

According to 3.3.1 (3), four individuals of each dominant tree species were selected as the representative species to be studied on their pollination mechanism. The study was carried out in 2000. (Except *Shorea siamensis* was carried out in 2002). Pollinators behavior were recorded twice per month at fixed period of time. The times and the numbers of the most efficient pollinators of individual dominant tree species were recorded within 5 minutes of beginning hourly from 7.00-17.00 h. Number of pollinators visitation were calculated in percentage.

3.3.3 Pollen efficiency

Method for pollen germination test

The study was carried out at Nong Rawiang DDF and The center for scientific and technology equipment, SUT from 2000-2001. Bloom flowers from tree species at Nong Rawiang DDF were selected. Using a pair of scissors, anthers were clipped from flowers before noon, then grounded in a beaker with distilled water and crushed the anthers into pollen suspension at ambient conditions. Pollen suspension was dusted onto Brewbaker's medium on 0.5 % agar slide and brought to laboratory for incubated at 20-25°C for up to 48 hours. Using a compound microscope, pollen was then scored as to whether it had germination or not, investigation by used 20 lens screens. Pollen was considered germination if the pollen tube was twice the diameter of the pollen. The results of pollen germination were calculated in percentage.

3.3.4 Seed production and seed dispersal

Method of studying seed production and seed dispersal

The study was carried out from 2000-2002. According to 3.3.1 (3), sixteen isolated individual or group of parent trees of four dominant tree species at Nong Rawiang were selected. (Except for *Xylia xylocarpa*, four individual parent trees were additionally selected for investigation of seed production). All parent trees were 10 m high up and had complete crown (Figures 3.5, 3.6).

For the wing-seed species, the number of fallen flowers, young and mature fruits in traps of 50 x 50 cm placed in eight directions and at 2 meter interval from parent trees were counted (Figure 3.7). The mature fruit's size and wing's size at various interval from the parent trees were measured. Total number of flowers and fruits production were calculated from circle area and trap area. For the wingless-seed species, the number of fallen flowers, young and mature fruits in plastic net placed under the crown cover area of parent trees were counted (Figure 3.8). Total number of flowers production were calculated from sampling dried flowers.

The young and mature fallen fruits defected by insects were observed. Life cycle, reproductive success and population of some parent trees were investigated. Sampled mature fruits at natural site were investigated for germination. Seedlings in seedbeds were observed for growth rate and development. The result of fallen fruits defected by insects and population of parent tree were calculated in percentage.

3.3.5 Seed quality

(1.) Method for seed moisture content determination

The study was carried out at Farm Mechanics division, RIT-NEC from 2000-2001. Mature seeds from each tree species at Nong Rawiang DDF were collected. Seed moisture content was determined following the procedure prescribed by ISTA (1996). Two replications of five grams of the seeds from individual trees species were weighed before and after oven drying at 103 ± 2°C for 17 ± 1 hours. Moisture content was calculated on fresh weight basis.

(2.) Method for seed X-ray test

The study was carried out at Silviculture Research Division, Forest Research Office, Royal Forest Department from 2000-2001. Bulked seeds from each tree species at Nong Rawiang DDF were arranged randomly and placed on cellotape. The seeds were irradiated with X-ray machine : Softex, model SV-125A The exposure condition was set at a voltage potential of 15 kilovolt, electron current 2.5 milli-ampere, focus-film distance 56.3 cm, and exposure time was variable from 5-35 seconds depending on the kind of seeds. Kodak industrex AA400 type films, 8.9 x 21.6 cm, were used. Four replications of 50 seeds in each tree species were used to evaluate germination potential. The X-ray radiographs of seed were evaluated for seed viability according to their appearance on the film. Seed would classified into two categories, viable and non viable. The results were used to compare seed quality determined by X-ray technique and standard seed germination in percentage.

(3.) Method for standard germination test

The study was carried out at Farm Mechanics division, RIT-NEC from 2000-2001. Mature seeds from each tree species at Nong Rawiang DDF were collected. Four replications of 50 seeds in each tree species were used to germination tests. Methods of seed preparation followed "Tree and shrub seed handbook" (ISTA,1991). All seeds were germinated in sterilized medium sand, covered lightly with sand moistened to field capacity in a covered plastic germination box, large enough to hold one replication. The seeds were incubated in ambient room, and illuminated by cool-white fluorescent lamp for 8 daily. A seed was considered to be germinated when the seedling emerged from sand layer. Germination was first counted at day 3-7 and final counted at day 21-56 depending on the tree species. At the end of the germination tests, the number of hard seeds, ungerminated seeds, and dead seeds were determined by dissection. Only normal seedlings were counted as germinated seeds (ISTA, 1996). Germination data of dominant tree species were statistically analysed.

(4.) Method for seedling vigor classification

This vigor test was similar to the standard germination test. The only difference between the two tests was that normal seedlings were further classified as "strong seedling" and "weak seedling" (AOSA, 1983).

(5.) Method of studying germination index

This germination was conducted similarly the standard germination test. Seedling growth was evaluated by speed of germination. Germination was first counted at day 3 and then counted daily until the last seedling germinated. Number of normal seedlings and days of counting were calculated for germination index.

3.3.6 Morphological database of fruits and seeds

Method of studying fruit and seed morphology

The study was carried out at Nong Rawiang DDF and Farm Mechanics division, RIT-NEC. from 2000-2001. Twenty fruits and seeds from individual trees species were studied on physical characteristics including class and type of fruits, ripe and unripe color of fruit, number of seeds per fruit, fruit and seed size, external color, testa and moisture content of seed. For seed weight determination, eight replications of 100 seeds of individual tree species were sampled and weighed in grams and calculated 1,000 seeds weight (ISTA, 1996).

Tree species numbers of fruit class, wind-dispersed species and animal-dispersed species which occurred in each month were investigated and compared.

3.4 Data analysis

3.4.1 Plant community description and analysis

1. The quantitative data of plants community were analysed in the following aspects

(1) Importance value index (IVI)

The importance value index of plot was determined as :

IVI of species i = relative frequency + relative density + relative dominance

$$\text{relative IVI} = \frac{\text{IVI of species i}}{\text{sum of IVI of all species}} \times 100$$

(2) Relative frequency

$$\text{frequency} = \frac{\text{number of occupied quadrats}}{\text{number of all quadrats}} \times 100$$

$$\text{relative frequency} = \frac{\text{frequency of species i}}{\text{sum of frequency of all species}} \times 100$$

(3) Relative density

$$\text{relative density} = \frac{\text{number of species i}}{\text{number of all species}} \times 100$$

(4) Relative dominance

$$\text{relative dominance} = \frac{\text{sum of basal area of species i}}{\text{sum of basal area of all species}} \times 100$$

(5) Abundance

$$\text{abundance} = \frac{\text{number of species i}}{\text{number of occupied quadrats}} \times 100$$

(6) Shannon-Wiener index of diversity H(S)

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

H = index of species diversity (bits/individual)

s = number of species

pi = proportion of total sample belonging of *i* species

2. The results of soil analysis were used to compare differences of individual values among quadrat sites and periods collection by using analysis of variance of Randomized Complete Block Design (RCBD). If there were significant differences among treatments, means were compared subsequently by using the Least significant difference (LSD).

3.4.2 Flowering phenomena and pollinator observation

$$\text{Percent pollinator visitation} = \frac{\text{number of pollinators visitation at that time} \times 100}{\text{total number of pollinators visitation in a day}}$$

3.4.3 Pollen efficiency

$$\text{Percent pollen germination} = \frac{\text{number of pollen germination in lens screen} \times 100}{\text{total number of pollen in lens screen}}$$

3.4.4 Seed production and seed dispersal

1. For the wing-seed species ; Total number of flowers or fruits production

$$= \text{area} \times \text{number of flowers or fruits per trap area}$$

area : calculated from various circle area at various interval from parent tree in each radius line, for example 0-2, 2-4, 4-6, 6-8 m.

2. Percent reproductive success

$$= \text{number of fruits/flowers} \times \text{seeds/ovules} \times 100$$

3. Relation values between crown-cover diameter, DBH, height of parent trees and number of fallen flowers, young fruits, mature fruits were analysed by simple linear correlation. For wing-seed species and exploding-seed species, relation values between fruit dispersal distance and crown-cover diameter, DBH, height of parent trees, between dispersal distance and fruit size, wing size, fruit weight of wing-seed species were also analysed by simple linear correlation.

3.4.5 Seed quality

1. Percent moisture content

$$= \frac{(\text{fresh weight} - \text{dry weight}) \times 100}{\text{fresh weight}}$$

2. Germination index

$$= \frac{\text{number of normal seedlings}}{\text{days of first count}} + \ldots\ldots\ldots + \frac{\text{number of normal seedlings}}{\text{days of final count}}$$

3. The results of seed germination, seedling vigor classification and X-ray test of dominant tree species were used to compare differences of individual tree by using analysis of variance of Completely Randomized Design (CRD). If there were significant differences among treatments, means were compared subsequently by using the Least significant difference (LSD).

Figure 3.5 Isolated individual of parent trees, (left) *Shorea siamensis*, (right) *Ellipanthus tomentosus*

Figure 3.6 Group of parent trees (left) *Xylia xylocarpa*, (right) *Sindora siamensis*

Figure 3.7 Traps of 50 x 50 cm placed in 8 directions and 2 m interval from *Shorea siamensis*

Figure 3.8 Plastic net placed under the crown cover area of *Xylia xylocarpa*

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Plant community description and analysis

4.1.1 Quantitative charateristics

1. Minimal area of quadrat

The species-area curves of tree species in the study sites are shown in Figure 4.1. They implied that the number of tree species was increased as the quadrat sizes increased. The curves reached the asymtote when the quadrat size was 40 x 40 m (0.16 hectare), and 22 species was the highest number of tree species at 40 x 40 m. The result of present study is the same size as studied at Nong Rawiang in 1997 (สุรศักดิ์ ราศรีและคณะ, 2542). This size would be the minimal size of quadrat for the community structure analysis. Thus, it was decided to use this quadrat size for the present study. The detail data were given in Appendix I, Table 1.1-1.12.

Comparing with dry dipterocarp forest (DDF) in other part of the country, such as at Hod district, Chiangmai (Khamyong, 1995), which the minnimal area of quadrat was 40 x 40 m. The study plot had the same quadrat size. Besides in many study site of DDF also used the same quadrat size such as at Pingkong (Ogawa et al., 1965a), Namphrom (Sahunalu et al., 1979), Somdet (Kanzaki et al., 1991) and Doi Inthanon (Khamyong, 1996).

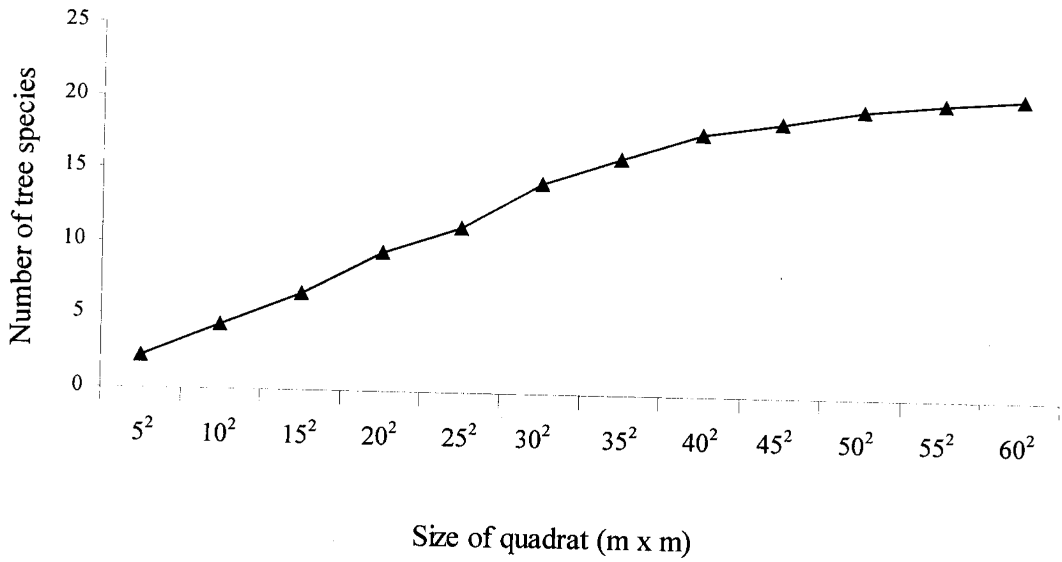


Figure 4.1 The species-area curves of the mean of eight sites in dry dipterocarp forest at Nong Rawiang.

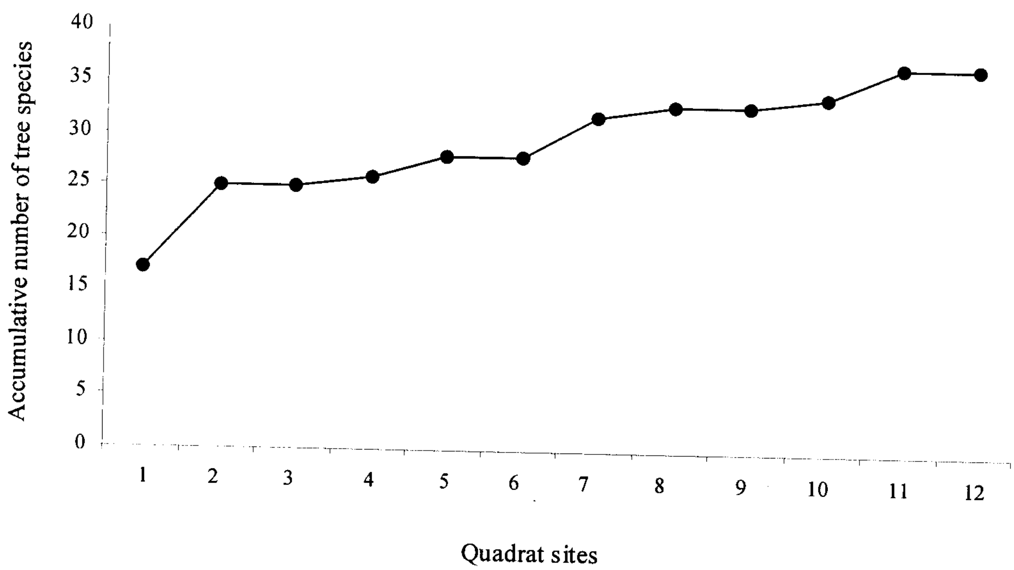


Figure 4.2 The curve of species-number of quadrats in dry dipterocarp forest at Nong Rawiang.

2. Minimal number of quadrat

The curve of species-number of quadrats is shown in Figure 4.2. The number of quadrat random placed in each patch of DDF for 12 quadrats. The number of tree species in various quadrats was different, varying from 10-22 species. The last point at which curve started flattening up was quadrat site 11, with 37 accumulative total number of species. The quadrat site which the species number does not increase will be cancel as in site 3, 6, 9 and 12. The asymtote was decided at 8 quadrats. Therefore, the minimal number of quadrats used in this study was eight, as shown in Figure 3.1. The detail data were given in Appendix I, Table 2. (Data of quadrat site 4, 6 and 8 were brought from สุรศักดิ์ ราตรีและคณะ, 2542)

3. Relative frequency

The data of frequency and relative frequency of all tree species in the study area are given in Table 4.1. The results indicated that *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus, Lannea coromandelica* and *Haldina cordifolia* had the frequency of 100 %. Other dominant trees of *Sindora siamensis, Canarium subulatum, Schleichera oleosa* and *Ochna integerrima* had frequency of 87.50 %. Many trees had the intermediate frequency such as *Aporosa villosa, Erythrophleum succirubrum, Morinda coreia, Rothmannia wittii. Gardenia sootepensis* and *Chukrasia tabularis*.

The tree species which had low frequency were thought to be the rare species in this forest. However, they may distribute in other forests. The tree species such as *Shorea roxburghii, Lagerstroemia floribunda, Senna garrettiana, Careya sphaerica* and *Diospyros ehretioides* had the low frequency of 12.50 %.

4. Relative density

The result of the relative density of all tree species are given in Table 4.1. *Shorea siamensis* had the highest density of 49.32 %. The dominant trees such as *Xylia xylocarpa, Ellipanthus tomentosus, Sindora siamensis, Lannea coromandelica* and *Shorea obtusa* had the lower relative density of 7.32, 7.64, 5.89, 5.57 and 6.36 % Other trees had very low density. The relative density of many species was lower than 1.0 %.

5. Relative dominance

The dominance was calculated from basal area at 1.3 m above ground level. The relative dominance was therefore depended on size of stem and tree density. In Table 4.1, *Shorea siamensis* had the highest dominance of 50.17 %. The dominant trees such as *Xylia xylocarpa, Ellipanthus tomentosus and Sindora siamensis* had rather low relative dominance of 10.60, 6.08 and 6.91 %, respectively. Other trees also showed low relative dominance.

6. Abundance

For the abundance, *Shorea siamensis* had the highest abundance, 77.50 individuals/quadrat. The dominant trees such as *Xylia xylocarpa*, *Ellipanthus tomentosus*, *Sindora siamensis*, *Lannea coromandelica* and *Shorea obtusa* had the lower abundance of 11.50, 12.00, 10.57, 8.75 and 40.00 individuals/quadrat, respectively. Other trees had very low abundance. Some trees had only one individuals/quadrat such as *Senna garrettiana*, *Shorea roxburghii*, *Diospyros ehretioide*, and *Bridelia retusa* (Table 4.1).

7. Importance value index (IVI)

The most important tree species was determined by the importance value index (IVI). The IVI of all tree species could be calculated from the sum of relative frequency, density and relative dominance. The relative IVI may also be calculated in percentage (Table 4.1). *Shorea siamensis* had the highest value of IVI of 105.08. The dominant trees such as *Xylia xylocarpa, Ellipanthus tomentosus and Sindora siamensis* had IVI of 23.51, 19.31 and 17.69, respectively. Other trees such as *Lannea coromandelica, Canarium subulatum* and *Shorea obtusa* had the IVI of about 11-14. The other trees had the IVI less than 10.

For the relative importance value index, the value of 35.03 % was calculated for *Shorea siamensis*. *Xylia xylocarpa, Ellipanthus tomentosus and Sindora siamensis* had the relative IVI of 7.84, 6.44 and 5.90 %, respectively. The high IVI species indicate that it has species performance in community better than low IVI species (Curtis, 1959). Therefore, base on the rank order value of IVI, the dominant species used in this study were four species consisted of *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus* and *Sindora siamensis.*

As compared to DDF at Sakaerat (Dhammanonda, 1992) which *Shorea floribunda* had the highest value of relative IVI of 45.65 % and obtained a number of 35 species, and at Nongteng-Jakkarat (จรัส ช่วยนะ, 2540) which *Dipterocarpus tuberculatus* had the highest value of relative IVI of 53.80 %, and obtained a number of 33 species. The study plot had lower value of IVI. When compared with DDF at Ngao district (ศิลปชัย พิพิธวิทยา, 2539) which *Dipterocarpus tuberculatus* had the highest value of relative IVI of 28.35 % and obtained a number of 48 species, and at Hod district (Khamyong, 1995) which *Shorea siamensis* had the highest value of relative IVI of 27.52 % and obtained a number of 41 species. The study plot had higher value of IVI. However, these comparisons indicated that the community with few species will have high relative IVI, whereas the community which consists of many species will normally have low values (Kimmins, 1987).

Table 4.1 Frequency, abundance, relative frequency, density and dominance, importance value index (IVI) and relative IVI of trees in 8 quadrats of the study sites.

No.	Tree species	Frequency (%)	Abundance (trees/quadrats)	Relative (%)			IVI (%)	Relative IVI (%)
				Freq.	Den.	Domi.		
1.	*Shorea siamensis*	100.00	77.50	5.59	49.32	50.17	105.08	35.03
2.	*Xylia xylocarpa*	100.00	11.50	5.59	7.32	10.60	23.51	7.84
3.	*Ellipanthus tomentosus*	100.00	12.00	5.59	7.64	6.08	19.31	6.44
4.	*Sindora siamensis*	87.50	10.57	4.89	5.89	6.91	17.69	5.90
5.	*Lannea coromandelica*	100.00	8.75	5.59	5.57	3.28	14.44	4.81
6.	*Canarium subulatum*	87.50	3.57	4.89	1.99	4.40	11.28	3.76
7.	*Shorea obtusa*	25.00	40.00	1.40	6.36	3.36	11.12	3.71
8.	*Erythrophleum succirubrum*	62.50	3.80	3.50	1.51	2.44	7.45	2.48
9.	*Haldina cordifolia*	100.00	1.87	5.59	1.19	0.47	7.25	2.42
10.	*Schleichera oleosa*	87.50	2.14	4.90	1.19	0.76	6.85	2.28
11.	*Aporosa villosa*	75.00	3.17	4.19	1.51	0.72	6.42	2.14
12.	*Ochna integerrima*	87.50	1.28	4.89	0.71	0.61	6.21	2.07
13.	*Morinda coreia*	62.50	3.20	3.50	1.27	1.20	5.97	1.99
14.	*Rothmannia wittii*	62.50	3.20	3.50	1.27	1.01	5.78	1.93
15.	*Gardenia sootepensis*	62.50	3.00	3.50	1.19	0.90	5.59	1.86
16.	*Chukrasia tabularis*	62.50	2.20	3.50	0.87	0.61	4.98	1.66
17.	*Irvingia malayana*	50.00	1.25	2.80	0.40	0.84	4.04	1.35
18.	*Vitex pinnata*	50.00	1.25	2.80	0.40	0.51	3.71	1.24
19.	*Phyllanthus emblica*	50.00	1.50	2.80	0.48	0.32	3.60	1.20
20.	*Strychnos nux-vomica*	50.00	1.50	2.80	0.48	0.17	3.45	1.15

Table 4.1 (cont.)

No.	Tree species	Frequency (%)	Abundance (trees/quadrats)	Relative (%) Freq.	Relative (%) Den.	Relative (%) Domi.	IVI (%)	Relative IVI (%)
21.	*Memecylon edule*	37.50	3.00	2.09	0.72	0.13	2.94	0.98
22.	*Morinda elliptica*	25.00	2.50	1.40	0.40	0.61	2.41	0.80
23.	*Pterocarpus macrocarpus*	25.00	1.50	1.40	0.24	0.56	2.20	0.73
24.	*Buchanania lanzan*	25.00	3.00	1.40	0.48	0.24	2.12	0.71
25.	*Bauhinia racemosa*	25.00	1.00	1.40	0.16	0.58	2.14	0.71
26.	*Cratoxylum cochinchinense*	25.00	2.00	1.40	0.32	0.42	2.14	0.71
27.	*Artocarpus lacucha*	25.00	1.50	1.40	0.24	0.21	1.85	0.62
28.	*Bridelia retusa*	25.00	1.00	1.40	0.16	0.22	1.78	0.59
29.	*Albizia lebbeck*	12.50	1.00	0.70	0.08	0.47	1.25	0.42
30.	*Shorea roxburghii*	12.50	1.00	0.70	0.08	0.34	1.12	0.37
31.	*Cratoxylum formosum*	12.50	1.00	0.70	0.08	0.22	1.00	0.33
32.	*Dipterocarpus intricatus*	12.50	1.00	0.70	0.08	0.17	0.95	0.32
33.	*Lagerstroemia floribunda*	12.50	1.00	0.70	0.08	0.19	0.97	0.32
34.	*Wrightia arborea*	12.50	1.00	0.70	0.08	0.08	0.86	0.29
35.	*Senna garrettiana*	12.50	1.00	0.70	0.08	0.10	0.88	0.29
36.	*Careya sphaerica*	12.50	1.00	0.70	0.08	0.07	0.85	0.28
37.	*Diospyros ehretioides*	12.50	1.00	0.70	0.08	0.03	0.81	0.27
	Total	1,787.50	217.75	100	100	100	300	100

Note : Freq. = Frequency
Den. = Density
Domi = Dominance

8. Shannon-Wiener index of diversity H(S)

The result of the Shannon-Wiener index of diversity H(S) are given in Table 4.2. H(S) was varied between 1.252 and 2.115. The mean value was 2.087. Comparing with other DDF in the same quadrat size (0.16 hectare) for example at Doi Inthanon sub-type *Shorea obtusa*, sub-type *Shorea siamensis*, sub-type

Dipterocarpus obtusifolius, sub-type *Dipterocarpus tuberculatus* in the same locality (Khamyong, 1996), at Pingkong sub-type Monsoon-savanna, sub-type Dipterocarp savanna in the same locality (Ogawa et al., 1965a) and at Somdet sub-type Secondary dry dipterocarp (Kanzaki et al., 1991), which had a H(S) of 2.943, 3.150, 3.372, 3.674, 3.673, 3.676 and 2.357, respectively. The study plot was less value of H(S).

However, The value of H(S) was larger than in a DDF at Namphrom (Sahunalu et al., 1979), which had a H(S) of 1.926. When compared with DDF in the same quadrat size (1 hectare) at Sakaerat sub-type *Shorea floribunda-Quercus kerrii* (Sahunalu and Dhanmanonda, 1991) which had 36 species, individuals/ha of 554, H(S) of 4.258, at Nongteng-Jakkarat (จรัส ช่วยนะ, 2540) which had 33 species, individuals/ha of 1,740, H(S) of 2.322, and at Huay Tak aboretum (ศิลปชัย พิพิธวิทยา, 2539) which had 48 species, individuals/ha of 628, H(S) of 4.584. The result indicated that a community that contains a few individuals of many species will have a higher diversity than a community containing the same number of individuals but with most of them confined to a few species (Smith, 1992).

Table 4.2 shows some ecological data of the study area. The number of trees per quadrat varied with quadrats, with the average of 157 individuals/quadrat (982 individuals/hectare). The number of tree species/quadrat was varied between 13-22. The mean value was 17 species/quadrat. The mean basal area was 1.87 m^2/quadrat or 11.70 m^2/ha.

Table 4.2 Quadrat size, number of trees species, basal area of trees with DBH larger than 3 cm and Shannon-Wiener index in the study sites.

	Quadrat site								
	Q1	Q2	Q4	Q5	Q7	Q8	Q10	Q11	Mean
Area of quadrat (m^2)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Number of trees/quadrat	165	210	123	181	153	83	163	179	157
Number of trees/ha	1031	1313	769	1131	956	519	1019	1119	982
Number of sp./quadrat	17	22	16	15	20	13	15	21	17
Basal area (m^2/quadrat)	1.74	1.79	1.42	2.07	1.84	1.85	1.87	2.39	1.87
Basal area (m^2/ha)	10.88	11.19	8.88	12.94	11.5	11.56	11.69	14.94	11.70
H(S) *	1.963	2.108	1.641	1.252	2.115	1.908	1.528	1.581	2.087

* Shannon-Wiener index of diversity

As compared to a nearby DDF at Nongteng-Jakkarat sub-type Secondary dry dipterocarp (จรัส ช่วยนะ, 2540) which had a density of 1,740 individuals/ha, the study plot was less dense. It was also less dense than DDF at Doi Inthanon sub-type Dipterocarp savanna, at Tak-Sukhothai Highway (Ogawa, Yoda and Kira, 1961), at Doi Inthanon sub-type *Shorea siamensis* (Khamyong, 1996), at Pingkong sub-type Dipterocarp savanna (Ogawa et al., 1965a) and at Somdet sub-type Secondary dry dipterocarp (Kanzaki et al., 1991) which had densities of 1,576, 1,340, 1,281, 1,488 and 1,444 individuals/ha, respectively.

When compared with other DDF at Sakaerat sub-type *Shorea floribunda-Quercus kerrii*, sub-type *Shorea obtusa-Shorea siamensis*, sub-type *Shorea obtusa-Pterocarpus macrocarpus*, sub-type *Shorea siamensis-Shorea floribunda* in the same locality (Sahunalu and Dhanmanonda, 1991), at Huay Tak aboretum (ศิลปชัย พิพิธ

วิทยา, 2539), at Doi Inthanon sub-type *Shorea obtusa*, sub-type *Dipterocarpus obtusifolius*, sub-type *Dipterocarpus tuberculatus* in the same locality (Khamyong, 1996), at Namphrom (Sahunalu et al., 1979), at Pingkong sub-type Monsoon-savanna (Ogawa et al.,1965a), at Somdet sub-type Primary dry dipterocarp (Kanzaki et al., 1991) and at Huay Hin Dam (Khamyong, 1995) which had densities of 544, 667, 733, 701, 628, 769, 450, 669, 938, 906, 316 and 813 individuals/ha, respectively. The stand density of the study plot was denser. The results of the study showed that tree density tends to increase in sub-type Dipterocarp savanna or Secondary dry dipterocarp more than in another sub-type of dry dipterocarp forest.

4.1.2 Qualitative characteristics

1. Species diversity

Community diversity refers to the number of different species in the community (Kimmins, 1987). Studying on species composition of tree in DDF was investigated from available literature relating to this forest type. There are 12-82 species list in the 23 sub-type of DDF (Ogawa, Yoda and Kira, 1961, 1965a, Sukwong et al., 1976, 1977, 1978, Bunyavejchewin, 1983, Sahunalu and Dhamma-nonda, 1991, Khamyong, 1995, 1996, Sahunalu et al., 1979, Kanzaki et al., 1991, ศิลปชัย พิพิธวิทยา, 2539, จรัส ช่วยนะ, 2540). The tree species of DDF at Nong Rawiang are reported in the species list. There were totally 38 species as showed in Table 4.2. Thirty-eight species belonged to 33 genera and 22 families of trees. Of all 22 families, the most dominant were Caesalpinioideae, Rubiaceae and Dipterocarpaceae which had 5, 5 and 4 of species, respectively (Figure 4.3). However, Table 4.1 shows only 37 species of trees because there were two varieties of *Sindora siamensis* consisted of var. *siamensis* and var. *maritima*. *Sindora siamensis* can be identified to variety until it reaches the time of fruiting.

Table 4.3 Species list of trees in dry dipterocarp forest at Nong Rawiang

Family	Scientific name
1. Anacardiaceae	1. *Buchanania lanzan* Spreng.
	2. *Lannea coromandelica* (Houtt.) Merr.
2. Apocynaceae	3. *Wrightia arborea* (Dennst.) Mabb.
3. Burseraceae	4. *Canarium subulatum* Guillaumin
4. Caesalpinioideae	5. *Bauhinia racemosa* Lam.
	6. *Erythrophleum succirubrum* Gagnep.
	7. *Senna garrettiana* (Craib) Irwin & Barneby
	8. *Sindora siamensis* Teijsm. & Miq. var. *siamensis*
	9. *Sindora siamensis* Teijsm. & Miq. var. *maritima* (Pierre) K. & S.S. Larsen
5. Connaraceae	10. *Ellipanthus tomentosus* Kurz var. *tomentosus*
6. Dipterocarpaceae	11. *Dipterocarpus intricatus* Dyer
	12. *Shorea obtusa* Wall. ex Blume
	13. *Shorea roxburghii* G.Don
	14. *Shorea siamensis* Miq.
7. Ebenaceae	15. *Diospyros ehretioides* Wall. ex G.Don
8. Euphorbiaceae	16. *Aporosa villosa* (Wall. ex Lindl.) Baill.
	17. *Bridelia retusa* (L.) A.Juss.
	18. *Phyllanthus emblica* L.
9. Guttiferae	19. *Cratoxylum cochinchinense* (Lour.) Blume
	20. *Cratoxylum formosum* (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogel.
10. Irvingiaceae	21. *Irvingia malayana* Oliv. ex A.W.Benn.
11. Labiatae	22. *Vitex pinnata* L.
12. Lecythidaceae	23. *Careya sphaerica* Roxb.
13. Lythraceae	24. *Lagerstroemia floribunda* Jack
14. Melastomataceae	25. *Memecylon edule* Roxb.
15. Meliaceae	26. *Chukrasia tabularis* A.Juss.
16. Mimosoideae	27. *Albizia lebbeck* (L.) Benth.
	28. *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen

Table 4.3 (cont.)

Family	Scientific name
17. Moraceae	29. *Artocarpus lacucha* Roxb.
18. Ochnaceae	30. *Ochna integerrima* (Lour.) Merr.
19. Papilionoideae	31. *Pterocarpus macrocarpus* Kurz
20. Rubiaceae	32. *Gardenia sootepensis* Hutch.
	33. *Haldina cordifolia* (Roxb.) Ridsdale
	34. *Morinda coreia* Ham.
	35. *Morinda elliptica* Ridl.
	36. *Rothmannia wittii* (Craib) Bremek.
21. Sapindaceae	37. *Schleichera oleosa* (Lour.) Oken
22. Strychnaceae	38. *Strychnos nux-vomica* L.

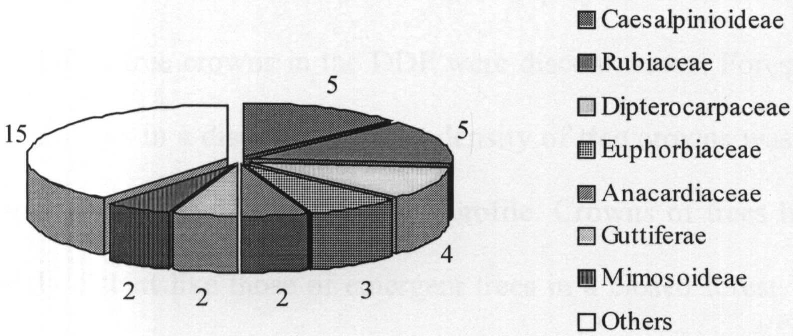


Figure 4.3 Number of species in each family list.

2. Stratification

Figure 4.4 and Table 4.4 illustrated an example of profile (for the trees over 15 cm in DBH) of a strip of 20 x 40 m, in quadrat site 8. The forest structure of this quadrat was basically the same as that of the other DDF. The top layer consisted of discontinuous crowns of big trees higher than 10 m, such as *Shorea siamensis, Xylia xylocarpa, Sindora siamensis, Canarium subulatum, Erythrophleum succirubrum.* The lower layer, lower than 10 m, consisted of small trees whose crowns were not continuous with each other, such as *Ochna integerrima, Bauhinia racemosa, Cratoxylum cochichinense, Lagerstroemia floribunda.*

The vertical arrangement of trees in the stand suggests that there are two layers of trees. The horizontal structure implied that the trees grew not so dense in the forest. Approximately 50 % of the quadrat area was covered by ground species such as *Vietnamosasa pusilla*, was without trees.

Crown distribution as shown by a horizontal projection of all tree crowns above 15 cm in DBH, tree crowns in the DDF were discontinuous. Forest floor can be seen through crowns in a distant view. The density of tree crowns was, however, different in upper and lower part of the forest profile. Crowns of trees higher than 10 m were widely distant like those of emergent trees in a closed forest. In a sense the forest has a two layered structure. The crown coverage of the top layer which by solid lines was about 40 % of the plot area, showing the normal coverage figure for this type of forest. Most of spaces not covered by the top layer were occupied by crowns of lower trees. The total coverage by crowns of trees layer less than 15 cm in DBH was about 50 % of the plot area indicating that the forest was opened by tree crowns.

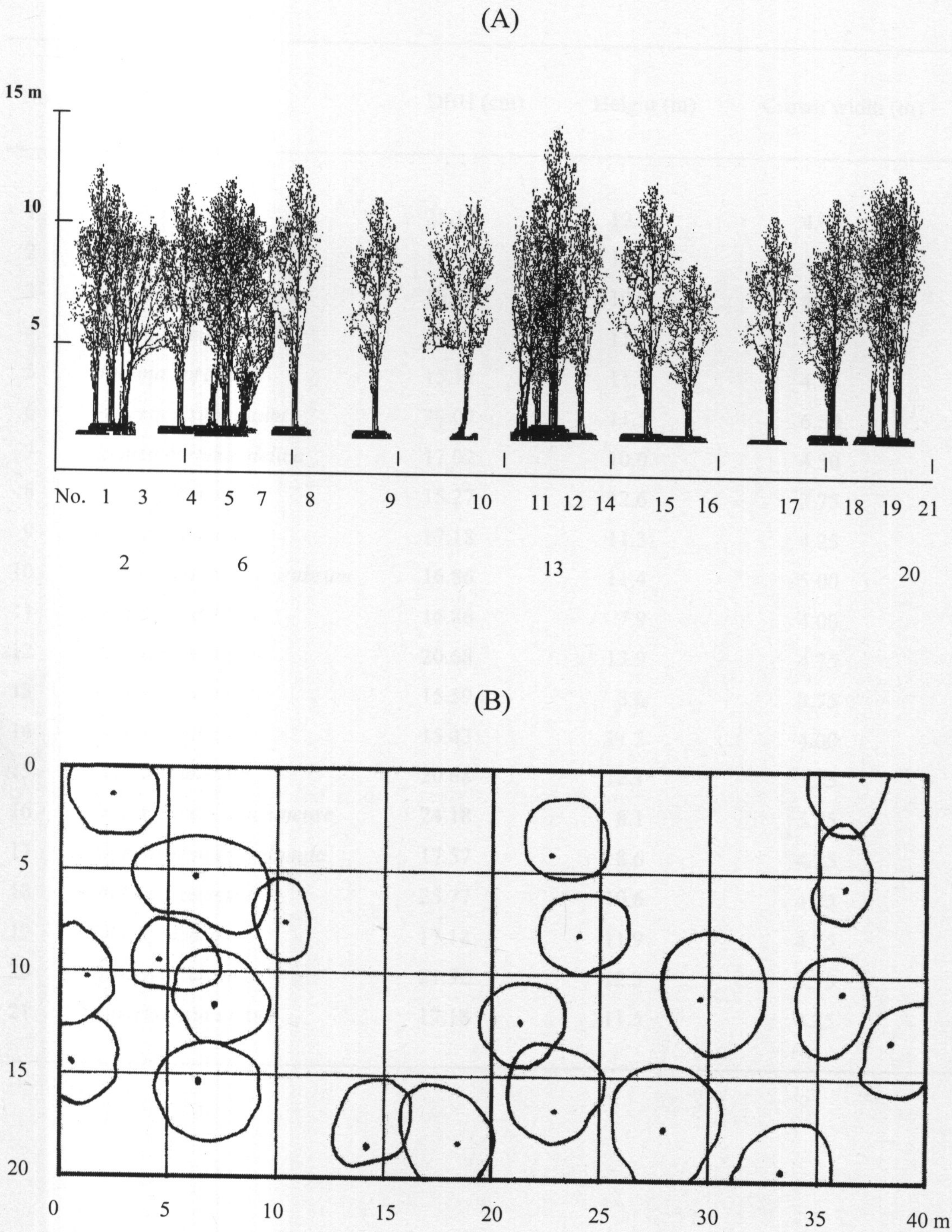


Figure 4.4 Vertical (A) and horizontal (B) structure of trees (DBH ≥ 15 cm) for site 8. (Adapted from สุรศักดิ์ ราตรีและคณะ, 2542)

Table 4.4 List of tree species and their growth in Figure 4.4.

No.	Name	DBH (cm)	Height (m)	Crown width (m)
1	*Xylia xylocarpa*	25.14	12.5	4.00
2	*Sindora siamensis*	17.18	11.7	4.25
3	*Ellipanthus tomentosus*	15.11	10.9	4.50
4	*Shorea siamensis*	19.57	11.1	4.00
5	*Haldina cordifolia*	15.11	11.1	4.75
6	*Canarium subulatum*	30.07	11.5	6.50
7	*Lannea coromandelica*	17.02	10.0	4.50
8	*Shorea siamensis*	15.27	12.6	3.75
9	*Shorea siamensis*	17.18	11.3	4.25
10	*Erythrophleum succirubrum*	16.86	11.4	5.00
11	*Ochna integerrima*	16.86	7.9	4.00
12	*Shorea siamensis*	20.68	13.9	4.75
13	*Bauhinia racemosa*	15.59	8.6	3.75
14	*Xylia xylocarpa*	15.43	11.2	4.00
15	*Shorea siamensis*	20.68	12.1	5.25
16	*Cratoxylum cochichinense*	24.18	8.1	5.25
17	*Lagerstroemia floribunda*	17.57	8.6	4.25
18	*Sindora siamensis*	25.77	10.6	4.75
19	*Xylia xylocarpa*	17.18	11.9	4.75
20	*Xylia xylocarpa*	21.32	12.3	3.75
21	*Canarium subulatum*	17.18	11.5	4.25

4.1.3 Soil analysis

As pointed out in Table 3.1 and 3.2, soil textures of DDF at Nong Rawiang were sandy. Top soil was loamy sand and sub soil was sandy loam. Soil reaction was acid in both top soil and sub soil, especially sub soil was very strongly acid of 4.5.

The chemical soil properties was shown in Table 4.5. The soil values varied among quadrat sites and collection periods. However, analysis of variance showed that there were no significant differences in the soil values. Almost soil pH in quadrat sites were acid except quadrat 5 on April collection was slightly alkaline of 7.3. The average of soil pH throughout study sites was 5.7. Percentage of organic matter was between 0.15-0.55 %. The average of organic matter was 0.34 %.

As compared to soil standard rating of Department of Land Development (Table 4.6), the average values of chemical soil properties in the study sites (Table 4.5) had very low values of soil fertility in electrical conductivity (EC), organic matter (OM), Nitrogen, Phosphorus, Potassium, Calcium and Magnesium of 0.02 ms/cm, 0.34 %, 0.017 %, 1.7 ppm, 23 ppm, 120 ppm and 30.4 ppm, respectively, had low values in pH and cation exchange capacity (CEC) of 5.7 and 3.79 me, respectively, and had medium value in Sulfur of 14.05 ppm. The results indicated that top soil in the study area was shallow and very poor soil. It was therefor though that these factors might have influence on the plant diversity and production in this forest as showed in Table 4.2.

Table 4.5 Chemical soil properties of dry dipterocarp forest for 8 sites and 3 periods collection at Nong Rawiang.

Source	pH (1:1 H_2O)	EC (ms/cm)	CEC (me/100g)	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
Q1/1	5.2	0.02	4.94	0.30	0.015	2.2	62.4	52	21.6	13.98
Q1/2	5.6	0.02	2.79	0.38	0.019	3.3	53.6	64	45.1	25.92
Q1/3	5.6	0.02	3.22	0.42	0.021	< 1	10.0	76	18.6	13.83
Q2/1	5.2	0.02	4.22	0.18	0.009	< 1	6.8	52	30.9	15.90
Q2/2	4.9	0.02	3.22	0.35	0.017	< 1	8.0	32	19.2	9.12
Q2/3	5.1	0.02	5.22	0.37	0.018	< 1	11.2	44	17.2	8.51
Q3/1	5.8	0.02	4.65	0.43	0.021	9.5	51.4	134	40.3	12.26
Q3/2	6.7	0.03	3.50	0.26	0.013	1.4	21.4	284	53.4	16.36
Q3/3	6.5	0.02	2.22	0.27	0.013	3.9	26.0	156	59.9	16.36
Q4/1	5.6	0.02	3.65	0.54	0.027	7.9	34.0	72	18.1	17.70
Q4/2	5.5	0.02	4.65	0.37	0.018	< 1	5.8	80	19.5	13.87
Q4/3	5.3	0.01	3.22	0.52	0.026	< 1	6.4	64	28.0	11.61
Q5/1	7.3	0.02	4.51	0.35	0.017	< 1	40.0	356	27.9	15.67
Q5/2	5.1	0.02	4.65	0.34	0.017	< 1	19.6	36	22.5	13.56
Q5/3	6.5	0.01	5.07	0.30	0.015	1.5	15.8	56	31.3	21.95
Q6/1	6.4	0.02	2.93	0.33	0.016	< 1	9.2	268	58.4	14.10
Q6/2	5.3	0.02	2.63	0.22	0.011	3.7	34.2	144	11.4	16.43
Q6/3	5.5	0.02	2.36	0.15	0.007	3.8	25.0	78	28.6	12.46
Q7/1	6.0	0.01	2.36	0.30	0.015	< 1	19.0	160	23.9	16.58
Q7/2	5.6	0.02	3.06	0.34	0.017	< 1	15.4	42	16.9	7.71
Q7/3	5.4	0.01	4.08	0.25	0.012	< 1	9.8	196	10.2	10.53
Q8/1	5.6	0.01	4.79	0.32	0.016	< 1	5.6	62	29.8	9.66
Q8/2	5.6	0.02	4.94	0.55	0.027	3.3	37.0	138	36.0	10.35
Q8/3	6.4	0.02	4.08	0.40	0.020	< 1	23.6	236	61.6	12.80
Average	5.7	0.02	3.79	0.34	0.017	1.7	23.0	120	30.4	14.05
ANOVA	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

(5[th] Regional Department of Land Development Khon Kaen, November 2001)

Note : Q1/... = site no. 1, Q 2/... = site no. 2, ns = non significant
Q.../1 = collected on Apr. 2000, Q.../2 = collected on Sep. 2000, Q.../3 = collected on Dec. 2000

Table 4.6 Standard value used for comparison of chemical soil properties as soil fertility level.

Value	Very low	Low	Medium	Hight	Very hight
pH (1:1 H_2O)	< 4.5	4.5 – 6.0	6.0 – 7.5	7.5 – 8.5	> 8.5
EC (1:5 H_2O) ds/m	< 2	2 – 4	4 – 8	8 – 16	> 16
OM (%)	< 0.5	0.5 – 1.5	1.5 – 2.5	2.5 – 4.5	> 4.5
N (%)	< 0.025	0.025 – 0.075	0.075 – 0.125	0.125 – 0.225	> 0.225
P (ppm)	< 3	3 – 10	10 – 15	15 – 25	> 25
K (ppm)	< 30	30 – 60	60 – 90	90 – 120	> 120
Ca (ppm)	< 400	400 – 1,000	1,000 – 2,000	2,000 – 4,000	> 4,000
Mg (ppm)	< 36	36 – 120	120 – 365	365 – 975	> 975
S (ppm)	< 3	3 – 10	10 – 15	15 – 45	> 45
CEC (me/100g)	< 3	3 – 10	10 – 15	15 – 30	> 30

(กรมพัฒนาที่ดิน, 2535)

4.1.4 Key to species

Artificial key to species of Nong Rawiang dry dipterocarp forest

1. Simple leaves
   2. Opposite
      3. Bark with white or yellow latex; flower white, sometimes tinged yellow or green; fruit brown with cream dots, narrowly cylindrical; seed with a long tuft of hairs at one end, pointing towards base of fruits *Wrightia arborea*(3)
      3. Bark without latex
         4. With pairs of stipules between
            5. Flowers and fruits in heads
               6. Flowers and fruits in tightly packed spherical head on long stalks, flower pale yellow or pinkish; fruit in globose heads *Haldina cordifolia*(33)
               6. Flower white in loose heads, calyx tubes fused at base; fruits fused in to an irregular, knobby mass, green, turning whitish, fleshy and juicy
                  7. Leaves ovate, hairy on the undersurface *Morinda coreia*(34)
                  7. Leaves ovate, smooth *M. elliptica*(35)
            5. Flowers and fruits free, not in head, flower > 3 cm
               8. White flowers with purple dots on inside, corolla narrowly campanulate shaped; leaf buds not sticky; fruit black, rounded; seed surrounded by a slimy pulp *Rothmannia wittii*(36)
               8. Flower large, pale green or white turning rich yellow-orange; leaf buds with sticky resin; fruit bright green, oval with distinct nipple at top and 5 shallow ridges *Gardenia sootepensis*(32)

4. No stipules

9. Leaves hairy, without teeth; delicate spreading petals with slender stalks; flower pale pink or purple, fading to white; fruit dark brown, oblong *Lagerstroemia floribunda*(24)

9. Leaves smooth

10. Leaves with fine, rounded teeth; individual flowers without stalks, petals pale green or yellowish, many white or red-purple stamens, twice as long as petals; fruit bright green ripening brownish, globose or ovoid *Careya sphaerica*(23)

10. Leaves without teeth, side veins forming a network

11. 3 main veins from base; flower creamy-white or pale green; fruit globose, bright orange with very thick smooth skin and fleshy pulp *Strychnos nux-vomica*(38)

11. 1 main vein from base

12. Twigs ridged, side vein very faint; flower bright blue-purple, grouped into tight clusters; fruit dark blue-purple, globose *Memecylon edule*(25)

12. Twigs not ridged

13. Young leaves red to pale pink, mature leaves bright green; flower delicate pale pink; fruit dark brown, narrowly ovoid with pointed tip *Cratoxylum formosum*(20)

13. Leaves pale greyish-green; flower crimson or dark red; fruit about 2/3 covered by the persistent sepals *C. cochinchinense*(19)

2. Alternate

14. Leaves with teeth; flower bright yellow, jointed with convex swelling at the top; fruit green turning black, globular or obovoid, surrounded by the enlarged, bright red sepals *Ochna integerrima*(30)

14. Leaves without teeth

15. Inner bark with white latex or resinous

16. Inner bark with white latex; leaf oval to broadly ovate, slightly heart-shaped base, often asymmetric; flower and fruit head dirty yellow to pale pink or orange *Artocarpus lacucha*(29)

16. Inner bark resinous or clear resin

17. Inner bark resinous, large stipules

18. Fruit a nut, with 2 large oblong and 3 shorter ear-shaped, wings; wings fused together at base, almost completely covering the nut; fruiting calyx-tube covered with 5 undulate ridges

Dipterocarpus intricatus(11)

18. Fruit a nut, with 3 longer and 2 slightly shorter wings, overlapping at the base but not completely covering the nut

19. Nut ovate-shaped

20. Leaf a heart-shaped base; flower bright yellow often with red tinge *Shorea siamensis*(14)

20. Leaf a obtuse-shaped base; flower white or creamy yellow

S. obtusa(12)

19. Nut spindle-shaped, wings often narrow and pointed; flower white or cream, sometimes tinged pink *S. roxburghii*(13)

17. Inner bark clear resin, no stipules; flower white, branched clusters; fruit purple, ovoid or mango-shaped *Buchanania lanzan*(1)

15. Inner bark without latex or resinous

21. Mature leaves distinctly hairy, no stipules; flower pale yellow; fruit brown, ovate; seed black with a yellowish to orange arillode at the base *Ellipanthus tomentosus*(10)

21. Mature leaves smooth or nearly so

22. Stipules not branched

23. Stipules forming a narrowly tube with curved, sharp point; flower greenish-white, short branched clusters; fruit green, turning yellowish with pale orange flesh *Irvingia malayana*(21)

23. Tiny stipules

24. Leaves < 0.4 x 2.5 cm, similar pinnately compound leaf, flower tiny, pale green or creamy-yellow, fruit no stalks, green and semitranslucent with pale veining, ripening yellowish, globose, juicy *Phyllanthus emblica*(18)

24. Leaves > 0.5 x 3.0 cm

25. Flower with corolla

26. Flower green or yellowish-green sometimes with orange or red tinge, in dense heads, spike-like clusters; fruit pale green ripening blackish, bark often slightly spiny when young *Bridelia retusa*(17)

26. Flower greenish-white or pale yellow, in slender unbranched clusters, buds distinctly curved; fruit often

curved; leaf circular 2 lobed with rounded tips

Bauhinia racemosa(5)

25. Flower no corolla, male and female on different trees, male yellow in spikes, female green in clusters, without stalks; fruit ovoid with curved tip, densely yellow-brown hairy, 1 seed with fleshy orange coating *Aporosa villosa*(16)

22. No stipules, male and female on different trees, male flower white, bell-shaped, female larger than male; fruit yellow to red-brown, ovoid with blunt tip *Diospyros ehretioides*(15)

1. Compound leaves

27. Trifoliate, main stalks narrowly winged or not at all; flowers white or pinkish, in open branched clusters; fruit purple or black, globose

Vitex pinnata(22)

27. Pinnate leaves

28. Leaflets with teeth, inner bark clear resin

29. 2-5 pairs of leaflets, main stalk with a pair of narrow stipules at the base; flower cream, narrow clusters; fruit clusters, yellowish-green, ovoid or bullet shaped *Canarium subulatum*(4)

29. 3-6 pairs of leaflets, young shoots with tiny star-shaped hairs; flower pale yellow or purplish-green, branched clusters; fruit pink turning dark red, slightly flattened lengthways *Lannea coromandelica*(2)

28. Leaflets without teeth

30. Leaflets typically blunt-tipped with faint side veins, usually smooth; leaflet stalks swollen

31. Once pinnate leaf

32. Even-opposite leaflets

33. Flower bright yellow, 5 petals; leaflets long pointed tips; fruit flattened, often twisted *Senna garrettiana*(7)

33. Flower yellow-green, 1 petal; leaflets elliptic with blunt; fruit dark green, round and flat with a short curved tip

34. Fruit covered in sticky spines *Sindora siamensis* var. *siamensis*(8)

34. Fruit without spines *Sindora siamensis* var. *maritima*(9)

32. Odd-alternate leaflets, inner bark with sparse drops of red sap; flower bright yellow in unbranched clusters; fruit circular, with a broad, wavy wing *Pterocarpus macrocarpus*(31)

31. Bipinnate leaf

35. Odd bipinnate; flower in spikes, greenish-white; fruit long-flattened *Erythrophleum succirubrum*(6)

35. Even bipinnate

36. Leaf a single pair of side stalks; flower pale yellow, in dense spherical heads; fruit thick and woody, slightly curved, pale creamy brown, splitting into 2 parts *Xylia xylocarpa*(28)

36. Leaf 2-4 pairs of side stalks; flower heads, greenish-white turning pale yellow, corolla with teeth as long as tube; fruit pale yellow, thin and flat *Albizia lebbeck*(27)

30. Leaflets often with pointed tip and distinct side-veins, smooth or hairy, leaflet stalks not pulvinate

37. 5-13 pairs of alternate or sub-opposite leaflets; flower pale yellow often tinged dull red outside, in spreading branched clusters; fruit yellow-grey, ovate, densely packed with winged seeds

Chukrasia tabularis(26)

37. 1-4 pairs of opposite leaflets; flower pale green or yellow-green, slender branched clusters, no petals; fruit bright green, turning brownish, globose; brown seeds covered with thin pale yellow sarcotesta *Schleichera oleosa*(37)

4.1.5 Plants description

1. Buchanania lanzan Spreng. (มะม่วงหัวแมงวัน)

Family : ANACARDIACEAE

Tree to 13 m. **Bark** dark gray with a dense network of deep, narrow cracks, inner bark pinkish with clear resin. **Leaf** 9.0-12.3 x 16.5-25.4 cm, simple, alternate, usually clustered at end of twigs, narrowly elliptic or oblong with rounded tip often notched, no teeth. Young leaves densely red-brown hairy, mature leaves rigidly leathery, usually hairy at least on veins below. 10-17 pairs of side veins, slightly raised above, smaller veins ladder-like, flat above, leaf stalks 1.2-2.0 cm. **Flower** 0.3-0.5 cm diameter, white, bisexual, branched clusters at end of twigs and upper leaf axils, 15-30 cm, main stalk stout, densely brown-hairy, individual stalks very short. Calyx 4-5 lobed, hairy outside. 4-5 petals, 8-10 fertile stamens with oblong anthers shorter than filaments, Disc yellow, deeply 5-lobed, style short, ovary hairy, superior. **Fruit** 1.2-1.4 cm long, 1.0-1.2 cm wide, purple, ovoid or mango-shaped with short style at top and persistent calyx at base, not hairy, thinly fleshy with very hard stone, stalks densely hairy.

2. *Lannea coromandelica* (Houtt.) Merr. (กุ๊ก)

Family : ANACARDIACEAE

Tree to 17 m with open crown and rather slender branches. **Bark** cream, smooth or with strips of wrinkled bark, inner bark pinkish with clear resin, fibrous. **Leaf** alternate, odd-pinnate, petiole and rachis 21.0-34.7 cm long, 3-6 pairs of opposite leaflets, 5.5-7.2 x 9.5-12.4 cm, narrowly elliptic with tapering tips and rounded, slightly oblique base, no teeth. Young shoots with tiny star-shaped hairs, mature leaves smooth, thin. 7-11 pairs of side veins, no marginal vein, finer veins faint. Side leaflet stalks short, often narrowly winged on one side only, end one 2-3 cm, slender. Twigs thick with large leaf scars. **Flower** 0.5 cm diameter, pale yellow or purplish-green, narrow unbranched or sparsely branched clusters dangling from leafless twigs, often clustered near tips, 12-30 cm, stalks minutely hairy. Calyx tiny, 4-5 lobed hairy outside, 4-5 petals, overlapping, smooth. 8-10 stamens, longer than petals, surrounding grooved, ring-shaped disc, ovary vivid red with 4 short styles. Male and female flowers on different trees. **Fruit** 1.0-1.3 cm long, 0.8-0.9 cm wide, pink turning dark red, slightly flattened lengthways, smooth, thin-skinned, crowned by persistent styles, single hard stone with 1 seed and 1-2 opercula at the top.

3. *Wrightia arborea* (Dennst.) Mabb. (โมกมัน)

Family : APOCYNACEAE

Shrub or tree to 17 m. **Bark** gray-brown with white or yellow latex, branchlets tomentose or puberulent, becoming glabrous and lenticellate. **Leaf** 4.5-5.2

x 8.7-11.5 cm, simple, opposite-planar, petiole 0.5-0.7 cm long, blade papery to subcoriaceous, elliptic, apex acuminate, base cuneate to obtuse. Mature leaves shortly hairy especially below, usually with glands in vein axils. **Flower** 3-4 cm diameter, tomentose, pedicels 0.8-1.0 cm long. Inflorescence cymose, 3.5-7.0 cm long. Sepals 5, greenish, ovate, apex rounded to obtuse, tomentose, colleters large and wide. Petal 5, white or yellowish, subrotate, tube 3.2-6.5 mm long, lobes 7.7-14.5 mm long, oblong, apex obtuse or rounded, pubescent-papillose on lobes inside and outside. Corona of antepetalous and alternipetalous lobes, pubescent on outside of lobes, wide and frequently overlapping, antepetalous lobes adnate to corolla for about half length, much shorter than stamens, crenate, 2.0-4.8 mm long, alternipetalous lobes notched, 1.2-3.5 mm long. Stamens 5, inserted at corolla mouth, filaments 0.4-0.7 mm long, anthers 1.1-1.5 x 4.7-6.0 mm, pubescent on both surfaces. Ovary 1.0-2.0 mm long, glabrous, carpels connate, superior ovary, ovules numerous, **Fruit** of connate follicles, splitting into two at dehiscence, 18.8-24.2 cm long, 1.6-1.9 cm wide, glabrous or rarely, locally minutely puberulent, lenticellate. **Seeds** linear, with a long tuft of hairs at one end, pointing towards base of fruits.

4. *Canarium subulatum* Guillaumin (มะกอกเกลื้อน)

Family : BURSERACEAE

Tree to 20 m with rounded crown and straight trunk. **Bark** gray-brown to dark gray, smooth or shallowly fissured, inner bark pale brown with white stripes, exuding a clear sap which turns blackish. **Leaf** alternate, odd-pinnate, petiole and rachis 27-47 cm long, 2-5 pairs of opposite leaflets plus an end one, 7.5-10.6 x 12.0-17.0 cm, oblong or lanceolate with pointed tip and oblique base, finely toothed.

Young shoots densely orange-brown hairy, mature leaflets smooth or sparsely hairy, especially below. Side leaflet stalks 1.5-2.5 cm, end one 2.5-5.0 cm, main stalk with a pair of narrow stipules at or near the base, 10-25 mm. Old leaves bright red. **Flower** 0.3 cm diameter, cream, narrow clusters in upper leaf axils, 7-25 cm. Calyx 2.5-3.5 mm, 3 lobed, softly hairy on both sides. 3 petals, twice as long as sepals, fused at base. 6 stamens, fused into short tube at base. **Fruit** 3.7-3.9 cm long, 2.8-3.0 cm wide, clusters 2.5-8 cm, individual fruits yellowish-green, not splitting, exuding a pale orange resin when cut, ovoid or bullet shaped with pointed tip and rounded base, persistent hard calyx. Stones slightly triangular in cross-section, very hard with 1-3 seeds.

5. *Bauhinia racemosa* Lam. (ชงโคนา)

Family : CAESALPINIACEAE

Tree to 15 m with broad dense crown and crooked dark gray trunk, roughly cracked, branches drooping, velvety when young, later nearly glabrous. **Leaf** 8.6-13.0 x 3.4-5.7 cm, simple, alternate, reniform, 7-9 main veins, bifid with very broad sinus, tip of lobes rounded, base truncate to deeply cordate, upper surface glabrous, lower grayish velvety to subglabrous. Stipules minute, triangular, early caducous. Petioles pubescent to subglabrous, 1-3 cm. **Flower** 1.0-1.5 cm diameter, greenish-white or pale yellow, in slender unbranched clusters. Racemes pubescent, lateral, drooping, lax-flowered, up to 15 cm long. Pedicels 5 mm long, bracts minute, bracteoles diminutive, inserted near base of the pedicel. Buds pubescent, fusiform, falcate, with curved, pointed apex, 5-7 mm long. Receptacle turbinate, 2-3 mm long. Calyx spathaceous. Petals linear-lanceolate, slightly longer than calyx. Stamens 10 fertile, 5 outer 7 mm long, the inner shorter, filaments densely hairy at base, anthers narrow oblong, hairy, 3-4 mm. Ovary glabrous, 2 mm on an equally long stipe, stigma inconspicuous. **Pods** indehiscent, turgid, glabrous, 22-36 cm long, 2.5-2.8 cm wide, often curved, not splitting. **Seeds** 7-30, oval 1 cm diameter.

6. *Erythrophleum succirubrum* Gagnep. (ซาด)

Family : CAESALPINIACEAE

Tree to 20 m with straight trunk and red sap. **Bark** pale brown or gray-brown, shallowly fissured. **Leaf** alternate, odd-bipinnate, petiole and rachis 22.0-35.5 cm long, pubescent, 3-4 pairs of opposite pinnae, 8-17 of alternate leaflets, ovate, 3.8-5.5 x 5.0-10.0 cm, obtuse, sometimes emarginate at the tip, rounded unequal or slightly cordate at the base, pubescent, petiolule 2 mm long. Stipules very small, soon caducous. **Flower** sessile in axillary spikes, greenish white, inflorescences 2.0-2.3 cm diameter, floret 0.5-0.6 cm diameter, bisexual, sometimes branched at base, tomentose, 8-10 cm long. Bracts small, very soon falling. Receptacle pubescent, 1 mm long. Sepals oblong, rounded at the top, 1 mm long, ciliate at margin. Petals linear-spathulate, 3 x 0.3 mm, ciliate at margin. Stamens with glabrous filamens, anther with brown margin. Ovary on 1 mm stipe, hirsute, ovules 6-10. **Pods** 5 mm stipitate, 14.8-21.6 cm long, 3.5-4 .0 cm wide. **Seeds** 2-9, funicle 6 mm long.

7. Senna garrettiana (Craib) Irwin & Barneby (แสมสาร)

Family : CAESALPINIACEAE

Small tree to 8-10 m. Young branch hairy, brownish bark. **Leaf** alternate, even-pinnate, petiole and rachis 23-33 cm long, 3-7 pairs of opposite leaflets, 4.6-7.0 x 8.8-11.3 cm, ovate to lanceolate, acuminate apex, round base, entire, glabrous, without teeth, no glands, petiolule 0.5-0.6 cm, stipules falling early. **Flower** 2.7-3.0 cm diameter, bright yellow, in narrow branched clusters at end of twigs, bisexual, inflorescence raceme, 12-15 cm long, pedicel 3-4.5 cm long, pubescent, complete. Sepals 5, 2 outer small, 3 inner bigger, elliptic. Petal 5, asymmetry, 1.5 x 2.0 cm, obovate. Stamen 10, 2 largest, 5 shorter with small anther, 3 sterile stamen, superior ovary, 1 locule. **Pods** 14.8-18.8 cm long, 3.0-4.0 cm wide, flattened, often twisted, smooth or with very scattered hairs, stalks 3 cm. **Seed** elliptic, brownish.

8. *Sindora siamensis* Teijsm. & Miq. var. *siamensis* (มะค่าแต้)

Family : CAESALPINIACEAE

Tree to 21 m with stout trunk, large branches and spreading, rounded crown, young branches finely pubescent, later glabrous. **Bark** dark brown, slightly cracked and flaking when older, inner bark pinkish and rather fibrous. **Leaf** alternate, even-pinnate, petiole and rachis 15-25 cm long, 3-4 pairs of opposite leaflets, 6-8 x 10-15 cm, petioles 2-4 cm long. Leaflets coriaceous, broadly elliptic or elliptic-oblong, base acutish (larger ones) to rounded (smaller ones), apex rounded, emarginate both surfaces reticulate, upper surface minutely short-hairy (rough to touch), lower surface often more densely hairy and softer to touch, marginal nerve of leaf on one side near the base with a small but distinct gland, dense network of finer veins. Stalks with curved stipules, soon falling. **Flower** 1.5 cm diameter, yellow-green, in narrow branched clusters at end of twigs and upper leaf axils. Inflorescences 14-35 cm long with straight or zig-zag axes. 4 fleshy green sepals with dense golden-brown hairs and scattered short soft spines outside. Single yellow-green or pinkish petal hidden inside the curve of the lowest sepal. 9 fertile and 1 sterile stamens, the fertile ones joined at base, 2 of them longer than others. 1.5-2.3 cm. 1 slender curved style with tiny stigma, ovary 0.7 cm long, 0.4-0.5 cm wide with densely hairy and softly spiny, 4-7 ovules. **Fruit** 4.8-8.0 cm long, 4.2-5.4 cm wide, dark green ripening dark brown, round and flat with a short curved tip, covered in sticky spines, 3-5 mm long. 1-3 large black seed, 1.5-2.0 cm.

9. *Sindora siamensis* Teijsm. & Miq. var. *maritima* (Pierre) K. & S.S. Larsen (มะค่าลิง)

Family : CAESALPINIACEAE

This variety deviates from var. *siamensis* in the pods being spineless or with few, small spines or warts. **Fruit** 5.5-9.2 cm long, 4.3-6.3 cm wide.

10. *Ellipanthus tomentosus* Kurz var. *tomentosus* (คำรอก)

Family : CONNARACEAE

Small tree to 16 m. **Bark** dark brown, very thick and hard with deep cracks. **Leaf** 5.4-7.4 x 14.4-17.7 cm, simple, alternate, coriaceous, elliptic to lanceolate, rounded to narrowed at base, obtuse to acuminate at apex, tomentose beneath, especially on the nerves, nerves 6-10 pairs, joined near the margin. Petiole glabous, 1.5-2.0 cm long. **Flowers** 0.7-0.8 cm diameter, pedicel 0.2 cm long. Inflorescence glomerulate to racemose, few-flowered, densely pilose, peduncle 0.5 cm long. Sepals 5, light green, ovate, blunt or acute, 0.3 cm long, pilose outside, glabrous inside, Petals 5, white to cream, twice as long as the sepals, pilose outside, tomentose inside. Mostly bisexual, however some individuals trees have well developed staminate and no well developed pistillate, 3 types of flowers were found; (1) short sterile pistil, no style and stigma in individuals with no well developed pistillate but only ovary appears, tomentose, ovary 0.2 cm long, superior, 2 ovules, stamen 5, creamy anthers when young turning brown when old, anther 0.6 cm long. (2) long sterile pistil, individuals with no well developed pistillate, ovary 0.4 cm long, with style and stigma, stamen 4-6, anther 0.6 cm long. (3) fertile flower, individuals have well developed pistillate, ovary 0.5 cm long, stamen 5-6, anther 0.15 cm long. (Appendix I, Figure 1). **Fruit** 4.0-4.5 cm long, 2.1-2.5 cm wide, pale brown, tomentose, short stipitate 5-10 mm, less than 90° geniculate, ventral suture smooth, **Seed** black with a yellowish to orange arillode at the base, endosperm present, hard.

11. *Dipterocarpus intricatus* Dyer (ยางกราด)

Family : DIPTEROCARPACEAE

Tree to 15 m. **Leaf** 12.3-17.3 x 20.6-28.2 cm, simple, alternate, broadly ovate, pubescent, veins hairy denser than blade, margin entire half lower part and undulate half upper part, apex obtuse, base cordate, stellate hairy on both sides, petioles about 3-4 cm long. **Flowers** 2.0-2.5 cm diameter, white with pink along the center, on short panicles, in leaf-axils, bisexual, peduncle 6 cm long, subpeduncle up to 9 cm long, receptacle 1 cm long. Sepals 5, united at base into a bell-shaped tube, with 5 undulate ridges on the outer part, light brown, 2 sepals triangular and 0.3 cm long, the other 3 lanceolate and 1.5 cm long. Petals 5, twisted, glabrous, with sticky glands, 3.0-3.5 cm long, convolute at the base. Stamens 30, arranged on three rings around pistil, yellow anthers, 10 mm long. Pistil 1, yellow white, 1.7 cm long. Ovary superior, tomentose outside, 6 ovules. **Fruit** a nut, with 2 large oblong, and 3 shorter ear-sharped, wings; fruiting calyx-tube covered with 5 undulate ridges.

12. *Shorea obtusa* Wall. ex Blume (เต็ง)

Family : DIPTEROCARPACEAE

Tree to 18 m. **Bark** red-brown when young, blackish when older, deeply cracked, inner bark yellowish-brown, fibrous, with yellow resin. **Leaf** 6.0-9.5 x 11.7-17.0 cm, up to 12 x 22 cm in young trees, simple, alternate, narrowly elliptic or oblong, usually blunt or rounded at both ends, sometimes slightly heart-shaped at base. Young leaves with grayish star-shaped hairs, mature leaves dull green, almost smooth or with scattered hairs, usually rather thick and leathery. Stalks 1.5-2.0 cm, short and quite stout, with small hairy stipules, 5-6 mm long which fall early. Old leaves yellow. **Flower** 0.5 cm diameter, white or creamy yellow, in drooping, branched clusters, 6-12 cm, bisexual, individual flowers with short stalks, buds oblong. Petals narrow and pointed, twisted and overlapping but not fused together at base, falling separately. 22-29 stamens in 3 rows, anthers hairy with short tips, style much shorter than ovary. **Fruit** 3 larger wings 1.2-1.5 x 5-6 cm, 2 shorter wings 1.5-3.0 cm, nuts 0.6-0.8 cm with short tip.

13. *Shorea roxburghii* G. Don (พะยอม)

Family : DIPTEROCARPACEAE

Tree to 17 m. **Bark** dark gray, 2-5 cm thick, deeply fissured, **Leaf** 6.7-8.3 x 14.3-17.5 cm, simple, alternate, narrowly elliptic or oblong with blunt or slightly pointed tip and blunt or rounded base. Mature leaves thin, dark green, smooth or very slightly hairy. 14-18 pairs of curved side veins. Stalks slender, 1.8-3.0 cm, twigs dark brown and glossy. **Flower** 0.8-1.0 cm diameter, cream, in slender, branched clusters near end of twigs, 7-10 cm, bisexual, receptacle 1.5 mm long. Sepals 5, petals 5, twisted in a spiral and fused at base, falling together in a rosette. 15 stamens in 3 whorls, anthers smooth with long tips, slender style as long as ovary with 3 minute stigmas, yellow anthers, 3 mm long, pistil 4 mm long, superior ovary, 6 ovules. **Fruit** 3 larger wings 0.6-1.0 x 6-8 cm, often narrow and pointed, 2 shorter wings 0.3-0.4 x 3-4 cm, nuts 1.2-1.4 cm with long, narrow tip.

14. *Shorea siamensis* Miq. (รัง)

Family : DIPTEROCARPACEAE

Tree to 23 m. **Bark** gray, very thick and hard with deep cracks, inner bark red-brown with pale yellow-brown resin. **Leaf** 10.4-13.5 x 14.2-22.0 cm, simple, alternate, broadly ovate or oval with rounded or slightly pointed tips and a heart-shaped base. Yong leaves pale red-brown with star-shaped hairs, mature leaves usually dull green and almost smooth, rarely densely hairy. 9-16 pairs of side veins. Stalks 3-5 cm, slender and slightly flattened, often tinged red. Stipules 1.5-2.0 cm, narrowly ovate, curved, falling early. **Flower** 1.0 cm diameter, bright yellow, in slender, branched clusters of 5-20 flowers near end of twigs, 15-25 cm, usually appearing just before young leaves. Sepal 5, petal 5, closely twisted together into an open mouthed globe with recurved tips, fused at base and falling together as a rosette with stamens attached. 15 stamens in 2 whorls, 10 in the outer and 5 in the inner whorl, anthers smooth with long narrow tips and short filaments, style as long the ovary with single stigma, inferior ovary, 6 ovules. **Fruit** 3 larger wings with blunt tips, 1.0-1.5 x 5-8 cm, 2 smaller wings 1 x 2-5 cm, nuts 1.4-1.6 cm with long tip. Three types of peduncle and wing of individual were found; (1) yellow peduncle, yellow wing, (2) red peduncle, red wing and (3) yellow peduncle, red wing (Appendix I, Figure 2).

15. *Diospyros ehretioides* Wall. ex G. Don (ตับเต่าต้น)

Family : EBENACEAE

Tree to 12 m. **Bark** dark red-brown, shallowly to quite deeply cracked. **Leaf** 17.5-26.5 x 29-43 cm, simple, alternate, oval, ovate to elliptic, base rounded, truncate or cordate, apex rounded or obtuse, coriaceous, glabrous on upper surface, pubescent, glabrescent on lower surface, secondary nerves 6-12 pairs, faint, impressed on upper surface, prominent on lower surface, tertiary veins inconspicuous on both surfaces, petiole 1.2-2.0 cm long, pubescent, glabrescent. Young leaves finely hairy, mature leaves leathery, smooth or nearly so. **Male flowers** 0.5-0.6 cm diameter, white, cymose, 4-merous, pedicel 3 mm long, pubescent. Calyx broadly campanulate, 2-3 mm long, divided to one third, pubescent outside, glabrous inside. Corolla ovoid or urceolate, 3-5 mm long, divided to one third, sparsely hairy outside, glabrous inside. Stamens 20-30 glabrous. Rudimentary ovary pilose. **Female flowers** 0.6 cm diameter, white, solitary or cymose, 4- merous, pedicel 1 cm long, pubescent. Calyx broadly campanulate, divided to the base, pubescent outside, glabrous inside. Corolla as in male flowers. Ovary ovoid, woolly, 6-locular, style simple, woolly. Staminodes absent. **Fruit** ovoid, 2.7-3.2 cm long, 2.6-3.1 cm wide, dry in maturity, pubescent, glabrescent, obtuse at both ends, fruiting calyx divided to one half or more, pubcscent outside, glabrous inside, lobes oblong, reflexed, not undulate nor plicate, with inconspicuous nerves, fruit-stalk 1 cm long, endosperm ruminate.

16. ***Aporosa villosa*** **(Wall. ex Lindl.) Baill.** **(เหมือดโลด)**

Family : EUPHORBIACEAE

Tree to 8-10 m. **Bark** gray-brown or red-brown, deeply cracked, thick, inner bark pale yellow or orange with thin brown rings. **Leaf** 9.0-13.5 x 14.0-19.7 cm, simple, alternate, spiral or planar, elliptic-oblong or narrowly obovate with blunt or abruptly pointed tip and rounded or slightly pointed base, untoothed or with scattered shallow rounded teeth. Mature leaves thick, densely covered by short soft brown hairs below and on veins only above. 7-10 pairs of arched side veins, joined at margin. Stalks 1.4-2.7 cm, thick, swollen with 2 small hairy glands at top, densely hairy. **Flower** male and female on different trees. Males in spikes, 1.8-3.5 cm long, greenish-yellow, several together at leaf axils or behind leaves, stalks hairy, 3-9 flowers per bract. Calyx cup-shaped, 3-4(5) sepals, usually hairy both sides, no corolla. 2-3(5) free stamens, no disc. Females 0.2-0.5 cm diameter, greenish, in clusters of 2-5 flowers on stout stumps, to 1 cm, individual flowers without stalks. Styles doubly forked with 4 stigmas, ovary brown-hairy. **Fruit** 1.4-1.6 cm long, 0.9-1.0 cm wide, ovoid with curved tip and persistent styles, densely yellow-brown hairy, splitting irregularly, 1 seed with fleshy orange aril.

17. ***Bridelia retusa*** **(L.) A. Juss.** **(เต็งหนาม)**

Family : EUPHORBIACEAE

Tree to 10 m with irregular, shabby crown and horizontal or drooping sprays of leaves. **Bark** pale gray or gray-brown and smooth when young, becoming dark brown and fissured with age, often slightly spiny when young. **Leaf** 8.2-12.5 x 15.6-21.7 cm, simple, alternate-planar, becoming much smaller towards end of twigs, oblong or elliptic, slightly pointed or blunt at both ends, without teeth, Young shoot finely gray-hairy, mature leaves leathery, smooth except on midvein above, finely hairy or almost smooth below. 16-24 pairs of straight and parallel side veins, forked but reaching margin and joined to a thin vein which runs along the very edge of the leaf. Stalks 1.0-1.5 cm, no glands. Stipules 2 mm pointed, falling early. Old leaves pinkish-brown. **Flower** 0.4-0.5 cm diameter, green or yellowish-green, sometimes with orange or red tinge, in dense heads of 8-15 flowers at axils of leaves or grouped into spike-like clusters at end of leafless twigs, male and females in different flowers but on same tree. Individual flowers with short stout stalks less than 2 mm. 5 thick triangular sepals 1.5-2.0 mm, not overlapping, smooth or hairy especially near base. 5 fragile, whitish petals with jagged tips, 1.0-1.5 mm. Males have stamens and sterile pistils fused into a stout column, 1.0-1.5 mm, with 5 spreading arms tipped with red-purple anthers. Females have 2 styles with forked stigmas, fused at base only, 1 mm. Ovary less than 1.5 mm, partly enclosed in flask-shaped disc. **Fruit** 1.4-1.6 cm long, 0.9-1.0 cm wide, pale green ripening blackish, globose or ovoid, sometimes 2 lobed, not splitting, thinly fleshy with 2 thin-walled stones.

18. *Phyllanthus emblica* L. (มะขามป้อม)

Family : EUPHORBIACEAE

Tree to 13 m with open irregular crown and crooked trunk. **Bark** gray-brown with creamy orange patches, thin, smooth, peeling in broad flakes, inner bark pink. **Leaf** 0.2-0.4 x 0.9-2.0 cm, simple, alternate, but strongly planar and appearing pinnate, oblong or linear with blunt or slightly pointed tip and rounded base, usually asymmetric, untoothed. Young leaves finely hairy, often tinged reddish, mature leaves completely smooth. Stalks less than 1 mm, with tiny red-brown stipules. Twigs slender, to 20 cm, often falling together with leaves. **Flower** 0.3-0.5 cm diameter tiny, pale green or creamy-yellow, tinged pink, monoecious, in dense simple clusters at leaf axils or behind them, sometimes on short side shoots with young leaves at top, usually with a few female and many males in each cluster. Male stalks 2.5 mm, 5-6 free sepals in 2 overlapping rows, 1.5-2.5 mm, no petals. 3-5 stamens fused into short column, shorter than sepals. Female stalks less than 0.5 mm, sepals slightly larger than males and fused at base, 3 fused styles with spreading, forked stigmas, ovary half-buried in fringed disc, carpels 3, locules 3. Inflorescence cymose type. **Fruit** 2.0-2.4 cm long, 2.1-2.4 cm wide, drupe, no stalks, green and semi-translucent with pale veining, ripening yellowish, globose, juicy and edible but rather acidic, with a hard 3-sectioned stone, each section with 2 seeds in light brown.

19. *Cratoxylum cochinchinense* (Lour.) Blume (ติ้วเกลี้ยง)

Family : GUTTIFERAE

Tree to 10 m. **Bark** light buff to pale brownish yellow, peeling off in angular pieces, middle bark bright green, inner bark pale cream with orange-green sap, sapwood yellow brown , young twigs slender, angled to flattened. **Leaf** 4.6-6.8 x 9.4-13.3 cm, simple, opposite, mature leaves pale greyish-green below, side veins faint, not joined in loops, blade elliptic to lanceolate to almost ovate, apex pointed, sometimes blunt to rounded, base narrowed, thinly leathery, midrib sunken above, secondary nerves faintly visible below, stalks 0.2-0.4 cm long. **Flower** 0.5-0.7 cm diameter, crimson or dark red, at end of twigs and in axils of mature leaves, sepal 5, petal 5, petals without gland at base but with 4 large yellow glands between the stamen bundles, Many yellow stamens, fused into 3 bundles, bundles 0.7 cm long, 0.2 cm wide, superior ovary. Inflorescence racemose type. **Fruit** 1.1-1.3 cm long, 0.6-0.7 cm wide, capsule, dry dehiscent, dark brown, about 2/3 covered by the persistent sepals or more its length. Seeds 6-8 per valve which are shortly winged at one end.

20. *Cratoxylum formosum* (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogel. (ติ้วขน)

Family : GUTTIFERAE

Tree to 12 m with open crown and slender branches. **Bark** dark gray, cracked and flaking in small irregular pieces. Inner bark with watery brownish sap. Young trees often with long woody spines. **Leaf** 4.2-5.6 x 11.0-18.1 cm, simple, opposite, usually planar, oval or elliptic with slightly pointed tips and blunt or rounded base, no teeth. Young leaves red to pale pink, silky, appearing just after flowers, mature leaves bright green, smooth. 7-12 pairs of very clear side veins which are joined in loops near margin, stalk 1.0-1.5 cm. **Flower** 3.0-3.5 cm diameter, delicate pale pink flowers in clusters of 3-5 on old leafless twigs. Sepal 5, petals 5-7, 1.5 cm long, slightly spreading with a narrow stalk and a sticky scale at the base on the inside. Many short yellow stamens, fused into 3 slender bundles slightly shorter than the 3 free, pale green styles, filament white, superior ovary. Inflorescence racemose type. **Fruit** 1.6-1.8 cm long, 0.7-0.8 cm wide, capsule, dry dehiscent, dark brown, narrowly ovoid with pointed tip, covered by persistent sepals at base, thinly woody, splitting into 3 sections, each with 12-17 seeds which are shortly winged at one end.

21. *Irvingia malayana* Oliv. ex A.W. Benn. (กระบก)

Family : IXONANTHACEAE

Tree to 20 m with dense spreading crown and massive, base with prominent, thin and steep buttress. **Bark** pale gray-brown, smooth, becoming irregularly cracked and flaky when old, inner bark pale orange, branchlets with conspicuous annular leaf-scars. **Leaf** 6.4-9.8 x 11.7-16.4 cm, simple, alternate, spiral, elliptic with pointed tips and blunt or slightly tapering base, untoothed. Mature leaves completely smooth, dark green and shiny above, usually pale gray-green below. 8-12 pairs of side veins. Stalks 1.2-1.5 cm, slender, twigs smooth, dark brown. Stipules 1.5-3 cm long, forming a narrowly tube with curved, sharped point, which soon fall leaving a distinct ring scar on the twigs. **Flower** 0.7-0.8 cm diameter, greenish-white, short branched clusters hidden in leaf axils, usually appearing just before young leaves, quickly falling. Panicles 5-15 cm long, bracts ovate with acute apex, 5 fused sepals, 5 overlapping petals, about 3 times as long as sepals, 10 free stamens, attached outside and below the central disc, 1 style with inconspicuous stigma, ovary superior, 2-locular. **Fruit** 3.5-4.6 cm long, 3.3-4.2 cm wide, green, eventually tuning yellowish with pale orange flesh, drupe ovoid or ellipsoid, pendulous on long stalks, fleshy with yellow exocarp, endocarp woody, seed white with fatty cotyledons.

22. *Vitex pinnata* L. (ตีนนก)

Family : LABIATAE

Tree to 15 m. **Bark** pale gray-brown, thin, slightly cracked and flaking. **Leaf** 3-5 leaflets, leaflets 3.8-8.2 x 7.2-22.3 cm, broadly obovate to lanceolate, tapering or pointed at both ends, untoothed or with scattered shallow teeth. Young shoots velvety-hairy, mature leaflets thin but firm, smooth or minutely hairy above, shortly and softly brownhairy below, usually with shiny, resinous glands. All leaflets with short stalks, 0.5-1.2 cm long, main stalks 6.0-10.5 cm, narrowly winged or not at all. **Flower** 1.5 cm diameter, white-pale purple, in open branched clusters at end of twigs to 15 cm. Individual flowers with short stalks, velvety-hairy, in dense bunches partly hidden by conspicuous leafy bracts, 7 mm. Calyx 6 mm, semi-spherical, mealy-hairy, cup or bell-shaped with 5 short teeth, corolla funnel sharped with short tube and 5 unequal lobes, lowest one usually much larger than other and lip-like. 4 stamens attached to corolla tube and projecting beyond it, one pair larger than the other, style slender with short 2-lobed stigma. ovary superior. **Fruit** 0.8-0.9 cm long, 0.8-1.0 cm wide, purple black, globose, thinly fleshy with persistent calyx and single hard 2-sectioned stone, each section with 1-2 seeds in brown.

23. *Careya sphaerica* Roxb. (กระโดน)

Family : BARRINGTONIACEAE

Tree to 12 m with spreading crown in good sites, remaining stunted and gnarled in poor sites, ovate crown. **Bark** gray-brown, cracked and flaking in thin strips. **Leaf** 9.7-16.4 x 18-30 cm, simple, alternate or spiral at branch terminal, broadly obovate, tips rounded with short point, base tapering into short stalk, margin usually with fine, rounded teeth. Mature leaves dull green, smooth. **Flower** 6-8 cm diameter, pink or red, open before noon, bisexual, in short thick-stemmed clusters at end of leafless twigs, 2-8 cm, individual flowers without stalks. Inflorescence in cymose type. Calyx 2 cm, bell-shaped with 4(5) fleshy, rounded lobes. 4(5) free petals, 3 cm, pale green or yellowish, very fragile and soon falling. Many stamens, filament long and white, usually red at the base, twice as long as petals, in 3 whorls - outer ones longest, without anthers, middle ones with anthers, inner ones much shorter and converging, without anthers- all united at base into a thick fleshy ring and falling together. 1 long slender style with inconspicuous stigma, inferior ovary, with thin cup-shaped disc at top. **Fruit** 5-6 cm long, 5.3-6.8 cm wide, bright green ripening brownish, globose or ovoid with persistent style and calyx teeth at top, thick- skinned with fleshy pulp and many seeds.

24. *Lagerstroemia floribunda* Jack (ตะแบกนา)

Family : LYTHRACEAE

Tree to 10 m, bole fluted at base, generally twisted, sometimes forked. Crown dense, conical. **Bark** light fawn- brown, flaking in large angular pieces, leaving patches of new whitish or yellowish bark. **Leaf** 6.6-9.3 x 19.2-24.2 cm, simple, opposite, elliptic or oblong, hairy at first, later glabrous, with blunt or slightly pointed tip and rounded base, secondary nerves 6-12 pairs, tertiary veins rather faint and widely-spaced. Young leaves pinkish-brown, densely covered with star-shaped hairs, mature leaves dark green and nearly smooth. Stalk 0.4-0.6 cm. Twigs sharply ridged. **Flower** 7 cm diameter, pale pink or purple, fading to white, in large clusters with long side branches to 40 cm, axes and buds densely covered with fine golden-brown hairs. Calyx with 10-12 blunt ridges and 5-6 large teeth, usually with 5-6 smaller teeth in-between, brown hairy outside and near tips inside, petals oblong, narrowing gradually to base. **Fruit** 1.5-1.9 cm long, 1.1-1.5 cm wide, dark brown, oblong-ellipsoid, finely pubescent, fruiting calyx cup-shaped, half of fruit covered by hairy calyx.

25. *Memecylon edule* Roxb. (พลองเหมือด)

Family : MELASTOMATACEAE

Shrubby tree to 4 m, often with crooked trunk. **Bark** dark brown, thin finely to deeply cracked, inner bark cream. **Leaf** 3.1-4.2 x 3.8-6.5 cm, simple, opposite-planar, narrowly elliptic or ovate with long tapering tip and pointed base, no teeth. Mature leaves leathery, dark green and shiny above, completely smooth. Side veins very faint, looped at margin. Stalks 0.3-0.5 cm, no stipules, twigs dark brown, circular in cross-section with 4 narrow ridges. **Flower** 1 cm diameter, bright blue-purple, regular, bisexual, grouped into tight clusters in leaf axils or behind leaves, individual stalks 2 mm, slender, with joint and bracts at base. Calyx funnel-shaped with 4 broad teeth, 2 mm, 4 free petals with recurved tips, falling early. 8 equal stamens with purple filaments, 2 mm long and yellow anthers with a curved spur at the base. Single slender style with inconspicuous stigma, style 3 mm long, inferior ovary, covered by an 8-grooved disc, ovules 8-14. Inflorescence in cymose type. **Fruit** 0.8-0.9 cm long, 0.8-1.0 cm wide, exocarp green to yellowish green, turning pinkish, finally dark purple to blackish when ripe, drying greenish-brown, often somewhat mottled, globose with remains of style on top, smooth and shiny, thinly fleshy with 1-2 large seed.

26. *Chukrasia tabularis* A. Juss. (ยมหิน)

Family : MELIACEAE

Tree to 15 m. **Bark** dark brown, coarsely fissured, inner bark red. **Leaf** alternate, odd-pinnate, in moist areas saplings and young trees often have bipinnate or even tripinnate leaves, petiole and rachis 53.4-86 cm long. (5) 8-13 pairs of alternate or sub-opposite leaflets, 3.5-8.9 x 6.5-17 cm, narrowly ovate or oblong with tapering tips and oblique base, no teeth. Young leaves finely hairy, mature leaves completely smooth. 7-10 pairs of side veins. Leaflet stalks 0.1-0.2 cm, main stalk 7-11 cm. **Flower** 1.5-1.7 cm diameter, pale yellow often tinged dull red outside, in spreading branched clusters at or slightly above upper leaf axils, sometimes appearing terminal, individual stalks 0.3 cm, smooth. Calyx 1-2 mm, densely brown-hairy, 4-5 narrow petals, 0.7 cm, curved backwards, minutely velvety. Stamen tube cylindrical, slightly narrower towards top with 10 anthers on flat or shallowly toothed rim. Ovary smooth, longer than style surrounded by thin cup-shaped disc. **Fruit** 2.5-2.8 cm long, 2.3-2.5 cm wide, yellow-gray, slightly hairy when young, wrinkled when ripe, splitting into 3 sections, densely packed with winged seeds.

27. *Albizia lebbeck* (L.) Benth. (พฤกษ์)

Family : MIMOSACEAE

Tree to 15 m with uneven, spreading crown and large, twisted branches. **Bark** dark brown, densely but shallowly cracked, branchlets glabrous, terete. **Leaf** opposite, even-bipinnate, with 2-3 pairs of pinnae, 8-9 cm, larger ones with 3-6(9) pairs of opposite leaflets, 2.5-3.8 x 5.2-7.2 cm, sessile, obovate, entire, rounded or almost flat at both ends, often notched, smooth or with scattered hairs below, main vein slightly asymmetric, stipules tiny. **Flower** heads 4-7 cm diameter, greenish-white turning pale yellow, 2-4 heads together in upper leaf axils, not grouped into branched clusters. Heads with slender stalks, 5-10 cm Individual flowers 0.1 cm diameter with stalks 2-4 mm, dimorphic flowers. Central flower different from others. Marginal flowers : pedicel up to 4 mm. Calyx 3.5-5 mm, light green, funnel-shaped, puberulous, teeth 0.75-1.0 mm, narrowly triangular. Corolla 7.5-11 mm with teeth as long as tube, funnel-shaped, tube glabrous, lobes 2.5-4.0 mm, broadly ovate, acute, puberulous at the apex. Staminal tube shorter than the corolla-tube, 4-5 mm, ovary glabrous, sessile, superior ovary, 1 locule. **Pods** 18.7-26.0 cm long, 3.0-4.0 cm wide, pale yellow, oblong, gradually narrowed at both ends, very thin and flat, with somewhat sinuate margins, obvious swellings over seeds, remaining on tree a long time, eventually splitting. **Seeds** 2-12, elliptic, flat, with pleurogram parallel to the margins of the seed.

28. *Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen (แดง)

Family : MIMOSACEAE

Tree to 18 m with straight trunk and slender drooping branches with small lenticels, branchlets terete, densely puberulous, glabrescent. **Bark** creamy brown or red-brown, thin, peeling in rounded flakes, inner bark pink. **Leaf** opposite, even-bipinnate, with a single pair of pinnae, 10-30 cm, each with 3-7 pairs of opposite leaflets, top ones largest, 6.4-13 x 12-20.3 cm narrowly ovate or elliptic with slightly pointed tips. Young shoots densely covered with yellowish hairs, mature leaves smooth above, usually with minute pale brown hairs below. Leaflet stalks 0.2-0.4 cm, main stalk 2.5-9.0 cm, all joints with rounded glands. Young leaves delicate pink. **Flower** head 1.5-2.5 cm diameter, pale yellow, in dense spherical heads, solitary or in very short, unbranched clusters in axils of fallen leaves. Head stalks 2- 5 cm, bearing heads of 104-136 sessile flowers, spoon-shaped bracts. Individual flowers 0.2 cm diameter without stalks. Calyx 2.9-4 mm long, funnel-shaped, tomentose to woolly, teeth 0.8-1.0 mm long, triangular-ovate, acute. 5 petals, 3.5-

4.6 mm long, narrowly oblong, acute, puberulous to tomentose, slightly fused at base, hairy outside, 10-12 free stamens, 5-12 mm, much longer than petals, 5 stamens longer than others, anthers eglandular, without glands, superior ovary 2-2.5 mm long. 7-11 ovule. **Pods** 15.6-19.4 cm long, 5.3-7.0 cm wide, thick and woody, slightly curved, tapering at base, pale creamy brown at first, later dark brown, splitting suddenly into 2 parts which curl backwards, remaining on the tree for a long time. 3-11 ellipsoid, flat, dark brown seeds.

29. *Artocarpus lacucha* Roxb. (มะหาด)

Family : MORACEAE

Tree to 14 m. **Bark** red-brown to dark brown, becoming rough and scaly with age. **Leaf** 9.3-12.8 x 17.5-26.4 cm, simple, alternate, planar, oval to broadly ovate or obovate with blunt or shortly pointed tip and rounded or slightly heart-shaped base, often asymmetric, untoothed or with minute teeth. Young shoots densely red-brown hairy, mature leaves leathery, dark green and slightly rough above, gray-green and finely hairy below. 8-20 pairs of conspicuous side veins, joined at margin, obvious network of smaller veins. Stalks 2-4 cm, finely brown-hairy with small lanceolate stipules which fall early. Twigs rather stout, without ring scars. **Flower** heads 0.8-2.0 cm diameter, dirty yellow to pale pink or orange, solitary at leaf axils or just behind leaves. Male heads 0.8-2 cm, globular, stalks 0.8-2 cm. Female heads 1.2-2.3 cm, oval or oblong, stalks 2.5-3.5 cm. **Fruit** 4.5-5.6 cm long, 3.6-4.6 cm wide, stalks 1.2-3.8 cm, pale yellow or orange, irregularly globose or fist-shaped, knobbly and velvety outside, pink inside with many oblong seeds.

30. ***Ochna integerrima*** **(Lour.) Merr. (ช้างน้าว)**

Family : OCHNACEAE

Tree to 10 m with spreading branches and short, twisted trunk. **Bark** pale brown, deeply cracked. **Leaf** 5.4-6.3 x 13.5-17.3 cm, simple, alternate, more or less planar, obovate with blunt or slightly pointed tip, finely and irregularly toothed. Mature leaves dull green, leathery, completely smooth. 7-15 pairs of steeply curved side veins with shorter intermediate ones, not joined. Stalks 0.5-0.7 cm, stout, with tiny deciduous stipules at base. Leaf buds covered with closely set scales which soon fall leaving rings of scars on the twigs. **Flower** 4.0-4.5 cm diameter, bright yellow, in short, sparsely branched clusters near end of leafless twigs, individual stalks 1.2-3 cm, jointed, with convex receptacle at the top. 5 free sepals, 1-1.6 cm, 5-6 free petals, 1.5-2.5 cm, obovate with blunt tips and narrow base, very thin and fragile, falling early. 25-60 free stamens, outer ones longer, anthers narrowly oblong, as long as filaments, single slender style attached to base of ovary, 10-15 mm, 9 tiny stigmas, often on short branches, 9-11 ovules. **Fruit** 1.1-1.2 cm long, 0.7-0.9 cm wide, green turning black, globular or obovoid, thinly-fleshy with a large stone. 1-4 fruits clustered together with the persistent filaments and style on a convex receptacle, surrounded by the enlarged, bright red sepals, 7-9 seeds

31. ***Pterocarpus macrocarpus*** **Kurz (ประดู่)**

Family : PAPILIONOIDEAE

Tree to 18 m with majestic, dome-shaped crown and large, spreading branches. **Bark** pale brown, slightly fissured, becoming darker and scaly with age, inner bark fibrous, red-brown with sparse drops of red sap. **Leaf** alternate, odd-pinnate with 3-6(9) pairs of alternate leaflets 5.0-7.0 x 8.6-10.5 cm, oval with abruptly pointed tip and rounded base, petiole and rachis 8-25 cm long. 2 stipules at petiole base. Young leaves densely hairy, mature leaves bright green, smooth above but usually with scattered brown hairs on stalks and veins below, grayish when dry. 11-17 pairs of side veins. **Flower** 1.0-1.2 cm diameter, bright yellow, in unbranched clusters at leaf axils, 7.0-18.5 cm long, pedicel 1.5-2.0 cm long. 1-2 bracts, elliptic, acute, 0.4 cm long Calyx 0.6-0.8 cm, bell-shaped with 5 subequal teeth, densely hairy. Corolla papilionaceous shaped with 4 free, crumpled petals, 1.3-1.5 cm long, 0.9 cm wide. 10 stamens fused in 2 bundles, filament 0.7-1.3 cm long, ovary densely hairy with short stalk, superior ovary. Inflorescence in raceme type. **Fruit** 6-7 cm diameter, circular, with a broad, wavy wing surrounding the central 1-3 seeded capsule and a short style in lower half, not splitting, densely covered with minute pale brown or whitish hairs when young, less so when mature.

32. *Gardenia sootepensis* Hutch. (คำมอกหลวง)

Family : RUBIACEAE

Tree to 11 m with open, straggly crown and stout, twisted trunk. **Bark** pale cream or gray, quite smooth, peeling in thin plates, no thorns. **Leaf** 12.8-16.0 x 20.3-29.5 cm, simple, opposite, oblong or obovate with blunt tip and rounded base. Young leaves pale orange, silvery-hairy, mature leaves glossy dark green above, finely hairy below. 16-20 pairs of straight, parallel side veins, curved and joined at margin. Stalks 0.3-0.6 cm, stipules 1.5-2.0 cm, fused into a sheath around the twigs, soon falling but leaving an obvious ring-like scar. Leaf buds broadly conical covered with sticky yellow resin. **Flower** 9.5-12.5 cm diameter, pale green or white turning rich yellow-orange, solitary at end of twigs or on stout stumps in leaf axils, stalks 1.5-2.0 cm. Calyx 1.2-2.0 cm, tubular with short pointed teeth, deeply split on one side, ribbed, dark green, sticky and finely hairy outside. Corolla tube 8.5-10 cm, narrowly cylindrical with 5 widely spreading, blunt-tipped lobes, 3-4 cm, closely twisted together in bud. 5 stamens alternating with corolla lobes and attached slightly below them, anthers sessile, style slightly longer than corolla tube, hairy at base, stigma club-shaped. **Fruit** 3.4-4.3 cm long, 2.3-2.8 cm wide, bright green, oval with distinct nipple at top and 5 shallow ridges, fleshy with many small seeds. Stalks thick, to 1 cm.

33. *Haldina cordifolia* (Roxb.) Ridsdale (ขว้าว)

Family : RUBIACEAE

Tree to 18 m with straight, slightly fluted trunk and open, rounded crown. **Bark** pale brown to dark gray, smooth or scaly and finely fissured, inner bark pink to dark brown. **Leaf** 11.0-16.5 x 12.0-17.5 cm, simple, opposite in 2 rows (decussate), circular or broadly ovate with short tip and heart-shaped base. Young leaves pale green with pink stalks, mature leaves thin with scattered rough hairs above and denser soft hairs below. 5-7 basal veins, 5-8 pairs of side veins. Stalks 5.5-9.5 cm, slender. Young twigs squarish with flat, rounded buds which are protected by a pair of pale green, ridged stipules, 1.2-1.8 cm. **Flower** head 1.5-2.5 cm diameter, pale yellow or pinkish, slightly fragrant, in dense spherical heads, several together in very young leaf axils, stalks 3-7 cm. Individual flowers 0.6-0.8 cm diameter. Calyx 0.25 cm, with short tube and 5 oblong lobes, hairy outside. Corolla 0.5 cm, with slender tube and 5 blunt lobes, finely hairy outside. 5 stamens with very short filaments attached to upper part of corolla tube, style much longer than corolla, 1 cm. **Fruit** 1.6-2.0 cm long, 2.2-2.5 cm, in globose heads, dry, with hard partitions between the seeds, each fruit splitting from top into sections with a persistent central axis and calyx. **Seeds** tiny, pointed at one end, narrowly winged.

34. *Morinda coreia* Ham. (ยอป่า)

Family : RUBIACEAE

Small tree to 5 m with straggly crown and short, twisted trunk. **Bark** brown, fissured. **Leaf** 14.0-18.5 x 22.5-31.0 cm, simple, opposite, spiral, oval or ovate with abrupt tip and pointed base. Mature leaves thin, softly hairy on both sides, dull dark green above, paler with dark dots scattered over surface below. 8-10 pairs of irregularly spaced side veins and a clear network of finer veins. Stalks 1.0-1.7 cm, stipules 1.5-4 mm, triangular, usually forked and fused into a sheath, falling early. **Flower** 1.6-2.0 cm diameter, pure white, in loose heads opposite a solitary leaf, or several heads together at end of twigs. Common stalks 1.2-2.5 cm with a cluster of large deciduous bracts at top, individual flowers without stalks. Calyx tubes flat at top, fused with neighbouring flowers at base, hairy inside. Corolla funnel-shaped with 5 (6) spreading, blunt lobes, half as long as tube, softly hairy on both sides. 5-6 short stamens attached at mouth of corolla tube and not projecting beyond it, filaments 5 mm, style longer than corolla tube, stigma 2-lobed, ovary with distinct disc, inferior ovary. **Fruit** 2-5 cm long, 1.5-3.0 cm wide, fused into an irregular, knobbly mass, green turning whitish, fleshy and juicy, each individual fruit with 1 pyrene.

35. *Morinda elliptica* Ridl. (ยอเถื่อน)

Family : RUBIACEAE

Similar *Morinda coreia*. **Leaf** 13.6-18.6 x 21.3-33.3 cm, pointed at both ends, completely smooth, shiny above, 5-6 pairs of side veins, tertiary veins flat below, stipules obovate and blunt. **Flower** 0.8-1.0 cm diameter, corolla smooth outside, **Fruit** 5.2-6.5 cm long, 3.3-4.0 cm wide.

36. *Rothmannia wittii* (Craib) Bremek. (หมักม่อ)

Family : RUBIACEAE

Tree to 8 m with sympodial branching. **Bark** dark gray-brown, finely cracked and flaking. **Leaf** 5.1-7.8 x 11.5-15.5 cm, simple, opposite, often planar, ovate with pointed tips and cuneate base. Mature leaves completely smooth, dull dark green above, pale green with sunken glands in vein axils below, 6-8 pairs of arched side veins, finer veins faint. Stalk 0.3-1.0 cm, stipules 0.4 cm, triangular, falling early. Twigs flattened when young, leaf buds broadly triangular. **Flower** 4.5-6.0 cm diameter, white with red-purple dots near mouth inside and yellow at base inside, in clusters of 1-5 flowers on a short common stalk at end of leaves, individual flowers without stalks. Calyx 6-10 mm, 5 narrow pointed lobes, densely hairy outside. Corolla bell shaped with 5 blunt lobes, much shorter than tube, lobes 1.2 x 1.8 cm, densely hairy inside. 5 stamens attached to upper part of corolla tube, anthers 1.4-1.5 cm, no filaments. Style 3.4 cm, smooth, at least as long as corolla tube, stigma 2-lobed, yellow, inferior ovary, many ovules. **Fruit** 4.2-4.8 cm long, 4.5-5.0 cm wide, dark brown or black, globose or subglobose, with several flattened-brown seeds, surrounded by a slimy orange pulp.

37. *Schleichera oleosa* (Lour.) Oken (ตะคร้อ)

Family : SAPINDACEAE

Tree to 11 m with irregular crown, short trunk and large, spreading branches. **Bark** creamy-brown, slightly flaking, becoming dark gray and more or less deeply cracked with age, inner bark cream or pink, turning brownish when cut. **Leaf** alternate, odd- or even-pinnate, 1-4 pairs of opposite leaflets, 10.2-13.0 x 16.2-23.0 cm, with or without an end one, upper pairs much larger, oval or broadly obovate with short tip and blunt or rounded base, usually slightly asymmetric, no teeth. Young leaves silky-hairy, dark red-purple, quickly changing to pale green, mature leaves thin, completely smooth or with hairy glands in vein axils below. 10-21 pairs of side veins, not joined or joined near apex only. Leaflet stalks 0.1-0.2 cm, main stalks 14-23 cm. **Flower** 0.5-0.7 cm diameter, pale green or yellow-green, slender branched or unbranched clusters in leaf axils, to 19 cm. Individual stalks 0.3 cm. 4-6 triangular sepals, subequal, white-hairy outside, no petals. 5-9 slender stamens, 2-3x longer than calyx, usually slightly hairy, disc thin and wavy but not broken, stigma 3-4 lobed, superior ovary, 2 ovules. Bisexual and male flowers usually on different trees. **Fruit** 2.4-2.6 cm long, 2.2-2.9 cm wide, bright green, turning brownish, globose with short tip, not lobed, smooth or with a few soft points, thin-skinned, not splitting. 1-2 brown seeds covered with thin pale yellow or translucent sarcotesta.

38. ***Strychnos nux-vomica*** **L. (แสลงใจ)**

Famity : STRYCHNACEAE

Tree to 8 m with a slender crown. **Bark** pale gray, smooth or with horizontal wrinkles, sometime spiny. **Leaf** 10.8-16.8 x 15.3-27.5 cm simple, opposite, broadly ovate, oval or almost circular with blunt or abruptly pointed tip and blunt, rounded or slightly heart-shaped base, untoothed. Mature leaves yellow-green, smooth or minutely hairy on veins. 3-5 main veins from base, 3-5 pairs of arched side veins. completely smooth both sides, stalks 0.7-1.2 cm, no stipules. **Flower** 0.3-0.4 cm diameter, creamy-white or pale green, bisexual, in forked clusters at end of twigs or on short side branches from upper leaf axils, 3.5-8.0 cm. Individual flowers with short stalks, 1.5 mm long, grouped in three on a common stalk, 0.8-3.0 cm long, stalks densely hairy with minute bracts. Calyx 0.5-1.5 mm, divided to base into 5 pointed lobes, hairy outside. Corolla with long narrow tube and 5 spreading lobes, 3 mm, smooth or finely hairy outside. 5 stamens attached to throat of corolla, 1.5 mm long, no filaments. 1 slender style projecting beyond corolla. **Fruit** 5.8-6.9 cm long, 5.8-7.1 cm wide, globose, bright orange with very thick, smooth skin and fleshy pulp, with 8-10 disc-like seeds, 0.6-0.8 cm thick.

4.2 Flowering phenomena and pollinator observation

4.2.1 Tree species and characteristics of flowers

Thirty-six out of the total of 38 tree species in DDF produced flowers in a one year period (Appendix II, Table 2). Flowers could be classify using the morphology of the flowers. Based on inflorescence type, flower shape, flower diameter, flower color, flower position, level of anther and stigma, and ovary type. Inflorescence type which means only arrangement of floret found that panicle and raceme was the dominant type of 43.90 %. Cymose, head, solitary and other types had 19.51, 14.64, 7.32 and 14.63 %, respectively (Figure 4.5 A). Other types consist of spike, thyrsoid, catkin and corymb type which had few in numbers.

Concerning with flower shape, 55.26 % of flowers had a cup shape. The other flower shapes were tube form of 31.58 % and papilionaceous of 13.16 % respectively (Figure 4.5 B). While flower diameter was also the important factor limited pollinator approach. The study found that most flowers had small size (<1.0cm) of 55.26 %. Small size and tube form flowers are preferred by butterflies using their long proboscis for feed nectar at the base of the flowers. The other flower size as 1-5 cm and the large size (>5 cm) had 34.21 % and 10.53 %, respectively (Figure 4.5 C).

Although pollen and nectar are the main factors for attraction of pollinators, flower color is also an important factor (Owens, Sornsathapornkul and Tangmitcharoen, 1991). Figure 4.5 D, shows a sharp peak in yellow color of 52.63 %. The flower number of 7.89 % belonged to purple and pink colors. These colors are attractive to insect-pollinators especially bees. While the red color had 2.63 %, which is preferred by bird-pollinators (Scogin, 1983). The last one is white color of 28.95 %

This kind of flower is usually self-pollination and petal color is not necessary for attraction of pollinator (Wilson and Lomis, 1962).

Flower position is one important factor which encourage to pollination and seed dispersal. Plant flowers which pollinate and seed disperse by wind are usually flowered at terminal position, for example grasses or *Zea may* (McGregor, 1976). Most bat-pollinated plants are trees, and the flowers tend to be exposed and easily accessible (Ghazoul, 1997). The study found that terminal flowering was the most common flower position of 55.26 % while axillary position had 36.84 % and stem/branch position had 7.89 % (Figure 4.6 A)

The stigma and anther in the flower could be used to indicate pollination system and type of pollinator (Siripatanadilok and Likitrammanit, 1991). When using the level of the stigma comparing to the anther as a criteria. The numbers of flower with stigma above anthers were 47.37 %, and unisexual flowers were 18.42 %. It is indicated that without life pollinators, it is difficult to pollination and fertilization in these tree species. The numbers of flower with stigma below anthers, and flower with stigma at the same level as anthers were 26.32 and 7.89 %, respectively (Figure 4.6 B).These flower characteristics are the type of self-pollination or wind-pollination flowers (Wilson and Loomis, 1962).

In addition, the species producing flowers with superior ovaries were the most dominant type (73.68 %), while those with an inferior ovary and half-inferior ovary shared a much lower percentage, 23.68 % and 2.63 %, respectively (Figure 4.6 C). More than 81.58 % of flowering tree species were bisexual.

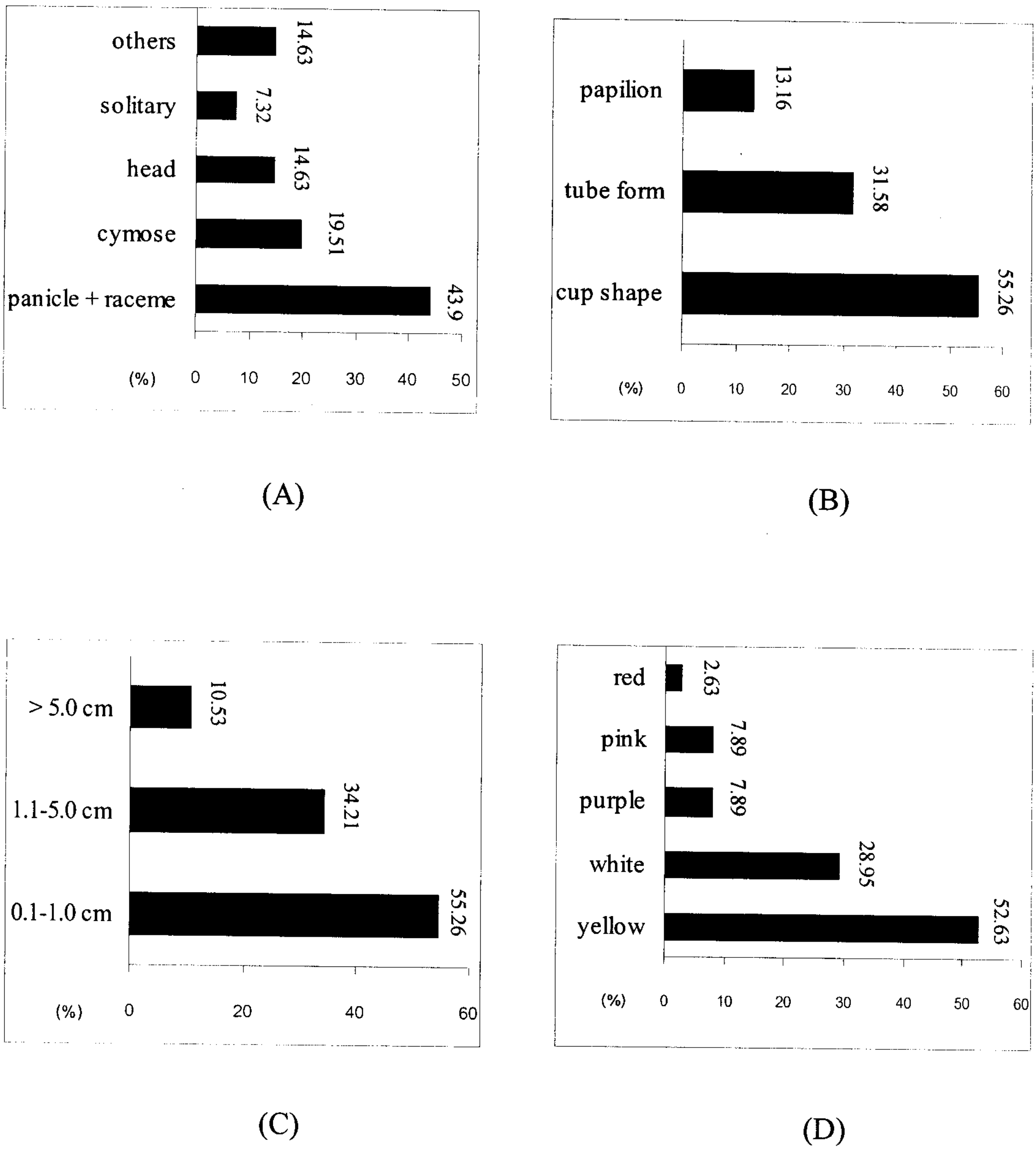
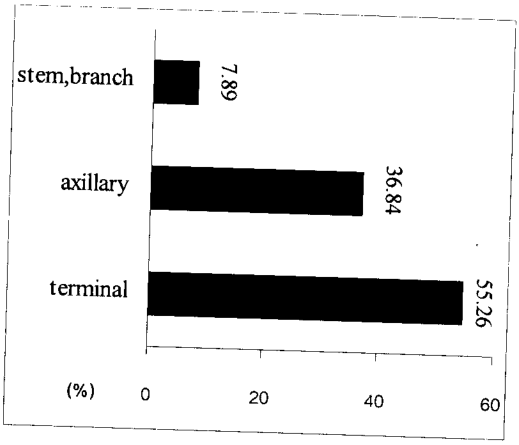
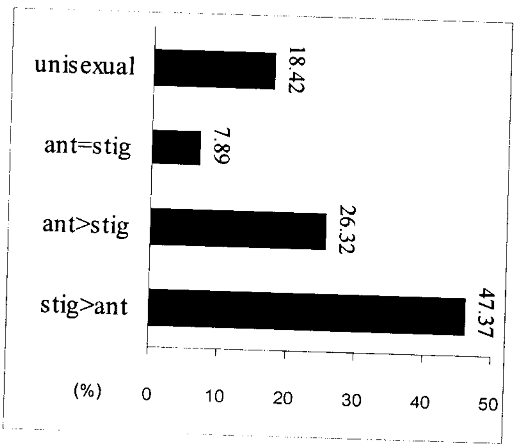


Figure 4.5 Numbers of flowering species separate by inflorescence type (A), flower shape (B), flower diameter (C), and flower color (D)

Note : papilion = papilionaceous form



(A)



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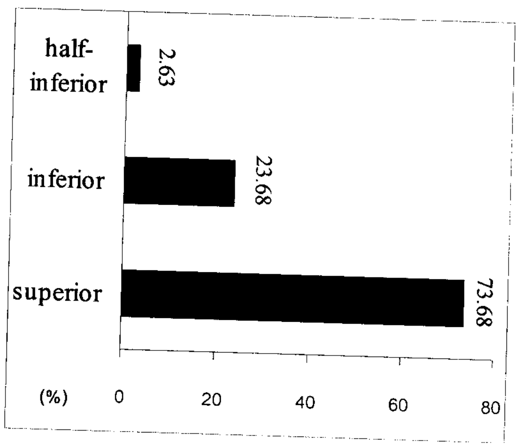


(C)

Figure 4.6 Numbers of flowering species separate by flower position (A), level of anther and stigma within flower (B), and ovary type (C)

Note : ant = anther

stig = stigma

4.2.2 Period of trees flowering and relation to environment

Based on the number of species in flower in each month over one year, Table 4.7 shows a continue flowering beginning from January and rising up in next month. A sharp peak in flowering is in March, when 21 of the 36 total species flowered, followed by a slow decrease of species flowering and a trough from October to November of only 1 species. The most trees started flowering from January to May when temperature was rising up from low temperature in the winter and rain has just started. Many tree species have finished flowering, pollination and seed dispersal before rainy season in June, for example Dipterocarpaceae species, *Ellipanthus tomentosus* and *Xylia xylocarpa*. Species flowering was rising up again in December of 5 species, coinciding with the report of Siripatanadilok and Likitrammanit (1991), and Elliott, Promkutkaew and Maxwell (1994) which plants flowering peaking sharply during February-April and in March, respectively. These results were associated with the rising up of light intensity, and it affected to higher flowering of tree species (Nanda, 1962, Jackson and Sweet, 1972, Hibbs and Fischer, 1979). As shown that the light intensity at Muang District, Nakhon Ratchasima from January to May 2000 had high value from 399.22-427.24 cal/cm^2/day (Table 4.7, Figure 4.7). In addition there were decrease of relative humility and soil moisture content in dry season at Nong Rawiang DDF. These activated more flowering in tree species (Table 4.8).

The association of intensified flowering activity with hot, dry weather is a commonly reported phenomenon in tropical forests. It has been reported for Singapore (Holttum,1931, Corlett, 1990), Nigeria (Njoku, 1963), Brazil (Ducke and Black, 1953), Malaysia (Medway, 1972), Costa Rica (Fournier and Salas, 1966, Daubenmire, 1972, Frankie, Baker and Opler, 1974, Reich and Borchert, 1984), Sri Lanka (Koelmeyer, 1959), India (Newton, 1988), Nepal (Dinerstein, 1979), Tanzania (Boaler, 1966), and Thailand (Sukwong, Dhamanitayakul and Pongumphai, 1975).

Table 4.7 Number of flowering trees species in each month at Nong Rawiang in the year 2000

Month	Total flowering trees species
Jan	10
Feb	16
Mar	21
Apr	16
May	10
Jun	7
Jul	4
Aug	2
Sep	2
Oct	1
Nov	1
Dec	5

Note :

Total flowering trees species = sum of tree species which just flowers in current month and tree species which flowered last month and continue flowers until current month.

Table 4.8 Mean data in each month of environmental factors at Nong Rawiang, Muang District, Nakhon Ratchasima during January to December 2000.

Month	Temp. (°C)	Rainfall (mm.)	RH. (%)	Radiation* (Cal/cm^2)	Evaporation* (mm.)	Soil Temp. (°C)	Soil Moist. (%)
Jan	24.03	0.53	81.00	399.22	4.33	25.53	1.89
Feb	24.78	20.38	76.52	437.10	4.79	24.72	1.76
Mar	28.01	10.23	77.81	475.79	5.43	26.84	4.38
Apr	29.32	19.16	79.77	479.14	4.53	27.34	6.47
May	28.52	28.99	81.16	427.24	4.22	27.25	7.18
Jun	28.11	19.54	81.40	389.89	4.08	26.06	7.17
Jul	27.87	9.15	79.97	381.13	3.80	26.44	5.93
Aug	27.94	46.74	83.97	403.21	4.26	27.75	3.85
Sep	27.09	22.42	87.17	347.54	3.40	26.06	8.30
Oct	27.10	14.27	87.84	335.35	3.84	25.44	6.34
Nov	23.17	0	78.17	414.66	4.28	23.19	4.27
Dec	24.05	0	79.45	348.25	4.65	23.97	2.75
Mean	26.67	15.95	81.18	403.21	4.30	25.88	5.02

Note : * Data from Hauybanyang Agricultural Irrigation Research Station Nakhon Ratchasima

Temp. = Temperature
RH = Relative Humility
Soil Temp. = Soil Temperature
Soil Moist. = Soil Moisture content

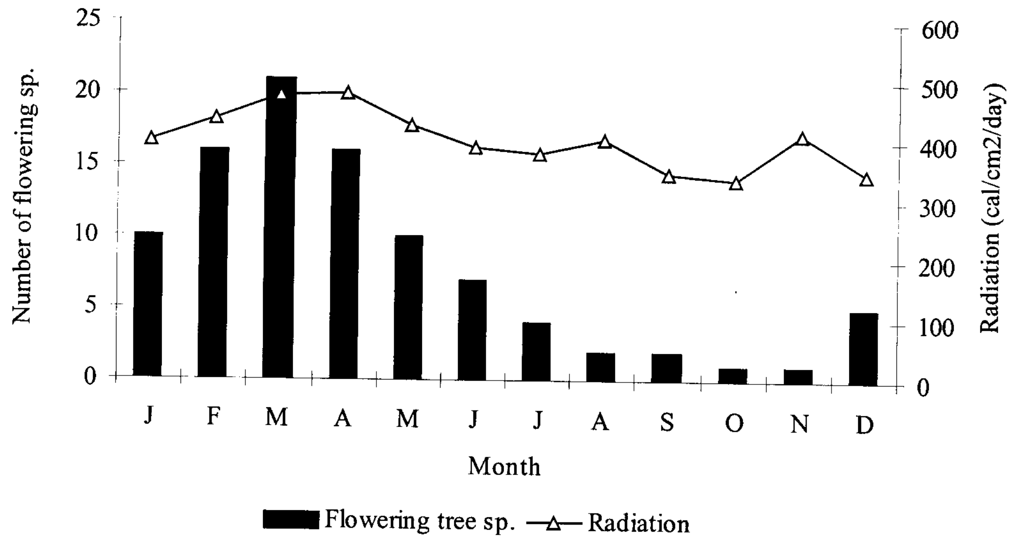


Figure 4.7 Relation of mean radiation to flowering species in each month

For the relationships between flowering and each environmental factor, analysis by simple regression showed that the radiation and evaporation were the most effective factors affecting the flowering of total species which the correlation value (r^2) was 67.10 and 61.50 %, respectively (Table 4.9). This evaporation factor involved the expression together of radiation, temperature, relative humidity and wind factor. Coinciding with เชิดศักดิ์ ทัพไหญ่ (2539) reported that the light intensity was the most effective factor affecting the flowering of new species in the disturbed mixed deciduous forest at Kanchanaburi.

The most likely factor, however, that triggers flowering during the dry season is water stress (Whitmore,1975), but high temperatures, hours of sunshine, or internal biological clocks may also play a role. It is unlikely that a single stimulus is responsible for triggering flowering in all species. Different species probably respond to different environmental factors so that flowering coincides with the most favourable season for sexual reproduction (Janzen, 1967).

It seems almost illogical that flowering should peak at the hottest and driest time of the year, when trees are under severe water stress, rates of water loss through the flowers must be very high and populations of pollinating animals may also be limited due to decreased water supplies. One possible advantage to flowering during the dry season is that because many trees are leafless at this time, flowers are more visible and accessible to pollinators. Food resources are in limited supply, so flowers bearing nectar would be particularly attractive to flying animal (Janzen, 1967). Another possibility is that dry season flowering is essential if fruits are to ripen and seeds are to be dispersed in time for the following rainy season, when conditions for seed germination and seedling survival are optimal.

Table 4.9 Coefficient of determination (r^2) between each environmental factor to total flowering species in one year period.

Flowering species	Environmental factor	Coefficient of determination (%)
Total species	Mean radiation	67.10 **
	Mean evaporation	61.50 **
	Mean relative humidity	38.00 *
	Mean soil temperature	8.40 ^{ns}
	Mean soil moisture content	6.20 ^{ns}
	Mean temperature	5.10 ^{ns}
	Mean rainfall	0.20 ^{ns}

Note : Calculation by simple regression at the 0.01 confidence level

ns = non significant

* = significant difference at the 0.05 confidence level

** = significant difference at the 0.01 confidence level

4.2.3 Study on flowering of dominant tree species

The study found that three kinds of dominant tree species, which are *Shorea siamensis, Ellipanthus tomentosus* and *Xylia xylocarpa*, had near flowering period. They had flowering during January-March, *E. tomentosus* had individuals which flowered twice per year. The flowering was rising up again in November-December. For *Sindora siamensis* had flowering during April-May. The flowering period had 2 months in *X. xylocarpa* and *Sindora siamensis*, 3 months in *Shorea siamensis* and 5 months in *E. tomentosus* (Figure 4.8).

For the present flowering of *Shorea siamensis* is the data of the year 2002, because *Shorea siamensis* contained a large proportion of individuals that failed to flower during the 2 years study period (2000-2001).

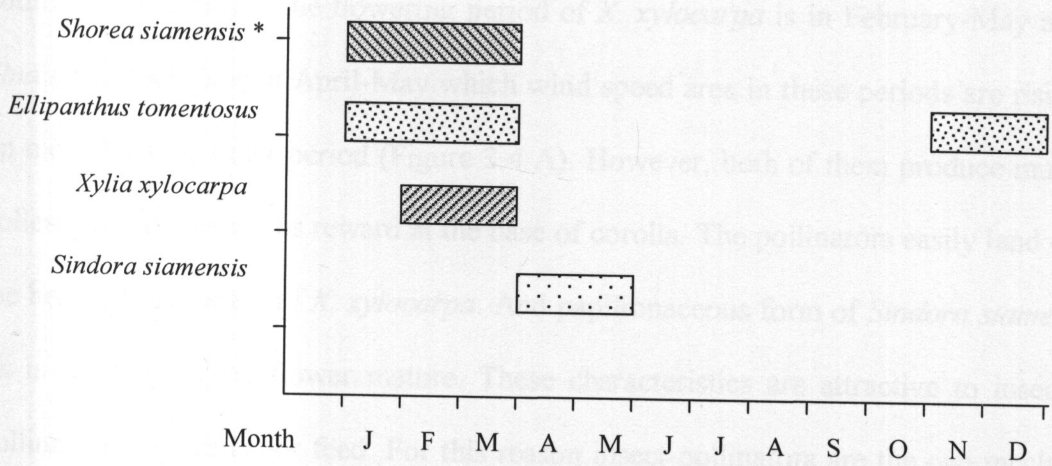


Figure 4.8 Flowering period of dominant trees species in one year period in 2000

Note : * data from the year 2002

4.2.4 Pollinators visitation of dominant tree species

For the relationships between pollinators and dominant tree species. *Shorea siamensis* has inflorescence of racemose panicle type, and flowers are located terminally. As for *Ellipanthus tomentosus* has raceme type and flowers are axillary. Both species have florets in cup shape, yellow color, bisexual and stigma above anthers. It is indicated that without life pollinators, it is difficult to pollination. As these flowers are cup shape which are about 0.7-1.0 cm wide and has nectar as a reward at the base of corolla. It is easily reached by insect-pollinators.

Xylia xylocarpa has head inflorescence, floret is tube form, pale yellow. For *Sindora siamensis* has panicle inflorescence, floret is papilionaceous, yellow-green. Both of them, the flowers are located terminally, bisexual and anthers above stigma. This flower characteristic is the type of wind-pollination which pollen can transfer to stigma by wind mechanism. Consider with flower produce the numbers of pollen. In addition, it found that the flowering period of *X. xylocarpa* is in February-May and *Sindora siamensis* is in April-May which wind speed area in these periods are rising up more than the other period (Figure 3.4 A). However, both of them produce much pollen and have nectar as reward at the base of corolla. The pollinators easily land on the head inflorescence of *X. xylocarpa*. And papilionaceous form of *Sindora siamensis* is open when the flower mature. These characteristics are attractive to insect-pollinators and easily for feed. For this reason insect-pollinators are the one mechanism for both tree species.

In this study, the most visitors and efficient pollinators of four dominant tree species are *Xylocopa* species and *Trigona apicalis* respectively. Pollinators activity were highest between 9.00-12.00 h. Since in this period four dominant tree species flowered more than another period, it caused the number of pollinators which feed for nectar and pollen followed rising up. For after 12.00 h, air temperature is hot especially in the open area, it caused the flowers wilted and fell off. Therefore pollinators followed decrease in number.

Xylocopa species have the peak visitation period in *Shorea siamensis, E. tomentosus, X. xylocarpa* and *Sindora siamensis* at 10.00, 12.00, 11.00 and 12.00 h, respectively. The total numbers of *Xylocopa* species visited *Shorea siamensis, E. tomentosus, X. xylocarpa* and *Sindora siamensis* in four days of observation are 1,300, 215, 44 and 540 individuals, respectively. For *Trigona apicalis*, the activities are highest in *Shorea siamensis, E. tomentosus, X. xylocarpa* and *Sindora siamensis* at 12.00, 12.00, 11.00 and 9.00 h, respectively. The total numbers of *T. apicalis* in four days of observation are 241, 65, 140 and 304 individuals, respectively (Figure 4.9, 4.10, 4.11, 4.12 and Appendix II, Table 3.1, 3.2, 3.3, 3.4). It indicated that *Xylocopa* species and *T. apicalis* which have high numbers of visitation in *Shorea siamensis* and *Sindora siamensis*, have the peak visitation period in each time. It caused the both pollinators which have behavior to feed in the same area, do not contend with each other. It shows that there is a good adaptation for sharing feed area of two the dominant pollinators.

The other pollinators which present in the study sites were listed in Appendix II, Table 4.

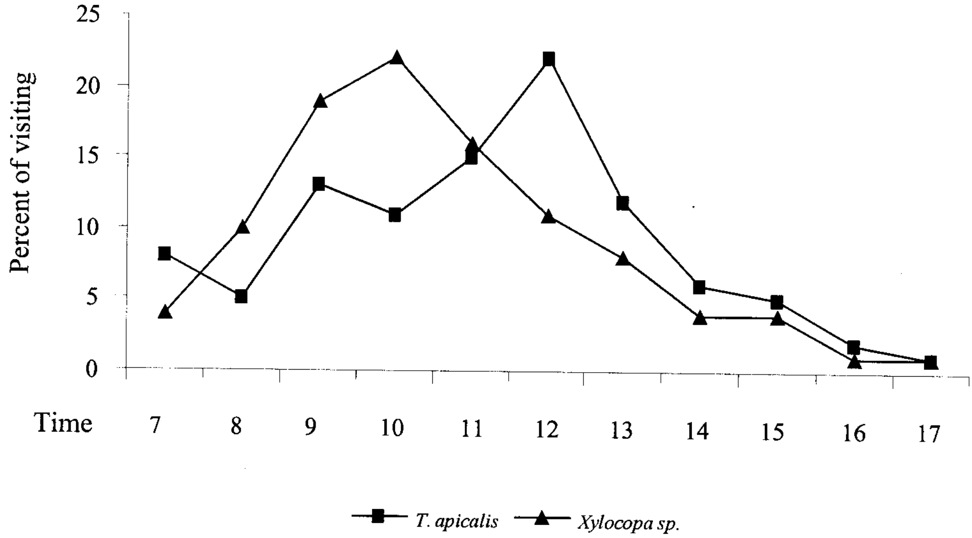


Figure 4.9 Percentages total of *Xylocopa* sp. and *Trigona apicalis* visited *Shorea siamensis* flowers within a day (4 days and 40 h of observation in total)

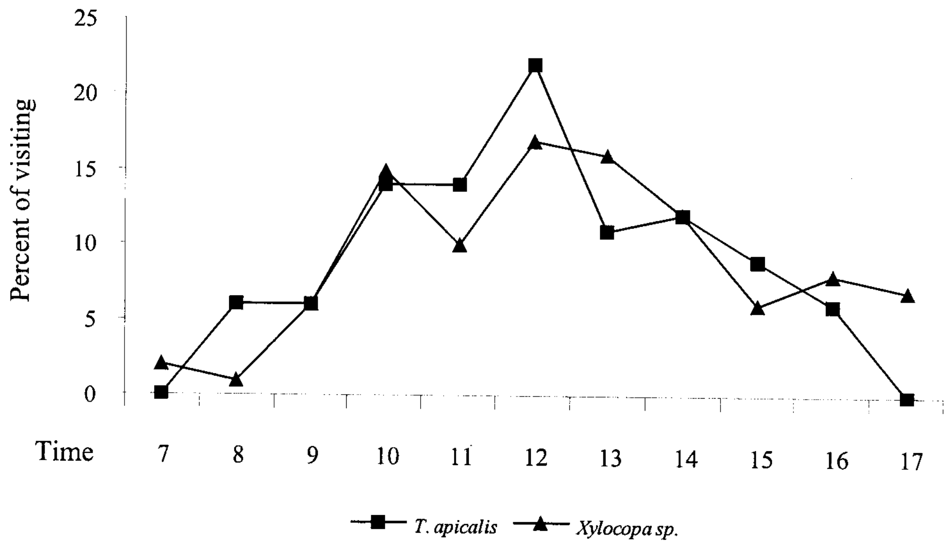


Figure 4.10 Percentages total of *Xylocopa* sp. and *Trigona apicalis* visited *Ellipanthus tomentosus* flowers within a day (4 days and 40 h of observation in total)

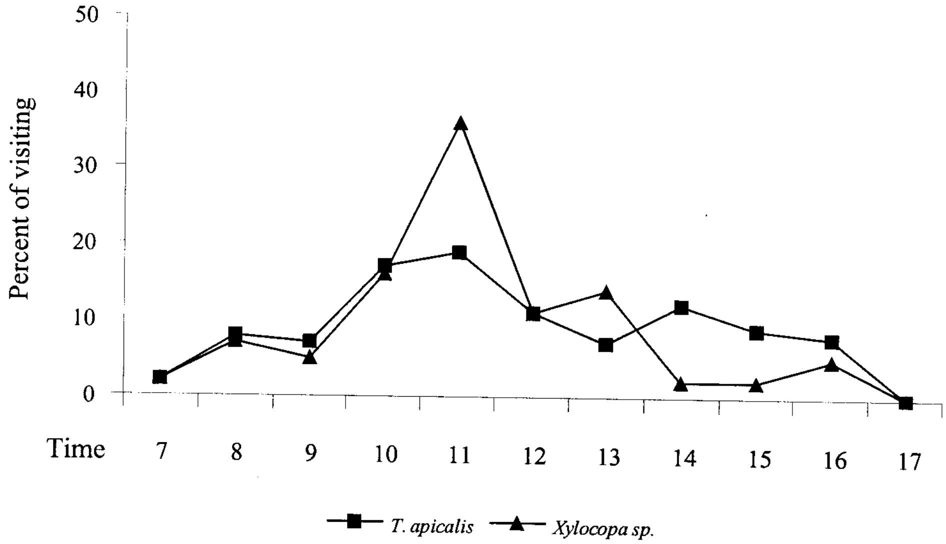


Figure 4.11 Percentages total of *Xylocopa* sp. and *Trigona apicalis* visited *Xylia xylocarpa* flowers within a day (4 days and 40 h of observation in total)

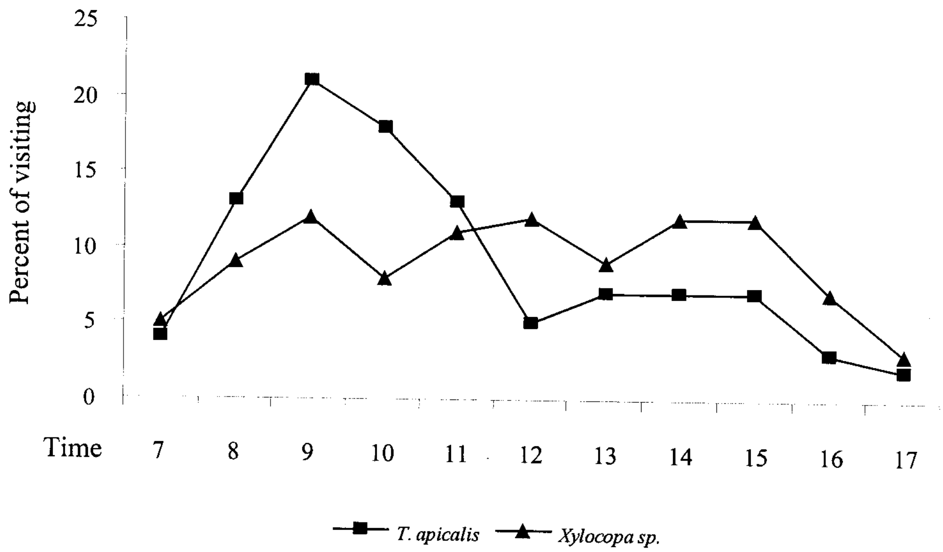


Figure 4.12 Percentages total of *Xylocopa* sp. and *Trigona apicalis* visited *Sindora siamensis* flowers within a day (4 days and 40 h of observation in total)

4.3 Pollen efficiency

4.3.1 Pollen germination of dominant tree species

According to quantitative characteristic in 4.1.1 and plants description in 4.1.5, five dominant tree species including *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus, Sindora siamensis* and *Lannea coromandelica* were found. Three types of *Shorea siamensis* (yellow peduncle-yellow wing, red peduncle-red wing, yellow peduncle-red wing) and *Ellipanthus tomentosus* (short sterile pistil, long sterile pistil, fertile flower) and two types of *Sindora siamensis* (v. *siamensis*, v. *maritima*) and *Lannea coromandelica* (male dominance, female dominance) were investigated. For this reason pollen germination of different types of each dominant tree species were used to compare. For *X. xylocarpa* and fertile flower of *E. tomentosus*, four individual trees were used to compare pollen germination, since *X. xylocarpa* had only one type species and *E. tomentosus* had to check the different pollen germination within fertile flowers.

Analysis of variance showed that there were highly significant differences (at the 0.01 confidence level) in pollen germination of *E. tomentosus* among three types. Pollen of *Sindora siamensis* showed significant differences (at the 0.05 confidence level) in germination among two types, but there were no significant differences for pollen germination among types of *Shorea siamensis* and type of *L. coromandelica*, among individual trees of *X. xylocarpa* and individual trees of fertile flowers of *E. tomentosus* (Table 4.10, 4.11).

The mean pollen germination percentage from *E. tomentosus* types found that fertile flower (31.75 %) was higher than long sterile pistil (13.19 %) and short sterile pistil (3.07 %), respectively. The results indicated that fertile flower was greater efficient in pollen germination than sterile flowers. It was suggested that pollen of sterile flowers can appear normal externally but be dead or lack vigor and therefore not function in fertilization (Philipson, Owens and Donnell, 1990). For the mean pollen germination percentage from *Sindora siamensis* types, found that v. *siamensis* (23.84 %) was higher than v. *maritima* (18.61 %). It showed that there were different pollen efficiencies in varieties of *Sindora siamensis* while there w ere not different pollen efficiencies in types of *Shorea siamensis*, and *L. coromandelica* and in individual trees of *X. xylocarpa*, and fertile flower of *E. tomentosus.* Despite, for all dominant tree species had pollen germination less than 32 %.

In the present study, the standard deviation of pollen germination seems to be high in some individual trees of X. *xylocarpa* (26.08 ± 16.75 %) and in female dominance type of *L. coromandelica* (13.25 ± 15.70 %).

Table 4.10 The analysis of variance of pollen germination of five dominant species

Sources	df	SS	MS	F
Shorea siamensis				
Types	2	69.3825	34.69	1.15 ^{ns}
Error	57	1,712.4486	30.04	
Xylia xylocarpa				
Individual trees	3	134.6396	44.88	0.27 ^{ns}
Error	76	12,568.6778	165.38	
Ellipanthus tomentosus (three types)				
Types	2	8,461.6097	4,230.80	33.18 **
Error	57	7,268.0804	127.51	
Ellipanthus tomentosus (fertile flowers)				
Individual trees	3	286.7089	95.57	0.72 ^{ns}
Error	76	10,095.4727	132.84	
Sindora siamensis				
Varieties	1	273.2153	273.22	5.71 *
Error	38	1,819.2953	47.88	
Lannea coromandelica				
Types	1	504.9524	504.95	3.66 ^{ns}
Error	38	5,242.5352	137.96	

^{ns} non significant.

* significant difference at the 0.05 confidence level

** significant difference at the 0.01 confidence level

Table 4.11 Mean pollen germination percentage and standard deviation of dominant tree species in the year 2000

Species	Pollen germinatiom (%)
Shorea siamensis (yellow peduncle - yellow wing) [1]	11.85 ± 5.14
Shorea siamensis (red peduncle - red wing) [1]	14.48 ± 7.12
Shorea siamensis (yellow peduncle - red wing) [1]	12.97 ± 3.60
(ns)	
Xylia xylocarpa (No. 1)	26.08 ± 16.75
Xylia xylocarpa (No. 2)	27.72 ± 9.95
Xylia xylocarpa (No. 3)	25.68 ± 10.39
Xylia xylocarpa (No. 4)	24.07 ± 13.19
(ns)	
Ellipanthus tomentosus (short sterile pistil)	3.07 ± 5.97
Ellipanthus tomentosus (long sterile pistil)	13.19 ± 13.35
Ellipanthus tomentosus (fertile flower)	31.75 ± 12.99
$LSD_{0.05}$ 7.14 $LSD_{0.01}$ 9.50	
Ellipanthus tomentosus (No.1)	28.90 ± 12.33
Ellipanthus tomentosus (No.2)	31.24 ± 10.37
Ellipanthus tomentosus (No.3)	27.03 ± 10.15
Ellipanthus tomentosus (No.4)	31.75 ± 12.99
(ns)	
Sindora siamensis v. *siamensis*	23.84 ± 7.37
Sindora siamensis v. *maritima*	18.61 ± 6.44
$LSD_{0.05}$ 4.42	
Lannea coromandelica (male dominance)	6.14 ± 5.41
Lannea coromandelica (female dominance)	13.25 ± 15.70
(ns)	

Note : [1] flower in the year 2002

4.3.2 Pollen germination of target tree species

There were 30 and 2 target tree species used to test pollen efficiency in the year 2000 and 2001, respectively. As shown in Table 4.12, the mean pollen germination percentage were ranging from 3.90 % in *Cratoxylum cochinchinense* to 30.31 % in *Schleichera oleosa*. There were 8, 15 and 9 target tree species had been ranked the mean pollen germination of 3-10, 10-20 and 20-30 %, respectively. It illustrates that pollen from different species differed greatly in pollen efficiency. Most of this study indicated simply that a few pollen species germinated badly. A pollen germination rate gave too low percentage in Dipterocarpaceae, *Morinda* sp., Guttiferae, *Rothmannia wittii, Pterocarpus macrocarpus*, and *Diospyros ehretioides*. A pollen germination rate gave 20-30 % in Caesalpinioideae, Mimosoideae, *Vitex pinnata, Wrightia arborea, Bridelia retusa, Careya sphaerica, Schleichera oleosa* and *Memecylon edule.*

However, for all pollen testing in this present study it seems to be low germination percentage when compared with germination of *Ornithogalum virens* in the same Brewbaker's medium, which had pollen germination of 54.70-60.00 % (Brewbaker and Kwack, 1963).

Table 4.12 Mean pollen germination percentage and standard deviation of target tree species in the year 2000

Family	Species	Pollen germinatiom (%)
Guttiferae	*Cratoxylum cochinchinense*	3.90 ± 1.71
Rubiaceae	*Rothmannia wittii*	4.87 ± 4.27
Dipterocarpaceae	*Shorea roxburghii*	5.96 ± 4.21
Ebenaceae	*Diospyros ehretioides*	6.88 ± 4.53
Papilionoideae	*Pterocarpus macrocarpus*	7.42 ± 3.64
Rubiaceae	*Morinda elliptica*	8.59 ± 5.08
Dipterocarpaceae	*Dipterocarpus intricatus*	9.57 ± 7.38
Rubiaceae	*Morinda coreia*	9.76 ± 6.91
Guttiferae	*Cratoxylum formosum*	10.95 ± 6.33
Meliaceae	*Chukrasia tabularis*	11.43 ± 4.51
Dipterocarpaceae	*Shorea obtusa* [1]	11.53 ± 8.88
Lythraceae	*Lagerstroemia floribunda*	11.59 ± 3.66
Moraceae	*Artocarpus lacucha*	12.07 ± 7.49
Euphorbiaceae	*Aporosa villosa*	12.50 ± 10.75
Rubiaceae	*Haldina cordifolia*	13.03 ± 5.80
Ochnaceae	*Ochna integerrima*	14.15 ± 6.22
Burseraceae	*Canarium subulatum*	14.23 ± 5.83
Strychnaceae	*Strychnos nux-vomica*	15.37 ± 7.10
Caesalpinioideae	*Bauhinia racemosa* [1]	18.32 ± 15.59
Rubiaceae	*Gardenia sootepensis*	18.62 ± 5.93
Euphorbiaceae	*Phyllanthus emblica*	18.77 ± 10.05
Anacardiaceae	*Buchanania lanzan*	19.53 ± 7.52
Irvingiaceae	*Irvingia malayana*	19.86 ± 8.99
Apocynaceae	*Wrightia arborea*	20.07 ± 9.78
Euphorbiaceae	*Bridelia retusa*	20.41 ± 8.22
Mimosoideae	*Albizia lebbeck*	21.02 ± 9.24
Melastomataceae	*Memecylon edule*	22.08 ± 14.42
Caesalpinioideae	*Senna garrettiana*	23.14 ± 7.58
Labiatae	*Vitex pinnata*	23.17 ± 6.90
Caesalpinioideae	*Erythrophleum succirubrum*	24.79 ± 6.34
Lecythidaceae	*Careya sphaerica*	25.37 ± 13.57
Sapindaceae	*Schleichera oleosa*	30.31 ± 12.36

Note : [1] flower in the year 2001

4.4 Seed production and seed dispersal

The study in this topic will concern only 4 dominant tree species which are *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus* and *Sindora siamensis*.

Part A : *Shorea siamensis*

4.4.1 Characteristics of parent trees and their environment

Four parent trees of *Shorea siamensis* are isolated individual trees which reach a height of 19.00-22.30 m, a DBH of 23.23-43.27 cm and a diameter of crown cover of 6.50-13.00 m (Table 4.13). All of them grew in DDF which its low tree density. The ground forest is covered with grasses and small herbs. The area is a level plain.

Table 4.13 Characteristics of parent trees of *Shorea siamensis*

Parent trees	Type	Occurrence	Height (m)	DBH (cm)	Crown width in each direction (m)				Mean diameter of crown cover (m)
					N	E	S	W	
No. 1	C	1	20.70	32.45	3.5	5.0	4.0	3.0	7.75
No. 2	C	2	22.30	43.27	4.5	4.0	3.5	5.0	8.50
No. 3	A	2	19.00	23.23	3.5	4.0	3.0	3.5	7.00
No. 4	B	1	19.70	41.05	4.0	6.0	5.0	7.0	11.00

Note : N = north, E = east, S = south, W = west, DBH = diameter base height
Type A = characteristic of *S. siamensis* show yellow peduncle, yellow wing
Type B = characteristic of *S. siamensis* show red peduncle, red wing
Type C = characteristic of *S. siamensis* show yellow peduncle, red wing
1 = parent tree grew as an isolated individual
2 = parent tree grew near another group trees

4.4.2 Flower and fruit dispersal of *Shorea siamensis*

4.4.2.1 Flower and young fruit dispersal

Parent tree No. 1, 2, 3 and 4 had a density of fallen flowers in traps of 50 x 50 cm at 2 m distance of 1,070.11, 473.99, 175.99 and 950.49 flowers and decreased in density at 8 m distance of 77.50, 24.00, 0 and 164.99 flowers, respectively. In the same way, they had a density of fallen young fruits in traps of 50 x 50 cm at 2 m distance of 465.11, 97.74, 56.00 and 470.37 fruits and decreased in density at 8 m distance of 13.99, 3.37, 0 and 47.49 fruits, respectively (Figure 4.13 and Appendix IV, Table 1.1-1.4). It indicated that flowers and young fruits had high density under the crown cover area of parent trees but decreased respectively as increase in distances.

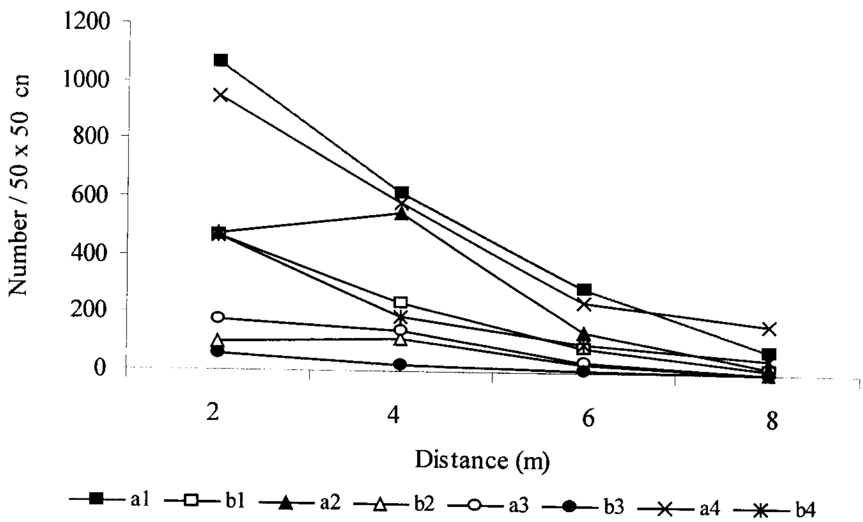


Figure 4.13 Dispersal of fallen flowers and young fruits of *Shorea siamensis* in each distance.

Note :					
a 1	=	flowers of parent tree No. 1	b 1	=	young fruits of parent tree No. 1
a 2	=	flowers of parent tree No. 2	b 2	=	young fruits of parent tree No. 2
a 3	=	flowers of parent tree No. 3	b 3	=	young fruits of parent tree No. 3
a 4	=	flowers of parent tree No. 4	b 4	=	young fruits of parent tree No. 4

There are clearly differences in number of flowers and young fruits in each parent tree (Appendix IV, Table 1.5, 1.6). For the relationships between DBH, crown cover of parent tree and number of fallen flowers, young fruits; the correlation value (r) were not significant (Appendix IV, Table 1.8, 1.9). Coinciding with the study of พรพิทักษ์ ปัญญารัตน์ (2539) found that DBH and crown cover of *Dipterocarpus alatus* and *D. turbinatus* were not significantly correlated with number of fallen flowers and young fruits. The results can be influenced by many factors such as environmental factors (e.g. light intensity, temperature, moisture content, wind speed, pollinators) and individual trees factors (e.g. age, genetic and fertility of parent tree).

4.4.2.2 Mature fruit dispersal

Fruits are initially wind-dispersed. The 5 wings cause the fruits to rapidly revolve, slowing their descent and increasing their chances of being dispersed away from the parent tree before landing. Mature fruits of the 4 parent trees had high density under the crown cover area of parent trees and decreased respectively as increase in distances (Figure 4.14). For the number of fallen mature fruits, it was found that parent tree No. 4, 1, 2, 3 had 20,936, 11,071, 4,327 and 2,686 fruits, respectively (Appendix IV, Table 1.7). The DBH and crown cover of parent trees also were not significantly correlated with number of fallen mature fruits (Appendix IV, Table 1.8, 1.9).

Due to the heaviness of the fruits, wind gusts of considerable force are required to ensure their dispersal over a significant distance. It is notable that dispersal occurs mostly in March to April when maximum wind gust speeds are at their highest, during powerful gales preceding onset of the monsoon (Figure 3.4).

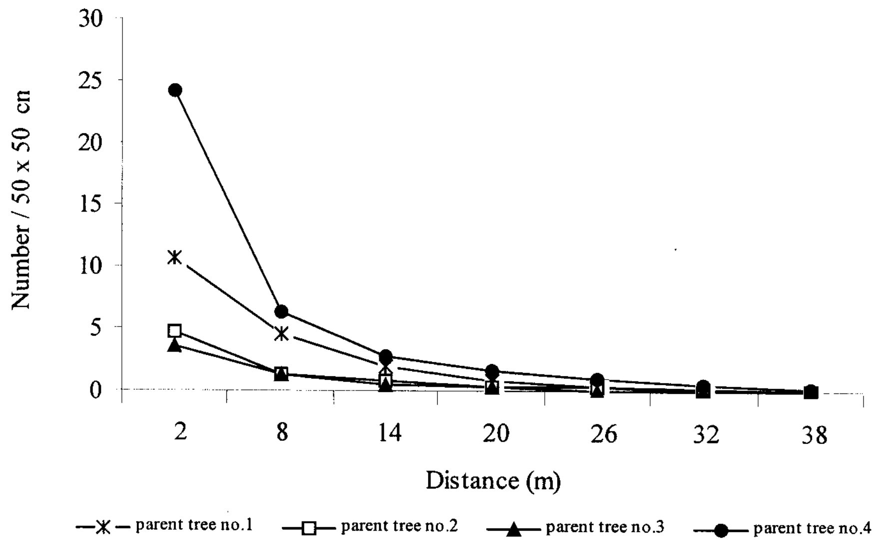


Figure 4.14 Dispersal of fallen mature fruits of *Shorea siamensis* at each distance.

Furthermore in the period of fallen fruits during March to April, most of nearby trees shed leaves, the forest is clear. This helps the fallen fruits can far disperse. It appeared that mature fruits of parent tree No. 4 could disperse at distance of 38 m (Figure 4.14) while the wind speed in March and April was 30.99 and 33.81 km/day, respectively (Table 4.14).

Table 4.14 Climatological data of Nong Rawiang in the year 2002.

Month	Temperature (°C)		RH	Evaporation *	Wind speed *			Rainy	Rain fall
	Max	Min	(%)	(mm)	Day	Night	All	day	(mm)
					(km/12hr)		(km/day)		
March	37.85	21.76	78.55	5.20	25.72	5.27	30.99	2	41.00
April	38.80	23.12	75.63	5.90	28.69	5.12	33.81	2	38.40
May	35.98	23.98	81.94	4.50	28.01	2.76	30.78	3	70.20

* Data from Hauybanyang Agricultural Irrigation Research Station Nakhon Ratchasima

Considering the relationships between the height of parent trees and fruits dispersal distance, the correlation value showed no significance (Appendix IV, Table 1.10). Similar results of seed dispersal of *D. alatus* and *D. turbinatus* were reported by พรพิทักษ์ ปัญญารัตน์ (2539). The distance of fruit dispersal by wind depends not only on the weight and type of dispersal unit but also on the local wind conditions and the exposure and isolation of the parent trees (Tamari and Jacalne, 1984).

4.4.3 Fruit size, wing size, fruit weight and wind dispersal

For the relationships between fruit size, wing size, fruit weight and dispersal distance, the correlation values (r) showed that fruit width, fruit length and fruit weight were the most effective parameter to determine dispersal distance. Wing width and wing length showed the poorest correlation (Table 4.14). The results revealed that there is a dispersal distance increase when fruit size and fruit weight decrease while wing size has no influence in dispersal distance.

Table 4.15 Correlation values (r) of *Shorea siamensis* fruits size, wings size, fruits weight and dispersal distance.

Categories/ Parent tree	No. 1	No. 2	No. 3	No. 4
Fruit width	- 0.88 *	- 0.96 **	- 0.98 *	- 0.98 **
Fruit length	- 0.99 **	- 0.95 *	- 0.98 *	- 0.97 **
Wing width	0.69 ^{ns}	- 0.66 ^{ns}	0.23 ^{ns}	- 0.64 ^{ns}
Wing length	0.14 ^{ns}	0.32 ^{ns}	0.25 ^{ns}	0.54 ^{ns}
Fruit weight	- 0.91 *	- 0.99 **	- 0.97 *	- 0.97 **
df (n – 2)	4	3	2	5

ns non significant

* significant difference at the 0.05 confidence level

** significant difference at the 0.01 confidence level

4.4.4 The production of *Shorea siamensis*

4.4.4.1 The fallen flowers and fruits of *Shorea siamensis* in each period

The periods of flowers and fruits development in each parent tree were near. Parent tree No. 3 had initiated flowering in early January 2002 while No. 1, 2 and 4 had in mid-January. Flowers began to fall since February. The highest fallen flowers and young fruits of most parent trees were on 24 February and 10 March, respectively. It showed that parent tree No. 3 had early flowering than another parent trees about 2 weeks (Figure 4.15 and Appendix IV, Table 1.5, 1.6).

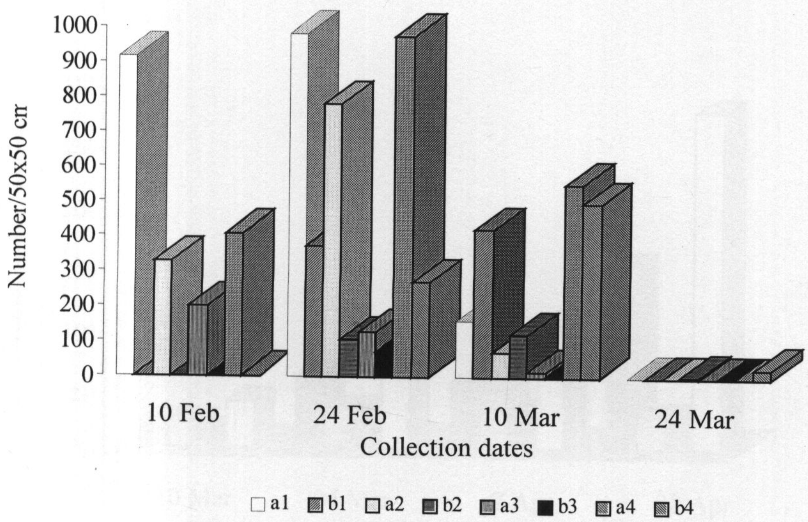


Figure 4.15 Collection dates of fallen flowers and young fruits of *Shorea siamensis* in the year 2002.

Note : a1 = fallen flowers of parent tree no. 1 b1 = fallen young fruits of parent tree no. 1
a2 = fallen flowers of parent tree no. 2 b2 = fallen young fruits of parent tree no. 2
a3 = fallen flowers of parent tree no. 3 b3 = fallen young fruits of parent tree no. 3
a4 = fallen flowers of parent tree no. 4 b4 = fallen young fruits of parent tree no. 4

Most of mature fruits began to fall in early March (5-14 March) and increased the fallen numbers as increased the periods. They finished to fall in late April (25-28 April). Parent tree No. 4 showed the highest number of fallen mature fruits on 28 April (Figure 4.16 and Appendix IV, Table 1.7).

The total period of initiated flowering, flowering fertilization, ovary development until to be the mature fruits took about 47-70 days. The total period of fallen mature fruits took about 45-55 days. The total period of initiated fallen flowers to finished fallen mature fruits took about 85 days (3 February-28 April 2002) as illustrated in Figure 4.17.

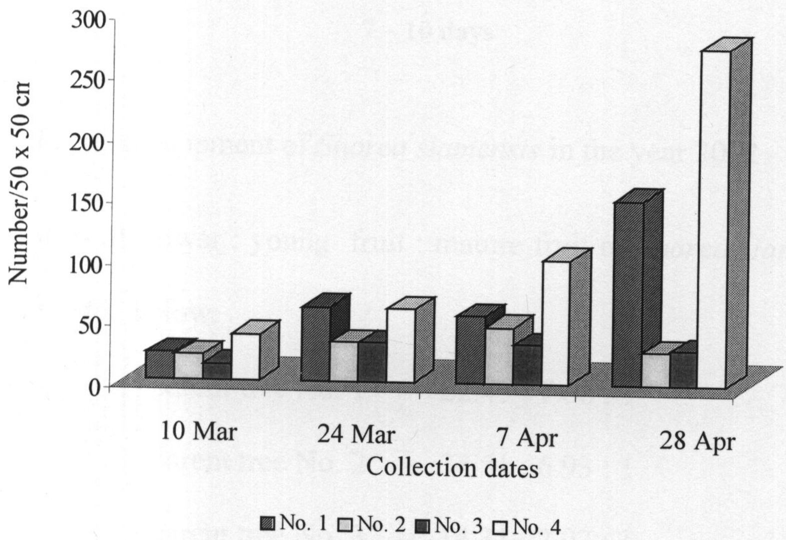


Figure 4.16 Collection dates of fallen mature fruits of *Shorea siamensis* in the year 2002.

Note :	No. 1	=	parent tree No. 1	No. 3	=	parent tree No. 3
	No. 2	=	parent tree No. 2	No. 4	=	parent tree No. 4

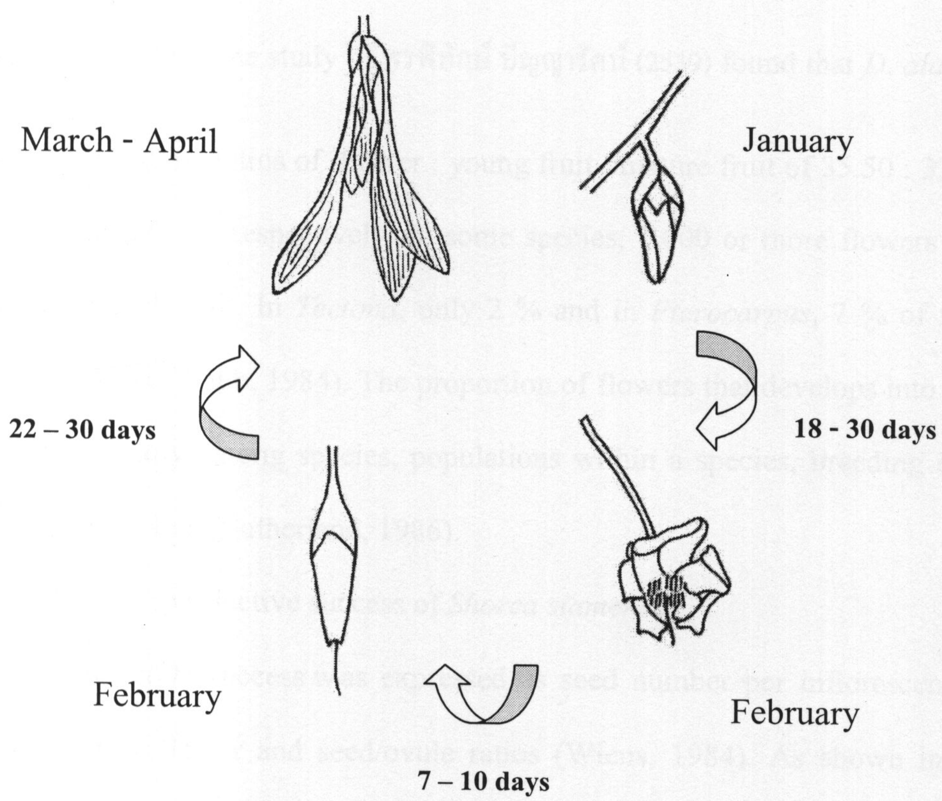


Figure 4.17 Fruit development of *Shorea siamensis* in the year 2002

The ratios of flower : young fruit : mature fruit of *Shorea siamensis* in each parent tree are listed below:

parent tree No. 1 = 22.45 : 7.68 : 1

parent tree No. 2 = 34.51 : 6.93 : 1

parent tree No. 3 = 14.31 : 2.92 : 1

parent tree No. 4 = 12.19 : 4.45 : 1

mean = 20.87 : 5.50 : 1

It indicated that each parent tree had different ability in flowering and fruiting. It is notable that the number of young fruits had highly fallen. A clue of the fallen young fruits, it was probably caused by insects destruction. Considering from the ratio, parent trees will produce many flowers and young fruits for only one mature fruit. Coinciding with the study of พรพิทักษ์ ปัญญารัตน์ (2539) found that *D. alatus* and *D. turbinatus* had the ratios of flower : young fruit : mature fruit of 35.50 : 32.27 : 1 and 17.90 : 13.36 : 1, respectively. In some species, 1,000 or more flowers can be produced for each fruit. In *Tectona*, only 2 % and in *Pterocarpus*, 7 % of flowers mature (Bawa and Webb, 1984). The proportion of flowers that develops into mature fruits varies greatly among species, populations within a species, breeding system, and from year to year (Sutherland, 1986).

4.4.4.2 Reproductive success of *Shorea siamensis*

Reproductive success was expressed as seed number per inflorescence and fruit and as fruit/flower and seed/ovule ratios (Wiens, 1984). As shown in Table 4.15, reproductive success of *Shorea siamensis* had low value of 5.57 ± 1.66, because each parent tree produce many flowers but a few mature fruits can be produced. Moreover within *Shorea siamensis* ovary, it contains 6 ovules and only 1 ovule can develop to be a fertile ovule (distinguished from 50 ovary). This reason brings to the low value of reproductive success.

In general, outcrossing species have a low preemergent reproductive success, often below 30 %, whereas inbreeding species have a high preemergent reproductive success, often greater than 90 % (Weins et al., 1987). Thus, *Shorea siamensis* should be a outcrossing species. Stepheson (1981) reported that both fruit/flower and seed/ovule are affected by predation, weather condition, and the ability of the maternal parent to provide the necessary resources for development.

Table 4.16 Reproductive success and standard deviation of *Shorea siamensis* in the year 2002.

Categories/Parent trees	No. 1	No. 2	No. 3	No. 4	Mean	SD
Number of fruits	96,045	34,317	10,540	114,051	63,738	
Number of flowers	248,571	149,322	38,433	255,187	172,878	
Number of seeds	96,045	34,317	10,540	114,051	63,738	
Number of ovules	576,270	205,902	63,240	684,306	382,430	
Reproductive success (%)	6.44	3.83	4.57	7.45	5.57	1.66

Note : number of ovules = number of fruits x 6 ovules

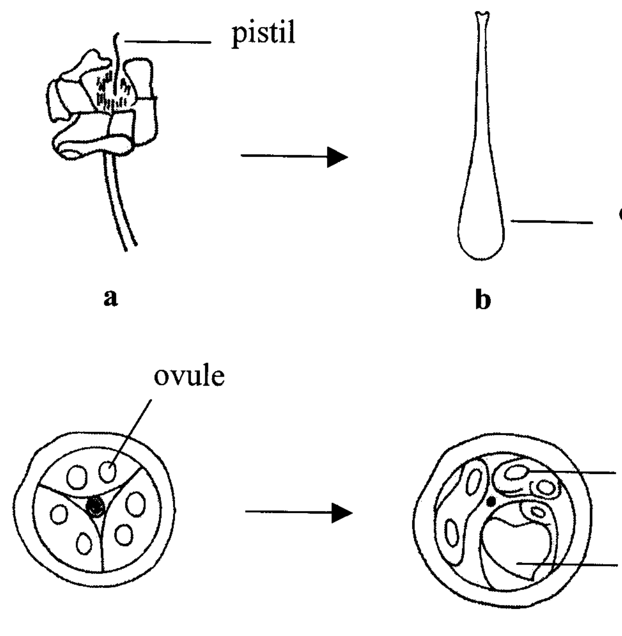


Figure 4.18 Development of *Shorea siamensis* ovules (a) flower, (b) long section of ovary (c) x-section of ovary shows 6 ovules, (d) x-section of ovary shows 1 fertile ovule and 5 aborted ovules

4.4.4.3 Normal and damaged fruits of *Shorea siamensis*

In the present study, the results found that about 72.25 % of *Shorea siamensis* fruits were damaged by seed predators, separated in young fruits of 33.78 % and mature fruits of 38.47 % (Table 4.17). The most of insect-caused seed losses were by *Omiodes* sp. (Family Pyralidae), *Sitophilus* sp. and *Anthonomus* sp. (Family Curculionidae),respectively (Figure 4.19)

Table 4.17 Percentage of normal and damaged fruits of *Shorea siamensis*

Parent trees	Normal fruits	Insect-damaged fruits		Total
		Young fruits	Mature fruits	Insect-damaged fruits
No. 1	28.87	37.52	33.61	71.13
No. 2	24.58	36.34	39.08	75.42
No. 3	19.94	31.78	48.28	80.06
No. 4	37.61	29.47	32.92	62.39
Mean	27.75	33.78	38.47	72.25

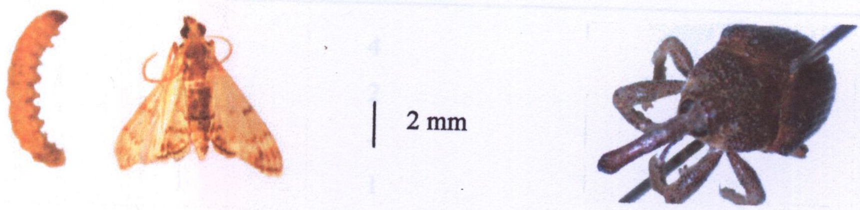


Figure 4.19 Worm and adult of *Omiodes* sp. Family Pyralidae (left), Adult of *Anthonomus* sp. Family Curculionidae (right)

4.4.5 Germination rate of *Shorea siamensis* in natural site

Shorea siamensis had fallen mature fruits since early March to late April 2002. For this period, it was found that there was a rainy period of only 4 days and the total rainfall of 79.40 mm which was not so much (Table 4.17). In addition it was a hot season that temperature and evaporation rised sharply. These lead to low moisture content in forest soil and since *Shorea siamensis* seeds are recalcitrant they will loss viability rapidly when they have low moisture content (Robert, 1973). For this reason the germination rate of *Shorea siamensis* at natural site was very low. There were only 9 seeds from 4 parent trees that could germinate and after 3 months, there were 7 survival seedlings (Table 4.18). It showed that *Shorea siamensis* did not succeed in seed germination and establishment of seedling in the study year. Thus, rainfall and its distribution are the most effective factors affecting germination rate in natural site.

Table 4.18 Number of *Shorea siamensis* seedlings in natural site

Parent trees	Number of seedling	
	germination	three months later
No. 1	5	4
No. 2	3	2
No. 3	-	-
No. 4	1	1

4.4.6 Germination characteristics and development of *Sh. siamensis* seedling

Seeds begin to germinate 2-5 days after sowing. Germination is hypogeal which means the cotyledons remain on or below the soil surface. Various stages of development are illustrated in Figure 4.20.

2-5 days of age : The fruit wall splits and radicle emerges downwards (Figure 4.20 a).

6-10 days of age : Secondary roots sparse along the tap root and a few around the point at which the primary root and hypocotyl meet. The length of hypocotyl and radicle is about 2-3 cm (Figure 4.20 b).

11-15 days of age : Epicotyl emerges, separates from the stalks of cotyledons and elongates rapidly. The primary and secondary roots elongate. The terminal bud has the first pair of leaves. The stem is about 3.5-8.5 cm tall (Figure 4.20 c).

16-20 days of age : The first pair of leaves have expanded with 0.5-1.5 cm wide by 1-2 cm long. Stipule occur at terminal bud (Figure 4.20 d).

26-40 days of age : The first pair of leaves and hypocotyl not enlarging. Simple leaves alternate, have fully expanded with 4.8 cm wide by 5.5-7.5 cm long. The root is 4.5-14.0 cm long, the base of stem to terminal bud is 11-23 cm tall with 3-9 simple leaves. (Figure 4.20 e).

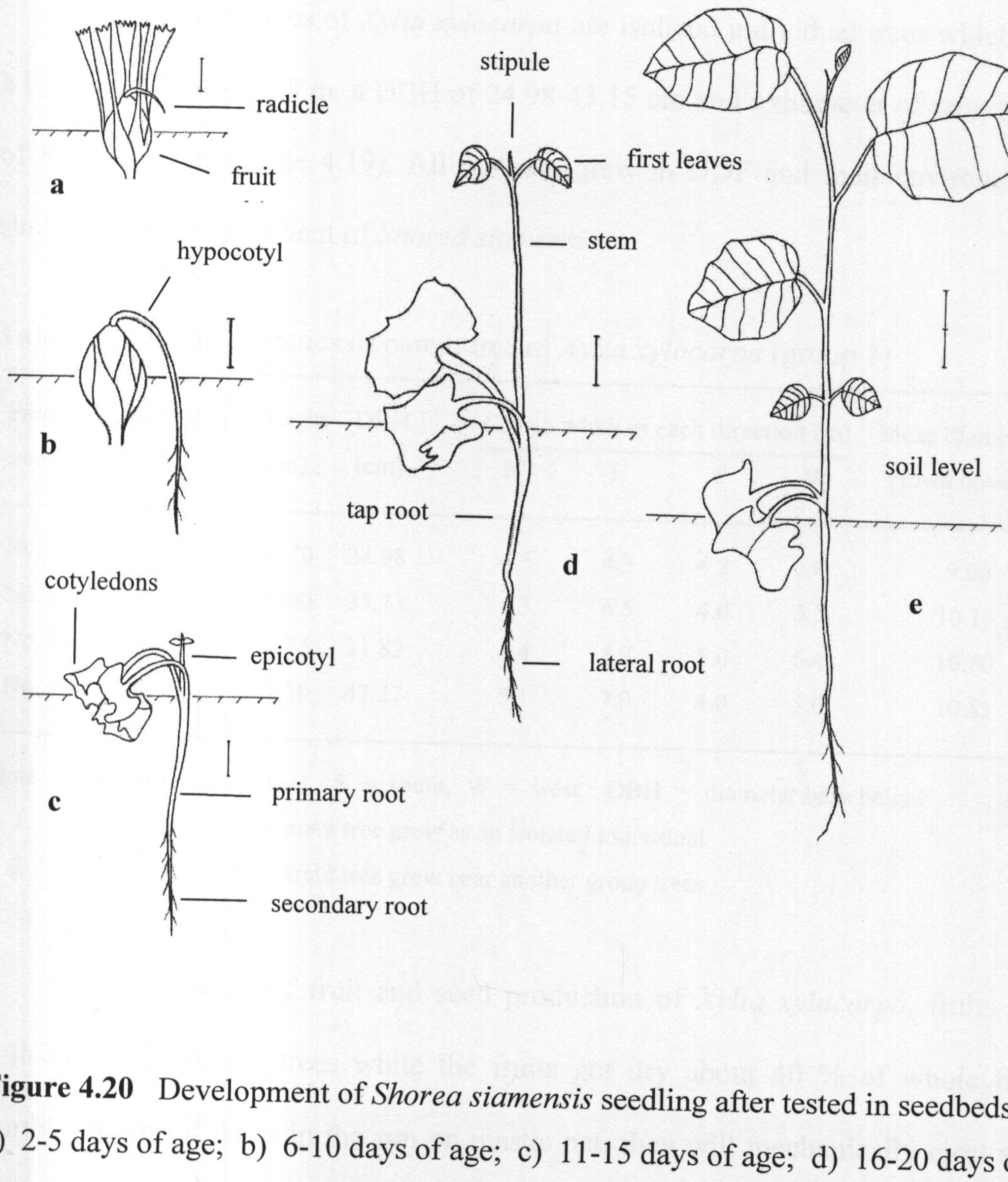


Figure 4.20 Development of *Shorea siamensis* seedling after tested in seedbeds a) 2-5 days of age; b) 6-10 days of age; c) 11-15 days of age; d) 16-20 days of age; e) 26-40 days of age. (scale 1 cm)

Part B : *Xylia xylocarpa*

4.4.7 Characteristics of parent trees and their environment

Four parent trees of *Xylia xylocarpa* are isolated individual trees which reach a height of 12.30-17.75 m, a DBH of 24.98-43.15 cm and a diameter of crown cover of 8.30-12.60 m (Table 4.19). All of them grew in DDF and their environment is similar as the environment of *Shorea siamensis*.

Table 4.19 Characteristics of parent tree of *Xylia xylocarpa* (group 1)

Parent trees	Occurrence	Height (m)	DBH (cm)	Crown width in each direction (m)				Mean diameter of crown cover (m)
				N	E	S	W	
No. 1	2	14.70	24.98	4.5	4.3	4.2	5.0	9.00
No. 2	1	15.90	33.73	4.3	6.5	4.0	5.5	10.15
No. 3	2	17.75	31.82	4.4	5.2	5.0	6.4	10.50
No. 4	1	12.30	43.27	5.1	7.0	4.0	5.6	10.85

Note : N = north, E = east, S = south, W = west, DBH = diameter base height
1 = parent tree grew as an isolated individual
2 = parent tree grew near another group trees

For the study of fruit and seed production of *Xylia xylocarpa*, fruits were collected from parent trees while the fruits got dry about 40 % of whole fruits. Further drying of fruits in the sun on plastic net, they will mechanically eject seeds with force.

4.4.8 The production of *Xylia xylocarpa*

4.4.8.1 The fallen flowers and fruits of *Xylia xylocarpa* in each period

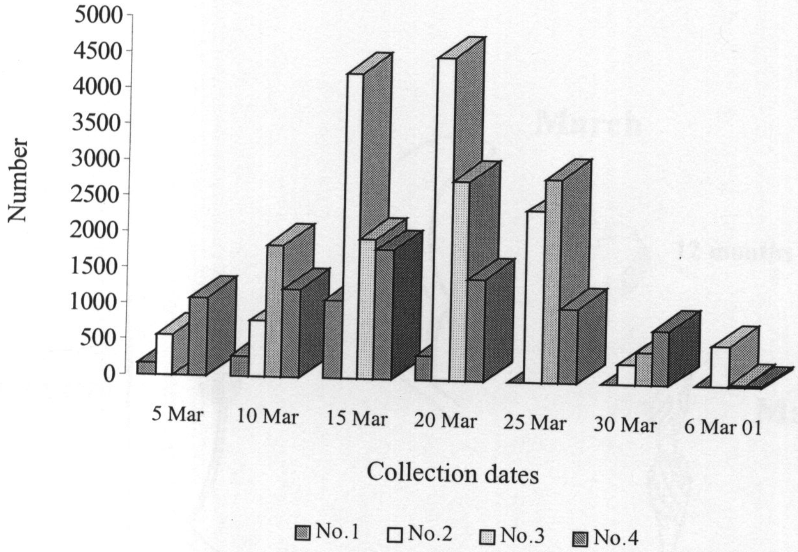
The periods of flowers and fruits development in each parent tree were near. Parent tree No. 4 had initiated flowering in early February 2000 while parent tree No. 1, 2 and 3 had in late February. It showed that parent tree No. 4 had early flowering than another parent trees about 3 weeks. Flowers began to fall since mid-February. The first collected data found both fallen young inflorescences and sessile flowers. Parent tree No. 2 had the highest fallen flowers in 20 March of 12,812 flowers while No. 1 had the lowest of 1,944 flowers. It was found that the number of fallen flowers had relation with the number of fruiting which parent tree No. 2 had 575 fruits while No. 1 had 10 fruits (Table 4.20, Figure 4.21).

For the relationships between DBH, height, crown cover of parent trees and number of fallen inflorescences, mature fruits, seeds; the correlation values revealed no significance (Appendix IV, Table 2.1-2.3).

Table 4.20 Number of fallen inflorescences, individual flowers, mature fruits, and seeds of *Xylia xylocarpa* in the year 2000-2001.

Categories/ Parent trees	No. 1	No. 2	No. 3	No. 4	Mean
Fallen inflorescences	1,944	12,812	9,934	8,257	8,237
Individual flowers	233,280	1,537,440	1,192,080	990,840	988,410
Mature fruits	10	575	52	32	167
Number of seeds	57	4,065	282	174	1,145
Initiated flowering	27 Feb	29 Feb	27 Feb	8 Feb	
Initiated fallen flower	9 Mar	11 Mar	10 Mar	19 Feb	
Finished fallen flowers	18 Mar	27 Mar	31 Mar	31 Mar	
Initiated young fruiting	20 Mar	22 Mar	25 Mar	18 Mar	
Collected mature fruits	6 Mar 01	6 Mar 01	6 Mar 01	6 Mar 01	

Note : 1 inflorescences of *Xylia xylocarpa* approximate 120 individual flowers



Figture 4.21 Collection dates of fallen inflorescences, and mature fruits of *Xylia xylocarpa* in the year 2000-2001.

Note : No. 1	=	Parent tree No. 1	No. 3	=	Parent tree No. 3
No. 2	=	Parent tree No. 2	No. 4	=	Parent tree No. 4
5 Mar – 30 Mar	=	Collection dates of fallen inflorescences			
6 Mar 01	=	Collection dates of mature fruits			

The study of fruit development of *Xylia xylocarpa* found that the period of initiated inflorescences to sessile flowers took about 4-7 days, initiated sessile flowers to bloom flowers took about 2-5 days, bloom flowers to shed flowers took about 7-12 days, flowering fertilization to young fruits took about 9-15 days. The total period of initiated inflorescences to young fruits took about 22-39 days and young fruits develop to mature fruits took about 1 year as illustrated in Figure 4.22.

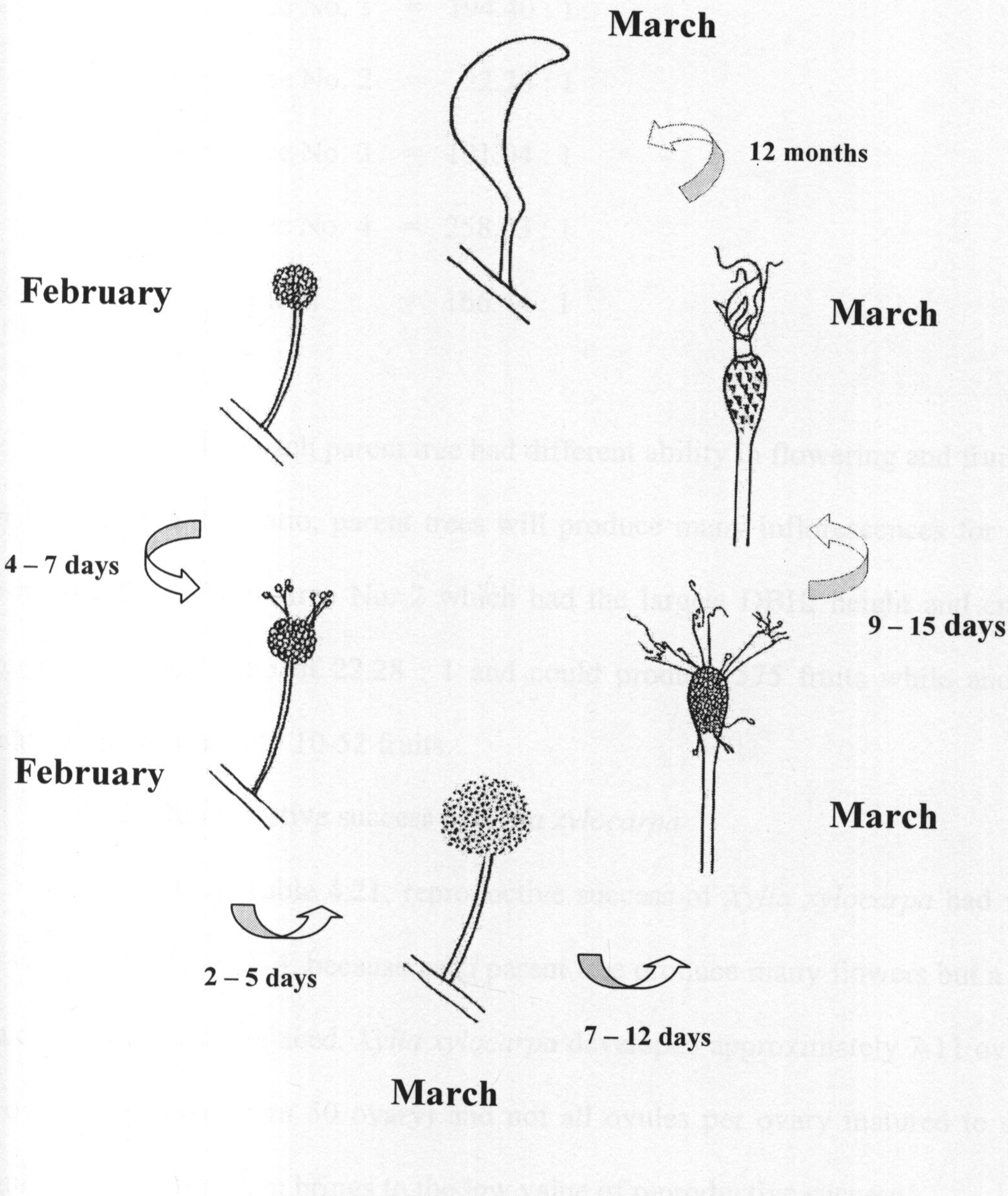


Figure 4.22 Life cycle of *Xylia xylocarpa* in the year 2000 – 2001.

As shown in Table 4.21, the ratios of inflorescences : mature fruit of *Xylia xylocarpa* in each parent tree are listed below :

parent tree No. 1	=	194.40 : 1
parent tree No. 2	=	22.28 : 1
parent tree No. 3	=	191.04 : 1
parent tree No. 4	=	258.03 : 1
mean	=	166.44 : 1

It indicated that each parent tree had different ability in flowering and fruiting. Considering from the ratio, parent trees will produce many inflorescences for only one mature fruit. Parent tree No. 2 which had the largest DBH, height and crown cover had the best ratio of 22.28 : 1 and could produce 575 fruits while another parent tree produced only 10-52 fruits.

4.4.8.2 Reproductive success of *Xylia xylocarpa*

The results in Table 4.21, reproductive success of *Xylia xylocarpa* had very low value of 0.01 ± 0.014, because each parent tree produce many flowers but a few mature fruits can be produced. *Xylia xylocarpa* developed approximately 7-11 ovules per ovary (dissected from 50 ovary) and not all ovules per ovary matured to seed (Figure 4.23). This reason brings to the low value of reproductive success.

Table 4.21 Reproductive success and standard deviation of *Xylia xylocarpa* in the year 2000-2001.

Categories/Parent trees	No. 1	No. 2	No. 3	No. 4	Mean	SD
Number of fruits	10	575	52	32	167	
Number of flowers	233,280	1,537,440	1,192,080	990,840	988,410	
Number of seeds	57	4,065	282	174	1,145	
Number of ovules	88	5,031	455	280	1,463	
Reproductive success (%)	0.003	0.030	0.003	0.002	0.010	0.014

Note : number of ovules = number of fruits x 8.75 ovules (average from 50 sessile flowers)

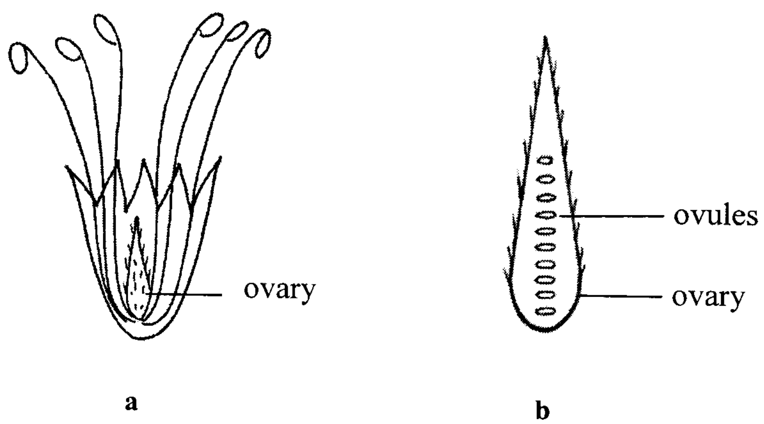


Figure 4.23 *Xylia xylocarpa* ovary (a) flower, (b) long section of ovary shows 10 ovules

4.4.8.3 Normal-abnormal fruits of *Xylia xylocarpa*

In the present study, the results found that most of mature fruits were abnormal fruits of 79.98 %. Characteristics of abnormal fruits including aborted fruits and damaged fruits. Considering all of the seeds, there were aborted seeds of 20.73 %, insect-damaged seeds of 1.37 % and fungal-damaged seeds of 15.44 % (Table 4.22 and Appendix IV, Table 2.4-2.7).

Table 4.22 Percentage of normal-abnormal fruits and seeds of *Xylia xylocarpa*

Parent trees	Normal fruits	Damaged fruits	Fully developed seeds	Aborted seeds	Insect-damaged seeds	Fungal-damaged seeds
No. 1	-	100	56.25	29.69	3.12	10.94
No. 2	32.22	66.78	76.40	15.53	1.03	7.04
No. 3	25.00	75.00	59.61	18.94	0	21.45
No. 4	21.88	78.12	57.59	18.75	1.34	22.32
Mean	20.02	79.98	62.46	20.73	1.37	15.44

4.4.9 Fruit dispersal of *Xylia xylocarpa*

Four parent trees of *Xylia xylocarpa* (group 2) are isolated individual trees which reach a height of 15.80-23.10 m, a DBH of 26.73-49.00 cm and a diameter of crown cover of 8.00-15.00 m (Table 4.23). All of them grew in DDF and their environments are similar as the environment of *Shorea siamensis*.

For dispersal mechanism of *Xylia xylocarpa*, when fruits get dry the seeds are discharged so forcefully that they travel far from the parent tree. Seeds dispersal of *Xylia xylocarpa* in natural site is difficult to observe. Thus, in this present study fruits dispersal will be measured instead of seeds dispersal.

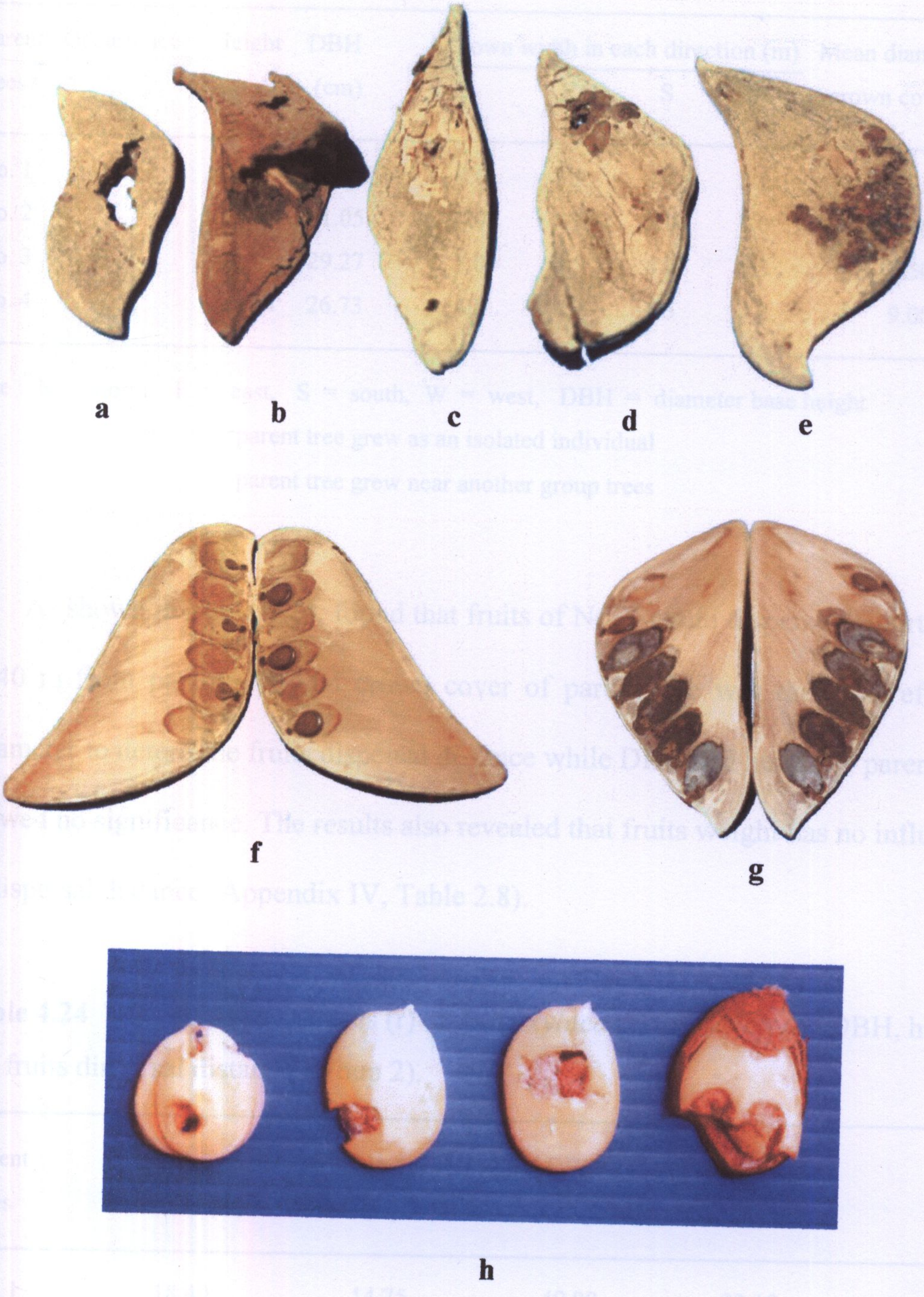


Figure 4.24 Characteristics of abnormal fruits and seeds of *Xylia xylocarpa*

- a-e damaged fruits
- f aborted seeds (left), fully developed seeds (right)
- g fungal-damaged seeds
- h insect-damaged seeds

Table 4.23 Characteristics of parent trees of *Xylia xylocarpa* (group 2)

Parent trees	Occurrence	Height (m)	DBH (cm)	Crown width in each direction (m)				Mean diameter of crown cover (m)
				N	E	S	W	
No. 1	1	23.10	49.00	7.0	6.5	7.5	8.5	14.75
No. 2	2	21.90	41.05	6.0	7.0	5.0	7.0	12.50
No. 3	1	16.80	29.27	5.0	5.5	4.0	6.5	10.50
No. 4	1	15.80	26.73	4.5	4.0	5.5	4.0	9.00

Note : N = north, E = east, S = south, W = west, DBH = diameter base height
1 = parent tree grew as an isolated individual
2 = parent tree grew near another group trees

As shown in Table 4.24, found that fruits of No. 4 could disperse the farthest of 18.40 m from parent tree and crown cover of parent tree was the most effective parameter to determine fruits dispersal distance while DBH and height of parent tree showed no significance. The results also revealed that fruits weight has no influence in dispersal distance (Appendix IV, Table 2.8).

Table 4.24 The correlation values (r) of *Xylia xylocarpa* crown cover, DBH, height and fruits dispersal distance (group 2).

Parent trees	Fruits dispersal distance (m)	Crown cover (m)	DBH (cm)	Height (m)
No. 1	18.40	14.75	49.00	23.10
No. 2	13.70	12.50	41.05	21.90
No. 3	13.50	10.50	29.27	16.80
No. 4	11.30	9.00	26.73	15.80
r		0.95 *	0.90 ^{ns}	0.82 ^{ns}

ns non significant

* significant difference at the 0.05 confidence level,

4.4.10 Germination rate of *Xylia xylocarpa* in natural site

Mature fruits of *Xylia xylocarpa* dried and discharged the seeds through out March 2001. Table 4.24 showed that there were 35-52 seeds from 4 parent trees that could germinate and after 3 months there were 11-26 survival seedlings. Considera-tion during March, April and May 2001, there were rainy periods of 4, 4, 6 days and the total rainfall per month of 37.70, 61.40 and 130.10 mm, respectively (Table 4.25). It indicated that, rainfall was well distributed and enough. Thus, *Xylia xylocarpa* moderately succeeded in seed germination and establishment of seedling in the study year.

Table 4.25 Number of *Xylia xylocarpa* seedlings in natural site

Parent trees	Number of seedling	
	germination	three months later
No. 1	38	13
No. 2	52	26
No. 3	40	16
No. 4	35	11

Table 4.26 Climatological data of Nong Rawiang in the year 2001.

Month	Temperature (°C)		RH	Evaporation *	Wind speed *			Rainy	Rain fall
	Max	Min	(%)	(mm)	Day	Night	All	day	(mm)
					(km/12hr)		(km/day)		
March	35.15	21.98	80.61	4.30	26.00	6.03	32.03	4	37.70
April	39.25	23.31	81.00	6.30	27.02	3.95	30.97	4	61.40
May	34.42	23.94	83.29	4.50	24.88	3.21	28.10	6	130.10

* Data from Hauybanyang Agricultural Irrigation Research Station Nakhon Ratchasima

4.4.11 Germination characteristics and development of *X. xylocarpa* seedling

Seeds begin to germinate 2-4 days after sowing. Germination is epigeal which means cotyledons are held above the soil and are free of the seed coat. Various stages of development are illustrated in Figure 4.25.

2-4 days of age :	Radicle emerges through the testa (Figure 4.25 a).
4-6 days of age :	Primary root elongates rapidly, secondary roots occur densely. Hypocotyl curvedly elongates and raises the cotyledons. The length of hypocotyl and radicle is about 8-12 cm (Figure 4.25 b).
6-14 days of age :	Hypocotyl straightly elongates, cotyledons split open and epicotyl emerges upwards from and between the cotyledonary petioles. The terminal bud has the first two pair of leaves which are opposite. The primary and secondary roots elongate. Stem is 8.5-11.0 cm tall (Figure 4.25 c).
15-40 days of age :	Hypocotyl not enlarging, cotyledons wilt. The first pair of leaves are fully expanded with 3.2-5.5 cm wide by 6.5-9.4 cm long, epicotyl elongates. The root is 5.5-15.0 cm long, the length between the base of stem and the terminal bud is 10.5-23.5 cm with 2-10 simple leaves (Figure 4.25 d).

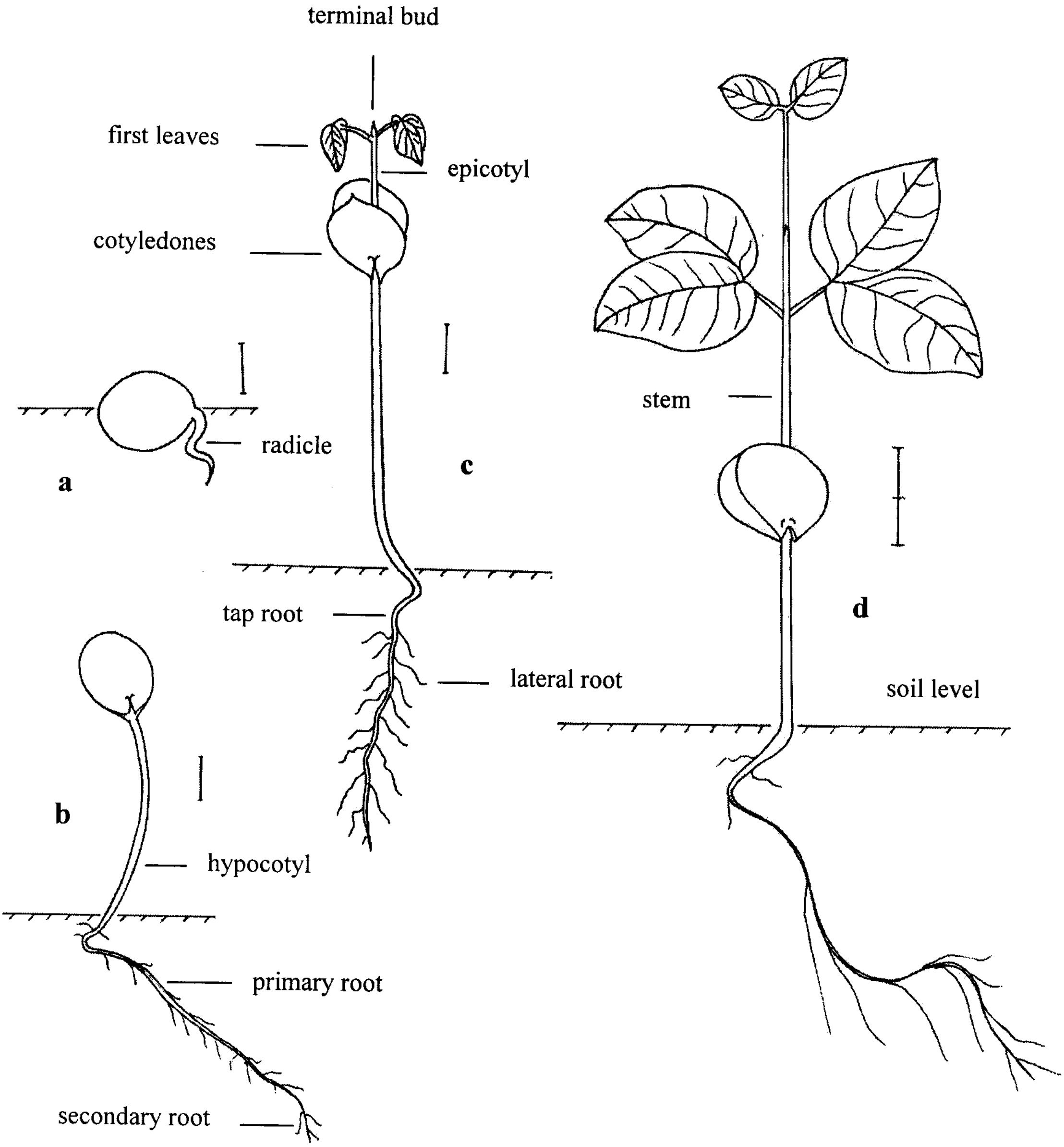


Figure 4.25 Development of *Xylia xylocarpa* seedling after tested in seedbeds

a) 2-4 days of age; b) 4-6 days of age; c) 6-14 days of age; d) 15-40 days of age. (scale 1 cm)

Part C : *Ellipanthus tomentosus*

4.4.12 Characteristics of parent trees and their environment

Four parent trees of *Ellipanthus tomentosus* are isolated individual trees which reach a height of 10.70-15.90 m, a DBH of 15.75-30.23 cm and a diameter of crown cover of 5.50-8.00 m (Table 4.27). All of them grew in DDF and their environment is similar as the environment of *Shorea siamensis.*

E. tomentosus has gravity-dispersed seeds which most of them fall under the crown cover of parent tree. So, this topic does not study seeds dispersal.

Table 4.27 Characteristics of parent trees of *Ellipanthus tomentosus*

Parent trees	Occurrence	Height (m)	DBH (cm)	Crown width in each direction (m)				Mean diameter of crown cover (m)
				N	E	S	W	
No. 1	1	14.70	30.23	3.3	3.5	4.0	4.5	7.65
No. 2	2	10.85	15.75	3.0	2.6	2.5	3.2	5.65
No. 3	1	10.70	18.45	3.0	4.0	3.7	4.0	7.35
No. 4	1	15.90	24.50	3.3	3.0	3.0	4.0	6.65

Note : N = north, E = east, S = south, W = west, DBH = diameter base height
1 = parent tree grew as an isolated individual
2 = parent tree grew near another group trees

4.4.13 The production of *Ellipanthus tomentosus*

4.4.13.1 The fallen flowers and fruits of *E. tomentosus* in each period

The periods of flowers, fruits development and production in each parent tree were near. Parent tree had initiated flowering in late December 1999. Parent tree No. 4 had early flowering than another parent trees about 2 weeks. Flowers began to fall since mid-January. Parent tree No. 3 had the highest fallen of 3,606 flowers while

No.1 had the highest fallen of 12,116 mature fruits during 15 June 2000 (Table 4.28 and Figure 4.26).

The results found that number of flower production was significantly correlated with height of parent trees while number of flower production, fallen young fruits and fallen mature fruits were not significantly correlated with DBH and crown cover of parent trees (Appendix IV, Table 3.1-3.3).

Table 4.28 Number of fallen flowers, young fruits, mature fruits, and seeds of *Ellipanthus tomentosus* in the year 1999-2000.

Categories/ Parent trees	No. 1	No. 2	No. 3	No. 4	Mean	A	B
Fallen flowers	3,227	2,674	3,606	2,690	3,049		
Fallen young fruits	3,154	5,451	4,170	6,559	4,834		
Fallen mature fruits	12,116	9,583	9,316	9,846	10,215		
Total produced flowers	18,497	17,708	17,092	19,095	18,098		
Number of seeds	12,005	9,428	9,132	9,681	10,061		
Initiated flowering	5 Jan	30 Dec	2 Jan	25 Dec		21 Dec	2 Jan
Initiated fallen flowers	20 Jan	14 Jan	17 Jan	9 Jan		5 Jan	17 Jan
Finished fallen flowers	27 Feb	17 Feb	24 Feb	13 Feb		5 Mar	7 Mar
Initiated young fruiting	27 Jan	16 Jan	22 Jan	9 Jan			
Finished fallen young fruits	11 May	4 May	5 May	13 Apr			
Initiated mature fruiting	29 Apr	20 Apr	27 Apr	16 Apr			
Finished fallen mature fruits	20 Jul	13 Jul	18 Jul	5 Jul			

Note : A = type of *E.tomentosus* show short sterile pistil

B = type of *E.tomentosus* show long sterile pistil

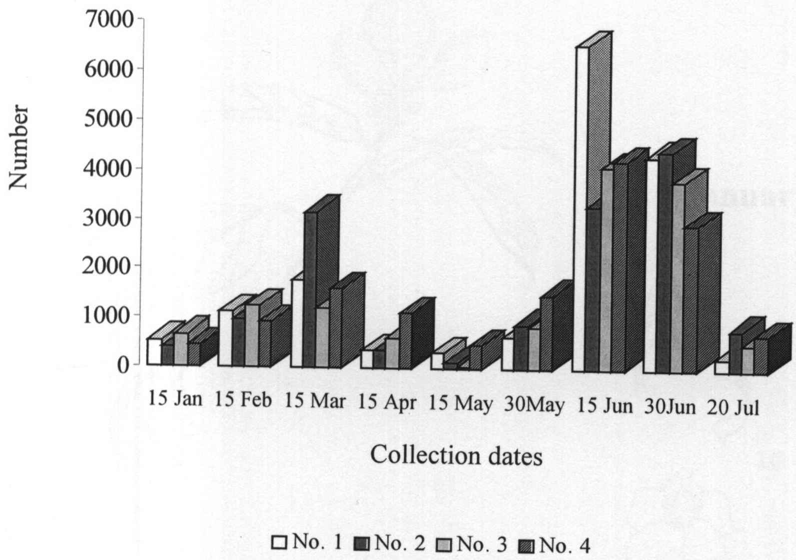


Figure 4.26 Collection dates of fallen flowers, young and mature fruits of *Ellipanthus tomentosus* in the year 2000.

Note : No. 1	=	parent tree No. 1	No. 3	=	parent tree No. 3
No. 2	=	parent tree No. 2	No. 4	=	parent tree No. 4
15 Jan-15 Feb	=	collection dates of fallen flowers			
15 Mar-15 Apr	=	collection dates of fallen young fruits			
15 May-20 Jul	=	collection dates of fallen mature fruits			

The study of fruit development of *Ellipanthus tomentosus* found that the period of initiated flowers to bloom flowers took about 10-15 days, bloom flowers to young fruits took about 5-7 days, young fruits to mature fruits took about 93-98 days, mature fruits to finished fallen mature fruits took about 80-84 days. The total period of initiated flowers to mature fruits took about 112-116 days as illustrated in Figure 4.27.

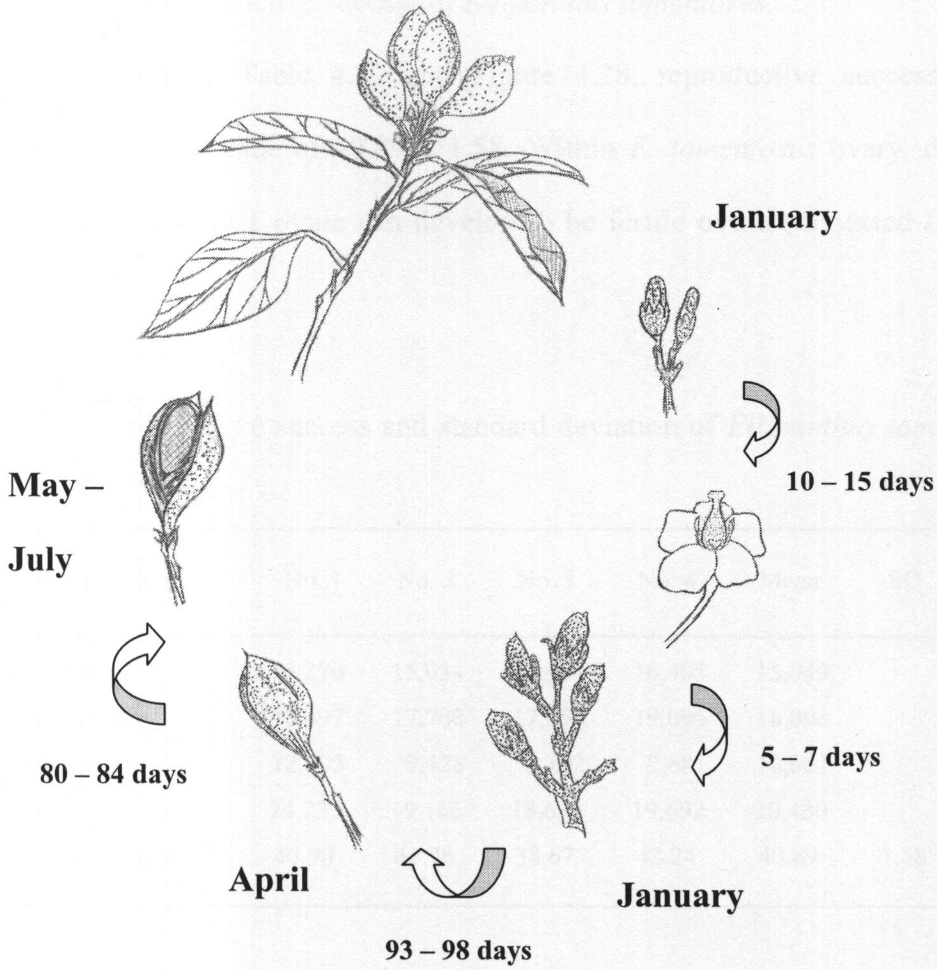


Figure 4.27 Fruit development of *Ellipanthus tomentosus* in the year 2000.

As shown in Table 4.29, the ratios of flowers : fruits of *E. tomentosus* in each parent tree are listed below : parent tree No. 1 = 1.21 : 1

parent tree No. 2 = 1.18 : 1

parent tree No. 3 = 1.27 : 1

parent tree No. 4 = 1.16 : 1

mean = 1.20 : 1

It indicated that each parent tree had very similar ability in flowering and fruiting. Considering the ratio, parent tree No. 1 was the best tree.

4.4.13.2 Reproductive success of *Ellipanthus tomentosus*

The results in Table 4.29 and Figure 4.28, reproductive success of *E. tomentosus* had high value of 40.89 ± 1.58. Within *E. tomentosus* ovary, contains with 2 ovules and only 1 ovule can develop to be fertile ovule (dissected from 50 ovary).

Table 4.29 Reproductive success and standard deviation of *Ellipanthus tomentosus* in the year 1999-2000.

Categories/Parent trees	No. 1	No. 2	No. 3	No. 4	Mean	SD
Number of fruits	15,270	15,034	13,486	16,405	15,049	
Number of flowers	18,497	17,708	17,092	19,095	18,098	
Number of seeds	12,005	9,428	9,132	9,681	10,061	
Number of ovules	24,232	19,166	18,632	19,692	20,430	
Reproductive success (%)	40.90	41.76	38.67	42.24	40.89	1.58

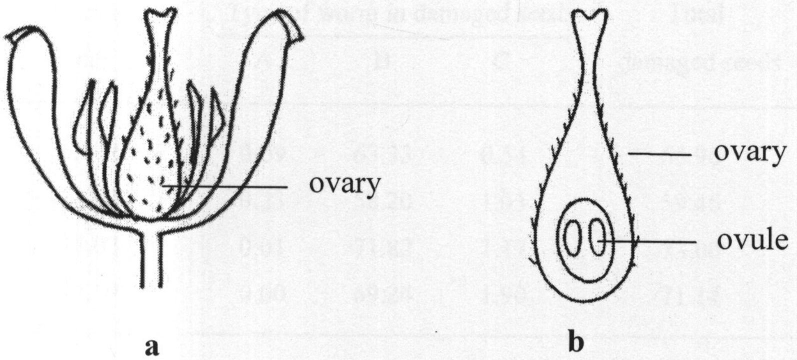


Figure 4.28 *Ellipanthus tomentosus* ovary (a) flower, (b) long section of ovary shows 2 ovules

4.4.13.3 Normal and abnormal seeds of *Ellipanthus tomentosus*

In the present study, the results found that most seed production of 4 parent trees were abnormal seeds of 68.44 %. Characteristics of abnormal seeds consist of empty seeds and damaged seeds. Damaged seeds destruction by insects of long worm (Unknown sp.), yellow worm (*Araecerus* sp.) and big worm (*Deadorix epijarbus*). *Araecerus* sp. is the most insect caused seed losses of 65.65 %. Some *E. tomentosus* seeds seem normal but there are *Araecerus* sp. worms inside. It could be that the adult lays eggs since *E. tomentosus* is flowering. (Table 4.30, Figure 4.29, 4.30 and Appendix IV, Table 3.4-3.7).

Dajoz (2000) reported that the factors which cause an insect to become harmful are very diverse. Many are climatic, and act either by inducing a state of stress which makes trees less resistant to attacks, or by increasing the reproductive potential of insects (increased fertility, increased survival rate).

Table 4.30 Percentage of normal and abnormal seeds of *Ellipanthus tomentosus*

Parent trees	Normal seeds	Type of worm in damaged seeds			Total damaged seeds	Empty seeds
		A	B	C		
No. 1	35.12	0.09	63.33	0.54	63.96	0.92
No. 2	38.92	0.23	58.20	1.03	59.46	1.62
No. 3	25.02	0.01	71.82	1.17	73.00	1.98
No. 4	27.19	0.00	69.24	1.90	71.14	1.67
Mean	31.56	0.08	65.65	1.16	66.89	1.55

Note : A = long worm (Unknown sp.)
B = yellow worm (*Araecerus* sp.)
C = big worm (*Deadorix epijarbus*)

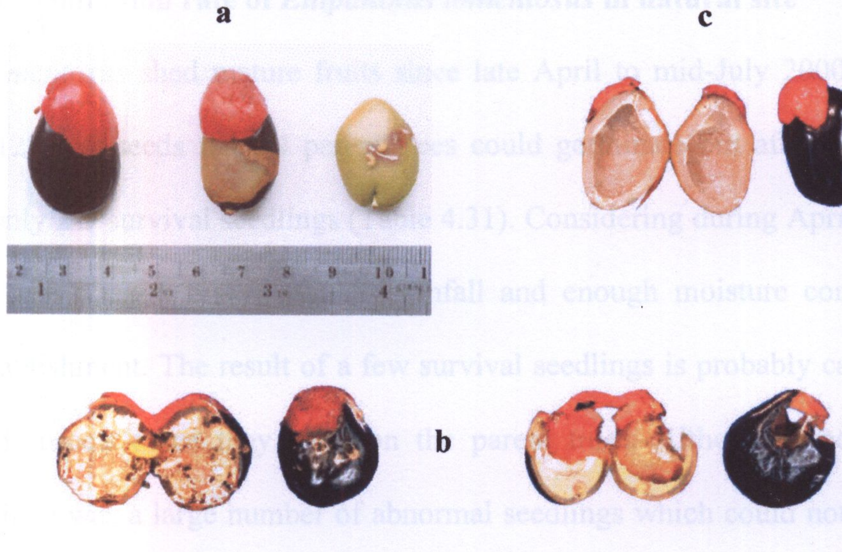


Figure 4.29 Abnormal seeds of *Ellipanthus tomentosus*

a. the seed seems normal but there are the worms inside

b. insect-damaged seeds by yellow worm (left) and by big worm (right)

c. empty seed

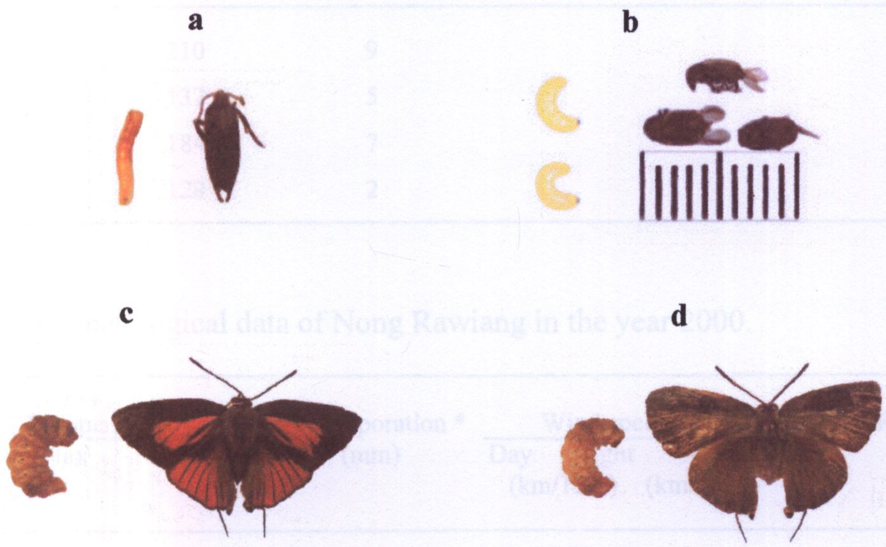


Figure 4.30 Seeds predators of *Ellipanthus tomentosus*

a. long worm and adult (Unknown sp.)

b. yellow worm and adults (*Araecerus* sp. Family Anthribidae), scale bars 1 mm

c-d. big worm and adult (*Deudorix epijarbus* Family Lycaenidae)

(c) male, (d) female

4.4.14 Germination rate of *Ellipanthus tomentosus* in natural site

E. tomentosus shed mature fruits since late April to mid-July 2000. It was found that 128-210 seeds from 4 parent trees could germinate but after 3 months there were only 2-9 survival seedlings (Table 4.31). Considering during April to July 2000, there was a good distribution of rainfall and enough moisture content for seedling establishment. The result of a few survival seedlings is probably caused by an attack of insects since they were on the parent trees. Although seeds could germinate, there was a large number of abnormal seedlings which could not survive in natural site. So, *E. tomentosus* succeeded in seed germination whereas it did not succeed in establishment of seedling in the study year.

Table 4.31 Number of *Ellipanthus tomentosus* seedlings in natural site

Parent trees	Number of seedling	
	germination	three months later
No. 1	210	9
No. 2	137	5
No. 3	184	7
No. 4	128	2

Table 4.32 Climatological data of Nong Rawiang in the year 2000.

Month	Temperature (°C)		RH	Evaporation *	Wind speed *			Rainy	Rain fall
	Max	Min	(%)	(mm)	Day	Night	All	day	(mm)
					(km/12hr)		(km/day)		
Apr	36.00	22.65	79.77	4.53	17.16	1.48	18.64	11	210.81
May	34.01	23.04	81.16	4.20	14.78	1.31	16.08	9	260.90
June	32.71	23.52	81.40	4.10	16.58	1.11	17.69	9	175.90
July	32.77	22.97	79.97	3.90	21.69	1.49	23.18	9	82.40
August	32.90	22.99	83.97	4.30	20.88	2.46	23.34	8	373.90

* Data from Hauybanyang Agricultural Irrigation Research Station Nakhon Ratchasima

4.4.15 Germination characteristics and development of *E. tomentosus* seedling

Seeds begin to germinate 2-4 days after sowing. Germination is epigeal which means cotyledons are held above the soil and are free of the seed coat. Various stages of development are illustrated in Figure 4.31.

2-4 days of age : Radicle emerges through the testa opposite the arill side (Figure 4.31 a).

8-12 days of age : Primary root elongates. Hypocotyl curvedly elongates and raises the cotyledons above the soil. The length of hypocotyl and radicle is about 2.5-4.0 cm (Figure 4.31 b).

12-20 days of age : Hypocotyl straightly elongates. Cotyledons split open, epicotyl emerges upwards from and between the cotyledonary petioles and elongates rapidly. The terminal bud has the first small pair of leaves which are opposite. The primary and secondary roots elongate. Stem is 2.5-5.0 cm tall (Figure 4.31 c).

20-60 days of age : Cotyledons spread out in straight line. The first pair of leaves have fully expanded 2.5-3.8 cm wide by 3.5-4.5 cm long. Terminal bud occurs 0.7-1.5 cm long. Hypocotyl does not enlarge. The root is 4-11 cm long, the length between the base of stem and terminal bud is 6.5-17.0 cm with 2-6 simple leaves (Figure 4.31 d-4.31 e).

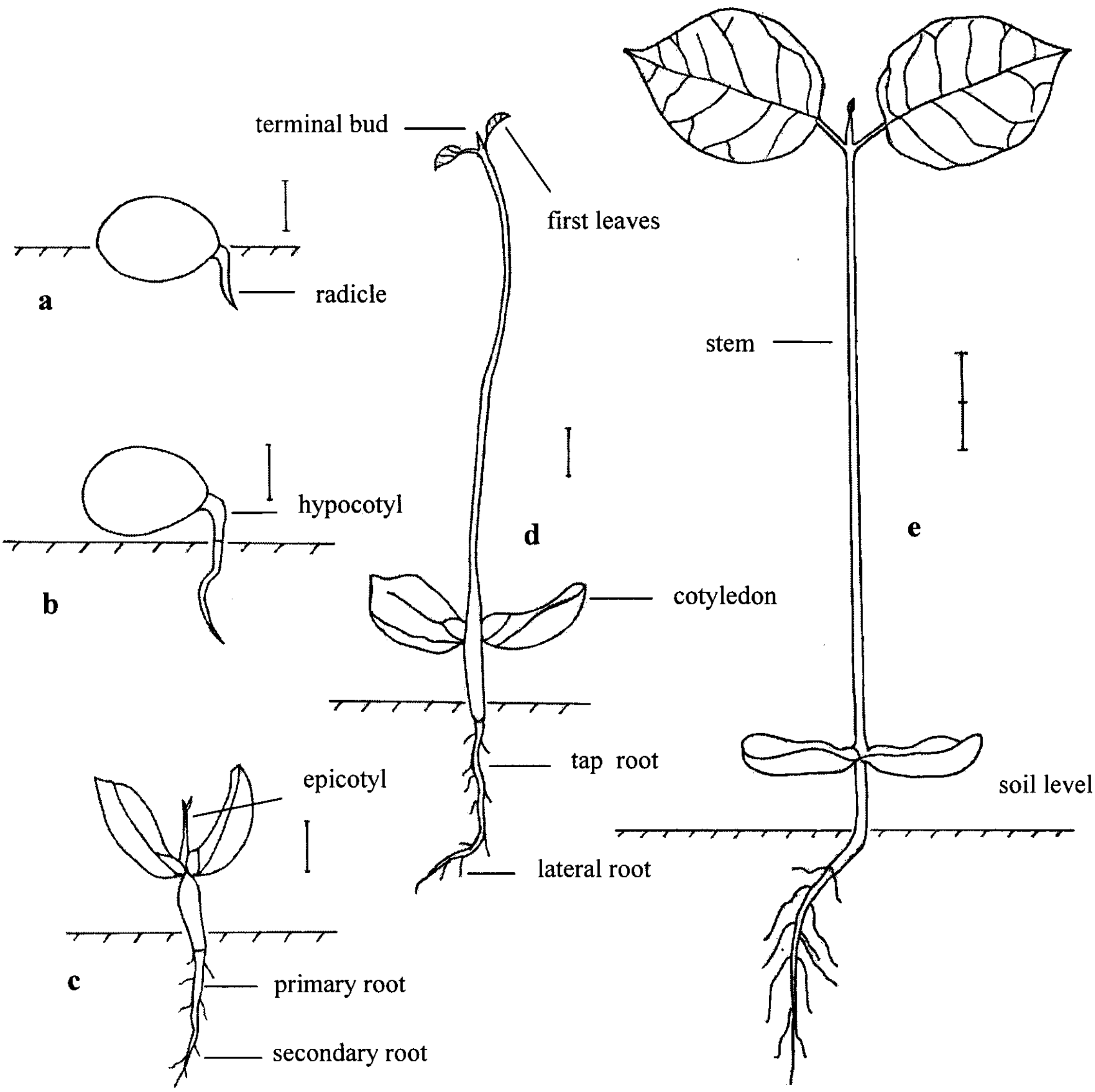


Figure 4.31 Development of *Ellipanthus tomentosus* seedling after tested in seed-beds a) 2-4 days of age; b) 8-12 days of age; c) 12-20 days of age; d) 20-30 days of age; e) 30-60 days of age. (scale 1 cm)

Part D : *Sindora siamensis*

4.4.16 Characteristics of parent trees and their environment

Four parent trees of *Sindora siamensis* are isolated individual trees which reach a height of 13.50-21.05 m, a DBH of 28.00-79.55 cm and a diameter of crown cover of 8.50-16.50 m (Table 4.33). All of them grew in DDF and their environment is similar as the environment of *Shorea siamensis*.

Sindora siamensis has gravity-dispersed seeds which most of them fall under the crown cover of parent tree. So, this topic does not study seeds dispersal.

Table 4.33 Characteristics of parent trees of *Sindora siamensis*

Parent trees	Type	Occurrence	Height (m)	DBH (cm)	Crown width in each direction (m) N	E	S	W	Mean diameter of crown cover (m)
No. 1	A	2	15.25	32.45	4.6	4.0	4.2	4.5	8.65
No. 2 *	A	1	21.05	79.55	7.0	9.0	8.0	7.5	15.75
No. 3	A	2	13.50	28.00	5.5	6.3	6.0	5.4	11.60
No. 4	B	1	15.90	30.12	6.0	7.5	7.0	8.0	14.25

Note : N = north, E = east, S = south, W = west, DBH = diameter base height

Type A = *Sindora siamensis* var. *siamensis*

Type B = *Sindora siamensis* var. *maritima*

1 = parent tree grew as an isolated individual

2 = parent tree grew near another group trees

* = grew in groups of trees

4.4.17 The production of *Sindora siamensis*

4.4.17.1 The fallen flowers and fruits of *Sindora siamensis* in each period

The period of flowers and fruits development in each parent tree were near. Parent tree had initiated flowering in early May 2000. Parent tree No. 3 had early flowering than another parent trees about 1 weeks. Flowers began to fall since mid-

May. Parent tree No.2 had the highest fall of 146,230 flowers on 4 June 2000 while No. 2 had the highest fall of 5,367 mature fruits during 29 October 2000 (Table 4.34 and Figure 4.32).

The results found that number of fallen mature fruits and seeds production were significantly correlated with DBH and height of parent trees while number of flower production, fallen mature fruits and seeds production were not significantly correlated with crown cover of parent trees (Appendix IV, Table 4.1-4.3).

Table 4.34 Number of fallen flowers, mature fruits and seeds of *Sindora siamensis* in the year 2000-2001.

Categories/ Parent trees	No. 1	No. 2	No. 3	No. 4	Mean
Fallen flowers	18,476	29,246	19,729	8,374	18,956
Total produced flowers	92,380	146,230	98,643	41,870	94,781
Fallen mature fruits	870	5,367	963	1,935	2,284
Number of seeds	1,058	3,860	933	1,839	1,923
Initiated flowering	8 May	10 May	2 May	9 May	
Initiated fallen flowers	15 May	17 May	9 May	16 May	
Finished fallen flowers	19 Jun	25 Jun	15 Jun	24 Jun	
Initiated young fruiting	4 Jun	7 Jun	1 Jun	5 Jun	
Initiated mature fruiting	11 Aug	21 Aug	8 Aug	13 Aug	
Finish fallen mature fruits	10 Dec 00	28 Jan 01	19 Nov 00	24 Dec 00	

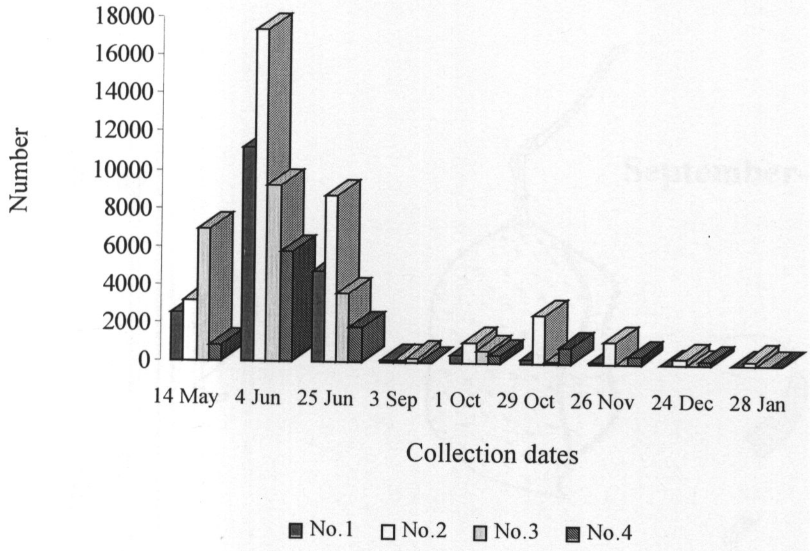


Figure 4.32 Collection dates of fallen flowers and mature fruits of *Sindora siamensis* in the year 2000.

Note : No. 1	=	parent tree No. 1	No. 3	=	parent tree No. 3
No. 2	=	parent tree No. 2	No. 4	=	parent tree No. 4
14 May-25 Jun	=	collection dates of fallen flowers			
3 Sep-28 Jan	=	collection dates of fallen mature fruits			

The study of fruit development of *Sindora siamensis* found that the period of initiated flowers to bloom flowers took about 5-7 days, bloom flowers to young fruits took about 20-25 days, young fruits to mature fruits took about 68-75 days, mature fruits to finished fallen mature fruits took about 103-160 days. The total period of initiated flowers to mature fruits took about 95-103 days and the total period of initiated fallen flowers to finished fallen mature fruits took about 196-267 days as illustrated in Figure 4.33.

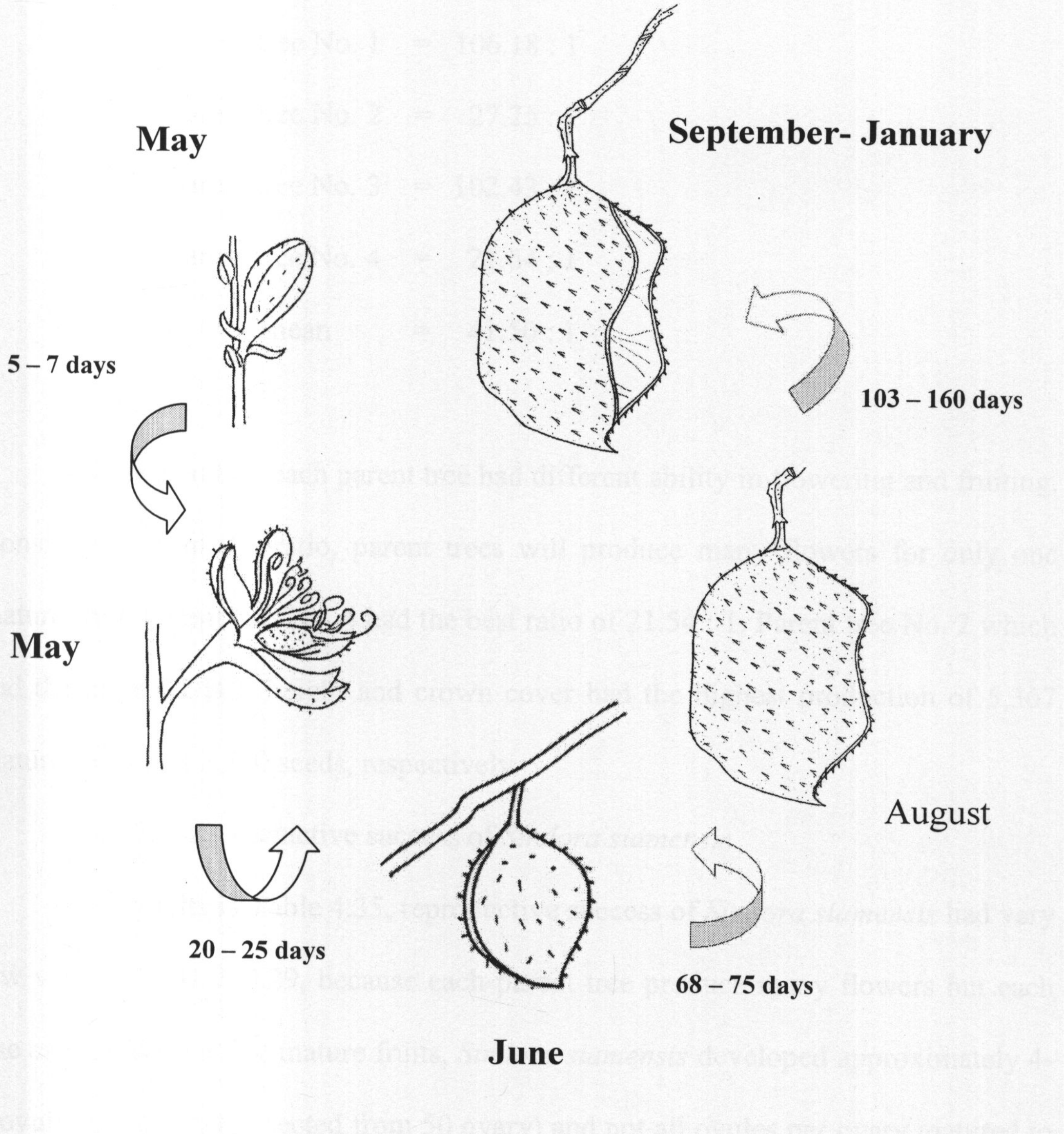


Figure 4.33 Life cycle of *Sindora siamensis* in the year 2000 to 2001.

As shown in Table 4.35, the ratios of flowers : mature fruit of *Sindora siamensis* in each parent tree are listed below :

parent tree No. 1	=	106.18 : 1
parent tree No. 2	=	27.25 : 1
parent tree No. 3	=	102.43 : 1
parent tree No. 4	=	21.64 : 1
mean	=	41.50 : 1

It indicated that each parent tree had different ability in flowering and fruiting. Considering from the ratio, parent trees will produce many flowers for only one mature fruit. Parent tree No. 4 had the best ratio of 21.54 : 1. Parent tree No. 2 which had the largest DBH, height and crown cover had the highest production of 5,367 mature fruits and 3,860 seeds, respectively.

4.4.17.2 Reproductive success of *Sindora siamensis*

The results in Table 4.35, reproductive success of *Sindora siamensis* had very low value of 0.41 ± 0.29, because each parent tree produce many flowers but each one can produce a few mature fruits. *Sindora siamensis* developed approximately 4-7 ovules per ovary (dissected from 50 ovary) and not all ovules per ovary matured to seed (Figure 4.34). This reason brings to the low value of reproductive success.

Table 4.35 Reproductive success and standard deviation of *Sindora siamensis* in the year 2000-2001.

Categories/Parent trees	No. 1	No. 2	No. 3	No. 4	Mean	SD
Number of fruits	870	5,367	963	1,935	2,284	
Number of flowers	92,380	146,230	98,643	41,870	94,781	
Number of seeds	1,058	3,860	933	1,839	1,923	
Number of ovules	4,785	29,519	5,297	10,642	12,561	
Reproductive success (%)	0.21	0.48	0.17	0.80	0.41	0.29

Note : number of ovules = number of fruits x 5.5 ovules (average from 50 flowers)

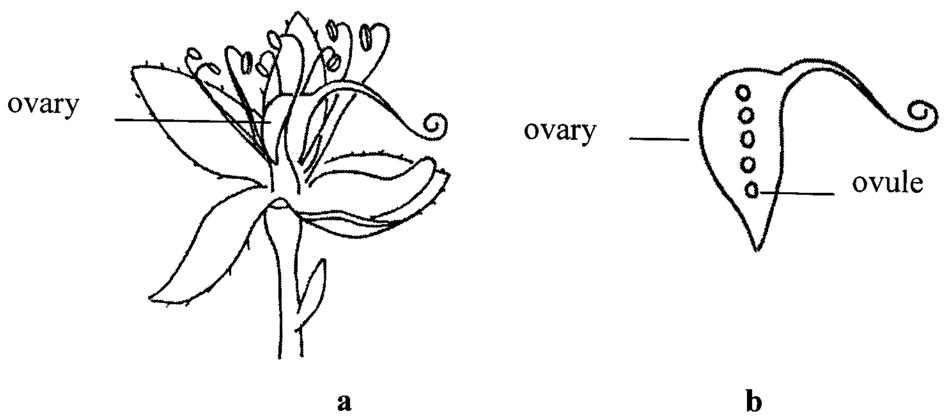


Figure 4.34 *Sindora siamensis* ovary (a) flower, (b) long section of ovary shows 5 ovules

4.4.17.3 Normal-abnormal fruits and seeds of *Sindora siamensis*

The present study found that fruits production of 4 parent trees were abnormal fruits of 11.78 %. Characteristics of abnormal fruits consist of aborted fruits and damaged fruits. Considering all of the seeds, there were aborted seeds, rotten seeds, broke coat seeds and insect-damaged seeds. Parent tree No. 2 had the most abnormal seeds of 81.79 %. *Carpophilus* sp. (Family Nitidulidae) is the insect that caused most of the seed losses. (Table 4.36 Figure 4.35-4.36, Appendix IV : Table 4.4-4.7).

Table 4.36 Percentage of normal-abnormal fruits and seeds of *Sindora siamensis*

Parent trees	Normal fruits	Abnormal fruits	Fully developed seeds	Aborted seeds	Rotten seeds	Insect-damaged seeds	Broke coat seeds
No. 1	90.80	9.20	53.03	1.32	0.76	36.86	8.03
No. 2	93.03	6.97	18.21	22.20	2.93	51.94	4.72
No. 3	82.04	17.96	58.74	9.00	0	22.29	9.97
No. 4	87.03	12.97	76.18	4.08	0.16	15.93	3.65
Mean	88.22	11.78	51.54	9.15	0.96	31.76	6.59

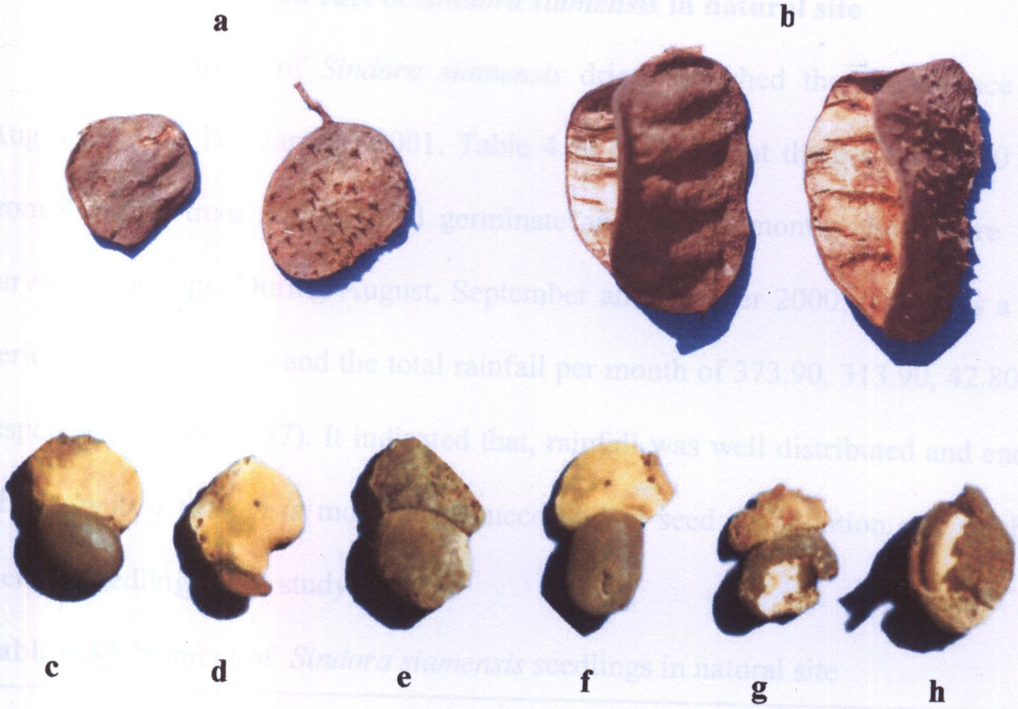


Figure 4.35 Characteristic of normal-abnormal fruits and seeds of *Sindora siamensis*

a	aborted fruits	b	normal fruits
c	fully developed seed	d	aborted seed
e	rotten seed	f-g	insect-damaged seed
h	broke coat seed		

Figure 4.36 Seeds predator of *Sindora siamensis* : (*Carpophilus* sp. Family Nitidulidae). Scale bars 1 mm

4.4.18 Germination rate of *Sindora siamensis* in natural site

Mature fruits of *Sindora siamensis* dried and shed the seeds since early August 2000 to late January 2001. Table 4.36 showed that there were 45-80 seeds from 4 parent trees which could germinate and after 3 months there were 18-37 survival seedlings. During August, September and October 2000, there was a rainy period of 8, 14, 3 days and the total rainfall per month of 373.90, 313.90, 42.80 mm, respectively (Table 4.37). It indicated that, rainfall was well distributed and enough. Thus, *Sindora siamensis* moderately succeeded in seed germination and establishment of seedling in the study year.

Table 4.37 Number of *Sindora siamensis* seedlings in natural site

Parent trees	Number of seedling	
	germination	*three months later*
No. 1	45	18
No. 2	53	24
No. 3	49	21
No. 4	80	37

Table 4.38 Climatological data of Nong Rawiang in the year 2000-2001.

Month	Temperature (°C)		RH	Evaporation *	Wind speed *			Rainy	Rain fall
	Max	Min	(%)	(mm)	Day	Night	All	day	(mm)
					(km/12hr)		(km/day)		
August	32.90	22.99	83.97	4.26	20.88	2.46	23.34	8	373.90
September	31.34	22.83	87.17	3.40	17.72	1.03	18.75	14	313.90
October	31.86	22.33	87.84	3.80	19.30	2.39	21.69	3	42.80
November	29.88	16.47	78.17	4.30	38.42	6.48	44.89	-	-
December	30.68	17.42	79.45	4.65	40.11	3.30	43.42	-	-
January 01	33.79	18.68	82.23	4.30	26.71	5.05	31.76	-	-
February 01	35.58	19.14	80.14	5.10	29.37	4.80	34.17	-	-

* Data from Hauybanyang Agricultural Irrigation Research Station Nakhon Ratchasima

4.4.19 Germination characteristics and development of *Si. siamensis* seedling

Seeds begin to germinate 4-6 days after sowing. Germination is epigeal which means cotyledons are held above the soil and are free of the seed coat. Various stages of development are illustrated in Figure 4.37.

4-6 days of age : Radicle emerges through the testa at the same side of arill (Figure 4.37 a).

8-10 days of age : Primary root elongates rapidly. Hypocotyl curvedly elongates and raises the cotyledons above the soil. The length of hypocotyl and radicle is about 6-16 cm (Figure 4.37 b).

12-18 days of age : Hypocotyl straightly elongates. Cotyledons split, epicotyl emerges upwards from and between the cotyledonary petioles and has the first two pair of leaves which are opposite and not yet spread out. The primary and secondary roots elongate. Stem is 8-12 cm tall (Figure 4.37 c).

20-40 days of age : The first pair of leaves have fully expanded 3.5-4.6 cm wide by 6.0-7.5 cm long. Hypocotyl does not enlarge. Cotyledons wilt and fell off. The root is 8.5-19.0 cm long, the length from the base of stem to terminal bud is 14.0-25.5 cm with 2-8 simple leaves (Figure 4.37 d).

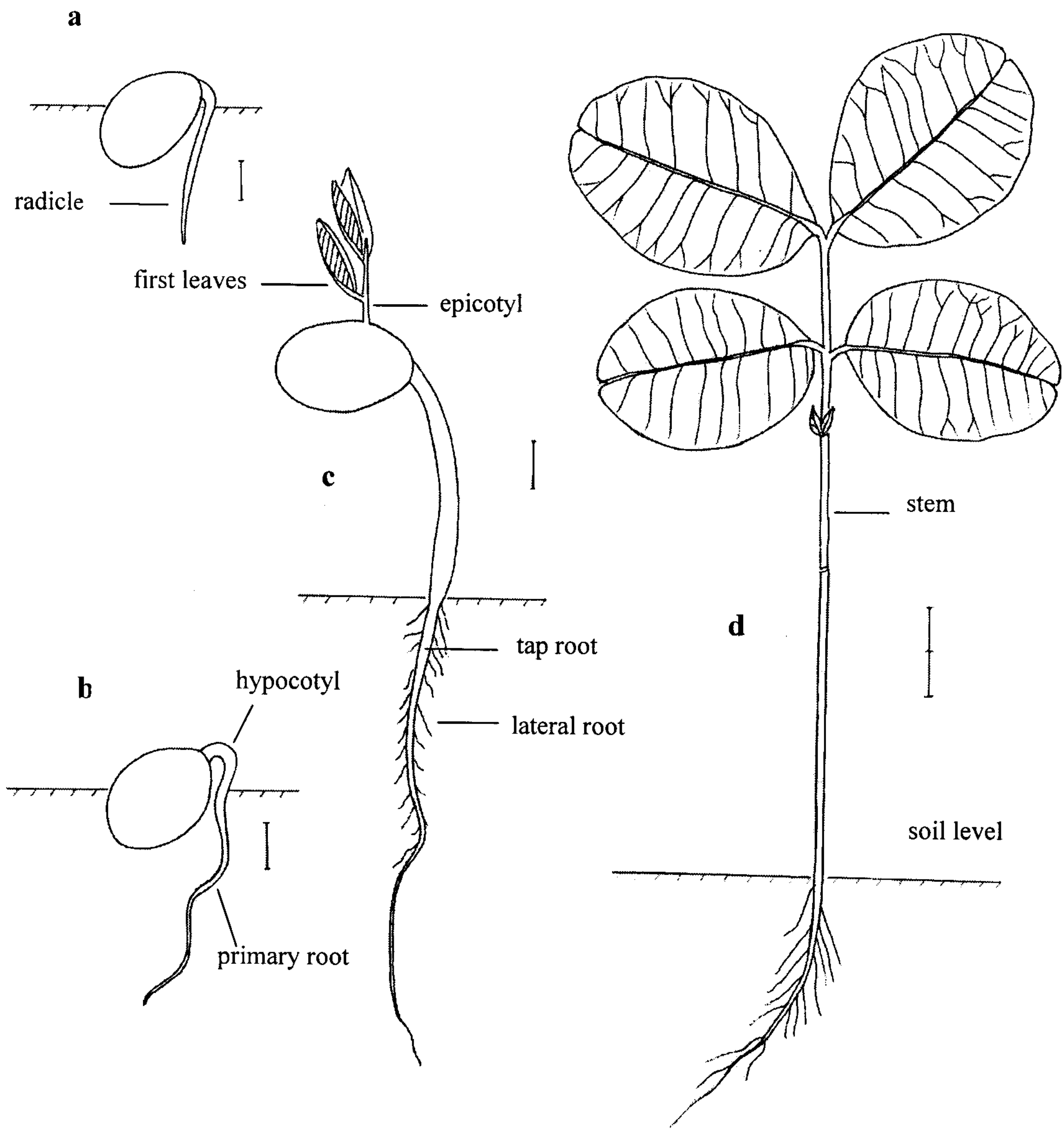


Figure 4.37 Development of *Sindora siamensis* seedling after tested in seedbeds a) 4-6 days of age; b) 8-10 days of age; c) 12-18 days of age; d) 20-40 days of age (scale 1 cm)

4.5 Seed Quality

4.5.1 Seed quality of target tree species

There were 32 target tree species used to test seed quality as presented in Table 4.39 The results showed that there was great variation in seed moisture content in each tree species. The moisture content of seeds varied from 7.71 % in *Canarium subulatum* to 50.02 % in *Aporosa villosa*. Seed moisture is the most important factor determining viability. In general, the moisture contents of the seeds had an inverse relationship to the germination percentage, except recalcitrant seeds which have a relative high moisture level when they are shed and if reduce their moisture level to 12-25 % it results in serious loss of viability (Roberts, 1973). In the present study *Shorea roxburghii* and *Shorea obtusa* are species with recalcitrant seeds. They had seed moisture content of 48.17 and 42.27 %, and seemed to be low in seed germination of 33 and 42 %, respectively. It was suspected that there have been a reduction of their seed moisture level, and such reduction affected seed germination.

The most significant part of seed testing is the germination test and its most important feature is evaluating the seedling. Table 4.39 revealed that there was great variation in the total germination of individual tree species. The seeds of *Bridelia retusa* and *Cratoxylum formosum* could not germinate. The results may be caused by the seeds were in the resting period, or exhibited seed coat dormancy or deteriorated by weathering effects. Tree species 14, 13, and 3 showed percentage of seed germination less than 50 %, more than 75 % and average 53-66 %, respectively. High seed germination occurred in *Strychnos nux-vomica, Haldina cordifolia, Dipterocarpus intricatus, Aporosa villosa, Memecylon edule, Pterocarpus macrocarpus, Senna garrettiana, Careya sphaerica, Albizia lebbeck, Bauhinia* *racemosa, Artocarpus lacucha, Erythrophleum succirubrum,* and *Wrightia arborea.* It implied that about half of number of tree species in this DDF have the maximum germination potential of a seed lot which can then in turn be used to compare the quality of different lots and also estimate the field planting value.

For the seedling vigor classification of all tree species, the results appeared that percentage of strong seedling conform with percentage of normal seedling in seed germination test. For the germination index, the highest number were *Albizia lebbeck* of 79.17 and *Senna garrettiana* of 71.25, respectively. However, more than half of tree species rather showed low number of germination index. (Figure 4.38). Some tree species such as *Aporosa villosa, Memecylon edule* and *Artocarpus lacucha* showed high seed germination of 85, 89 and 97 % but had low germination index of 17.05, 6.42 and 14.82, respectively. It indicated that even though these tree species had high seed germination, they had low germination energy of activity and performance of the seed during seedling emergence.

There were 25 target tree species for the determination of seed quality by using X-ray technique. The results showed high viable seeds of most tree species. They were ranging from 37-99 % (Table 4.39). As shown in Figure 4.39, when compared the results with the standard germination test, it was found that the X-ray tests had higher viable seeds of all target tree species of 65.77 % average. The X-ray test generally overestimate viability, for example in this present study it was estimated that 49 % of *Bridelia retusa* seeds and 53 % of *Cratoxylum formosum* seeds were viable, whereas their seeds did not germinate. The results from this study however, can be show that X-radiography could be used as an effective, rapid technique for evaluating seed viability of tree species.

Table 4.39 Seed moisture content, standard germination test, seed vigor tests, seed viability test and standard deviation of target tree species

Species	Seed moisture content (%)	Seed germination test (%)				Seedling vigor class. (%)		Germination Index	X – ray test (%)	
		Normal	Abnormal	Empty	Ungerm.	Strong	Weak		Viable	Non viable
1. *Bridelia retusa*	13.00 ±0.22	-	-	-	100	-	-	-	49 ±5.00	51 ±5.00
2. *Cratoxylum formosum*	13.30 ±0.13	-	-	-	100	-	-	-	53 ±4.16	47 ±4.16
3. *Lannea coromandelica*	14.79 ±0.40	14 ±1.63	-	13 ±2.58	73 ±1.15	12 ±1.00	2 ±1.91	3.43 ±1.33	37 ±2.75	63 ±2.75
4. *Buchanania lanzan*	11.27 ±0.31	17 ±4.43	1 ±1.15	-	82 ±3.4 0	15 ±3.42	2 ±1.15	6.11 ±2.85	-	-
5. *Morinda elliptica*	10.33 ±0.51	17 ±2.58	-	-	83 ±2.58	16 ±1.00	1 ±1.91	3.36 ±1.50	-	-
6. *Schleichera oleosa*	25.60 ±0.97	19 ±2.58	-	-	81 ±2.58	19 ±2.58	-	2.99 ±1.05	78 ±3.50	22 ±3.50
7. *Phyllanthus emblica*	15.17 ±0.25	20 ±5.74	1 ±3.00	-	79 ±7.75	18 ±4.43	2 ±1.63	3.09 ±1.41	58 ±7.55	42 ±7.55
8. *Irvingia malayana*	7.91 ±0.52	29 ±1.91	1 ±1.15	-	70 ±3.00	21 ±3.46	8 ±2.52	2.78 ±1.44	69 ±2.22	31 ±2.22
9. *Shorea roxburghii*	48.17 ±0.25	33 ±4.76	3 ±1.15	-	64 ±4.90	31 ±3.46	2 ±1.63	5.91 ±1.38	-	-
10. *Lagerstroemia floribunda*	10.86 ±0.33	34 ±5.89	-	-	66 ±5.89	29 ±4.76	5 ±1.15	5.22 ±0.89	66 ±4.30	34 ±4.30
11. *Canarium subulatum*	7.71 ±0.07	36 ±4.32	10 ±2.52	-	54 ±5.51	24 ±3.65	12 ±2.83	10.89 ±1.76	76 ±4.43	24 ±4.43
12. *Chukrasia tabularis*	13.32 ±0.33	36 ±3.42	-	-	64 ±3.42	34 ±2.52	2 ±1.63	14.16 ±2.69	64 ±5.91	36 ±5.91
13. *Vitex pinnata*	14.66 ±0.10	37 ±3.42	-	-	63 ±3.42	35 ±4.43	2 ±1.63	4.54 ±1.23	75 ±3.42	25 ±3.42
14. *Shorea obtusa*	42.27 ±0.28	42 ±5.16	2 ±1.63	-	56 ±3.65	38 ±3.42	4 ±1.91	26.61 ±3.33	-	-
15. *Ochna integerrima*	31.47 ±1.28	44 ±2.52	24 ±2.83	-	32 ±3.00	33 ±3.83	11 ±1.91	11.22 ±2.00	76 ±3.42	24 ±3.42
16. *Gardenia sootepensis*	9.64 ±0.36	46 ±4.83	1 ±0.58	-	53 ±5.26	43 ±5.80	3 ±2.38	6.48 ±1.01	79 ±4.76	21 ±4.76
17. *Cratoxylum cochinchinensis*	21.39 ±0.11	53 ±5.51	2 ±1.63	-	45 ±5.26	53 ±5.51	-	14.30 ±4.00	84 ±3.42	16 ±3.42

Table 4.39 (cont.)

Species	Seed moisture content (%)	Seed germination test (%)				Seedling vigor class. (%)		Germination Index	X – ray test (%)	
		Normal	Abnormal	Empty	Ungerm.	Strong	Weak		Viable	Non viable
18. *Rothmannia wittii*	15.89 ±0.34	63 ±5.29	2 ±2.31	-	35 ±4.76	58 ±3.79	5 ±4.43	7.61 ±2.66	88 ±3.65	12 ±3.65
19. *Diospyros ehretioides*	39.17 ±0.59	66 ±4.43	1 ±1.91	-	33 ±2.58	58 ±5.97	8 ±1.63	20.13 ±4.39	-	-
20. *Strychnos nux-vomica*	17.51 ±0.73	76 ±6.32	2 ±1.91	-	22 ±8.22	70 ±7.55	6 ±1.91	30.69 ±4.96	98 ±1.92	2 ±1.92
21. *Haldina cordifolia*	12.06 ±0.06	77 ±5.71	-	-	23 ±5.71	75 ±5.00	2 ±1.29	20.07 ±3.66	-	-
22. *Dipterocarpus intricatus*	35.59 ±1.17	78 ±5.97	1 ±1.00	-	21 ±6.83	75 ±8.23	3 ±2.58	52.89 ±10.46	91 ±3.46	9 ±3.46
23. *Aporosa villosa*	50.02 ±0.32	85 ±6.22	1 ±1.15	-	14 ±5.66	79 ±9.31	6 ±4.32	17.05 ±1.42	90 ±4.12	10 ±4.12
24. *Memecylon edule*	40.66 ±0.40	89 ±3.00	1 ±3.00	-	10 ±2.83	82 ±3.42	7 ±1.15	6.42 ±2.77	98 ±1.63	2 ±1.63
25. *Pterocarpus macrocarpus*	9.87 ±0.13	90 ±4.43	2 ±1.63	-	8 ±5.26	72 ±4.43	18 ±2.83	36.32 ±6.47	98 ±1.63	2 ±1.63
26. *Senna garrettiana*	8.96 ±0.08	93 ±1.00	5 ±1.15	-	2 ±1.00	86 ±2.31	7 ±1.91	71.25 ±0.69	96 ±1.63	4 ±1.63
27. *Careya sphaerica*	41.53 ±0.66	94 ±2.31	4 ±1.91	-	2 ±2.52	92 ±4.32	2 ±2.83	27.86 ±2.48	97 ±1.92	3 ±1.92
28. *Albizia lebbeck*	8.80 ±0.57	95 ±3.46	1 ±1.15	-	4 ±4.32	86 ±2.83	9 ±1.15	79.17 ±9.18	96 ±2.16	4 ±2.16
29. *Bauhinia racemosa*	15.29 ±0.16	97 ±1.15	-	-	3 ±1.15	92 ±2.52	5 ±2.52	46.43 ±4.52	-	-
30. *Artocarpus lacucha*	38.63 ±1.12	97 ±1.91	1 ±1.00	-	2 ±1.63	93 ±2.58	4 ±1.00	14.82 ±0.59	99 ±1.92	1 ±1.92
31. *Erythrophleum succirubrum*	8.85 ±0.23	98 ±1.91	-	-	2 ±2.31	72 ±3.65	26 ±1.91	45.61 ±2.64	99 ±1.15	1 ±1.15
32. *Wrightia arborea*	8.68 ±0.11	98 ±1.63	1 ±1.00	-	1 ±1.00	97 ±1.15	1 ±1.15	35.38 ±3.28	99 ±1.15	1 ±1.15

Note : Ungerm. = Ungerminated
Seedling vigor class. = Seedling vigor classification

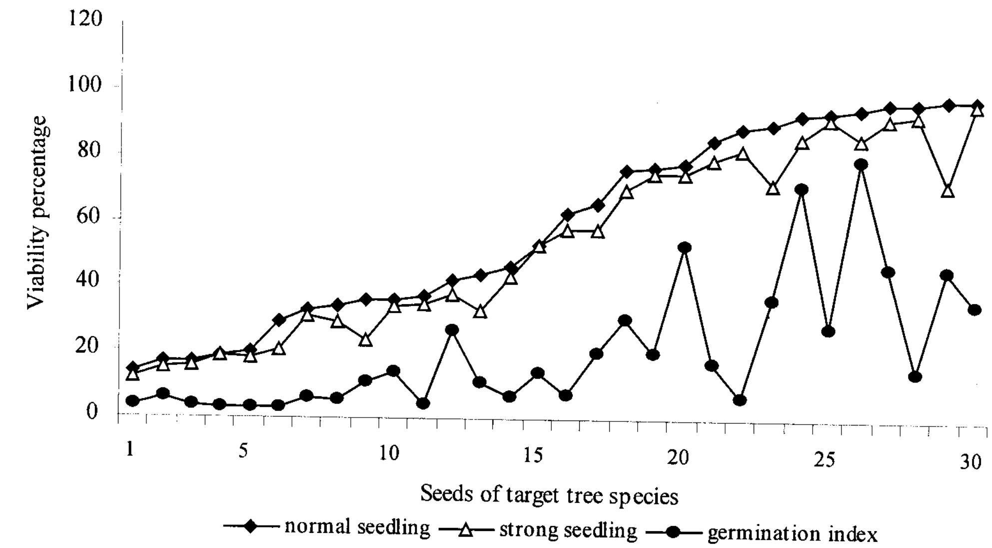


Figure 4.38 Comparison of results of seedling vigor classification and germination index with standard germination test of target tree species

Note : 1 = *L. coromamdelica,* 2 = *B. lanzan,* 3 = *M. elliptica,* 4 = *S. oleosa,* 5 = *P. emblica,* 6 = *I. malayana,* 7 = *S. roxburghii,* 8 = *L. floribunda,* 9 = *C. subulatum,* 10 = *C. tabularis,* 11 = *V. pinnata,* 12 = *S. obtusa,* 13 = *O. integerrima,* 14 = *G. sootepensis,* 15 = *C. cochinchinensis,* 16 = *R. wittii,* 17 = *D. ehretioides,* 18 = *S. nux-vomica,* 19 = *H. cordifolia,* 20 = *D. intricatus,* 21 = *A. villosa,* 22 = *M. edule,* 23 = *P. macrocarpus,* 24 = *S. garrettiana,* 25 = *C. sphaerica,* 26 = *A. lebbeck,* 27 = *B. racemosa,* 28 = *A. lacucha,* 29 = *E. succirubrum,* 30 = *W. arborea*

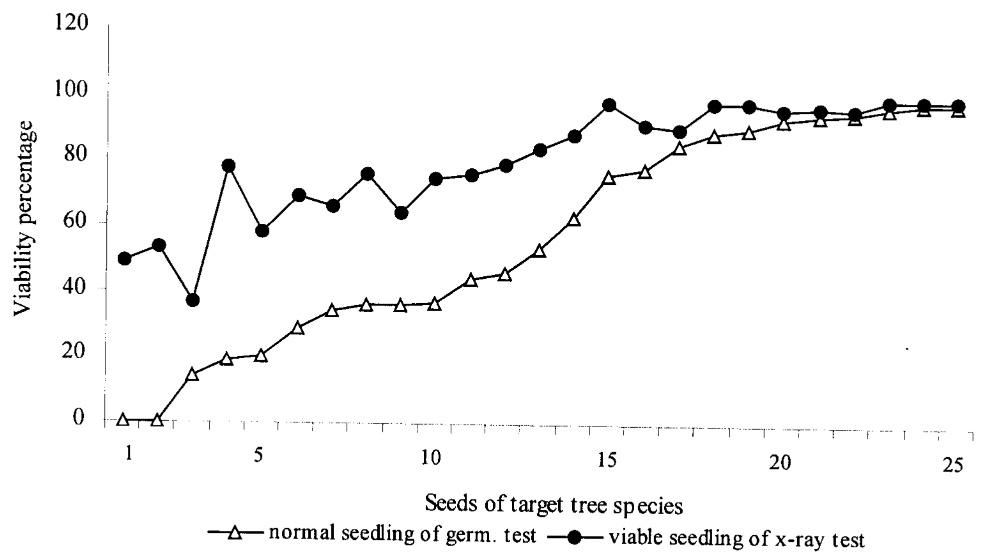


Figure 4.39 Comparison of results of X-ray test with standard germination test of target tree species

Note : 1 = *B. retusa,* 2 = *C. formosum,* 3 = *L. coromamdelica* 4 = *S. oleosa,* 5 = *P. emblica,* 6 = *I. malayana,* 7 = *L. floribunda,* 8 = *C. subulatum,* 9 = *C. tabularis,* 10 = *V. pinnata* 11 = *O. integerrima,* 12 = *G. sootepensis,* 13 = *C. cochinchinensis,* 14 = *R. wittii,* 15 = *S. nux-vomica,* 16 = *D. intricatus,* 17 = *A. villosa,* 18 = *M. edule,* 19 = *P. macrocarpus,* 20 = *S. garrettiana,* 21 = *C. sphaerica,* 22 = *A. lebbeck,* 23 = *A. lacucha,* 24 = *E. succirubrum,* 25 = *W. arborea*

4.5.2 Seed Quality of dominant tree species

Similar the topic of 4.3.1, the four dominant tree species consisted of *Shorea siamensis, Xylia xylocarpa, Ellipanthus tomentosus,* and *Sindora siamensis* which were used to compare seed quality testing.

For *Shorea siamensis*, analysis of variance showed significant differences in normal seedling and highly significant differences in X-ray test among 3 types, but there were no significant differences in seed moisture content, seedling vigor classification and germination index (Table 4.40). For the mean normal seedling percentage and the mean viable seed percentage, it was found that Y-Y type (89 %, 95 %) was higher than R-R type (87 %, 94 %) and Y-R type (80 %, 90 %), respectively (Table 4.44). It points out that there were variations in germination among seed types and Y-Y type showed the highest germination percentage. The results showed high seed germination of 80-89 %, high strong seedling of 75-80 % and high viable seeds of 90-95 % of all 3 types, but there were rather low values in germination index of 18.40-29.38 which affected these seeds (low speed of germination).

The analysis of variance of *Xylia xylocarpa* showed highly significant differences in seed moisture content, normal and ungerminated seedling, strong and weak seedling and germination index among 4 individual trees, while there were no significant differences in X-ray test (Table 4.41). Among individual trees, the mean seed moisture content was 13.41 % in No. 3, 12.53 % in No. 1, 12.03 % in No. 2 and 10.41 % in No. 4. For the mean normal seedling percentage and strong seedling percentage, it was found that No. 2 was higher than No.1, 3 and No. 4, respectively. The mean germination index was 48.03 in No. 2, 40.51 in No. 1, 33.74 in No. 3 and 30.58 in No. 4 (Table 4.44). The results showed that there was great variation in the total germination among individual trees. This was due to the different vigor of seeds in each individual trees. However, all of them showed high seed quality in seed germination (82-95 %), seedling vigor classification (62-89 %), germination index (30.58-48.03) and viable seeds (95-98 %). It indicated that these seed lots had the good properties and availability of high quality parent trees.

As shown in Table 4.42, the analysis of variance of *Ellipanthus tomentosus* showed significant differences in seed moisture content, and highly significant differences in abnormal and ungerminated seedling, and X-ray test among 4 individual trees, but there were no significant differences in normal seedling, seedling vigor classification and germination index. Among individual trees, the mean seed moisture content was 72.22 % in No.2, 68.80 % in No.4, 64.53 % in No. 3 and 62.94 % in No.1. For the mean viable seed percentage, it was found that No. 4 (35 %) was higher than No.1 (31 %), No.3 (30 %) and No.2 (22 %), respectively (Table 4.44). It appeared that there was not variation germination among individual trees, although there were highly significant differences in X-ray test, this probably was due to overestimate of the X-radiography test. For all individual trees, the results gave very low percentage of seed germination (15-18 %), strong seedling (8-12 %), germination index (2.94-3.60) and viable seed (22-35 %). This was due to the attack of insects as showed in the results of non viable seeds in the X-radiography test (Appendix V, Figure 2).

For *Sindora siamensis*, analysis of variance showed significant differences in seed moisture content, normal and ungerminated seedling and highly significant differences in seedling vigor classification and germination index among 2 types, while there were no significant differences in X-ray test as revealed in Table 4.43.

Among 2 types, the mean seed moisture content was 12.44 % in *Si. siamensis* v. *siamensis* and 11.46 % in *Si. siamensis* v. *maritima*. The mean normal seedling percentage, strong seedling percentage and germination index were 93 %, 87 %, 62.02 in *Si. siamensis* v. *maritima* and were 85 %, 72 %, 37.03 in *Si. siamensis* v. *siamensis*, respectively (Table 4.44). It indicated that the seeds of *Si. siamensis* v. *maritima* gave better germination and vigor than *Si. siamensis* v. *siamensis*. The results showed that two of varieties had the good seed properties and availability of high quality parent trees.

When comparing seedling vigor classification and germination index with standard germination test in all dominant tree species, it was found that the results showed in the same direction (Figure 4.40). While comparing the results of the X-ray tests with the standard germination test, it indicated that the X-ray tests had higher viable seeds of all dominant tree species of. 32.08 % average as illustrated in Figure 4.41. The details of seed quality testing were given in Appendix V.

Table 4.40 The analysis of variance of seed moisture content, seed germination, seed vigor, and seed viability of *Shorea siamensis*

Sources	df	SS	MS	F
Seed moisture content				
Type	2	15.9453	7.97	2.85 ^{ns}
Error	9	25.2096	2.80	
Normal seeds				
Types	2	178.6667	89.33	6.70 *
Error	9	120.0000	13.33	
Abnormal seeds				
Individual trees	2	32.0000	16.00	1.29 ^{ns}
Error	9	112.0000	12.44	
Ungerminated seeds				
Types	2	98.6667	49.33	1.79 ^{ns}
Error	9	248.0000	27.56	
Strong seedlings				
Varieties	2	56.0000	28.00	1.24 ^{ns}
Error	9	204.0000	22.67	
Weak seedlings				
Types	2	138.6667	69.33	3.18 ^{ns}
Error	9	196.0000	21.78	
Germination index				
Types	2	270.9997	135.50	3.54 ^{ns}
Error	9	344.9366	38.33	
Viable seeds				
Types	2	64.6667	32.33	8.03 **
Error	9	36.2500	4.03	
Non viable seeds				
Types	2	64.6667	32.33	8.03 **
Error	9	36.2500	4.03	

^{ns} non significant.

* significant difference at the 0.05 confidence level.

** significant difference at the 0.01 confidence level.

Table 4.41 The analysis of variance of seed moisture content, seed germination, seed vigor, and seed viability of *Xylia xylocarpa*

Sources	df	SS	MS	F
Seed moisture content				
Type	3	18.9919	6.33	36.96 **
Error	12	2.0552	0.17	
Normal seeds				
Types	3	394.7500	131.58	7.78 **
Error	12	203.0000	16.92	
Abnormal seeds				
Individual trees	3	29.0000	9.67	0.95 ^{ns}
Error	12	112.0000	10.17	
Ungerminated seeds				
Types	3	210.7500	70.25	6.24 **
Error	12	135.0000	11.25	
Strong seedlings				
Varieties	3	1568.7500	522.92	18.40 **
Error	12	341.0000	28.42	
Weak seedlings				
Types	3	499.0000	166.33	8.46 **
Error	12	236.0000	19.67	
Germination index				
Types	3	720.1190	240.04	18.27 **
Error	12	157.6588	13.14	
Viable seeds				
Types	3	16.6875	5.56	2.07 ^{ns}
Error	12	32.2500	2.69	
Non viable seeds				
Types	3	16.6875	5.56	2.07 ^{ns}
Error	12	32.2500	2.69	

^{ns} non significant.

** significant difference at the 0.01 confidence level.

Table 4.42 The analysis of variance of seed moisture content, seed germination, seed vigor, and seed viability of *Ellipanthus tomentosus*

Sources	df	SS	MS	F
Seed moisture content				
Type	3	212.0614	70.69	5.53 *
Error	12	153.2536	12.77	
Normal seeds				
Types	3	20.7500	6.92	0.24 ns
Error	12	343.0000	28.58	
Abnormal seeds				
Individual trees	3	1533.0000	511.00	9.80 **
Error	12	626.0000	52.17	
Ungerminated seeds				
Types	3	1602.7500	534.25	6.12 **
Error	12	1047.0000	87.25	
Strong seedlings				
Varieties	3	65.0000	21.67	1.02 ns
Error	12	254.0000	21.17	
Weak seedlings				
Types	3	66.7500	22.25	1.77 ns
Error	12	151.0000	12.58	
Germination index				
Types	3	1.4359	0.48	0.16 ns
Error	12	35.6367	2.97	
Viable seeds				
Types	3	393.1875	131.06	15.01 **
Error	12	104.7500	8.73	
Non viable seeds				
Types	3	393.1875	131.06	15.01 **
Error	12	104.7500	8.73	

ns non significant.

** significant difference at the 0.01 confidence level.

Table 4.43 The analysis of variance of seed moisture content, seed germination, seed vigor, and seed viability of *Sindora siamensis*

Sources	df	SS	MS	F
Seed moisture content				
Type	1	1.9281	1.93	7.99 *
Error	6	1.4470	0.24	
Normal seeds				
Types	1	128.0000	128.00	9.60 *
Error	6	80.0000	13.33	
Abnormal seeds				
Individual trees	1	24.5000	24.50	3.77 ^{ns}
Error	6	39.0000	6.50	
Ungerminated seeds				
Types	1	40.5000	40.50	5.65 *
Error	6	43.0000	7.17	
Strong seedlings				
Varieties	1	450.0000	450.00	28.72 **
Error	6	94.0000	15.67	
Weak seedlings				
Types	1	98.0000	98.00	15.47 **
Error	6	38.0000	6.33	
Germination index				
Types	1	1249.0001	1249.00	27.98 **
Error	6	267.7928	44.63	
Viable seeds				
Types	1	8.0000	8.00	1.14 ^{ns}
Error	6	42.0000	7.00	
Non viable seeds				
Types	1	8.0000	8.00	1.14 ^{ns}
Error	6	42.0000	7.00	

^{ns} non significant.

* significant difference at the 0.05 confidence level.

** significant difference at the 0.01 confidence level.

Table 4.44 Seed moisture content, standard germination test, seed vigor tests, seed viability test and standard deviation of dominant tree species

Species	Seed moisture content (%)	Seed germination test (%)				Seedling vigor class. (%)		Germination Index	X – ray test (%)	
		Normal	Abnormal	Empty	Ungerm.	Strong	Weak		Viable	Non viable
Shorea siamensis										
S. siamensis (Y – Y)	46.61 ±0.81	89 ±2.00	6 ±4.00	-	5 ±5.03	76 ±3.27	13 ±5.03	29.38 ±0.85	95 ±1.71	5 ±1.71
S. siamensis (R – R)	49.34 ±2.20	87 ±2.00	4 ±3.27	-	9 ±2.00	80 ±4.62	7 ±3.83	27.22 ±5.57	94 ±1.71	6 ±1.71
S. siamensis (Y – R)	48.60 ±1.71	80 ±5.66	8 ±3.27	-	12 ±7.30	75 ±6.00	5 ±5.03	18.40 ±9.12	90 ±2.50	10 ±2.50
LSD $_{0.05}$	-	5.84	-	-	-	-	-	-	3.21	3.21
LSD $_{0.01}$									4.61	4.61
Xylia xylocarpa										
X. xylocarpa (No.1)	12.53 ±0.27	85 ±4.16	4 ±3.27	-	11 ±3.46	75 ±5.97	10 ±5.00	40.51 ±1.99	98 ±1.71	2 ±1.71
X. xylocarpa (No.2)	12.03 ±0.71	95 ±1.15	2 ±1.91	-	3 ±1.91	89 ±3.79	6 ±3.00	48.03 ±3.03	95 ±2.00	5 ±2.00
X. xylocarpa (No.3)	13.41 ±0.26	85 ±5.51	4 ±3.79	-	11 ±3.83	75 ±6.00	10 ±5.74	33.74 ±5.54	96 ±1.71	4 ±1.71
X. xylocarpa (No.4)	10.41 ±0.19	82 ±4.32	5 ±3.46	-	13 ±3.83	62 ±5.26	20 ±3.42	30.58 ±2.96	96 ±0.96	4 ±0.96
LSD $_{0.05}$	0.64	6.34	-	-	5.17	8.21	6.83	5.58	-	-
LSD $_{0.01}$	0.89	8.89			7.25	11.52	9.58	7.83		

Table 4.44 (cont.)

Species	Seed moisture content (%)	Seed germination test (%)				Seedling vigor class. (%)		Germination Index	X – ray test (%)	
		Normal	Abnormal	Empty	Ungerm.	Strong	Weak		Viable	Non viable
Ellipanthus tomentosus										
E. tomentosus (No.1)	62.94 ±2.35	15 ±4.76	10 ±1.91	-	75 ±6.40	12 ±5.42	3 ±1.15	3.55 ±1.59	31 ±3.30	69 ±3.30
E. tomentosus (No.2)	72.22 ±1.10	16 ±3.42	36 ±11.82	-	48 ±9.93	8 ±2.52	8 ±4.32	2.94 ±1.37	22 ±3.70	78 ±3.70
E. tomentosus (No.3)	64.53 ±2.68	16 ±6.32	28 ±2.83	-	56 ±8.64	8 ±4.00	8 ±3.65	3.01 ±1.93	30 ±2.38	70 ±2.38
E. tomentosus (No.4)	68.80 ±6.09	18 ±6.32	23 ±7.57	-	59 ±11.60	11 ±5.74	7 ±4.12	3.60 ±1.93	35 ±2.16	65 ±2.16
LSD $_{0.05}$	5.51	-	11.13	-	14.39	-	-	-	4.55	4.55
LSD $_{0.01}$			15.60		20.18				6.38	6.38
Sindora siamensis										
S. siamensis v. *siamansis*	12.44 ±0.36	85 ±3.46	5 ±3.46	-	10 ±2.31	72 ±4.43	13 ±1.00	37.03 ±6.74	96 ±3.27	4 ±3.27
S. siamensis v. *maritima*	11.46 ±0.59	93 ±3.83	2 ±1.00	-	5 ±3.00	87 ±3.42	6 ±3.42	62.02 ±6.62	98 ±1.83	2 ±1.83
LSD $_{0.05}$	0.85	6.32	-	-	4.63	6.85	4.35	11.56	-	-
LSD $_{0.01}$						10.38	6.59	17.51		

Note : Y – Y = type of *S. siamensis* show yellow peduncle, yellow wing

R – R = type of *S. siamensis* show red peduncle, red wing

Y – R = type of S. siamensis show yellow peduncle, red wing

Ungerm. = Ungerminated

Seedling vigor class. = Seedling vigor classification

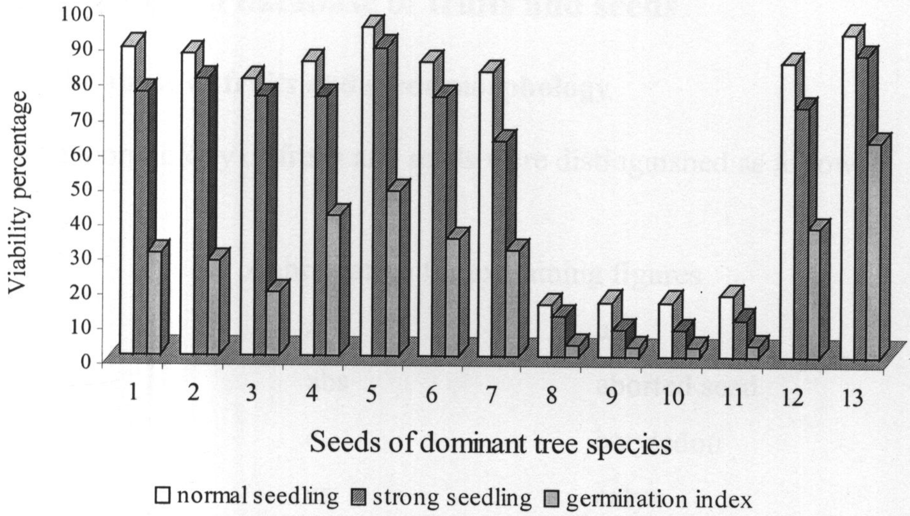


Figure 4.40 Comparison of results of seedling vigor classification and germination index with standard germination test of dominant tree species

Note : 1 = *Shorea siamensis* (Y-Y), 2 = *Sh. siamensis* (R-R), 3 = *Sh. siamensis* (Y-R), 4 = *X. xylocarpa* (no.1), 5 = *X. xylocarpa* (no.2), 6 = *X. xylocarpa* (no.3), 7 = *X. xylocarpa* (no.4), 8 = *E. tomentosus* (no.1), 9 = *E. tomentosus* (no.2), 10 = *E. tomentosus* (no.3), 11 = *E. tomentosus* (no.4), 12 = *Sindora siamensis v. siamansis*, 13 = *Sindora siamensis v. maritima*

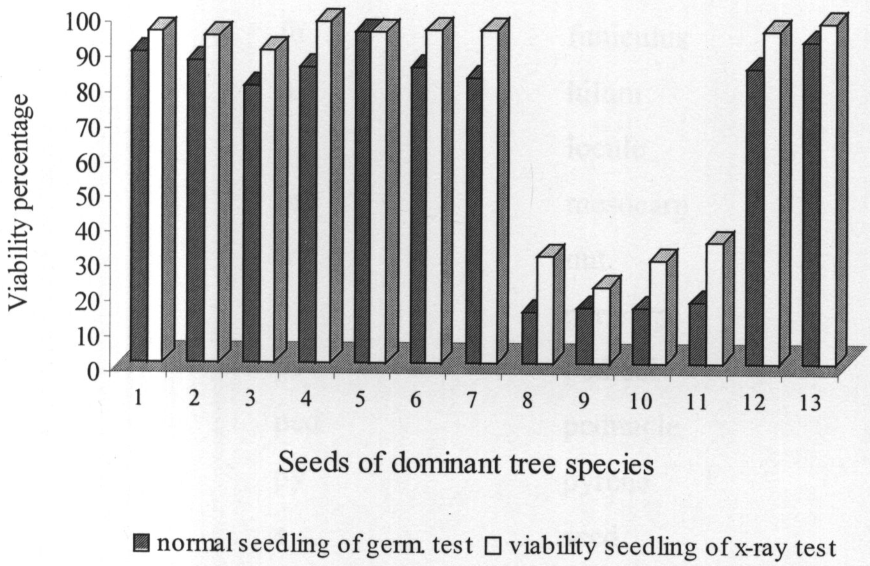


Figure 4.41 Comparison of results of X-ray test with standard germination test of dominant tree species

Note : 1 = *Shorea siamensis* (Y-Y), 2 = *Sh. siamensis* (R-R), 3 = *Sh. siamensis* (Y-R), 4 = *X. xylocarpa* (no.1), 5 = *X. xylocarpa* (no.2), 6 = *X. xylocarpa* (no.3), 7 = *X. xylocarpa* (no.4), 8 = *E. tomentosus* (no.1), 9 = *E. tomentosus* (no.2), 10 = *E. tomentosus* (no.3), 11 = *E. tomentosus* (no.4), 12 = *Sindora siamensis v. siamansis*, 13 = *Sindora siamensis v. maritima*

4.6 Morphological database of fruits and seeds

4.6.1 Database of fruits and seeds morphology

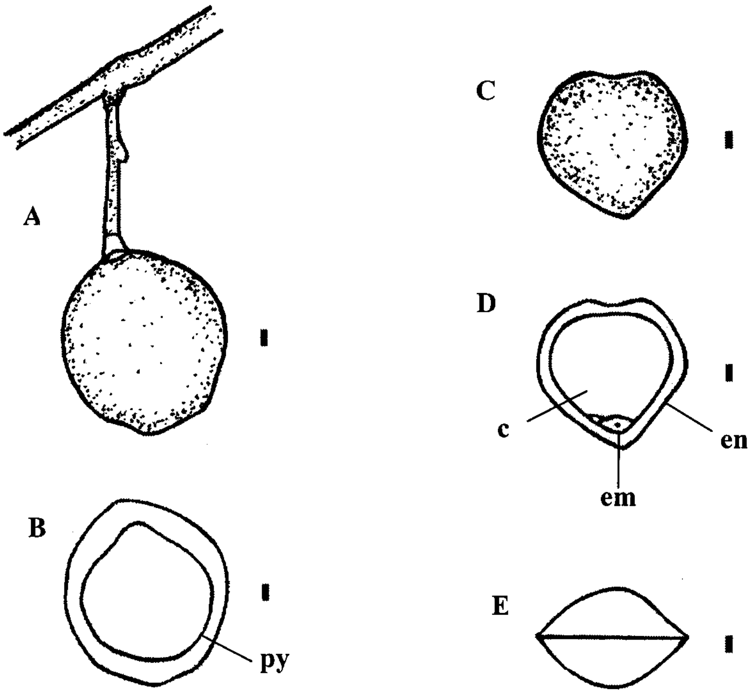
The morphology of fruits and seeds were distinguished as follows :

Abbreviation for explaining figures

a	aril
abs	aborted seed
c	cotyledon
ca	calyx
co	coma
ct	calyx tube
em	embryo
en	endocarp
end	endosperm
ex	exocarp
f	fruit
fu	funiculus
h	hilum
l	locule
me	mesocarp
n	nut
p	pericarp
pe	pedicel
ped	peduncle
py	pyrene
s	seed
sa	sarcotesta
se	sepal
st	stigma
t	testa
w	wing

1. ANACARDIACEAE

Buchanania lanzan Spreng.



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. pyrene ; D. longitudinal section through pyrene ; E. transverse section through pyrene.

Scale bars : 1 mm units.

Dispersal Unit : fruit Collection Date : 9 / 04 / 2000 Specimen No. : 012

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : light green Ripe color : purple - black

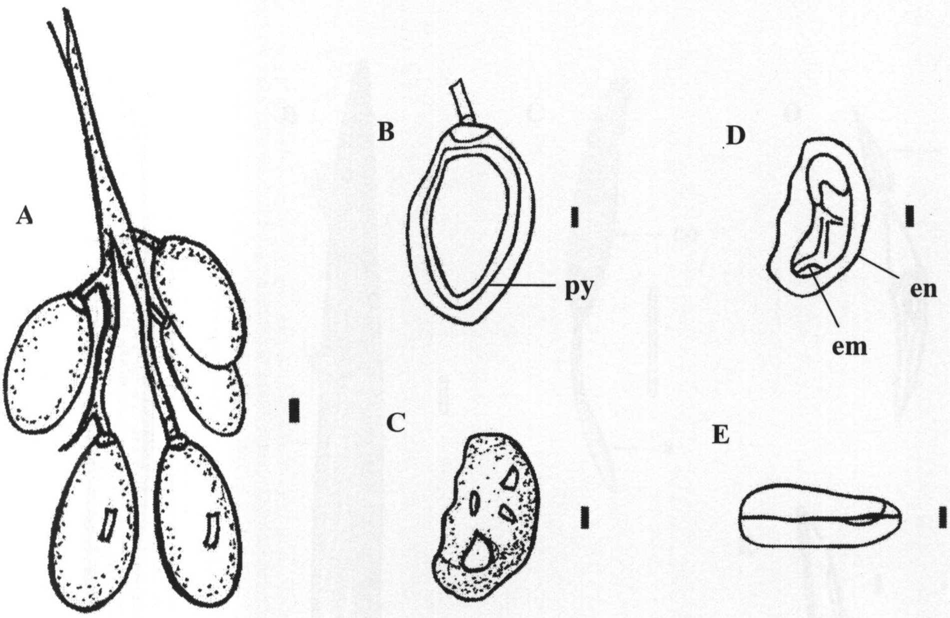
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 4,524

	FRUIT (Mean)	SEED (Mean)
Length	12.758 mm ± 1.315	9.561 mm ± 0.852
Width	11.247 mm ± 0.965	9.280 mm ± 1.133
Thickness	9.572 mm ± 0.804	6.603 mm ± 0.543
Wet weight		5.105 g ± 0.030
Dry weight		4.530 g ± 0.042
% moisture		11.270 % ± 0.309
1000 seed weight		221.033 g ± 13.597

<u>SEEDS</u> Testa : muricate External color : light brown

2. ANACARDIACEAE

Lannea coromandelica (Houtt.) Merr.



Legend Fruits and seeds. A. part of an infructescence ; B. longitudinal section through fruit ; C. pyrene; D. longitudinal section through pyrene; E. transverse section through pyrene.

Scale bars : 1 mm units.

Dispersal Unit : fruit Collection Date : 8 / 04 / 2000 Specimen No. : 010

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : green Ripe color : dark red

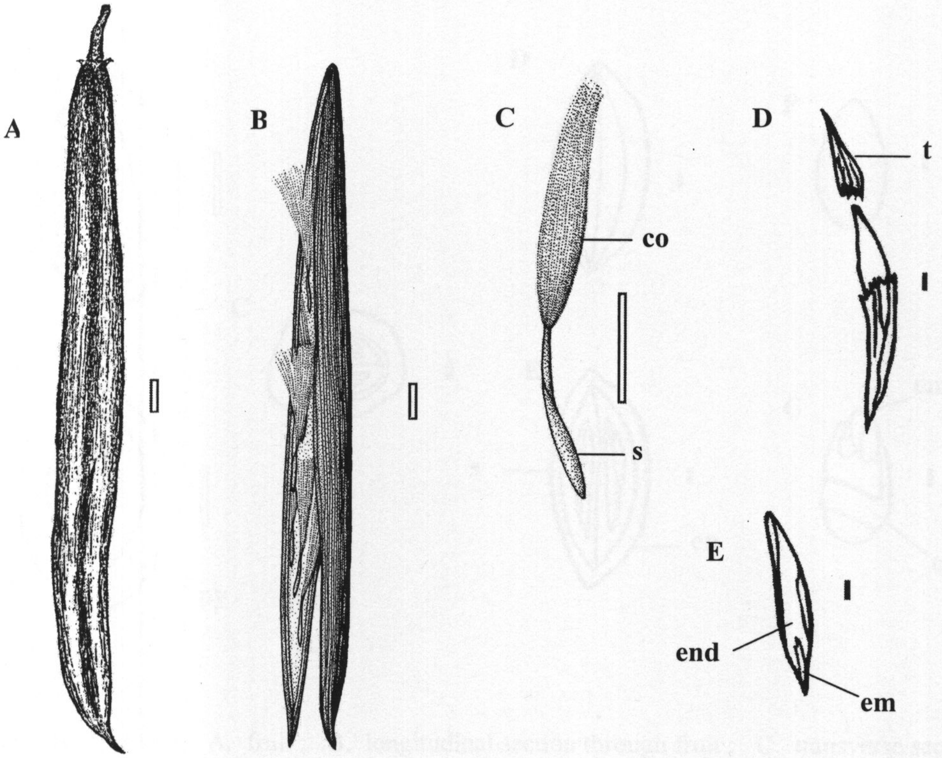
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 918

	FRUIT (Mean)	SEED (Mean)
Length	12.189 mm ± 0.889	9.280 mm ± 0.916
Width	8.249 mm ± 0.474	6.807 mm ± 0.673
Thickness	6.232 mm ± 0.535	4.675 mm ± 0.549
Wet weight		5.097 g ± 0.049
Dry weight		4.343 g ± 0.049
% moisture		14.794 % ± 0.403
1000 seed weight		108.932 g ± 19.748

<u>SEEDS</u> Testa : reticulate coat External color : light brown

3. APOCYNACEAE

Wrightia arborea (Dennst.) Mabb.



Legend Fruits and seeds. A. fruit ; B. fruit spit into two at dehiscent ; C. seed with coma ; D. seed with testa ; E. longitudinal section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 5 / 03 / 2000 Specimen No. : 001

<u>FRUITS</u> Class : dry dehiscent Type : connate follicles

Unripe color : green Ripe color : dark brown

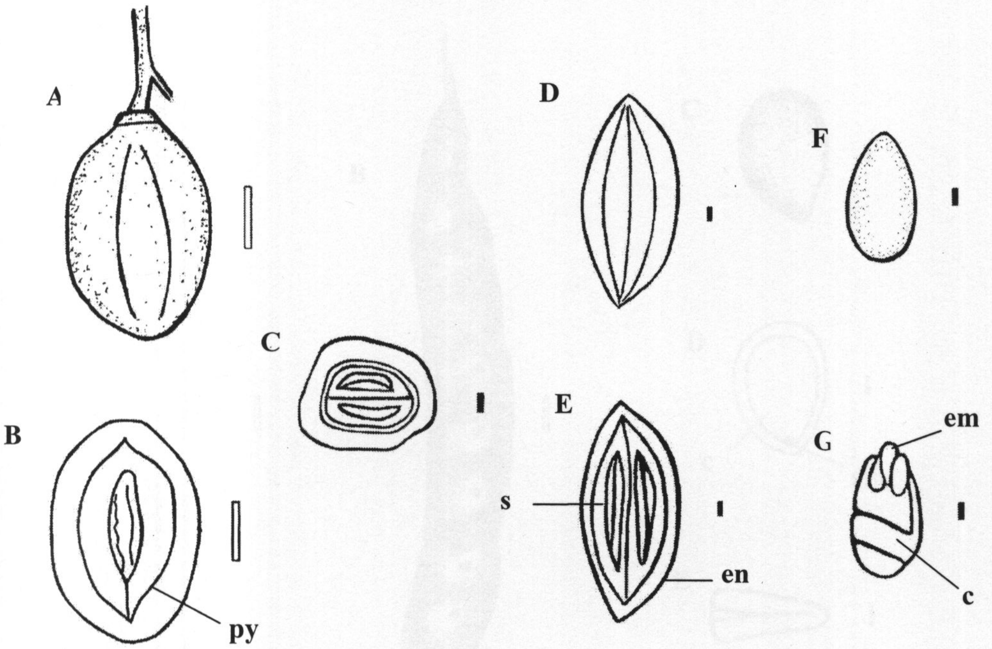
No. seeds per fruit : Max : 374, Min : 44, No. of seed / kg : 51,538

	FRUIT (Mean)	SEED (Mean)
Length	214.932 mm ± 27.288	12.642 mm ± 2.339
Width	17.752 mm ± 1.500	2.132 mm ± 0.190
Thickness	13.130 mm ± 1.489	1.638 mm ± 0.164
Wet weight		5.120 g ± 0.015
Dry weight		4.675 g ± 0.019
% moisture		8.682 % ± 0.110
1000 seed weight		19.404 g ± 0.269

<u>SEEDS</u> Testa : smooth External color : yellow

4. BURSERACEAE

Canarium subulatum Guillaumin



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. transverse section through fruit ; D. pyrene ; E. longitudinal section through pyrene ; F. seed ; G. longitudinal section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 5 / 08 / 2000 Specimen No. : 021

FRUITS Class : fleshy Type : drupe

Unripe color : light green Ripe color : yellowish - green

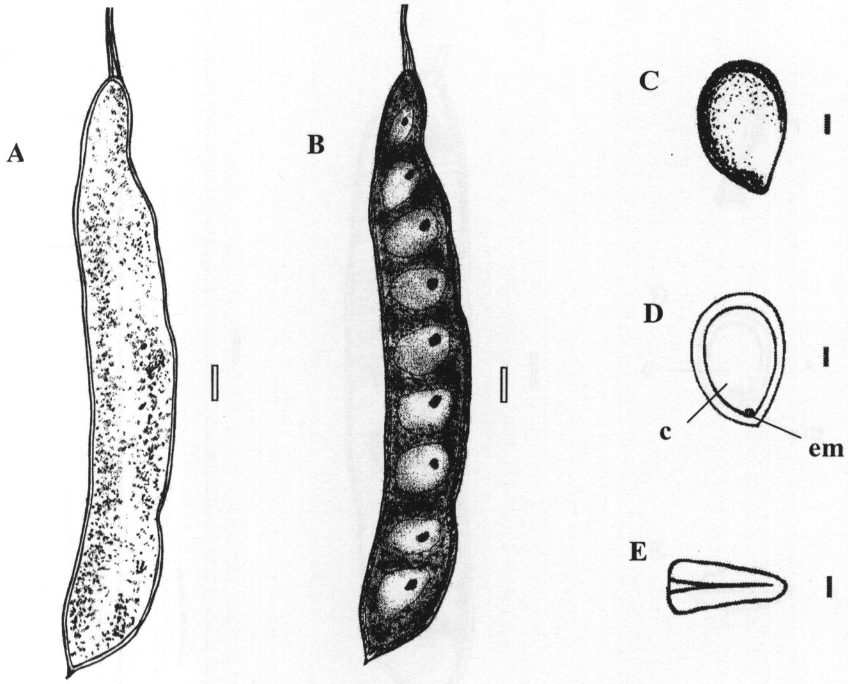
No. seeds per fruit : Max : 3, Min : 1 No. of seed / kg : 6,260

	FRUIT (Mean)	SEED (Mean)
Length	37.979 mm ± 1.242	14.288 mm ± 0.862
Width	28.972 mm ± 1.230	8.054 mm ± 0.658
Thickness	27.879 mm ± 1.283	3.167 mm ± 0.319
Wet weight		5.053 g ± 0.017
Dry weight		4.663 g ± 0.016
% moisture		7.713 % ± 0.070
1000 seed weight		159.729 g ± 2.730

SEEDS Testa : smooth External color : brown

5. LEGUMINOSAE, CAESALPINIOIDEAE

Bauhinia racemosa Lam.



Legend Fruits and seeds. A. pod ; B. longitudinal section through part of pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : both Collection Date : 3 / 02 / 2002 Specimen No. : 037

FRUITS Class : dry dehiscent Type : pod

Unripe color : green Ripe color : dark brown

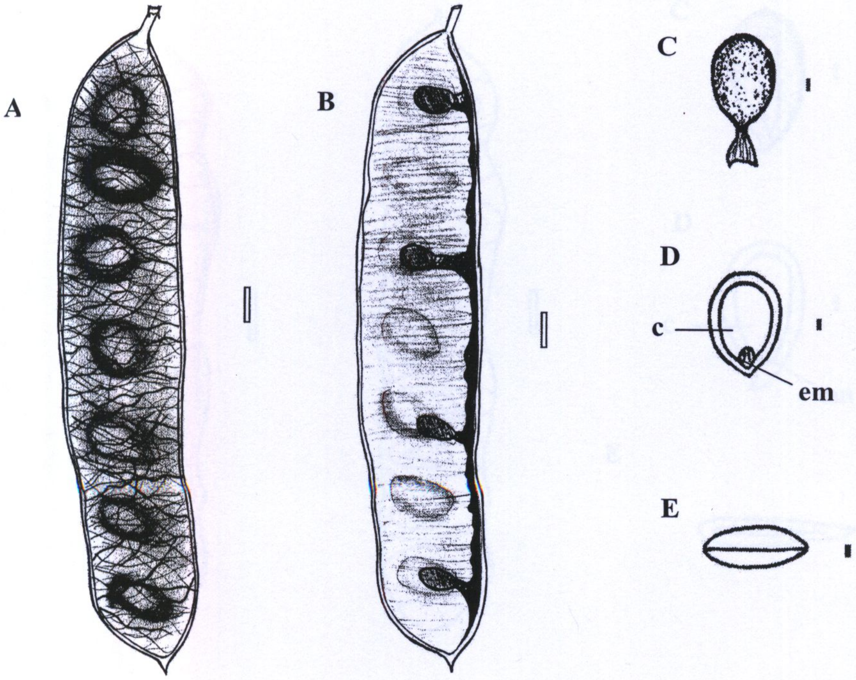
No. seeds per fruit : Max : 30, Min : 7 No. of seed / kg : 6,150

	FRUIT (Mean)	SEED (Mean)
Length	291.850 mm ± 68.454	10.423 mm ± 0.563
Width	26.657 mm ± 1.749	7.173 mm ± 0.297
Thickness	7.515 mm ± 0.715	3.662 mm ± 0.217
Wet weight		5.222 g ± 0.048
Dry weight		4.423 g ± 0.041
% moisture		15.295 % ± 0.160
1000 seed weight		162.614 g ± 6.449

SEEDS Testa : smooth External color : black

6. LEGUMINOSAE, CAESALPINIOIDEAE

Erythrophleum succirubrum Gagnep.



Legend Fruits and seeds. A. pod ; B. longitudinal section through part of pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : both Collection Date : 22 / 03 / 2000 Specimen No. : 006

FRUITS Class : dry dehiscent Type : pod

Unripe color : green Ripe color : dull brown

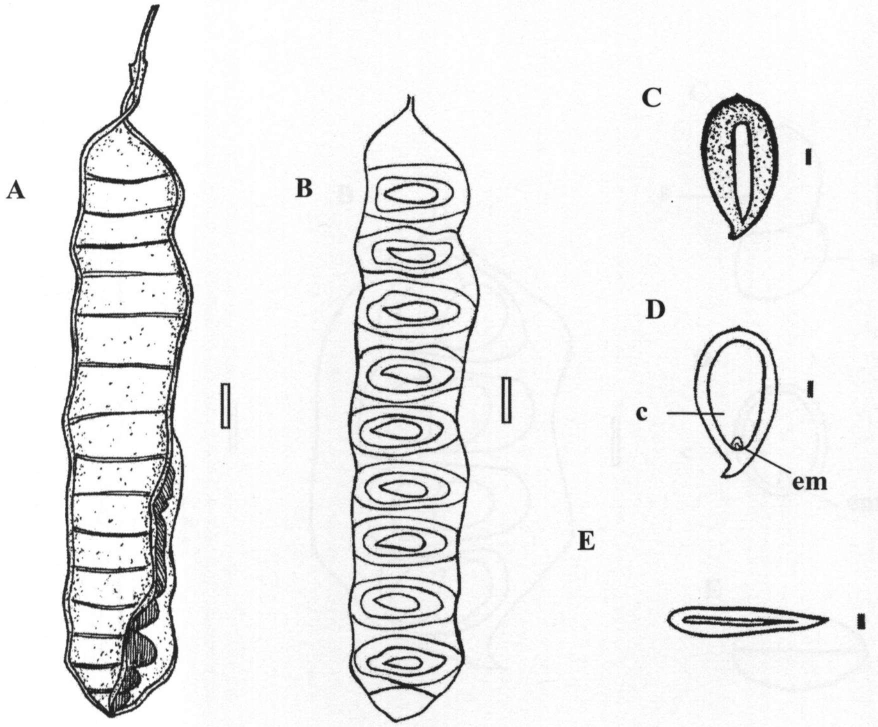
No. seeds per fruit : Max : 9, Min : 2 No. of seed / kg : 2,238

	FRUIT (Mean)	SEED (Mean)
Length	182.145 mm ± 34.121	12.409 mm ± 1.219
Width	37.711 mm ± 2.517	9.783 mm ± 1.059
Thickness	5.825 mm ± 0.347	4.693 mm ± 0.337
Wet weight		5.048 g ± 0.062
Dry weight		4.601 g ± 0.059
% moisture		8.851 % ± 0.228
1000 seed weight		446.819 g ± 6.465

SEEDS Testa : muricate External color : brown

7. LEGUMINOSAE, CAESALPINIOIDEAE

Senna garrettiana (Craib) Irwin & Barneby



Legend Fruits and seeds. A. pod ; B. longitudinal section through part of pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : both Collection Date : 19 / 11 / 2000 Specimen No. : 028

FRUITS Class : dry dehiscent Type : pod

Unripe color : green Ripe color : black

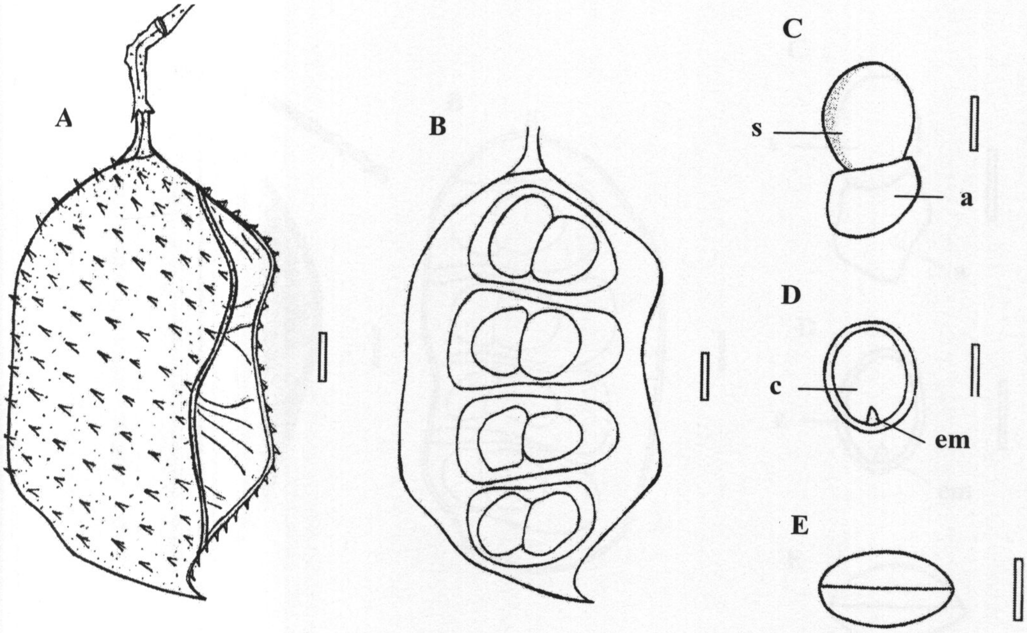
No. seeds per fruit : Max : 21, Min : 3 No. of seed / kg : 25,605

	FRUIT (Mean)	SEED (Mean)
Length	168.450 mm ± 20.351	9.800 mm ± 0.852
Width	37.138 mm ± 4.049	4.652 mm ± 0.523
Thickness	2.305 mm ± 0.468	1.201 mm ± 0.272
Wet weight		5.008 g ± 0.006
Dry weight		3.419 g ± 0.007
% moisture		8.960 % ± 0.077
1000 seed weight		39.055 g ± 1.459

SEEDS Testa : smooth External color : dark brown

8. LEGUMINOSAE, CAESALPINIOIDEAE

Sindora siamensis Teijsm. & Miq. var. *siamensis*



Legend Fruits and seeds. A. pod ; B. longitudinal section through part of pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : 1 cm units.

Dispersal Unit : both Collection Date : 9 / 09 / 2000 Specimen No. : 022

FRUITS Class : dry dehiscent Type : pod

Unripe color : dark green Ripe color : dark brown

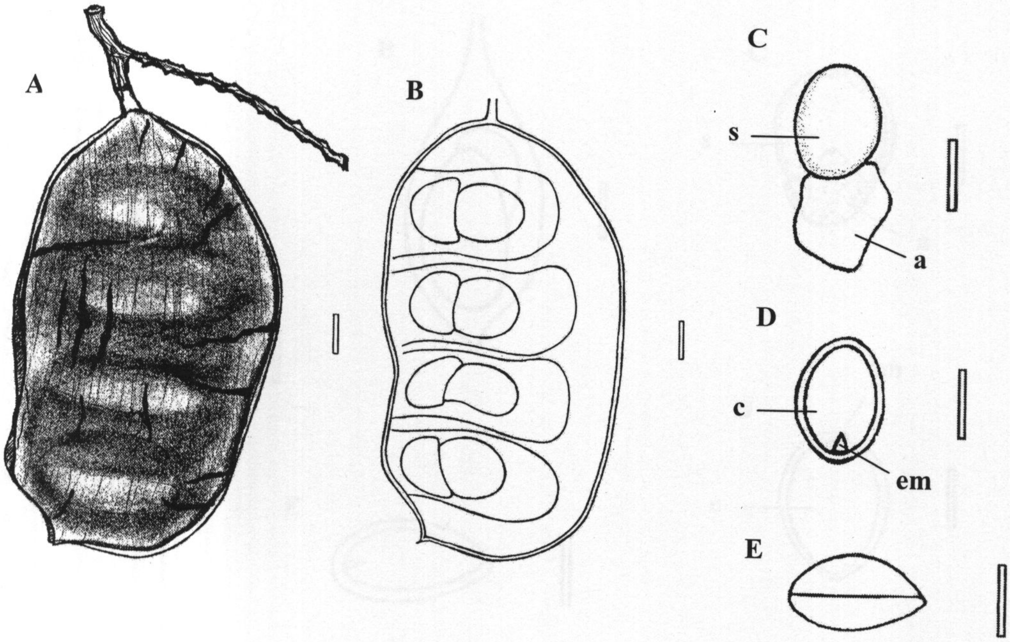
No. seeds per fruit : Max : 6, Min : 1 No. of seed / kg : 564

	FRUIT (Mean)	SEED (Mean)
Length	63.746 mm ± 15.745	17.018 mm ± 2.480
Width	48.095 mm ± 5.714	13.525 mm ± 1.485
Thickness	13.738 mm ± 1.421	10.751 mm ± 1.226
Wet weight		5.033 g ± 0.027
Dry weight		4.407 g ± 0.042
% moisture		12.440 % ± 0.359
1000 seed weight		1,773.087 g ± 139.864

SEEDS Testa : smooth, arillate External color : black

9. LEGUMINOSAE, CAESALPINIOIDEAE

Sindora siamensis Teijsm. & Miq. var. *maritima* (Pierre) K. & S.S. Larsen



Legend Fruits and seeds. A. pod ; B. longitudinal section through part of pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : 1 cm units.

Dispersal Unit : both Collection Date : 11 / 11 / 2000 Specimen No. : 026

FRUITS Class : dry dehiscent Type : pod

Unripe color : dark green Ripe color : dark brown

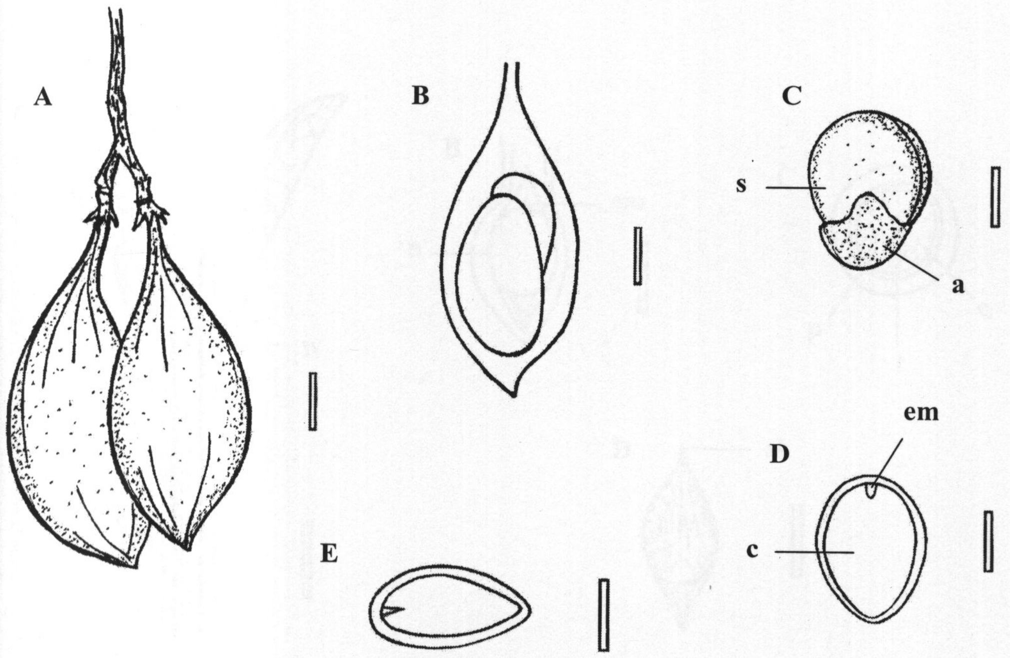
No. seeds per fruit : Max : 7, Min : 1 No. of seed / kg : 685

	FRUIT (Mean)	SEED (Mean)
Length	73.570 mm ± 18.262	17.217 mm ± 1.700
Width	52.994 mm ± 9.664	13.466 mm ± 1.686
Thickness	12.074 mm ± 0.533	9.266 mm ± 0.914
Wet weight		5.060 g ± 0.026
Dry weight		4.542 g ± 0.028
% moisture		10.237 % ± 0.460
1000 seed weight		1,460.226 g ± 42.898

SEEDS Testa : smooth, arillate External color : black

10. CONNARACEAE

Ellipanthus tomentosus Kurz var. *tomentosus*



Legend Fruits and seeds. A. part of an infructescence ; B. longitudinal section through fruit ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : 1 cm units.

Dispersal Unit : both Collection Date : 18 / 05 / 2000 Specimen No. : 017

<u>FRUITS</u> Class : dry dehiscent Type : follicle

Unripe color : green Ripe color : brown

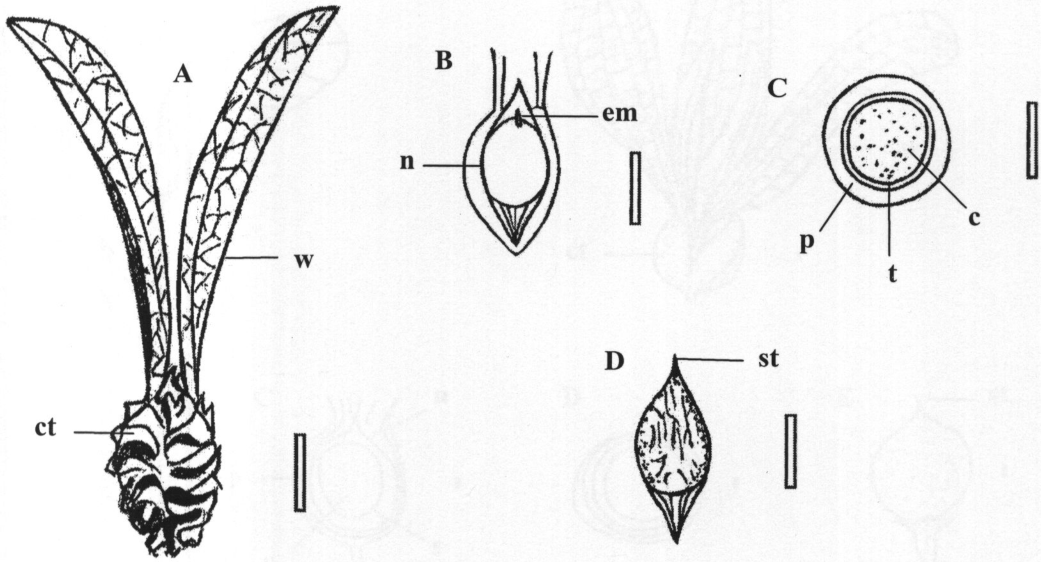
No. seeds per fruit : Max : 2, Min : 1 No. of seed / kg : 470

	FRUIT (Mean)	SEED (Mean)
Length	42.582 mm ± 2.781	25.046 mm ± 1.809
Width	22.854 mm ± 1.790	17.026 mm ± 1.202
Thickness	17.809 mm ± 1.500	11.784 mm ± 0.441
Wet weight		5.337 g ± 0.187
Dry weight		1.483 g ± 0.078
% moisture		72.219 % ± 1.098
1000 seed weight		2,128.035 g ± 112.124

<u>SEEDS</u> Testa : smooth, arillate External color : black

11. DIPTEROCARPACEAE

Dipterocarpus intricatus Dyer



Legend Fruits and seeds. A. nut with winged calyx ; B. longitudinal section through nut with calyx tube ; C. transverse section through nut with calyx tube ; D. nut.

Scale bars : 1 cm units

Dispersal Unit : fruit Collection Date : 5 / 03 / 2000 Specimen No. : 002

FRUITS Class : dry indehiscent Type : samara

Unripe color : red Ripe color : brown

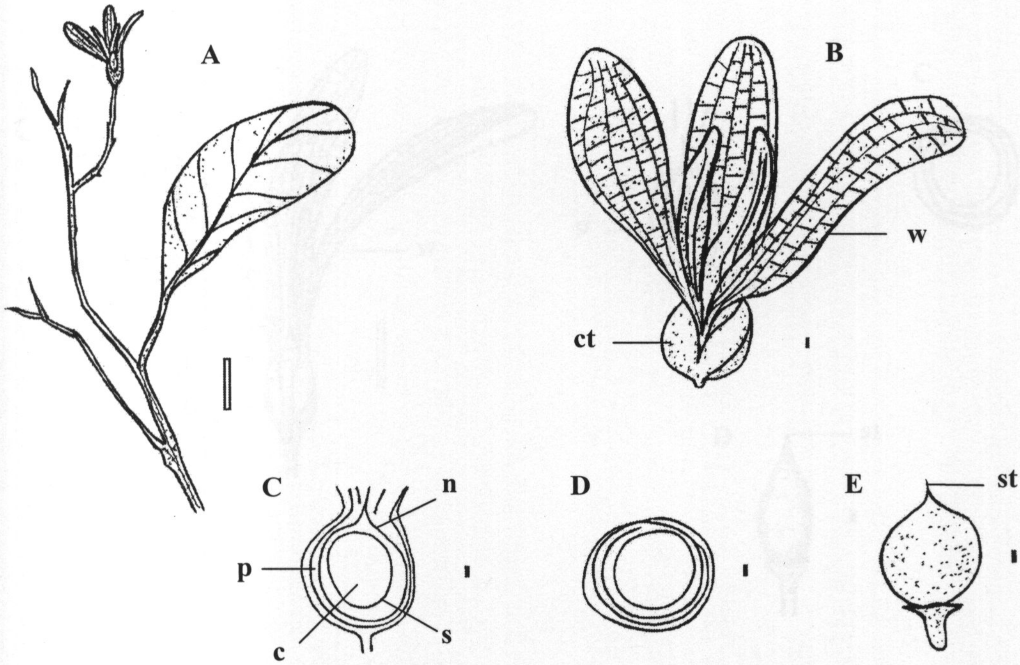
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 3,072

	FRUIT (Mean)	SEED (Mean)
Length	91.091 mm ± 4.503	19.270 mm ± 1.124
Width	15.541 mm ± 1.152	8.342 mm ± 0.594
Thickness	13.335 mm ± 0.843	8.033 mm ± 0.524
Wet weight		4.988 g ± 0.095
Dry weight		3.213 g ± 0.110
% moisture		35.589 % ± 1.175
1000 seed weight		325.507 g ± 24.387

SEEDS Testa : muricate External color : brown

12. DIPTEROCARPACEAE

Shorea obtusa Wall. ex Blume



Legend Fruits and seeds. A. part of an infructescence ; B. nut with winged calyx ; C. longitudinal section through nut with calyx tube ; D. transverse section through nut with calyx tube ; E. nut.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 11 / 04 / 2001 Specimen No. : 032

<u>FRUITS</u> Class : dry indehiscent Type : samara

Unripe color : light green Ripe color : brown

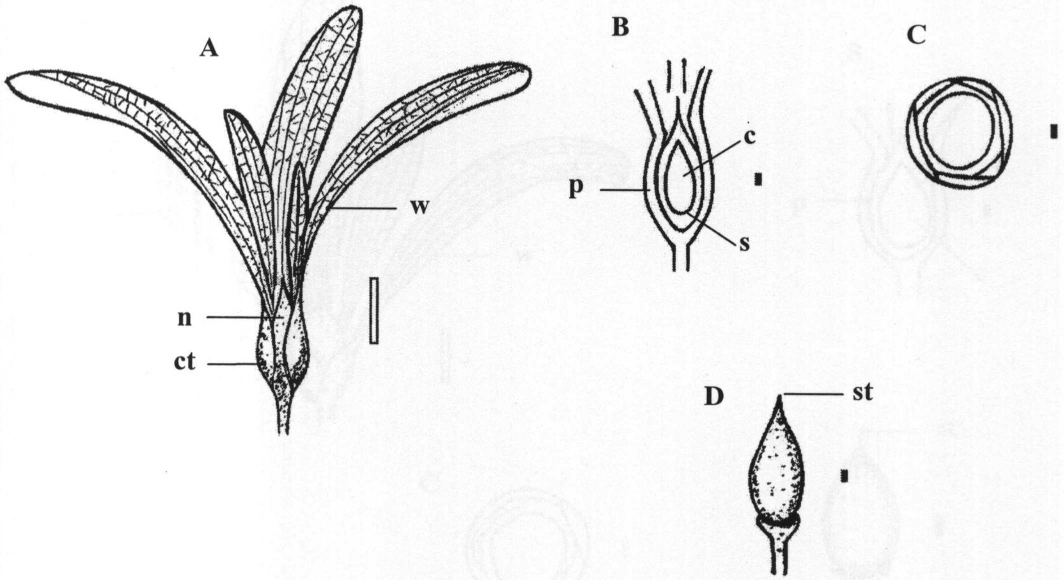
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 11,925

	FRUIT (Mean)	SEED (Mean)
Length	37.947 mm ± 3.363	10.308 mm ± 0.867
Width	6.015 mm ± 0.490	4.817 mm ± 0.604
Thickness	5.410 mm ± 0.384	4.440 mm ± 0.565
Wet weight		5.129 g ± 0.015
Dry weight		2.961 g ± 0.007
% moisture		42.274 % ± 0.280
1000 seed weight		83.859 g ± 7.672

<u>SEEDS</u> Testa : muricate External color : brown

13. DIPTEROCARPACEAE

Shorea roxburghii G. Don



Legend Fruits and seeds. A. nut with winged calyx ; B. longitudinal section through nut with calyx tube ; C. transverse section through nut with calyx tube ; D. nut.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 19 / 03 / 2000 Specimen No. : 005

FRUITS Class : dry indehiscent Type : samara

Unripe color : light green Ripe color : brown

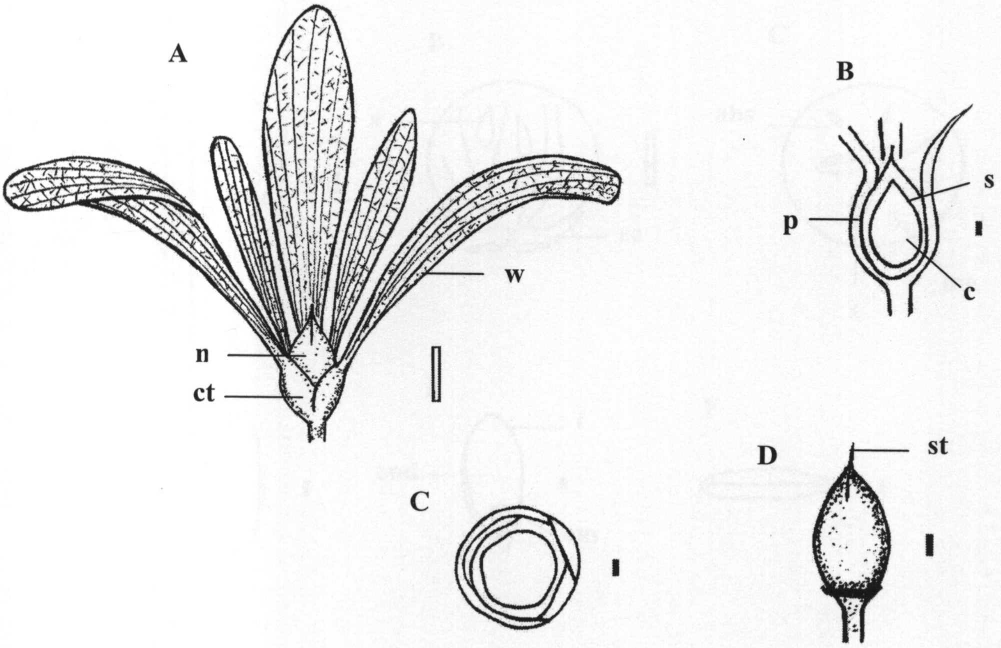
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 7,155

	FRUIT (Mean)	SEED (Mean)
Length	68.902 mm ± 7.483	15.110 mm ± 1.172
Width	8.203 mm ± 0.420	7.621 mm ± 0.768
Thickness	7.597 mm ± 0.392	6.750 mm ± 0.559
Wet weight		5.106 g ± 0.043
Dry weight		2.646 g ± 0.024
% moisture		48.171 % ± 0.246
1000 seed weight		139.750 g ± 3.917

SEEDS Testa : muricate External color : brown

14. DIPTEROCARPACEAE

Shorea siamemsis Miq.



Legend Fruits and seeds. A. nut with winged calyx ; B. longitudinal section through nut with calyx tube ; C. transverse section through nut with calyx tube ; D. nut.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 25 / 03 / 2000 Specimen No. : 007

FRUITS Class : dry indehiscent Type : samara

Unripe color : yellowish – green, red Ripe color : brown

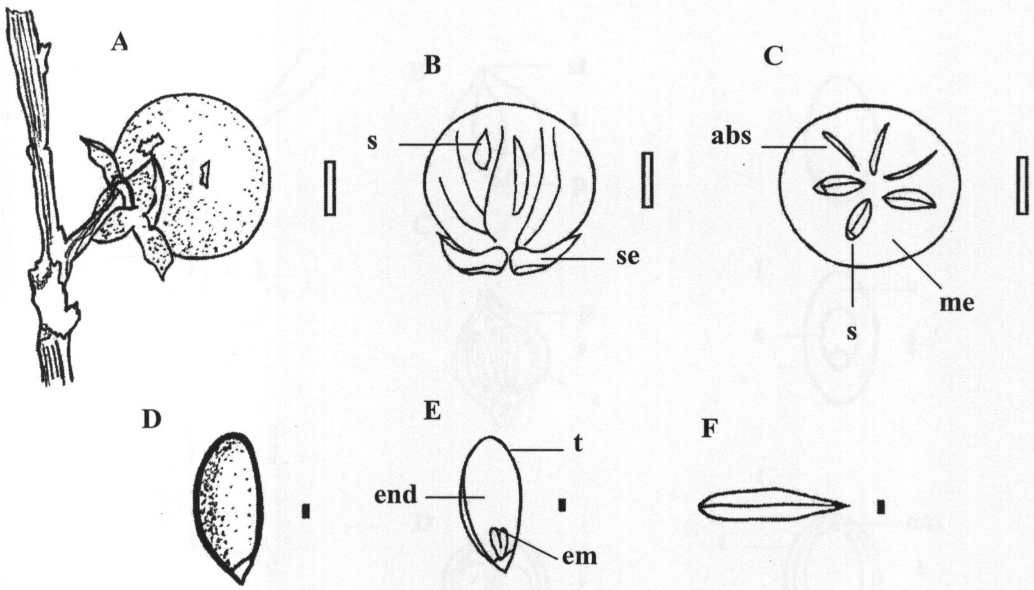
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 815

	FRUIT (Mean)	SEED (Mean)
Length	87.405 mm ± 7.330	17.347 mm ± 1.434
Width	13.635 mm ± 1.012	12.747 mm ± 0.893
Thickness	13.187 mm ± 0.945	12.289 mm ± 0.807
Wet weight		5.129 g ± 0.150
Dry weight		2.318 g ± 0.087
% moisture		54.818 % ± 0.697
1000 seed weight		1,227.329 g ± 68.510

SEEDS Testa : muricate External color : brown

15. EBENACEAE

Diospyros ehretioides Wall. ex G.Don



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. transverse section through fruit ; D. seed ; E. longitudinal section through seed ; F. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 27 / 10 / 2001 Specimen No. : 036

FRUITS Class : leathery fleshy Type : berry

Unripe color : light green Ripe color : red - brown

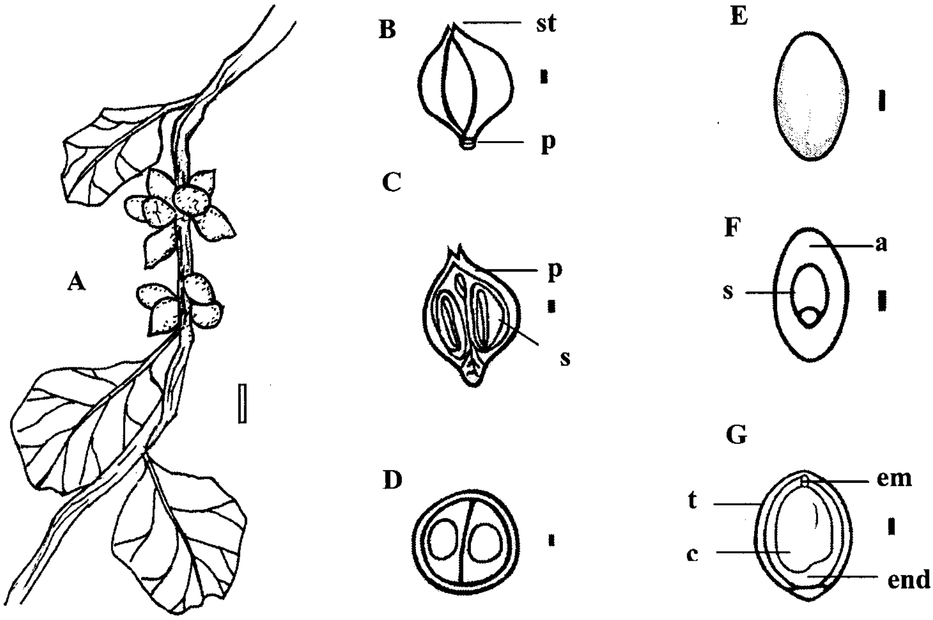
No. seeds per fruit : Max : 8, Min : 1 No. of seed / kg : 2,625

	FRUIT (Mean)	SEED (Mean)
Length	29.432 mm ± 2.744	17.022 mm ± 1.617
Width	28.107 mm ± 2.573	8.561 mm ± 1.604
Thickness	27.561 mm ± 2.521	5.270 mm ± 0.736
Wet weight		5.099 g ± 0.076
Dry weight		3.102 g ± 0.073
% moisture		39.171 % ± 0.586
1000 seed weight		380.999 g ± 15.488

SEEDS Testa : smooth External color : dark brown

16. EUPHORBIACEAE

Aporosa villosa (Wall. ex Lindl.) Baill.



Legend Fruits and seeds. A. part of an infructescence ; B. capsule ; C. longitudinal section through capsule ; D. transverse section through capsule ; E. seed with aril ; F. longitudinal section through seed with aril. G. longitudinal section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 20 / 04 / 2000 Specimen No. : 013

FRUITS Class : dry dehiscent Type : septicidal capsule

Unripe color : green Ripe color : light green - yellow

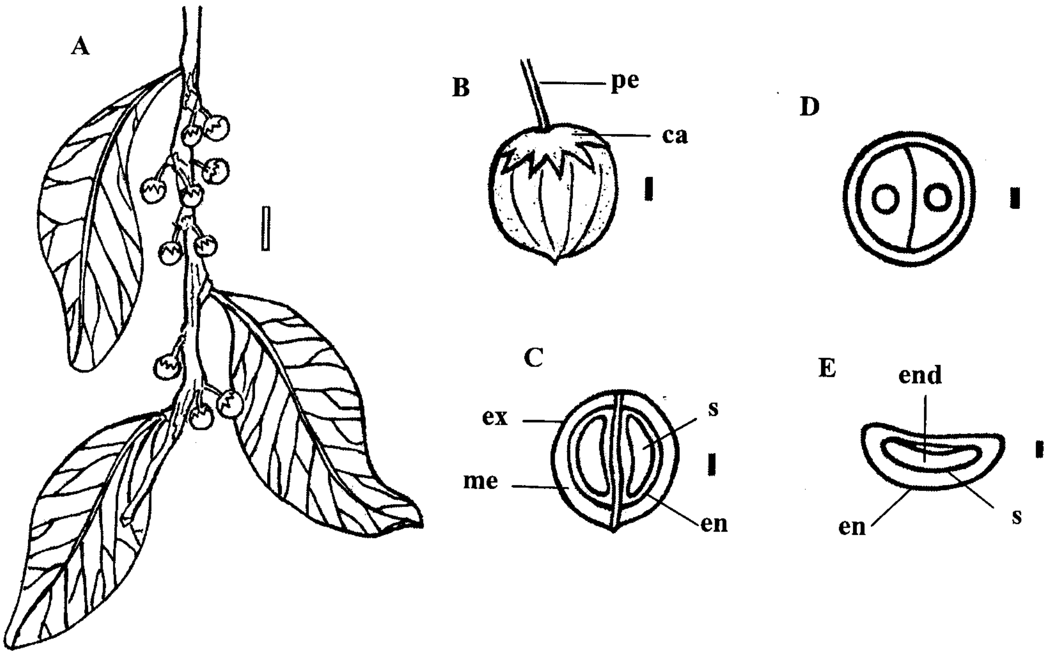
No. seeds per fruit : Max : 2, Min : 1 No. of seed / kg : 7,868

	FRUIT (Mean)	SEED (Mean)
Length	14.835 mm ± 0.931	7.875 mm ± 0.532
Width	9.513 mm ± 0.833	5.678 mm ± 0.433
Thickness	8.150 mm ± 0.585	4.498 mm ± 0.670
Wet weight		5.105 g ± 0.043
Dry weight		2.552 g ± 0.022
% moisture		50.019 % ± 0.322
1000 seed weight		127.101 g ± 2.364

SEEDS Testa : smooth, arillate External color : cream

17. EUPHORBIACEAE

Bridelia retusa (L.) A.Juss.



Legend Fruits and seeds. A. part of an infructescence ; B. fruit ; C. longitudinal section through fruit ; D. transverse section through fruit ; E. pyrene.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 12 / 11 / 2000 Specimen No. : 027

FRUITS Class : fleshy Type : drupe

Unripe color : light green Ripe color : blackish

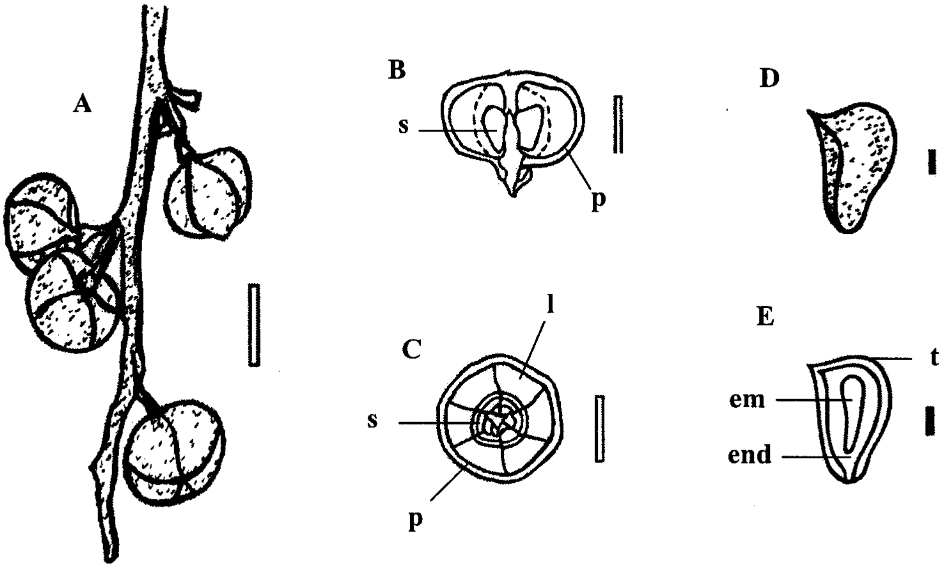
No. seeds per fruit : Max : 2, Min : 2 No. of seed / kg : 9,459

	FRUIT (Mean)	SEED (Mean)
Length	6.939 mm ± 0.243	5.754 mm ± 0.287
Width	7.212 mm ± 0.256	4.661 mm ± 0.296
Thickness	7.063 mm ± 0.266	2.963 mm ± 0.245
Wet weight		5.056 g ± 0.019
Dry weight		4.399 g ± 0.014
% moisture		12.999 % ± 0.220
1000 seed weight		105.722 g ± 2.344

SEEDS Testa : smooth External color : brown

18. EUPHORBIACEAE

Phyllanthus emblica L.



Legend Fruits and seeds. A. part of an infructescence ; B. longitudinal section through fruit ; C. transverse section through fruit ; D. seed ; E. longitudinal section through seed ;

Scale bars: white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 24 / 09 / 2000 Specimen No. : 024

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : light green Ripe color : yellowish

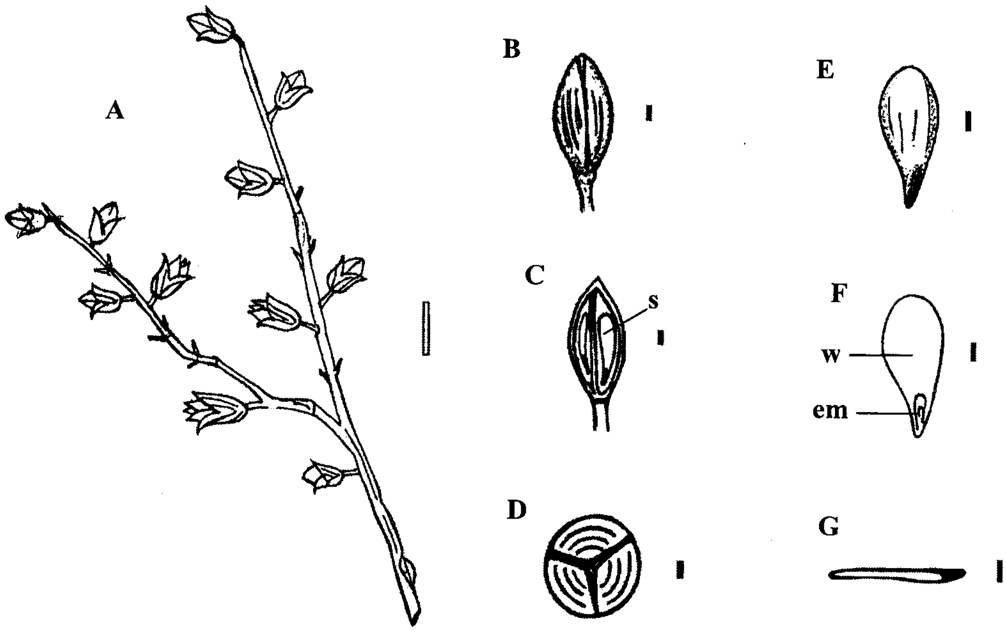
No. seeds per fruit : Max : 6, Min : 6 No. of seed / kg : 85,598

	FRUIT (Mean)	SEED (Mean)
Length	22.421 mm ± 1.836	5.838 mm ± 0.429
Width	22.610 mm ± 1.612	3.324 mm ± 0.298
Thickness	22.163 mm ± 1.592	2.914 mm ± 0.297
Wet weight		2.498 g ± 0.011
Dry weight		2.119 g ± 0.011
% moisture		15.171 % ± 0.251
1000 seed weight		11.682 g ± 1.197

<u>SEEDS</u> Testa : smooth External color : light brown

19. GUTTIFERAE

Cratoxylum cochinchinense (Lour.) Blume



Legend Fruits and seeds. A. part of an infructescence ; B. capsule ; C. longitudinal section through capsule ; D. transverse section through capsule ; E. seed ; F. longitudinal section through seed ; G. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 16 / 03 / 2000 Specimen No. : 004

FRUITS Class : dry dehiscent Type : loculicidal capsule

Unripe color : green Ripe color : dark brown

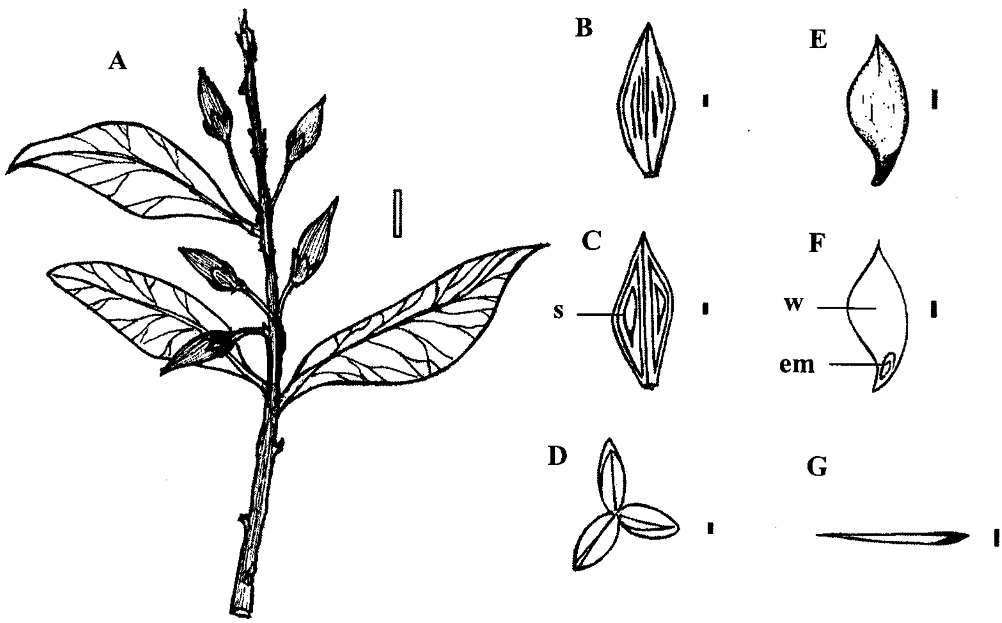
No. seeds per fruit : Max : 23, Min : 15 No. of seed / kg : 1,324,503

	FRUIT (Mean)	SEED (Mean)
Length	11.974 mm ± 0.721	7.863 mm ± 0.394
Width	6.733 mm ± 0.540	2.542 mm ± 0.233
Thickness	6.222 mm ± 0.528	0.531 mm ± 0.141
Wet weight		5.062 g ± 0.015
Dry weight		3.980 g ± 0.016
% moisture		21.393 % ± 0.106
1000 seed weight		0.755 g ± 0.049

SEEDS Testa : smooth, wing External color : brown

20. GUTTIFERAE

Cratoxylum formosum (Jack) Dyer subsp. *pruniflorum* (Kurz) Gogel.



Legend Fruits and seeds. A. part of an infructescence ; B. capsule ; C. longitudinal section through capsule ; D. transverse section through capsule ; E. seed ; F. longitudinal section through seed ; G. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 22 / 07 / 2000 Specimen No. : 020

FRUITS Class : dry dehiscent Type : loculicidal capsule

Unripe color : green Ripe color : dark brown

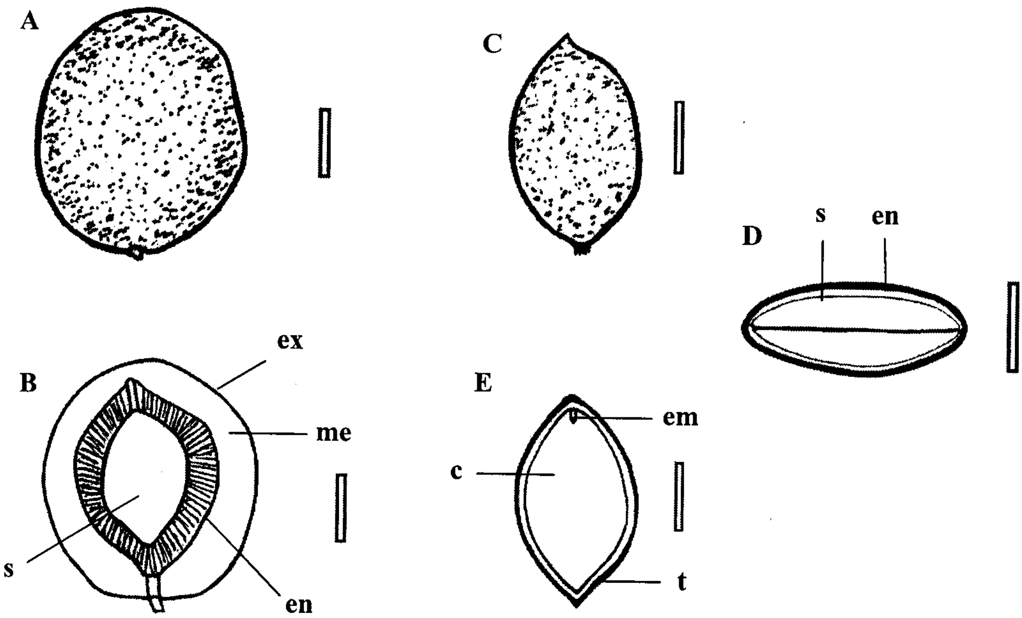
No. seeds per fruit : Max : 62, Min : 44 No. of seed / kg : 986,436

	FRUIT (Mean)	SEED (Mean)
Length	17.070 mm ± 1.035	9.186 mm ± 0.514
Width	7.350 mm ± 0.433	3.163 mm ± 0.362
Thickness	7.188 mm ± 0.446	0.507 mm ± 0.105
Wet weight		5.049 g ± 0.029
Dry weight		4.378 g ± 0.027
% moisture		13.303 % ± 0.126
1000 seed weight		1.014 g ± 0.085

SEEDS Testa : smooth, wing External color : brown

21. IRVINGIACEAE

Irvingia malayana Oliv. ex A.W.Benn.



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. pyrene ; D. transverse section through pyrene ; E. longitudinal section through seed.

Scale bars : 1 cm units.

Dispersal Unit : fruit Collection Date : 7 / 07 / 2000 Specimen No. : 019

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : green Ripe color : yellow - green

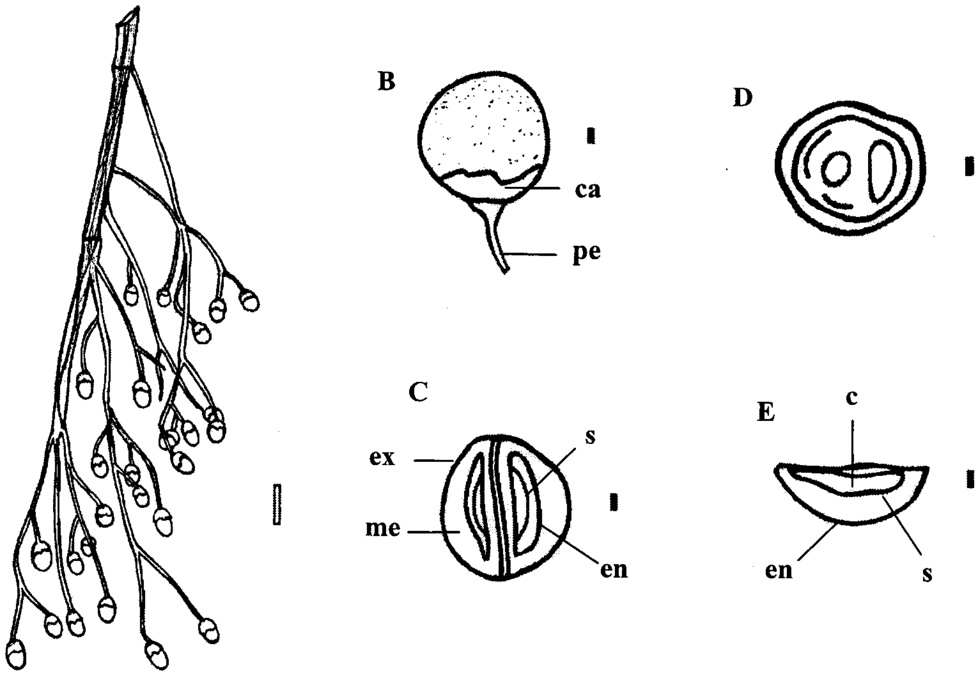
No. seeds per fruit : Max : 2, Min : 1 No. of seed / kg : 1,084

	FRUIT (Mean)	SEED (Mean)
Length	40.671 mm ± 5.805	26.168 mm ± 2.511
Width	37.541 mm ± 4.166	14.617 mm ± 2.652
Thickness	32.571 mm ± 3.721	7.998 mm ± 1.228
Wet weight		5.075 g ± 0.029
Dry weight		4.674 g ± 0.050
% moisture		7.908 % ± 0.520
1000 seed weight		922.873 g ± 9.725

<u>SEEDS</u> Testa : muricate External color : light brown

22. LABIATAE

Vitex pinnata L.



Legend Fruits and seeds. A. part of an infructescene ; B. fruit ; C. longitudinal section through fruit ; D. transverse section through fruit ; E. transverse section through pyrene.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 16 / 09 / 2000 Specimen No. : 023

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : green Ripe color : purple black

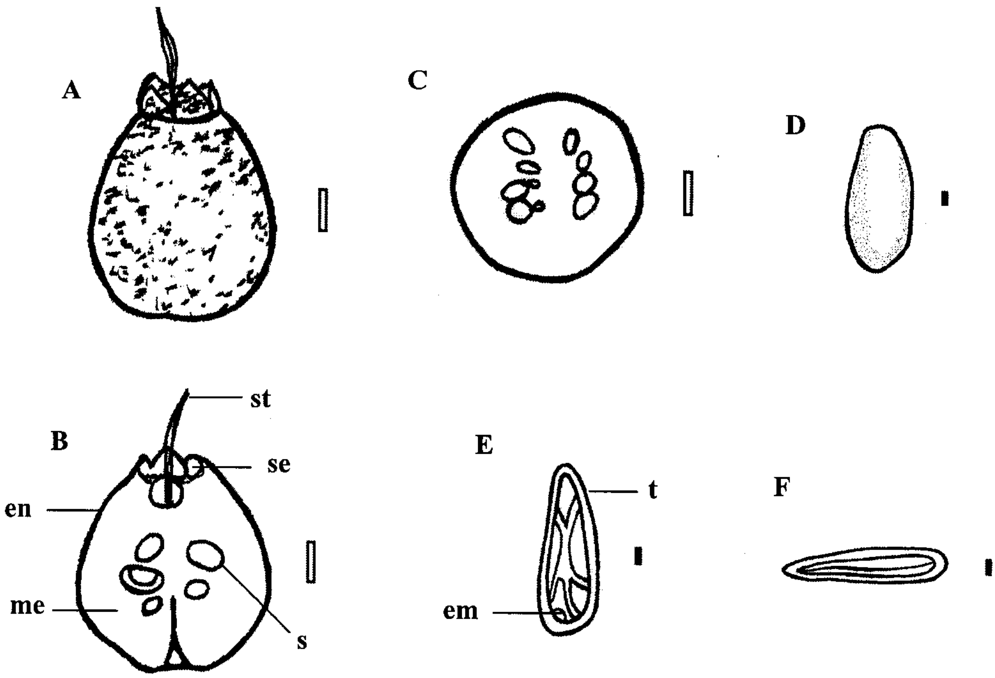
No. seeds per fruit : Max : 4, Min : 2 No. of seed / kg : 10,343

	FRUIT (Mean)	SEED (Mean)
Length	8.171 mm ± 0.430	6.414 mm ± 0.483
Width	9.160 mm ± 0.684	5.709 mm ± 0.376
Thickness	8.697 mm ± 0.681	5.318 mm ± 0.310
Wet weight		5.012 g ± 0.023
Dry weight		4.277 g ± 0.017
% moisture		14.664 % ± 0.100
1000 seed weight		96.680 g ± 4.109

<u>SEEDS</u> Testa : muricate External color : brown

23. LECYTHIDACEAE

Careya sphaerica Roxb.



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. transverse section through fruit ; D. seed ; E. longitudinal section through seed ; F. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit   Collection Date : 20 / 04 / 2000   Specimen No. : 014

<u>FRUITS</u> Class : leathery fleshy   Type : berry

Unripe color : light green   Ripe color : yellowish - brown

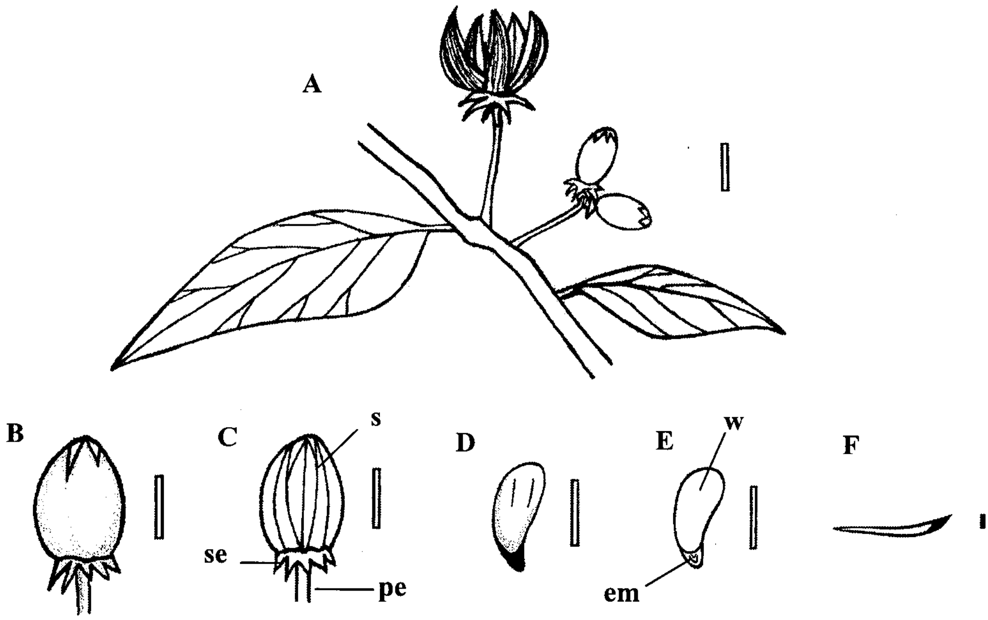
No. seeds per fruit : Max : 77, Min : 3   No. of seed / kg : 4,055

	FRUIT (Mean)	SEED (Mean)
Length	56.183 mm ± 5.196	10.852 mm ± 1.632
Width	60.841 mm ± 7.538	7.509 mm ± 0.564
Thickness	59.576 mm ± 7.611	5.762 mm ± 0.492
Wet weight		5.165 g ± 0.070
Dry weight		3.020 g ± 0.037
% moisture		41.532 % ± 0.662
1000 seed weight		246.575 g ± 6.673

<u>SEEDS</u> Testa : smooth   External color : light brown

24. LYTHRACEAE

Lagerstroemia floribunda Jack



Legend Fruits and seeds. A. part of an infructescence ; B. capsule ; C. longitudinal section through capsule ; D. seed ; E. longitudinal section through seed ; F. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 10 / 02 / 2001 Specimen No. : 029

FRUITS Class : dry dehiscent Type : loculicidal capsule

Unripe color : green Ripe color : dark brown

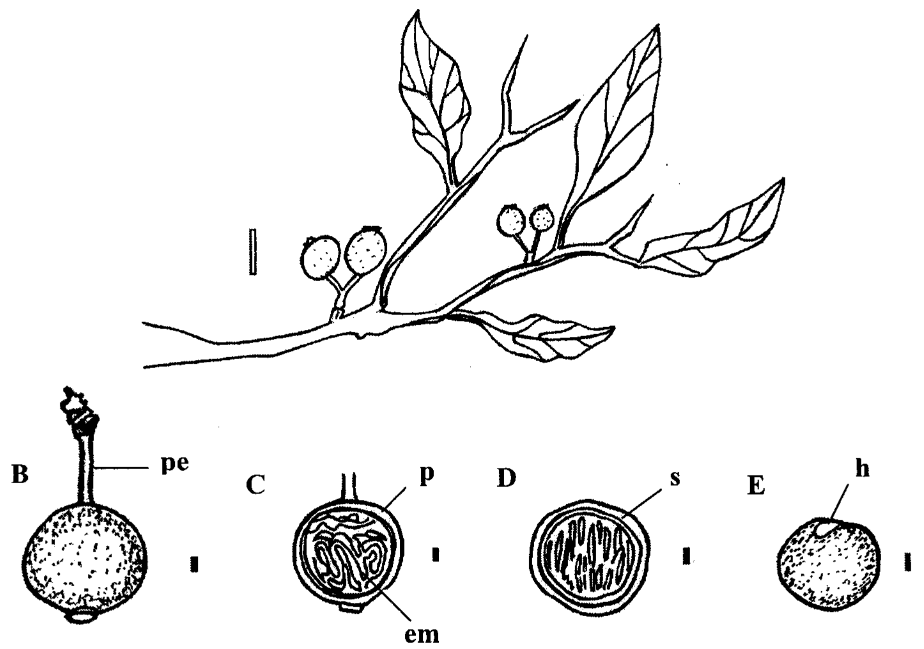
No. seeds per fruit : Max : 36, Min : 20 No. of seed / kg : 89,646

	FRUIT (Mean)	SEED (Mean)
Length	17.130 mm ± 1.717	11.305 mm ± 1.893
Width	13.118 mm ± 1.723	4.853 mm ± 0.511
Thickness	12.836 mm ± 1.745	1.886 mm ± 0.292
Wet weight		5.012 g ± 0.006
Dry weight		4.468 g ± 0.016
% moisture		10.859 % ± 0.335
1000 seed weight		11.155 g ± 0.490

SEEDS Testa : smooth, wing External color : light brown

25. MELASTOMATACEAE

Memecylon edule Roxb.



Legend Fruits and seeds. A. part of an infructescence ; B. fruit ; C. longitudinal section through fruit ; D. transverse section through fruit ; E. seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 26 / 03 / 2000 Specimen No. : 008

<u>FRUITS</u> Class : fleshy Type : drupe

Unripe color : green Ripe color : dark blue - purple

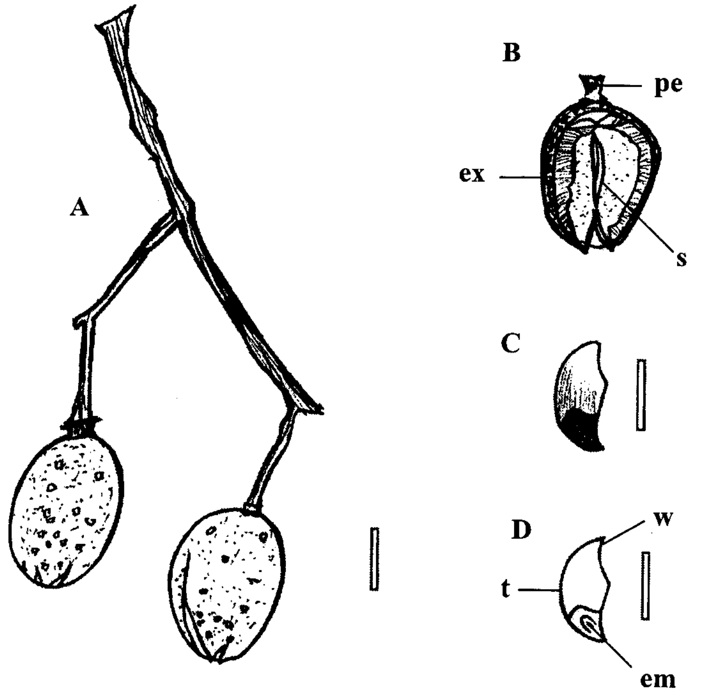
No. seeds per fruit : Max : 2, Min : 1 No. of seed / kg : 9,108

	FRUIT (Mean)	SEED (Mean)
Length	8.550 mm ± 0.473	5.710 mm ± 0.355
Width	9.391 mm ± 1.006	5.876 mm ± 0.342
Thickness	8.869 mm ± 0.808	5.696 mm ± 0.414
Wet weight		5.002 g ± 0.023
Dry weight		2.968 g ± 0.026
% moisture		40.659 % ± 0.401
1000 seed weight		109.794 g ± 11.516

<u>SEEDS</u> Testa : smooth External color : black

26. MELIACEAE

Chukrasia tabularis A.Juss.



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. seed ; D. longitudinal section through seed.

Scale bars : 1 cm units.

Dispersal Unit : both Collection Date : 14 / 10 / 2001 Specimen No. : 035

FRUITS Class : dry dehiscent Type : loculicidal capsule

Unripe color : green Ripe color : yellow - grey

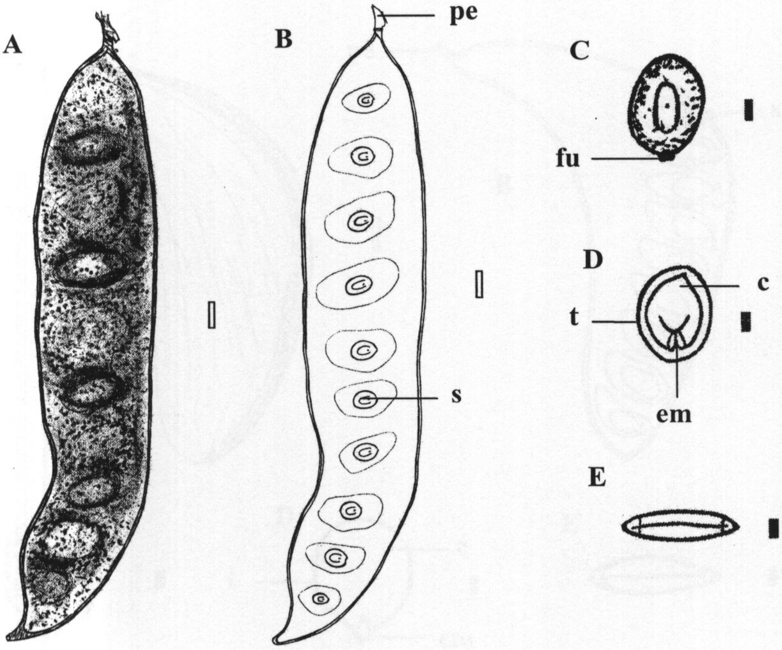
No. seeds per fruit : Max : 156, Min : 132 No. of seed / kg : 351,185

	FRUIT (Mean)	SEED (Mean)
Length	26.927 mm ± 1.511	12.484 mm ± 2.118
Width	23.859 mm ± 1.178	6.128 mm ± 0.777
Thickness	23.295 mm ± 1.193	0.623 mm ± 0.165
Wet weight		0.499 g ± 0.021
Dry weight		0.432 g ± 0.017
% moisture		13.322 % ± 0.335
1000 seed weight		2.848 g ± 0.421

SEEDS Testa : smooth, wing External color : dark brown

27. LEGUMINOSAE, MIMOSOIDEAE

Albizia lebbeck (L.) Benth.



Legend Fruits and seeds. A. pod ; B. longitudinal section through pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : both   Collection Date : 10/ 02 / 2001   Specimen No. : 030

<u>FRUITS</u> Class : dry dehiscent   Type : pod

Unripe color : green   Ripe color : pale yellow

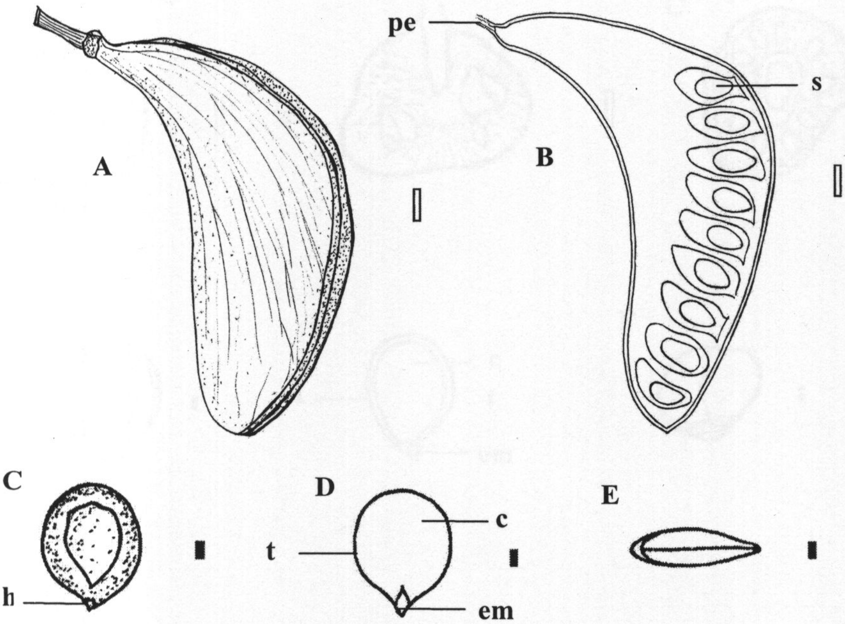
No. seeds per fruit : Max : 12, Min : 2   No. of seed / kg : 7,860

	FRUIT (Mean)	SEED (Mean)
Length	224.058 mm ± 37.388	10.119 mm ± 0.738
Width	35.196 mm ± 5.703	7.487 mm ± 0.590
Thickness	4.296 mm ± 0.579	2.409 mm ± 0.234
Wet weight		5.043 g ± 0.016
Dry weight		4.599 g ± 0.038
% moisture		8.805 % ± 0.566
1000 seed weight		127.226 g ± 2.848

SEEDS Testa : smooth   External color : light brown

28. LEGUMINOSAE, MIMOSOIDEAE

Xylia xylocarpa (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) I.C.Nielsen



Legend Fruits and seeds . A. pod ; B. longitudinal section through pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : both   Collection Date : 27 / 03 / 2000   Specimen No. : 009

<u>FRUITS</u> Class : dry dehiscent   Type : pod

Unripe color : light green   Ripe color : light brown

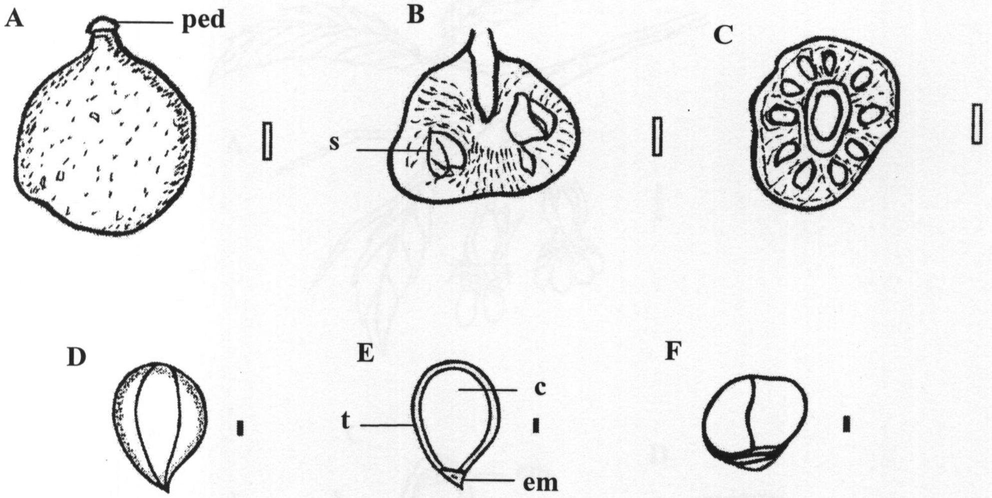
No. seeds per fruit : Max : 11, Min : 3   No. of seed / kg : 3,450

	FRUIT (Mean)	SEED (Mean)
Length	176.420 mm ± 17.379	14.823 mm ± 1.017
Width	61.700 mm ± 8.445	10.096 mm ± 0.817
Thickness	11.262 mm ± 0.727	2.733 mm ± 0.433
Wet weight		5.124 g ± 0.107
Dry weight		4.508 g ± 0.079
% moisture		12.034 % ± 0.711
1000 seed weight		289.890 g ± 9.471

<u>SEEDS</u> Testa : smooth   External color : dark brown

29. MORACEAE

Artocarpus lacucha Roxb.



Legend Fruits and seeds. A. multiple fruit ; B. longitudinal section through multiple fruit ; C. transverse section through multiple fruit ; D. seed ; E. longitudinal section through seed ; F. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit   Collection Date : 25 / 04 / 2000   Specimen No. : 015

<u>FRUITS</u> Class : fleshy multiple   Type : drupe

Unripe color : green   Ripe color : yellow - pink

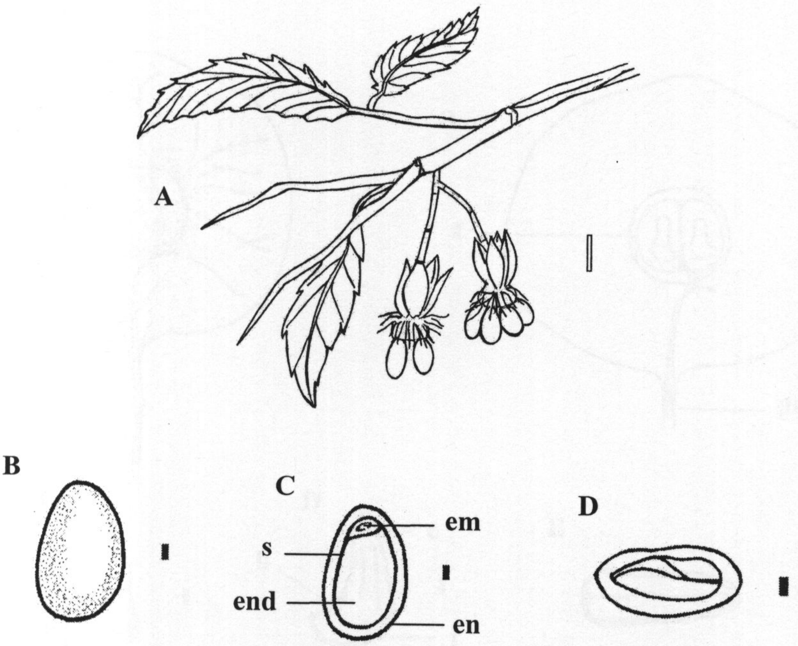
No. seeds per fruit : Max : 10, Min : 1   No. of seed / kg : 2,490

	FRUIT (Mean)	SEED (Mean)
Length	50.503 mm ± 5.203	10.117 mm ± 0.966
Width	41.003 mm ± 5.179	7.890 mm ± 0.842
Thickness	36.692 mm ± 4.272	7.029 mm ± 0.500
Wet weight		5.155 g ± 0.104
Dry weight		3.164 g ± 0.087
% moisture		38.631 % ± 1.116
1000 seed weight		401.560 g ± 11.143

<u>SEEDS</u> Testa : smooth   External color : light white

30. OCHNACEAE

Ochna integerrima (Lour.) Merr.



Legend   Fruits and seeds. A. part of an infructescence ; B. fruit ; C. longitudinal section through fruit ; D. transverse section through fruit .

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit   Collection Date : 9 / 05 / 2000   Specimen No. : 016

FRUITS Class : fleshy   Type : drupe

Unripe color : green   Ripe color : black

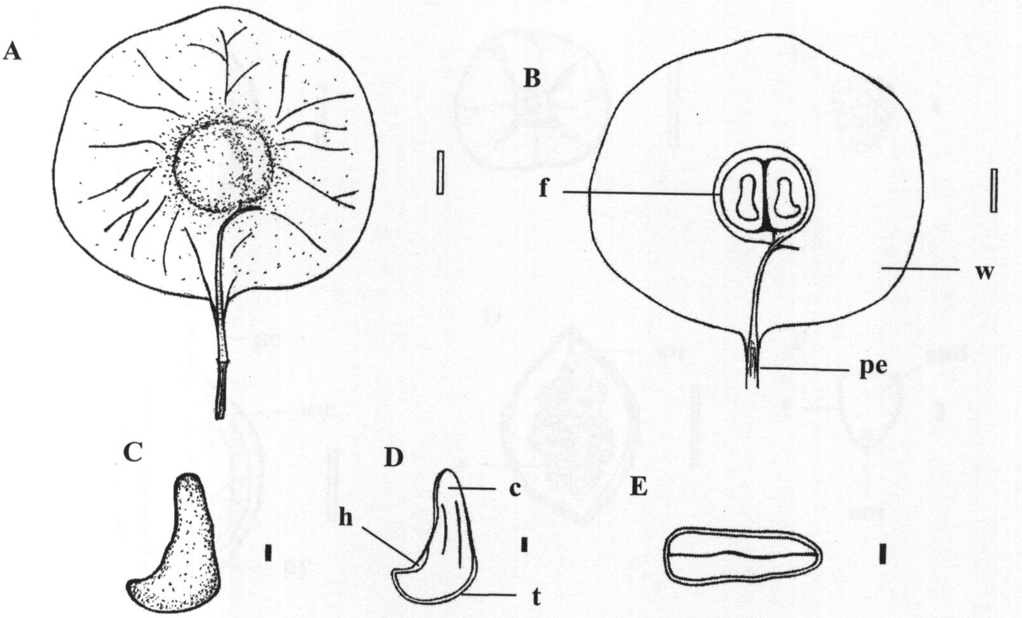
No. seeds per fruit : Max : 9, Min : 7   No. of seed / kg : 2,587

	FRUIT (Mean)	SEED (Mean)
Length	11.700 mm ± 0.798	10.871 mm ± 0.688
Width	8.037 mm ± 0.667	7.042 mm ± 0.653
Thickness	6.681 mm ± 0.416	5.819 mm ± 0.345
Wet weight		5.136 g ± 0.067
Dry weight		3.520 g ± 0.053
% moisture		31.466 % ± 1.283
1000 seed weight		386.592 g ± 13.536

SEEDS Testa : reticulate coat   External color : light brown

31. LEGUMINOSAE, PAPILIONOIDEAE

Pterocarpus macrocarpus Kurz



Legend Fruits and seeds. A. pod with wing ; B. transverse section through pod ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 6 / 03 / 2000 Specimen No. : 003

FRUITS Class : dry indehiscent Type : samara

Unripe color : green Ripe color : light brown

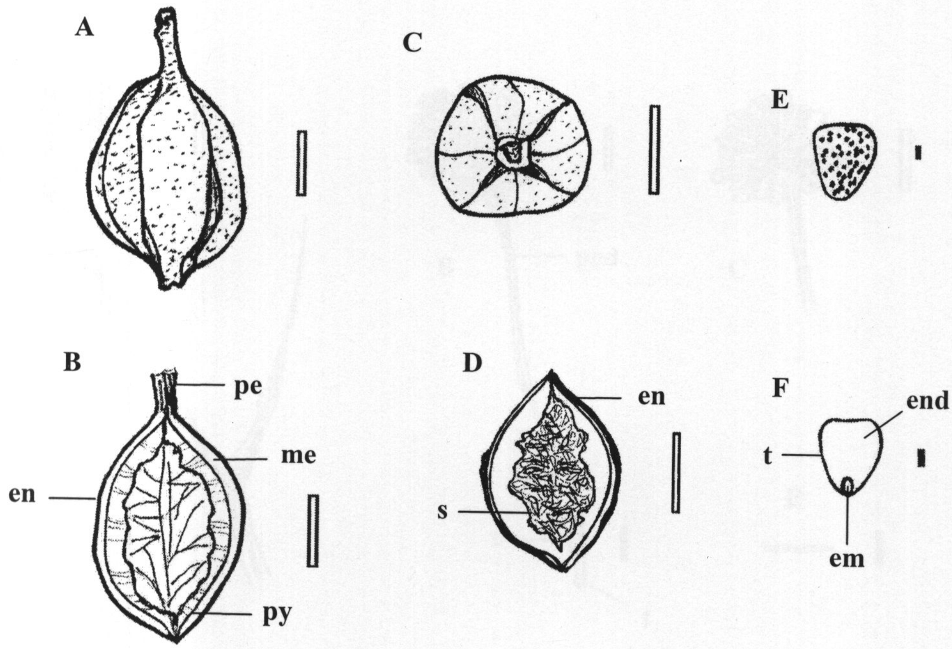
No. seeds per fruit : Max : 3, Min : 1 No. of seed / kg : 15,208

	FRUIT (Mean)	SEED (Mean)
Length	65.300 mm ± 3.974	9.197 mm ± 0.297
Width	65.260 mm ± 5.013	4.776 mm ± 0.258
Thickness	5.869 mm ± 0.701	2.428 mm ± 0.179
Wet weight		5.053 g ± 0.082
Dry weight		4.554 g ± 0.071
% moisture		9.865 % ± 0.130
1000 seed weight		65.752 g ± 3.050

SEEDS Testa : muricate External color : light brown

32. RUBIACEAE

Gardenia sootepensis Hutch.



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit ; C. transverse section through fruit ; D. longitudinal section through pyrene ; E. seed ; F. longitudinal section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 26 / 09 / 2000 Specimen No. : 025

<u>FRUITS</u> Class : fleshy Type : berry

Unripe color : light green Ripe color : dark brown

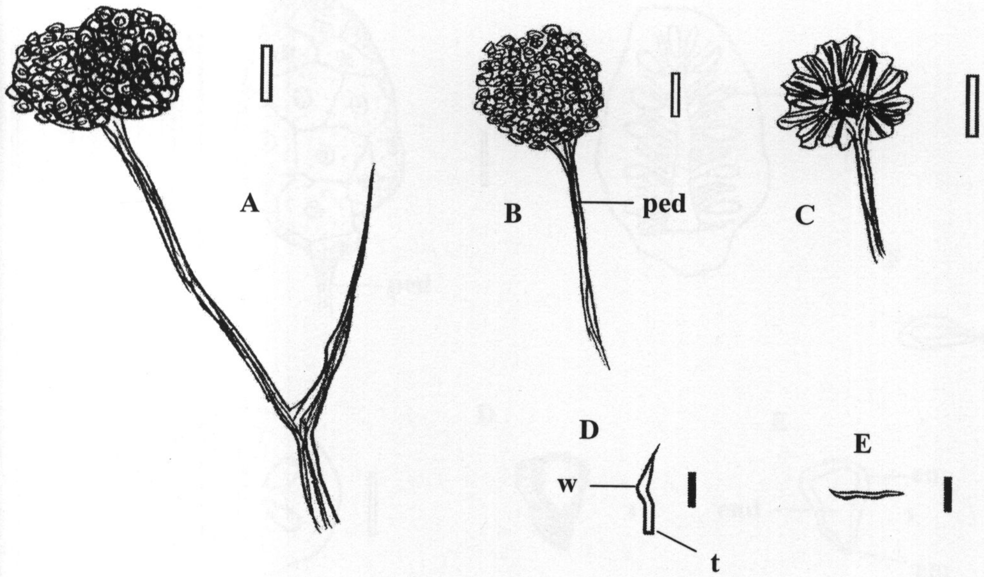
No. seeds per fruit : Max : 207, Min : 61 No. of seed / k : 95,520

	FRUIT (Mean)	SEED (Mean)
Length	38.672 mm ± 4.534	5.101 mm ± 0.538
Width	25.509 mm ± 2.218	4.039 mm ± 0.272
Thickness	24.285 mm ± 1.814	0.797 mm ± 0.110
Wet weight		5.038 g ± 0.010
Dry weight		4.552 g ± 0.024
% moisture		9.638 % ± 0.364
1000 seed weight		10.469 g ± 0.502

<u>SEEDS</u> Testa : muricate External color : brown

33. RUBIACEAE

Haldina cordifolia (Roxb.) Ridsdale



Legend Fruits and seeds. A. part of an infructescence ; B. fruit ; C. longitudinal section through fruit ; D. seed ; E. transverse section through seed.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : seed Collection Date : 29 / 04 / 2001 Specimen No. : 033

FRUITS Class : dry dehiscent Type : capsule

Unripe color : yellowish – brown Ripe color : dark brown

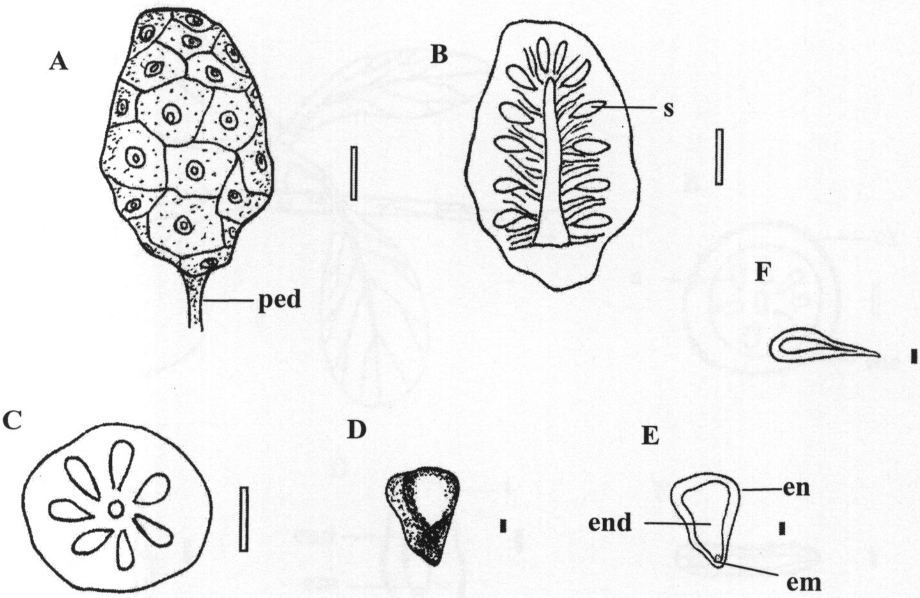
No. seeds per fruit : Max : many, Min : many No. of seed / kg :

	FRUIT (Mean)	SEED (Mean)
Length	18.036 mm ± 1.655	2.543 mm ± 0.306
Width	23.561 mm ± 1.474	0.463 mm ± 0.073
Thickness	19.952 mm ± 2.126	0.295 mm ± 0.057
Wet weight		5.027 g ± 0.014
Dry weight		4.420 g ± 0.014
% moisture		12.065 % ± 0.060
1000 seed weight		

SEEDS Testa : smooth, wing External color : dark brown

34. RUBIACEAE

Morinda elliptica Ridl.



Legend Fruits and seeds. A. multiple fruit ; B. longitudinal section through multiple fruit ; C. transverse section through multiple fruit ; D. pyrene ; E. longitudinal section through pyrene ; F. transverse section through pyrene.

Scale bars : white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 29 / 07 / 2001 Specimen No. : 034

<u>FRUITS</u> Class : fleshy multiple Type : drupe

Unripe color : light green Ripe color : pale yellow

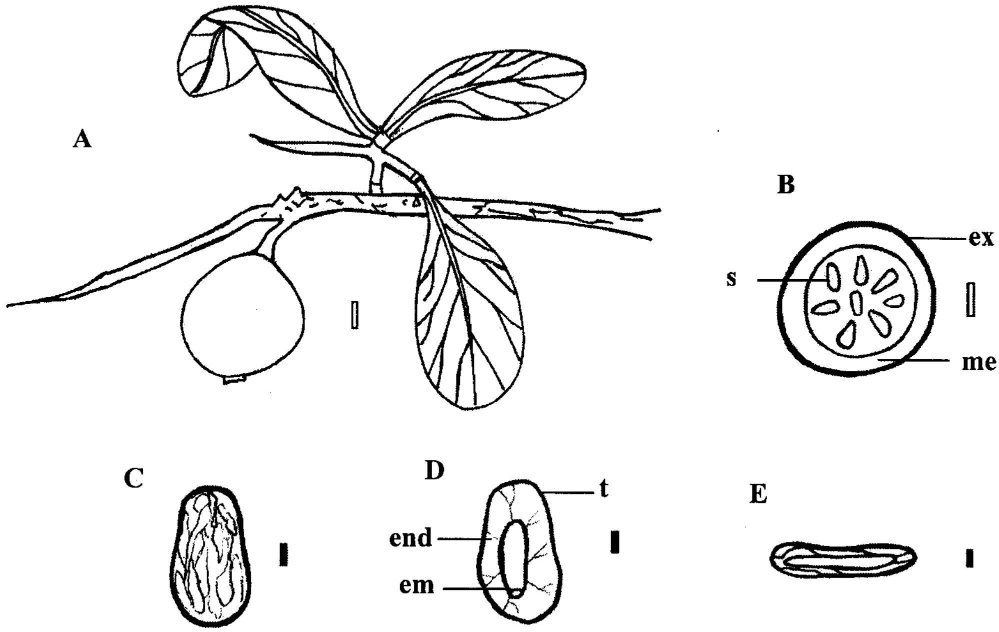
No. seeds per fruit : Max : 158, Min : 20 No. of seed / kg : 43,673

	FRUIT (Mean)	SEED (Mean)
Length	58.600 mm ± 6.447	7.744 mm ± 1.673
Width	36.569 mm ± 3.922	5.215 mm ± 1.227
Thickness	35.054 mm ± 3.793	2.678 mm ± 0.546
Wet weight		5.006 g ± 0.007
Dry weight		4.489 g ± 0.022
% moisture		10.331 % ± 0.515
1000 seed weight		22.897 g ± 0.588

<u>SEEDS</u> Testa : muricate External color : light brown

35. RUBIACEAE

Rothmannia wittii (Craib) Bremek.



Legend Fruits and seeds. A. fruit ; B. transverse section through fruit ; C. seed ; D. longitudinal section through seed ; E. transverse section through seed .

Scale bars: white, 1 cm units ; black , 1 mm units.

Dispersal Unit : fruit Collection Date : 8 / 04 / 2000 Specimen No. : 011

<u>FRUITS</u> Class : leathery fleshy Type : berry

Unripe color : green Ripe color : black

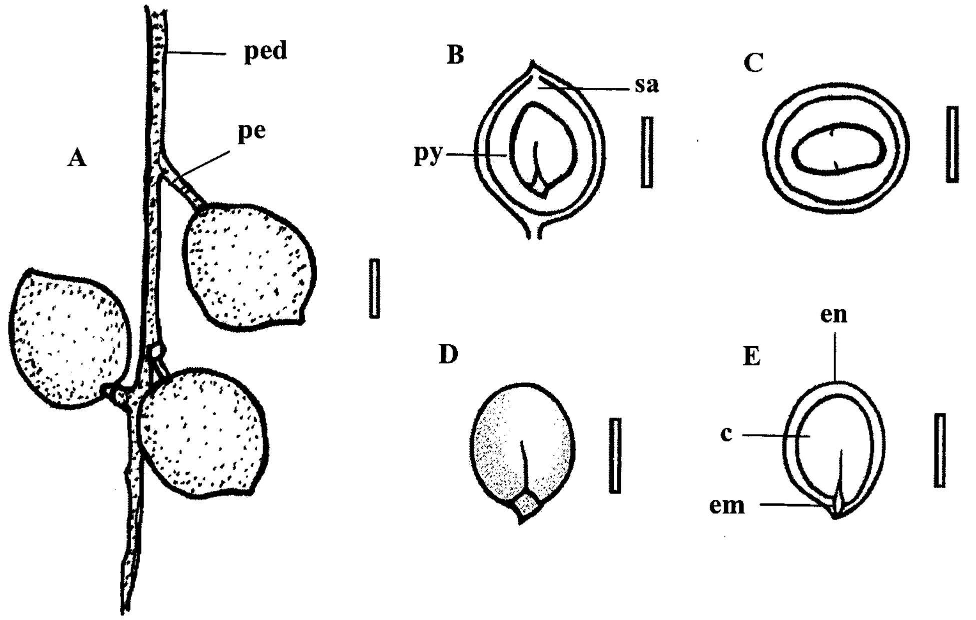
No. seeds per fruit : Max : 100, Min : 11 No. of seed / kg : 12,098

	FRUIT (Mean)	SEED (Mean)
Length	45.193 mm ± 3.101	7.575 mm ± 0.696
Width	47.569 mm ± 2.523	5.645 mm ± 0.591
Thickness	44.849 mm ± 2.517	3.101 mm ± 0.420
Wet weight		5.097 g ± 0.042
Dry weight		4.287 g ± 0.025
% moisture		15.895 % ± 0.336
1000 seed weight		82.660 g ± 2.141

<u>SEEDS</u> Testa : muricate External color : dark brown

36. SAPINDACEAE

Schleichera oleosa (Lour.) Oken



Legend Fruits and seeds. A. fruit ; B. longitudinal section through fruit; C. transverse section through fruit ; D. pyrene ; E. longitudinal section through pyrene.

Scale bars : 1 cm units.

Dispersal Unit : fruit Collection Date : 24 / 06 / 2000 Specimen No. : 018

FRUITS Class : fleshy Type : drupe

Unripe color : light green Ripe color : brown

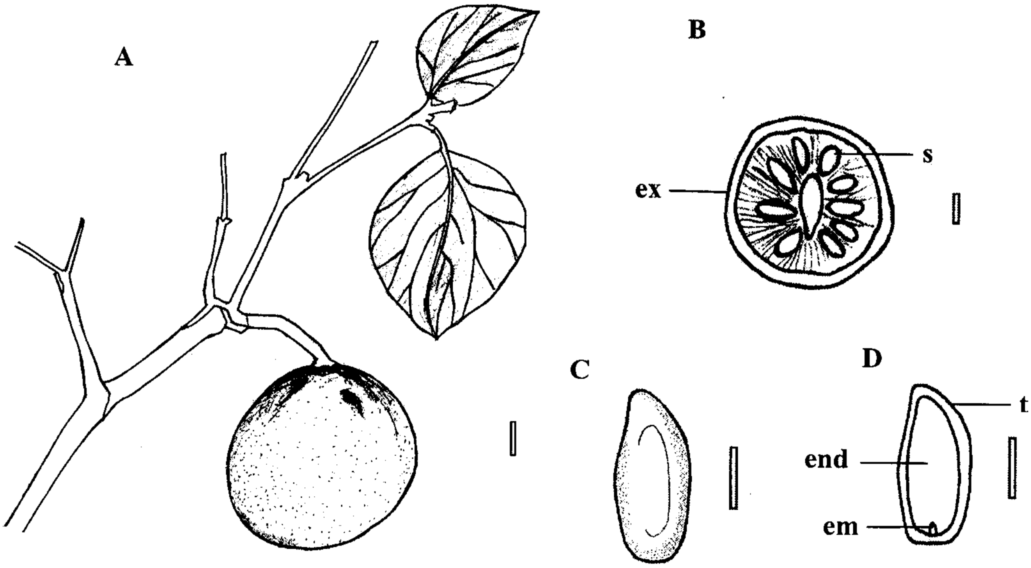
No. seeds per fruit : Max : 1, Min : 1 No. of seed / kg : 889

	FRUIT (Mean)	SEED (Mean)
Length	24.863 mm ± 1.228	15.456 mm ± 1.398
Width	25.596 mm ± 3.212	13.727 mm ± 1.264
Thickness	23.337 mm ± 1.920	9.704 mm ± 0.985
Wet weight		5.102 g ± 0.045
Dry weight		3.796 g ± 0.063
% moisture		25.597 % ± 0.966
1000 seed weight		1,125.157 g ± 6.446

SEEDS Testa : smooth, arillate External color : brown

37. STRYCHNACEAE

Strychnos nux-vomica L.



Legend Fruits and seeds . A. fruit ; B. longitudinal section through fruit ; C. seed ; D. longitudinal section through seed.

Scale bars : 1 cm units.

Dispersal Unit : fruit Collection Date : 18 / 02 / 2001 Specimen No. : 031

FRUITS Class : leathery fleshy Type : berry

Unripe color : green Ripe color : light orange

No. seeds per fruit : Max : 10, Min : 8 No. of seed / kg : 732

	FRUIT (Mean)	SEED (Mean)
Length	63.762 mm ± 5.684	22.011 mm ± 1.575
Width	64.258 mm ± 6.548	17.173 mm ± 1.174
Thickness	62.358 mm ± 7.458	7.213 mm ± 1.252
Wet weight		1.498 g ± 0.112
Dry weight		1.235 g ± 0.085
% moisture		17.515 % ± 0.735
1000 seed weight		1,365.625 g ± 105.476

SEEDS Testa : muricate External color : brown

4.6.2 Fruit class and fruit type

In this DDF, 37 out of the total of 38 tree species produced fruits in a one year fruiting period. Figure 4.42 showed a sharp fruit class in fleshy and dry dehiscent, when 15 and 15 species fruited, followed by dry indehiscent and fleshy multiple, when 5 and 2 species were in fruiting. For fruit type, showed a peak in drupe with 12 species followed by pod, capsule, berry, samara and follicle with 7, 6, 5, 5 and 2 species, respectively (Figure 4.43).

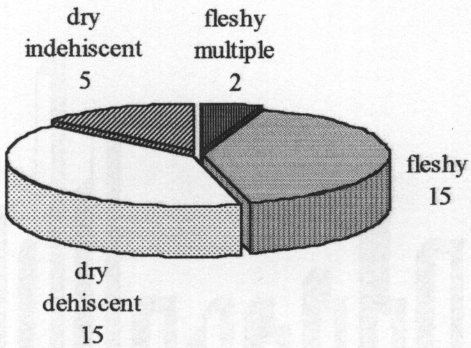


Figure 4.42 Fruit class of trees in Nong Rawiang DDF

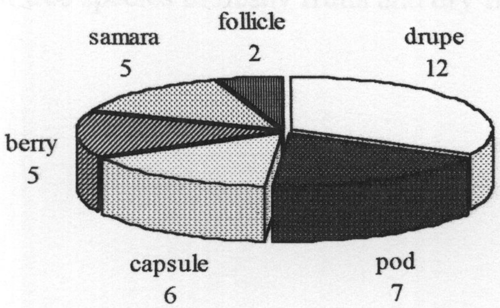


Figure 4.43 Fruit type of trees in Nong Rawiang DDF

As shown in Figure 4.44 fleshy fruits tended to be slightly variable in each month, with peak in April and September, whereas dry fruits presented more number of tree species with peak in March-April and November-December. The reason may have been due to the adaptation of wind-dispersed species for coinciding with the period of wind speed which usually peak in summer and winter or the adaptation of tree species to produce dry fruits for protect loss of water during dry season.

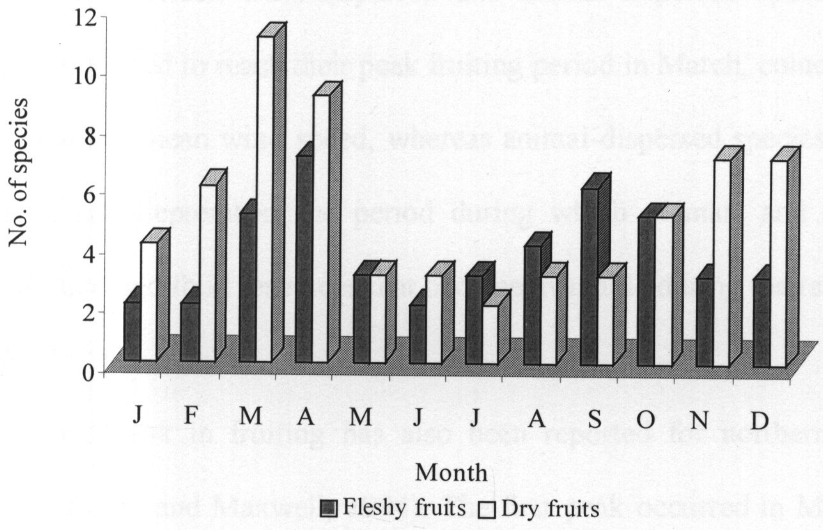


Figure 4.44 Number of tree species in fleshy fruits and dry fruits for each month.

4.6.3 Fruiting phenology

Fruiting of 16 species that peak in March and April before the rainy season showed less extreme fluctuation than flowering. The lowest fruiting level of 5 species occurred in June and July (Figure 4.45). A double peak in fruiting is also evident, when the first peak occurred in March-April and the second in October-December, suggesting a tendency for tree species to disperse and germinate their seeds when soil moisture availability is at a maximum.

A double peak in fruiting might be due, at least in part, to differences in the timing of fruiting between wind-dispersed and animal-dispersed species. Wind-dispersed species tended to reach their peak fruiting period in March, coinciding with the period of highest mean wind speed, whereas animal-dispersed species tended to peak in March and September, the period during which animals and birds take advantages of increased food resources that become available during the rainy season (Figure 4.46).

The double peak in fruiting has also been reported for northern Thailand (Elliott, Promkutkaew and Maxwell, 1994). The first peak occurred in March-April as the same period at Nong Rawiang and the second in July in all three years (1989-1991). The second peak of northern occurred faster than Nong Rawiang. This may be because in northern, the monsoon rains peak a month faster than in Nakhon Ratchasima. A partial temporal separation between the production of wind-dispersed and animal-dispersed fruits has not been reported before for a dry tropical forest, although Lieberman (1982) reported that in Ghana, fleshy fruits (usually animal-dispersed) are most abundant during the wet season, whereas dry fruits (often wind-dispersed) are more common during the dry season.

As well as coinciding with the availability of dispersal agents, whether strong winds or migratory animals, fruit production in Doi Suthep-Pui National Park, Thailand peaks slightly before or during the rainy season when soil moisture, needed for seed germination and seedling development, is plentiful (Elliott, Promkutkaew and Maxwell, 1994). Small showers, which usually occur in April, are sufficient to enable seed germination, and the high temperature that occurs at this time of the year (Figure 3.3) also seems to encourage germination if soil moisture is available (Hard wick and Elliott, 1992). Newton (1988) also reported that fruiting peaked immediately before and during the rainy season in a deciduous forest in India, although he could not detect any seasonal differences in the production of dry and fleshy fruits. In contrast, Murphy and Lugo (1986) found that in dry tropical forests in southern Puerto Rico, the largest number of species fruit at the end of the wet season.

Data on fruiting phenology for each species are presented in Appendix VI, Table 3. Fruiting period varied from less than 1 month (*Shorea* sp.) to more than 5 months (*Phyllanthus emblica, Lagerstroemia floribunda*). On average, fruits remain on the trees longer than flowers (mean of all species are 2.92 months compared with 2.58 months for flowers). In many species, fruiting was less synchronous than flowering due to high intraspecific variability in the length of the fruit-development period (defined as the mean time from peak flowering to peak fruiting). The fruit-development period was significantly longer for animal-dispersed tree species than for wind-dispersed tree species. This is to be expected, because wind-dispersed fruits must necessarily be small and light in weight, whereas animal-dispersed fruits tend to be large, heavy and need time to develop large quantities of pulp as a reward to attract animal dispersal agents (Elliott, Promkutkaew and Maxwell, 1994).

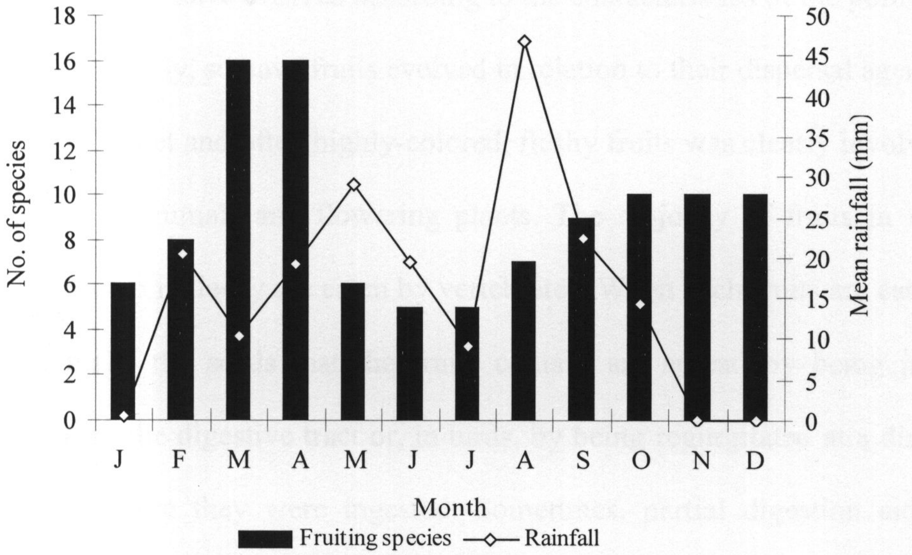


Figure 4.45 Number of tree species in fruits and mean rainfall for each month in the year 2000

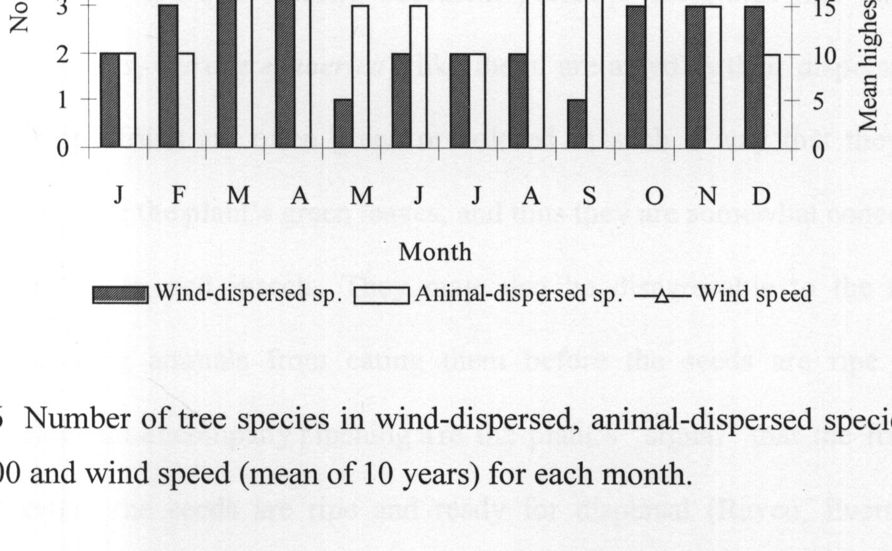


Figure 4.46 Number of tree species in wind-dispersed, animal-dispersed species in the year 2000 and wind speed (mean of 10 years) for each month.

4.6.4 Fruiting and dispersal

Just as flowers have evolved according to the characteristics of the pollinators that visit them regularly, so have fruits evolved in relation to their dispersal agents. The evolution of sweet and often highly-colored, fleshy fruits was clearly involved in the coevolution of animals and flowering plants. The majority of fruits in which much of the pericarp is fleshy are eaten by vertebrates. When such fruits are eaten by birds or mammals, the seeds that the fruits contain are spread by being passed unharmed through the digestive tract or, in birds, by being regurgitated at a distance from the place where they were ingested. Sometimes, partial digestion aids the germination of the seeds by weakening their seed coats.

When fleshy fruits ripen, they undergo a series of characteristic changes. Among these changes are a rise in sugar content, a softening of the fruit caused by the breakdown of pectic substances, and often a change in color from inconspicuous, leaf-like green to bright red, yellow, blue, or black (*Phyllanthus emblica*, *Lannea coromandelica*, *Artocarpus lacucha*, *Memecylon edule* etc.). The seeds of some trees have fleshy appendages, or arils with the bright colors characteristic of fleshy fruits (*Schleichera oleosa, Aporosa villosa*), succulent pericarp (*Strychnos nux-vomica*, *Diospyros ehretioides*, *Careya sphaerica*), like them, are aided in their dispersal by vertebrates. Unripe fruits are often green or colored in such a way that they are inconspicuous among the plant's green leaves, and thus they are somewhat concealed from birds, mammals, and insects. They may also be disagreeable to the taste, thereby discouraging animals from eating them before the seeds are ripe. The changes in color that accompany ripening are the plant's "signal" that the fruit is ready to be eaten, the seeds are ripe and ready for dispersal (Raven, Evert and

Eichhorn, 1992). In general, mammals tend to disperse larger fruits and seeds than birds do (Foster and Janson, 1985).

Dry fruits are classified as dehiscent and indehiscent. Dehiscent fruit in this forest involves pod, capsule and follicle, indehiscent includes samara. The dispersal mechanism is different from fleshy fruit. These trees comprise with animal-dispersed species and wind-dispersed species.

For animal-dispersed species, some dry seeds have bright colors arils, for example *Ellipanthus tomentosus* and *Sindora siamensis*. Many dry seeds are gathered and stored by rodents, such as squirrels and mice, some seeds are subsequently eaten but some may escape to germinate in the new situation.

Dispersal by wind is assisted when the seeds are very light and small e.g. the pericarp possesses wings with serve to prolong flight (*Pterocarpus macrocarpus*), develop a plumelike coma, which aids in keeping the light fruits aloft (*Wrightia arborea*). Fruits may also be winged by the enlargement of persistent sepals (*Shorea siamensis, S. obtusa, S. roxburghii, Dipterocarpus intricatus*). In some trees, the seed itself, rather than the fruit, bears the wing (*Lagerstroemia floribunda, Cratoxylum cochinchinense, C. formosum* and *Chukrasia tabularis*).

For other dispersal mechanisms, fruits of many trees mechanically eject seeds sometime with considerable force. In *Xylia xylocarpa*, when the fruit dries discharging the seeds so forcefully that they sometimes travel as far as 18 m from the parent trees. In *Sindora siamensis, Senna garrettiana, Erythrophleum succirubrum,* and *Albizea lebbeck* the pods separate suddenly, throwing seeds for some distance.

In general, moisture content is the most important single factor in determining seed longevity. Reduction in moisture content causes a reduction in respiration and thus slows down ageing of the seed and prolongs viability (Holmes and Buszewicz, 1958). Most of seeds in high moisture content usually loss their viability rapidly and difficult to disperse because their high seed weight, whereas seeds in low moisture content easy to disperse for far distance. As shown in Figure 4.47, the number of tree species in each seed moisture content peaks in the range of 10-20 % MC and decrease the species number steadily until zero in the range of 60-70 % MC and 80-100 % MC. It indicated that most of tree species are seeds in low moisture content. For tree species had seed moisture content more than 50 % MC including *Aporosa villosa, Shorea siamensis* and *Ellipanthus tomentosus*.

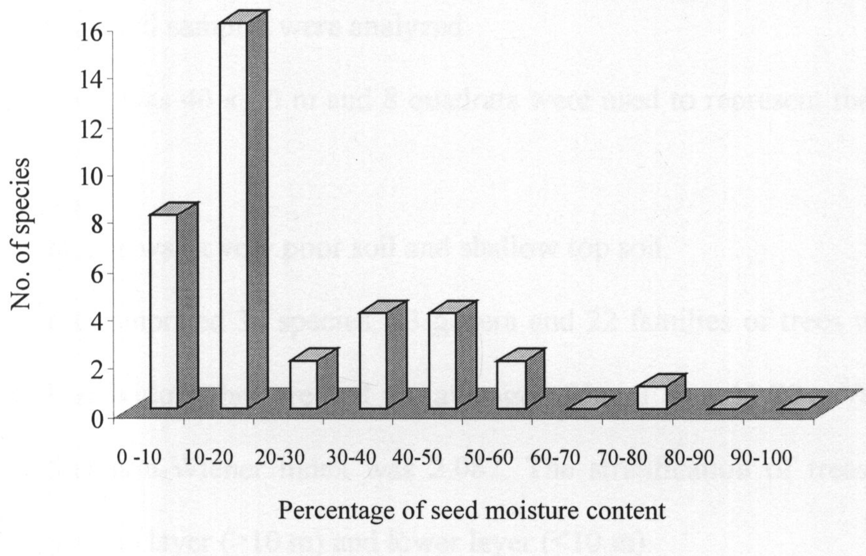


Figure 4.47 Number of tree species in each percentage of seed moisture content

CHAPTER V

CONCLUSIONS

5.1 Plant community description and analysis

From the study, structure and floristic composition of dry dipterocarp forest were investigated. The eight of 40 x 40 m plots were laid. All trees with DBH $\geq$ 3 cm were counted. Diameter at breast high and total height of trees were measured for calculating the basal area and for analysis of the vertical structure. The importance value index and Shannon-Wiener index were calculated. Tree species from each quadrat were described and soil samples were analyzed.

1. Quadrat size was 40 x 40 m and 8 quadrats were used to represent the whole study area.

2. The forest site was a very poor soil and shallow top soil.

3. The forest comprised 38 species, 33 genera and 22 families of trees with the average of 982 individuals/hectare and the average of basal area 11.70 m^2/hectare. The value of Shannon-Wiener index was 2.087. The stratification of trees had 2 layers which were top layer (>10 m) and lower layer (<10 m).

4. *Shorea siamensis* showed the highest relative importance value index of 35.03 %, and also in frequency, abundance, relative density and relative dominance. Another dominant tree species were *Xylia xylocarpa, Ellipanthus tomentosus* and *Sindora siamensis*.

5. Three types of *Shorea siamensis* and *Ellipanthus tomentosus* were found.

5.2 Flowering phenomena and pollinator observation

Flowering of tree species was observed throughout DDF area every week in one year period. Flower morphological features were studied. Relational values between flowering tree species and environmental factors in each month were analysed. Four individuals of each dominant tree species were selected as the representative species to be studied on their pollination mechanism. Pollinators behavior were recorded twice per month in fixed period of time. The following conclusion can be deduced.

1. There were 36 out of the total of 38 tree species in DDF which produced flowers in a one year period. The flowering time of most trees started flowering from January to May. A sharp peak in flowering was in March.

2. The major number of tree species produced flowers in panicle inflorescence, cup shape, yellow petal, mean floral diameter being 0.1-1.0 cm and terminal flower position. There were 81.58 % of perfect flowers, the numbers of these flowers with stigma above anther were 47.37 % of total flowers.

3. Light intensity and evaporation were the most effective factors affecting the flowering of total species which the relative correlation (r^2) were 67.10 and 61.50 %, respectively.

4. *Xylocopa* species and *Trigona apicalis* were the most frequent dominant flower pollinators. The peak visitation period in *Shorea siamensis* and *Sindora siamensis* of *Xylocopa* species and *Trigona apicalis* were 10.00, 12.00 h and 12.00, 9.00 h, respectively.

5.3 Pollen efficiency

Bloom flowers from tree species at Nong Rawiang DDF were selected. Anthers were clipped from flowers before noon, and crushed the anthers in a beaker with distilled water. Pollen suspension was dusted onto Brewbaker's medium on 0.5 % agar slide. The results of pollen germination led to following conclusions.

1. There were highly significant differences in pollen germination of *Ellipanthus tomentosus* among three types by means. Fertile flower (31.75 %) had the mean pollen germination percentage higher than long sterile pistil (13.19 %) and short sterile pistil (3.07 %).

2. Pollen of *Sindora siamensis* showed significant differences in germination among two types, through *Si. siamensis* v. *siamensis* (23.84 %) had the mean pollen germination percentage higher than *Si. siamensis* v. *maritima* (18.61 %).

3. The dominant tree species had pollen germination less than 32 %.

4. The mean pollen germination percentage of target tree species ranked from 3.90 % in *Cratoxylum cochinchinense* to 30.31 % in *Schleichera oleosa*.

5.4 Seed production and seed dispersal

Sixteen isolated individual or group of parent trees of 4 dominant tree species at Nong Rawiang were selected. For the wing-seed species, the number of fallen flowers and fruits in traps of 50 x 50 cm placed in 8 directions at 2 meter intervals from parent trees were counted. The fruit and wing's size at various interval from the parent trees were measured. For the wingless-seed species, the number of fallen flowers and fruits in plastic net placed under the crown cover area of parent trees were counted. The fallen fruits defected by insects were observed. Life cycle, reproductive success of parent trees and sampled mature fruits at natural site were investigated. Seedlings in seedbeds were observed for growth rate and development.

1. The dispersal radius of mature fruits of *Xylia xylocarpa* and *Shorea siamensis* were longer than 18 m and 30 m, respectively.

2. The average fruit size and fruit weight of *Sh. siamensis* found at various distance from the parent trees were clearly different. The crown width of *X. xylocarpa* was correlated with the distance of fruit dispersal and the height of *Ellipanthus tomentosus* parent trees was also correlated with the number of flowers.

3. The ratio of flowers : young fruits : mature fruits of *Sh. siamensis* was 20.87 : 5.50 : 1. The ratio of flowers : fruits of *X. xylocarpa, E. tomentosus* and *Sindora siamensis* were 166.44 : 1, 1.20 : 1 and 41.50 : 1, respectively.

4. Reproductive success of *Sh. siamensis*, *X. xylocarpa, E. tomentosus* and *Si. siamensis* were 5.57, 0.01, 40.89 and 0.41 %, respectively.

5. The mature fruits of *Sh. siamensis*, *E. tomentosus* and *Si. siamensis* had an attack by insects since they were on the parent trees, these insects consisted of *Omiodes* sp., *Araecerus* sp. and *Carpophilus* sp., respectively.

6. The germination type of *X. xylocarpa, E. tomentosus* and *Si. siamensis* was epigeal germination except for *Sh. siamensis* was hypogeal germination.

7. In natural site for the study year, *Sh. siamensis* did not succeed in seed germination and establishment of seedlings, *X. xylocarpa* and *Si. siamensis* moderately succeeded in seed germination and establishment of seedlings and *E. tomentosus* succeeded in seed germination whereas it did not succeed in establishment of seedlings. Rainfall and its distribution is the most effective factor affecting the success of seed germination and seedling establishment.

5.5 Seed quality

Mature seeds from each tree species at Nong Rawiang DDF were collected. Seed moisture content and seed germination tests were determined following the procedure prescribed by ISTA (1996). Number of normal seedlings and days of counting were calculated for germination index. The normal seedlings were further classified as "strong" and "weak" for seedling vigor classification. Target seeds of tree species were irradiated with X-ray machine and seed classified into 2 categories, viable and non viable. The results of seed quality testing were the following conclusions.

1. There were 13 out of the total of 32 target tree species that showed percentage of seed germination more than 75 %.

2. There were significant differences in seed germination test among 3 types of *Shorea siamensis* and the yellow peduncle-yellow wing type showed the highest germination percentage.

3. There were highly significant differences in seed germination test, seedling vigor classification and germination index among individual trees of *Xylia xylocarpa,* but there were no significant differences in germination and vigor among individual trees of *Ellipanthus tomentosus.*

4. The seed of *Sindora siamensis* v. *maritima* gave better germination and vigor than *Sindora siamensis* v. *siamensis.*

5. All of 3 dominant tree species had seed germination more than 80 % except *Ellipanthus tomentosus* had 16.25 %, this was due to the attack of insects.

6. The highest numbers of germination index were 79.17 in *Albizia lebbeck* and 71.25 in *Senna garrettiana.*

5.6 Morphological database of fruits and seeds

Twenty fruits and seeds from individual trees species at Nong Rawiang DDF were studied on physical characteristics. Number of tree species in fruit class, wind-dispersed species and animal-dispersed species were investigated and compared for each month.

1. Thirty-seven out of the total of 38 tree species produced fruits in a one year fruiting period.

2. Tree fruiting showed the first peak period of 16 species in March and April before rainy season and the second peak of 10 species in October to December.

3. Fleshy and dry dehiscent fruits were the most common fruit type found all year round.

4. The peak fruiting period for wind-dispersed species was in March, coinciding with the period of highest mean wind speed whereas animal-dispersed species tended to peak in March and September.

Limitations of the research

1. Tropical forest trees are extremely variable in frequency of flowering especially in DDF. They range from more than once per year to an interval of several years. As shown in the study year of 2000, *Bauhinia racemosa* and *Shorea obtusa* did not flower whereas in *Shorea siamensis* trees a few flowers occurred and the same trees showed abundant flowering in the year 2002. Thus, all the data is not the same in years on the results.

2. For the study on seed dispersal of *Shorea siamensis*, it is difficult to choose isolated individual of parent trees in the natural site. Most of them grew in groups of trees. This tree species has wind-dispersed seeds, so the seed-traps of target parent trees may be disturbed by other *Shorea siamensis* seeds.

Application from the research

1. Based on the plant community analysis, the results can be applied for the development of forest conservation and management programmes. For example, in the natural forest on degraded land, reforestation method should be used. In the secondary DDF which has low trees density and more distant from seed sources it should be used enrichment planting method by planting various indigenous tree species. This involves selecting mixtures of native forest trees species for their ability to grow fast, shade out weeds, recover rapidly after burning and attract seed-dispersing wildlife. In the secondary DDF which has high trees density and where there is still an adequate seed source, given enough time and protection from disturbance, forests will regenerate themselves. Tree cover can be restored within decades. Nong Rawiang forest is a secondary DDF with rather low trees density of 982 trees/hectare when compared with another DDF. The RIT-NEC can provide the appropriate methods to restore this DDF, but whether or not these methods are put into practice depends on political and economic factors.

2. Failure of a species to produce seed can be traced to the absence of pollinators or lack of synchronization between pollinators and floral receptivity. If a tree species has many pollinators, there may always be adequate vectors for seed production, whereas species that rely on a single pollinator may frequently have low seed production. Thus, a basic understanding of flowering, pollination and pollinator is essential background information for reproductive and breeding system, for instance, a study of flower morphology is expected to understand compatibility patterns and pollination mechanism of the vegetation and could be used to indicate the types of

pollinators. A study of type, number and peak period visitation of pollinators could be use to predict the success of plant production.

3. The second most important deterrent to successful reproduction, following failure to initiate flowers, is the failure of flowers to be pollinated. The value of pollen efficiency can be use to explain the success of plant pollination.

4. The constancy of plant community in the nature depends on the reproductive success of new regeneration beneath the parent plant or within the gap of the canopy which is a result of seed production, seed dispersal, seed germination and seedling establishment. Seed production in forest trees is the culmination of a series of developmental events. Many things can go wrong during development and it is that something will occur to reduce the amount of seed produced. In addition, survival and growth of young seedlings under the parent tree is often difficult, because of lack of light and intense root competition. Dispersal over a wide area can ensure that some seeds find conditions suitable for germination and survival. So we can use the knowledge of seed dispersal, seed production, reproductive success and seedling establishment to explain the entire reproductive process.

5. Efficiency and success in raising plants in their subsequent establishment in forest plantations depend to a great extent on the quality of the seeds used. It follows that foresters need accurate estimates of the quality of the seeds in which they deal or which form the basis of their afforestation projects. For the practising forester, the most important object of seed testing is the provision of an accurate estimate of the capacity of a given seedlot to produce healthy, vigorous plants suitable and to determine the value of seed for field planting. Thus, the quality and vigor of

seedlings used for planting are among the most important factors in determining the success of plantation establishment.

6. For a study of the tree phenology, trees are observed for the presence of flowers and fruits. This work will provide information on the seasonal availability of seed for planting. The phenological data could be used to plant seed collection and nursery work programs for forest restoration projects and to determine which treatments might be appropriate to break seed dormancy. For example, seed produced during the dry season might respond to desiccation or heat treatments, whereas for those produced during the rainy season, soaking might be more appropriate. Flower and fruit phenology may indicate the habitat preference of tree species because individuals in suboptimal habitats may have low flowering intensity and low rates of seed set. Phenological observations usually also yield valuable information about pollination and seed dispersal mechanisms. In northern Thailand, for example, the local extirpation of pollinators and seed dispersers (e.g., bats, hornbills, and gibbons) is a serious problem. Tree species that rely on such animals for reproduction will have to be propagated in nurseries if they are not to become extinct. Phenological studies also enable the identification of "keystone" tree species, i.e., those that flower or fruit at times when other food resources are in short supply, thus supporting a wide range of animal pollinators and seed dispersers, which, in turn, are essential to the survival of many other plant species. Knowledge of the seasonality of flowering and fruiting, therefore, has much to contribute towards the development of effective management strategies for the conservation of tropical forests (Elliott, Promkutkaew and Maxwell (1994).

7. Fruit and seed characteristics are being entered into a database that will act as an identification guide for find out the tree species which may be affected with seed dispersal and to correlate seed characteristics with germination success. If trees along the phenology trails are observed in fruit, seeds are collected for germination trials. In addition, a target list of tree species fruiting is generated for each month, using the database. Extra trips are then made to collect the seeds of any fruiting species not present on the phenology trails. Furthermore, since most floras identify plant species on the basis of flower characteristics. Fruit and seed morphology also can be used for the beginning identification before further distinguish in laboratory. Database output of this kind can have considerable value for research in forest conservation and related field.

Recommendations

1. Seed and fruit production of tropical forest trees are extremely variable from year to year and from tree to tree. For follow-up research on the reproductive ecology of individual dominant tree species should be continual study for 3-4 years in order to relies on the judgement of the observer and to a certain extent.

2. Moreover, the study in detail of the reproductive ecology should be involve in another target tree species especially dominant tree species of Mix Deciduous Forest in Nong Rawiang.

3. It is also recommended that further work is needed for study the method to protect the loss of young fruits which have highly fallen from parent tree in order to solve the lack of seeds.

4. One of the most frequent causes of reduces seed production is large quantities of forest seeds are destroyed by seed insects. Study life cycle of seed insects should be included in further research.

5. There should be a study on causes of the failure in seed germination test of *Bridelia retusa* and *Cratoxylum formosum* seeds.

6. In Nong Rawiang forest, fruits and seeds that fall during the first fruiting peak in March and April may be endangered by forest fires that continue well into May. The seeds of most tree species in the dipterocarp forest and mix deciduous forest of Nong Rawiang forest are killed by fire. The seeds of a few species may survive the fires with considerably reduced rates of germination, but very young seedlings would almost certainly be killed. No species tested so far seems to require exposure to fire to encourage germination. Because the distribution of fires is very patchy, however, many seeds are unaffected. Further studies on the effect of fire on the reproduction of forest trees are clearly necessary.

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APPENDICES

APPENDIX I

PLANT COMMUNITY DESCRIPTION AND ANALYSIS

Table 1.1 Number and species of trees in different quadrat sizes for site 1

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	2	2	*Shorea siamemsis*
			Xylia xylocarpa
10 x 10	3	5	*Memecylon edule*
			Aporosa villosa
			Ellipanthus tomentosus
15 x 15	4	9	*Bridelia retusa*
			Shorea obtusa
			Rothmannia wittii
			Canarium subulatum
20 x 20	1	10	*Schleichera oleosa*
25 x 25	1	11	*Ochna integerrima*
30 x 30	2	13	*Lannea coromandelica*
			Chukrasia tabularis
35 x 35	3	16	*Morinda coreia*
			Vitex pinnata
			Irvingia malayana
40 x 40	1	17	*Haldina cordifolia*
45 x 45	1	18	*Sindora siamensis*
50 x 50	1	19	*Strychnos nux-vomica*
55 x 55	1	20	*Phyllanthus emblica*
60 x 60	1	21	*Artocarpus lacucha*

Table 1.2 Number and species of trees in different quadrat sizes for site 2

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	3	3	*Shorea obtusa*
			Buchanania lanzan
			Ellipanthus tomentosus
10 x 10	5	8	*Canarium subulatum*
			Aporosa villosa
			Chukrasia tabularis
			Lannea coromandelica
			Shorea siamensis

Table 1.2 (cont.)

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
15 x 15	3	11	*Xylia xylocarpa* *Pterocarpus macrocarpus* *Rothmannia wittii*
20 x 20	_	11	_
25 x 25	2	13	*Irvingia malayana* *Gardenia sootepensis*
30 x 30	5	18	*Ochna integerrima* *Phyllanthus emblica* *Schleichera oleosa* *Sindora siamensis* *Memecylon edule*
35 x 35	1	19	*Strychnos nux-vomica*
40 x 40	3	22	*Haldina cordifolia* *Diospyros ehretioides* *Dipterocarpus intricatus*
45 x 45	1	23	*Vitex pinnata*
50 x 50	2	25	*Artocarpus lacucha* *Senna garrettiana*
55 x 55	1	26	*Cratoxylum cochinchinense*
60 x 60	_	26	_

Table 1.3 Number and species of trees in different quadrat sizes for site 3

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	1	1	*Morinda coreia*
10 x 10	1	2	*Lannea coromandelica*
15 x 15	2	4	*Shorea siamemsis* *Sindora siamensis*
20 x 20	2	6	*Canarium subulatum* *Xylia xylocarpa*
25 x 25	1	7	*Ochna integerrima*
30 x 30	1	8	*Phyllanthus emblica*
35 x 35	1	9	*Ellipanthus tomentosus*
40 x 40	2	11	*Rothmannia wittii* *Aporosa villosa*
45 x 45	1	12	*Haldina cordifolia*
50 x 50	1	13	*Senna garrettiana*
55 x 55	1	14	*Schleichera oleosa*
60 x 60	_	14	_

Table 1.4 Number and species of trees in different quadrat sizes for site 4

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	4	4	*Pterocarpus macrocarpus*
			Lannea coromandelica
			Ellipanthus tomentosus
			Shorea siamensis
10 x 10	2	6	*Morinda coreia*
			Sindora siamensis
15 x 15	2	8	*Ochna integerrima*
			Chukrasia tabularis
20 x 20	5	13	*Haldina cordifolia*
			Erythrophleum succirubrum
			Schleichera oleosa
			Strychnos nux-vomica
			Xylia xylocarpa
25 x 25	_	13	_
30 x 30	_	13	_
35 x 35	3	16	*Vitex pinnata*
			Canarium subulatum
			Phyllanthus emblica
40 x 40	_	16	_
45 x 45	1	17	*Gardenia sootepensis*
50 x 50	1	18	*Wrightia arborea*
55 x 55	_	18	_
60 x 60	1	19	*Aporosa villosa*

Table 1.5 Number and species of trees in different quadrat sizes for site 5

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	2	2	*Shorea siamensis*
			Morinda elliptica
10 x 10	3	5	*Erythrophleum succirubrum*
			Schleichera oleosa
			Gardenia sootepensis
15 x 15	1	6	*Sindora siamensis*
20 x 20	4	10	*Xylia xylocarpa*
			Ellipanthus tomentosus
			Vitex pinnata
			Lannea coromandelica
25 x 25	3	13	*Haldina cordifolia*
			Morinda coreia
			Aporosa villosa
30 x 30	2	15	*Buchanania lanzan*
			Ochna integerrima
35 x 35	1	16	*Albizia lebbeck*
40 x 40	_	16	_
45 x 45	_	16	_
50 x 50	_	16	_
55 x 55	1	17	*Senna garrettiana*
60 x 60	_	17	_

Table 1.6 Number and species of trees in different quadrat sizes for site 6

Size of plots (m x m)	Number of species: Number	Number of species: Accumulation	Scientific names
5 x 5	2	2	*Lannea coromandelica*
			Sindora siamensis
10 x 10	1	3	*Shorea siamensis*
15 x 15	1	4	*Xylia xylocarpa*
20 x 20	1	5	*Erythrophleum succirubrum*
25 x 25	1	6	*Albizia lebbec*
30 x 30	3	9	*Schleichera oleosa*
			Phyllanthus emblica
			Morinda coreia
35 x 35	_	9	_
40 x 40	1	10	*Rothmannia wittii*
45 x 45	_	10	_
50 x 50	1	11	*Vitex pinnata*
55 x 55	_	11	_
60 x 60	2	13	*Ellipanthus tomentosus*
			Ochna integerrima

Table 1.7 Number and species of trees in different quadrat sizes for site 7

Size of plots (m x m)	Number of species: Number	Number of species: Accumulation	Scientific names
5 x 5	2	2	*Shorea siamensis*
			Sindora siamensis
10 x 10	1	3	*Morinda coreia*
15 x 15	2	5	*Erythrophleum succirubrum*
			Xylia xylocarpa
20 x 20	3	8	*Gardenia sootepensis*
			Aporosa villosa
			Ellipanthus tomentosus
25 x 25	3	11	*Lannea coromandelica*
			Ochna integerrima
			Cratoxylum cochichinense
30 x 30	5	16	*Senna garrettiana*
			Rothmannia wittii
			Haldina cordifolia
			Wrightia arborea
			Memecylon edule
35 x 35	2	18	*Chukrasia tabularis*
			Canarium subulatum
40 x 40	2	20	*Vitex pinnata*
			Bauhinia racemosa
45 x 45	2	22	*Pterocarpus macrocarpus*
			Schleichera oleosa
50 x 50	_	22	_
55 x 55	_	22	_
60 x 60	_	22	_

Table 1.8 Number and species of trees in different quadrat sizes for site 8

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	1	1	*Xylia xylocarpa*
10 x 10	_	1	_
15 x 15	1	2	*Shorea siamensis*
20 x 20	6	8	*Erythrophleum succirubrum*
			Sindora siamensis
			Canarium subulatum
			Haldina cordifolia
			Ellipanthus tomentosus
			Lannea coromandelica
25 x 25	_	8	_
30 x 30	1	9	*Lagerstroemia floribunda*
35 x 35	1	10	*Cratoxylum cochichinense*
40 x 40	3	13	*Ochna integerrima*
			Schleichera oleosa
			Bauhinia racemosa
45 x 45	1	14	*Morinda coreia*
50 x 50	_	14	_
55 x 55	_	14	_
60 x 60	_	14	_

Table 1.9 Number and species of trees in different quadrat sizes for site 9

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	1	1	*Lannea coromandelica*
10 x 10	2	3	*Sindora siamensis*
			Shorea siamensis
15 x 15	2	5	*Erythrophleum succirubrum*
			Ellipanthus tomentosus
20 x 20	1	6	*Buchanania lanzan*
25 x 25	2	8	*Xylia xylocarpa*
			Canarium subulatum
30 x 30	1	9	*Haldina cordifolia*
35 x 35	1	10	*Ochna integerrima*
40 x 40	2	12	*Gardenia sootepensis*
			Rothmannia wittii
45 x 45	1	13	*Morinda coreia*
50 x 50	_	13	_
55 x 55	1	14	*Pterocarpus macrocarpus*
60 x 60	1	15	*Phyllanthus emblica*

Table 1.10 Number and species of trees in different quadrat sizes for site 10

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	1	1	*Shorea siamensis*
10 x 10	2	3	*Sindora siamensis*
			Ellipanthus tomentosus
15 x 15	2	5	*Rothmannia wittii*
			Chukrasia tabularis
20 x 20	2	7	*Aporosa villosa*
			Irvingia malayana
25 x 25	2	9	*Lannea coromandelica*
			Canarium subulatum
30 x 30	4	13	*Haldina cordifolia*
			Schleichera oleosa
			Gardenia sootepensis
			Strychnos nux-vomica
35 x 35	1	14	*Morinda coreia*
40 x 40	3	17	*Artocarpus lacucha*
			Xylia xylocarpa
			Phyllanthus emblica
45 x 45	1	18	*Erythrophleum succirubrum*
50 x 50	1	19	*Ochna integerrima*
55 x 55	1	20	*Vitex pinnata*
60 x 60	_	20	–

Table 1.11 Number and species of trees in different quadrat sizes for site 11

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	2	2	*Shorea siamensis*
			Ellipanthus tomentosus
10 x 10	2	4	*Phyllanthus emblica*
			Xylia xylocarpa
15 x 15	2	6	*Sindora siamensis*
			Gardenia sootepensis
20 x 20	2	8	*Irvingia malayana*
			Haldina cordifolia
25 x 25	4	12	*Aporosa villosa*
			Rothmannia wittii
			Erythrophleum succirubrum
			Morinda elliptica
30 x 30	6	18	*Ochna integerrima*
			Artocarpus lacucha
			Strychnos nux-vomica
			Lannea coromandelica
			Careya sphaerica
			Canarium subulatum

Table 1.11 (cont.)

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
35 x 35	2	20	*Schleichera oleosa* *Cratoxylum formosum*
40 x 40	2	22	*Bridelia retusa* *Shorea roxburghii*
45 x 45	_	22	_
50 x 50	2	24	*Pterocarpus macrocarpus* *Buchanania lanzan*
55 x 55	1	25	*Vitex pinnata*
60 x 60	1	26	*Wrightia arborea*

Table 1.12 Number and species of trees in different quadrat sizes for site 12

Size of plots (m x m)	Number of species		Scientific names
	Number	Accumulation	
5 x 5	1	1	*Phyllanthus emblica*
10 x 10	4	5	*Shorea siamensis* *Ellipanthus tomentosus* *Chukrasia tabularis* *Gardenia sootepensis*
15 x 15	3	8	*Rothmannia wittii* *Canarium subulatum* *Strychnos nux-vomica*
20 x 20	1	9	*Schleichera oleosa*
25 x 25	2	11	*Xylia xylocarpa* *Morinda coreia*
30 x 30	5	16	*Artocarpus lacucha* *Haldina cordifolia* *Lannea coromandelica* *Aporosa villosa* *Sindora siamensis*
35 x 35	1	17	*Irvingia malayana*
40 x 40	1	18	*Buchanania lanzan*
45 x 45	1	19	*Ochna integerrima*
50 x 50	2	21	*Pterocarpus macrocarpus* *Erythrophleum succirubrum*
55 x 55	1	22	*Albizia lebbeck*
60 x 60	_	22	_

Table 2 Presence and absence of tree species in all quadrat sites.

Species	Quadrat sites											
	1	2	3	4	5	6	7	8	9	10	11	12
1. *Shorea siamemsis*	+	+	+	+	+	+	+	+	+	+	+	+
2. *Xylia xylocarpa*	+	+	+	+	+	+	+	+	+	+	+	+
3. *Memecylon edule*	+	+	-	-	-	-	+	-	-	-	-	-
4. *Aporosa villosa*	+	+	+	-	+	-	+	-	-	+	+	+
5. *Ellipanthus tomentosus*	+	+	+	+	+	-	+	+	+	+	+	+
6. *Bridelia retusa*	+	-	-	-	-	-	-	-	-	-	+	-
7. *Shorea obtusa*	+	+	-	-	-	-	-	-	-	-	-	-
8. *Rothmannia wittii*	+	+	+	-	-	+	+	-	+	+	+	+
9. *Canarium subulatum*	+	+	+	+	-	-	+	+	+	+	+	+
10. *Schleichera oleosa*	+	+	-	+	+	+	-	+	-	+	+	+
11. *Ochna integerrima*	+	+	+	+	+	-	+	+	+	-	+	-
12. *Lannea coromandelica*	+	+	+	+	+	+	+	+	+	+	+	+
13. *Chukrasia tabularis*	+	+	-	+	-	-	+	-	-	+	-	+
14. *Morinda coreia*	+	-	+	+	+	+	+	-	-	+	-	+
15. *Vitex pinnata*	+	-	-	+	+	-	+	-	-	-	-	-
16. *Irvingia malayana*	+	+	-	-	-	-	-	-	-	+	+	+
17. *Haldina cordifolia*	+	+	-	+	+	-	+	+	+	+	+	+
18. *Buchanania lanzan*	-	+	-	-	+	-	-	-	+	-	-	+
19. *Pterocarpus macrocarpus*	-	+	-	+	-	-	-	-	-	-	-	-
20. *Gardenia sootepensis*	-	+	-	-	+	-	+	-	+	+	+	+
21. *Sindora siamensis*	-	+	+	+	+	+	+	+	+	+	+	+
22. *Phyllanthus emblica*	-	+	+	+	-	+	+	-	-	+	+	+
23. *Strychnos nux-vomica*	-	+	-	+	-	-	-	-	-	+	+	+
24. *Dipterocarpus intricatus*	-	+	-	-	-	-	-	-	-	-	-	-
25. *Diospyros ehretioides*	-	+	-	-	-	-	-	-	-	-	-	-
26. *Erythrophleum succirubrum*	-	-	-	+	+	+	+	+	+	-	+	-
27. *Morinda elliptica*	-	-	-	-	+	-	-	-	-	-	+	-
28. *Albizia lebbeck*	-	-	-	-	+	+	-	-	-	-	-	-
29. *Cratoxylum cochichinense*	-	-	-	-	-	-	+	+	-	-	-	-
30. *Senna garrettiana*	-	-	-	-	-	-	+	-	-	-	-	-

Table 2 (cont.)

Species	Quadrat sites											
	1	2	3	4	5	6	7	8	9	10	11	12
31. *Wrightia arborea*	-	-	-	-	-	-	+	-	-	-	-	-
32. *Bauhinia racemosa*	-	-	-	-	-	-	+	+	-	-	-	-
33. *Lagerstroemia floribunda*	-	-	-	-	-	-	-	+	-	-	-	-
34. *Artocarpus lacucha*	-	-	-	-	-	-	-	-	-	+	+	+
35. *Careya sphaerica*	-	-	-	-	-	-	-	-	-	-	+	-
36. *Cratoxylum formosum*	-	-	-	-	-	-	-	-	-	-	+	-
37. *Shorea roxburghii*	-	-	-	-	-	-	-	-	-	-	+	-
Accumulating total of no.sp.	17	25	25	26	28	28	32	33	33	34	37	37

\+ = tree species presented

Table 3 Number of individuals per species in each quadrat.

Tree species	Quadrat sites							
	Q1	Q2	Q4	Q5	Q7	Q8	Q10	Q11
1. *Buchanania lanzan*	-	5	-	1	-	-	-	-
2. *Lannea coromandelica*	15	13	9	5	15	10	2	1
3. *Wrightia arborea*	-	-	-	-	1	-	-	-
4. *Canarium subulatum*	3	6	1	-	3	7	3	2
5. *Bauhinia racemosa*	-	-	-	-	1	1	-	-
6. *Erythrophleum succirubrum*	-	-	2	4	7	4	-	2
7. *Senna garrettiana*	-	-	-	-	1	-	-	-
8. *Sindora siamensis*	-	1	17	6	12	5	17	16
9. *Ellipanthus tomentosus*	19	21	5	9	7	1	15	19
10. *Dipterocarpus intricatus*	-	1	-	-	-	-	-	-
11. *Shorea obtusa*	10	70	-	-	-	-	-	-
12. *Shorea roxburghii*	-	-	-	-	-	-	-	1
13. *Shorea siamemsis*	67	48	70	132	68	25	100	110
14. *Diospyros ehretioides*	-	1	-	-	-	-	-	-

Table 3 (cont.)

Tree species	Quadrat sites							
	Q1	Q2	Q4	Q5	Q7	Q8	Q10	Q11
15. *Aporosa villosa*	3	6	-	3	4	-	1	2
16. *Bridelia retusa*	1	-	-	-	-	-	-	1
17. *Phyllanthus emblica*	-	2	2	-	-	-	1	1
18. *Cratoxylum cochinchinense*	-	-	-	-	3	1	-	-
19. *Cratoxylum formosum*	-	-	-	-	-	-	-	1
20. *Irvingia malayana*	1	1	-	-	-	-	1	2
21. *Vitex pinnata*	1	-	1	1	2	-	-	-
22. *Careya sphaerica*	-	-	-	-	-	-	-	1
23. *Lagerstroemia floribunda*	-	-	-	-	-	1	-	-
24. *Memecylon edule*	5	2	-	-	2	-	-	-
25. *Chukrasia tabularis*	2	2	2	-	1	-	4	-
26. *Albizia lebbeck*	-	-	-	1	-	-	-	-
27. *Xylia xylocarpa*	28	20	4	1	4	24	3	8
28. *Artocarpus lacucha*	-	-	-	-	-	-	1	2
29. *Ochna integerrima*	3	1	1	1	1	1	-	1
30. *Pterocarpus macrocarpus*	-	1	2	-	-	-	-	-
31. *Gardenia sootepensis*	-	2	-	1	9	-	2	1
32. *Haldina cordifolia*	1	1	4	5	1	1	1	1
33. *Morinda coreia*	1	-	1	4	9	-	1	-
34. *Morinda elliptica*	-	-	-	4	-	-	-	1
35. *Rothmannia wittii*	2	2	-	-	2	-	7	3
36. *Schleichera oleosa*	3	1	1	3	-	2	3	2
37. *Strychnos nux-vomica*	-	3	1	-	-	-	1	1
Total	165	210	123	181	153	83	163	179

Table 4 Basal area of individuals per species in each quadrat (cm^2)

Tree species	Quadrat sites						
	Q1	Q2	Q4	Q5	Q7	Q8	Q10	Q11
1. *Buchanania lanzan*	-	319	-	44	-	-	-	-
2. *Lannea coromandelica*	661	681	656	278	847	1282	495	16
3. *Wrightia arborea*	-	-	-	-	121	-	-	-
4. *Canarium subulatum*	205	850	160	-	670	3615	341	753
5. *Bauhinia racemosa*	-	-	-	-	81	780	-	-
6. *Erythrophleum succirubrum*	-	-	506	806	1383	640	-	321
7. *Senna garrettiana*	-	-	-	-	147	-	-	-
8. *Sindora siamensis*	-	336	1302	1311	2285	1553	2076	1493
9. *Ellipanthus tomentosus*	1942	1732	366	908	329	140	1271	2424
10. *Dipterocarpus intricatus*	-	250	-	-	-	-	-	-
11. *Shorea obtusa*	694	4346	-	-	-	-	-	-
12. *Shorea roxburghii*	-	-	-	-	-	-	-	509
13. *Shorea siamemsis*	7898	3192	8970	14389	9234	4176	12557	14735
14. *Diospyros ehretioides*	-	39	-	-	-	-	-	-
15. *Aporosa villosa*	81	358	-	107	377	-	54	96
16. *Bridelia retusa*	20	-	-	-	-	-	-	305
17. *Phyllanthus emblica*	-	88	96	-	-	-	39	251
18. *Cratoxylum cochinchinense*	-	-	-	-	171	459	-	-
19. *Cratoxylum formosum*	-	-	-	-	-	-	-	336
20. *Irvingia malayana*	455	560	-	-	-	-	29	213
21. *Vitex pinnata*	115	-	306	115	222	-	-	-
22. *Careya sphaerica*	-	-	-	-	-	-	-	103
23. *Lagerstroemia floribunda*	-	-	-	-	-	279	-	-
24. *Memecylon edule*	89	37	-	-	68	-	-	-
25. *Chukrasia tabularis*	93	112	243	-	199	-	267	-
26. *Albizia lebbeck*	-	-	-	703	-	-	-	-
27. *Xylia xylocarpa*	4345	3979	611	37	507	5033	159	1204
28. *Artocarpus lacucha*	-	-	-	-	-	-	10	312
29. *Ochna integerrima*	325	17	54	161	43	223	-	92
30. *Pterocarpus macrocarpus*	-	306	526	-	-	-	-	-

Table 4 (cont.)

Tree species	Quadrat sites							
	Q1	Q2	Q4	Q5	Q7	Q8	Q10	Q11
31. *Gardenia sootepensis*	-	283	-	29	666	-	125	249
32. *Haldina cordifolia*	50	18	182	210	46	140	54	8
33. *Morinda coreia*	32	-	35	600	1007	-	130	-
34. *Morinda elliptica*	-	-	-	907	-	-	-	10
35. *Rothmannia wittii*	284	130	-	-	54	-	835	209
36. *Schleichera oleosa*	153	151	160	116	-	163	192	202
37. *Strychnos nux-vomica*	-	144	13	-	-	-	35	67
Total	17,442	17,928	14,186	20,721	18,457	18,483	18,669	23,908

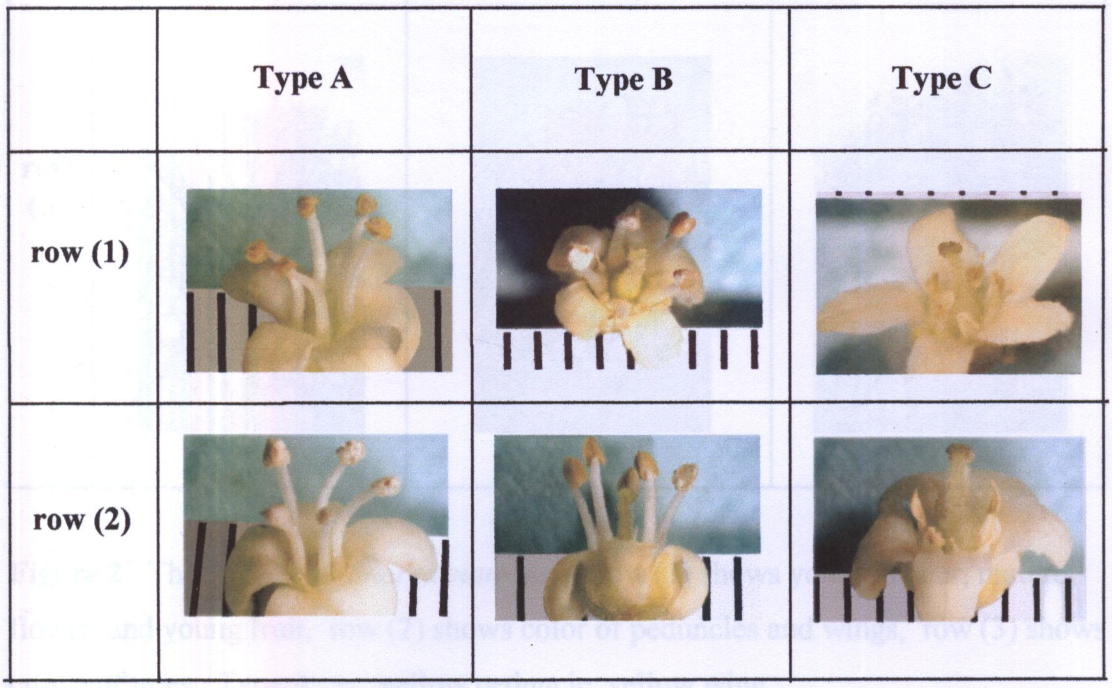


Figure 1 Three types of *Ellipanthus tomentosus* flowers; row (1) shows top view row (2) shows side view; Type A = short sterile pistil, Type B = long sterile pistil, Type C = fertile flower.

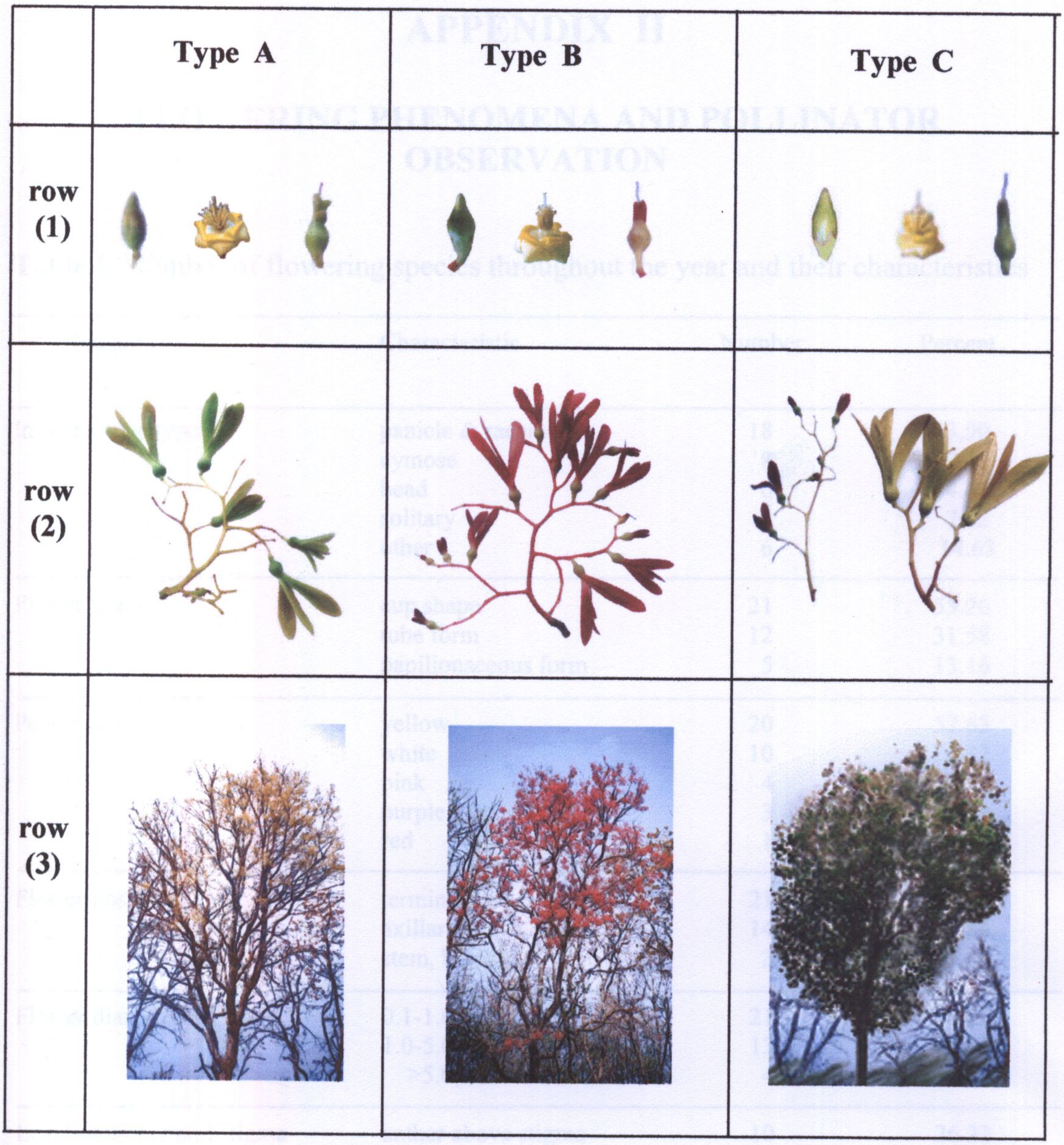


Figure 2 Three types of *Shorea siamensis*; row (1) shows young flower, mature flower, and young fruit, row (2) shows color of peduncles and wings, row (3) shows crown of trees; Type A = yellow peduncle, yellow wing

Type B = red peduncle, red wing

Type C = yellow peduncle, red wing

APPENDIX II

FLOWERING PHENOMENA AND POLLINATOR OBSERVATION

Table 1 Number of flowering species throughout the year and their characteristics

Category	Characteristic	Number	Percent
Inflorescence type	panicle & raceme	18	43.90
	cymose	8	19.51
	head	6	14.63
	solitary	3	7.32
	other	6	14.63
Flower shape	cup shape	21	55.26
	tube form	12	31.58
	papilionaceous form	5	13.16
Petal color	yellow	20	52.63
	white	10	26.32
	pink	4	10.53
	purple	3	7.89
	red	1	2.63
Flower position	terminal	21	55.26
	axillary	14	36.84
	stem, branch	3	7.89
Flower diameter	0.1-1.0 cm.	21	55.26
	1.0-5.0 cm.	13	34.21
	>5.0 cm.	4	10.53
Level of anther and stigma within flower	anther above stigma	10	26.32
	stigma above anther	18	47.37
	anther equal stigma	3	7.89
	unisexual	7	18.42
Ovary type	superior	28	73.68
	inferior	9	23.68
	half-inferior	1	2.63
Sexual	bisexual	31	81.58
	unisexual	7	18.42

Table 2 List of species that flowered in one-year period (January to December 2000) and the characteristics of flowers.

Species	Period	Position	Inflorescence	Sexual	Level above	Ovary	Shape	Size (cm)	Color
1. *Buchanania lanzan*	Jan - Feb	terminal	panicle	bisexual	anther	superior	cup	0.3	white
2. *Lannea coromandelica*	Feb - Mar	terminal	panicle	unisexual	-	superior	cup	0.5	pale yellow
3. *Wrightia arborea*	Mar - Apr	terminal	cymose	bisexual	anther	superior	tube	3.0 – 4.0	white
4. *Canarium subulatum*	Mar - Apr	axillary	thyrsoid, raceme	unisexual	-	superior	tube	0.3	cream
5. *Bauhinia racemosa* *	Apr	axillary	raceme	bisexual	anther	superior	papilion	1.0 – 1.5	pale yellow
6. *Erythrophleum succirubrum*	Jun	axillary	catkin	bisexual	anther	superior	cup	0.5 – 0.6	greenish white
7. *Senna garrettiana*	Apr - Oct	terminal	panicle	bisexual	stigma	superior	papilion	2.7 – 3.0	bright yellow
8. *Sindora siamensis* var. *siamensis*	Apr - May	terminal	panicle	bisexual	anther	superior	papilion	1.5	yelllow-green
9. *Sindora siamensis* var. *maritima*	Apr – May	terminal	panicle	bisexual	anther	superior	papilion	1.2 – 1.5	yelllow-green
10. *Ellipanthus tomentosus*	Jan-Mar, Nov-Dec.	axillary	raceme	bisexual	stigma	superior	cup	0.7 – 0.8	pale yellow
11. *Dipterocarpus intricatus*	Jan-Mar, Dec.	axillary	panicle	bisexual	stigma	superior	cup	2.0 – 2.5	white - pink
12. *Shorea obtusa* *	Feb - Mar	terminal	panicle	bisexual	stigma	superior	cup	0.5	creamy yellow
13. *Shorea roxburghii*	Jan - Feb	terminal	panicle	bisexual	stigma	superior	cup	0.8 – 1.0	cream
14. *Shorea siamemsis*	Jan - Mar	terminal	racemose panicle.	bisexual	stigma	inferior	cup	1.0	bright yellow
15. *Diospyros ehretioides*	Feb - Mar	branch	cymose, solitary	unisexual	-	superior	cup	0.5 – 0.6	white
16. *Aporosa villosa*	Jan - Feb	branch	spike, cymose	unisexual	-	superior	cup	0.2 – 0.5	** greenish yellow
17. *Bridelia retusa*	Jun - Jul	terminal	spike	unisexual	-	superior	cup	0.4 – 0.5	yellowish green

Table 2 (cont.)

Species	Period	Position	Inflorescence	Sexual	Level above	Ovary	Shape	Size (cm)	Color
18. *Phyllanthus emblica*	Jan-Mar, Dec.	axillary	cymose	unisexual	-	superior	cup	0.3 – 0.5	creamy yellow
19. *Cratoxylum cochinchinense*	Mar - May	axillary	raceme	bisexual	equal	superior	cup	0.5 – 0.7	dark red
20. *Cratoxylum formosum*	Feb - Mar	branch	raceme	bisexual	anther	superior	cup	3.0 – 3.5	pale pink
21. *Irvingia malayana*	Apr	axillary	panicle	bisexual	anther	superior	cup	0.7 – 0.8	greenish white
22. *Vitex pinnata*	May - Jul	terminal	panicle	bisexual	stigma	superior	tube	1.5	white-pale purple
23. *Careya sphaerica*	Jan-Mar, Dec.	terminal	cymose	bisexual	stigma	inferior	cup	6.0 – 8.0	pink
24. *Lagerstroemia floribunda*	Feb - May	terminal	cymose	bisexual	stigma	half - inferior	cup	7.0	pale pink
25. *Memecylon edule*	Mar - May	axillary	cymose	bisexual	equal	inferior	cup	1.0	bright blue- purple
26. *Chukrasia tabularis*	Jul - Sep	axillary	panicle	bisexual	anther	superior	cup	1.5 – 1.7	pale yellow
27. *Albizia lebbeck*	Mar - Apr	axillary	heads	bisexual	stigma	superior	tube	0.1	pale yellow
28. *Xylia xylocarpa* var. *kerrii*	Feb - Mar	terminal	heads	bisexual	anther	superior	tube	0.2	pale yellow
29. *Artocarpus lacucha*	Jan-Feb, Dec.	axillary	heads	unisexual	-	inferior	tube	0.8 – 2.0	yellowish orange
30. *Ochna integerrima*	Jan - Mar	terminal	thyrsoid	bisexual	stigma	superior	cup	4.0 – 4.5	bright yellow
31. *Pterocarpus macrocarpus*	Mar	axillary	raceme	bisexual	stigma	superior	papilion	1.2	bright yellow
32. *Gardenia sootepensis*	Mar - Apr	terminal	solitary	bisexual	stigma	inferior	tube	9.5 – 12.5	yellow-orange
33. *Haldina cordifolia*	Apr - Jun	axillary	heads	bisexual	stigma	inferior	tube	0.6 – 0.8	pale yellow
34. *Morinda coreia*	Apr - Jun	terminal	heads	bisexual	stigma	inferior	tube	1.6 – 2.0	pure white

Table 2 (cont.)

Species	Period	Position	Inflorescence	Sexual	Level above	Ovary	Shape	Size (cm)	Color
35. *Morinda elliptica*	Apr - Jun	terminal	heads	bisexual	stigma	inferior	tube	0.8 – 1.0	pure white
36. *Rothmannia wittii*	Mar - Apr	terminal	solitary	bisexual	equal	inferior	tube	4.5 – 6.0	white with purple
37. *Schleichera oleosa*	Feb - Mar	terminal	cymose	bisexual	stigma	superior	cup	0.5 – 0.7	** greenish yellow
38. *Strychnos nux-vomica*	Mar - Apr	terminal	corymb	bisexual	stigma	superior	tube	0.3 – 0.4	creamy white

Note * = flowering in the year 2001
** = there are no petals but the color of calyx is greenish yellow and obvious
papilion = papilionaceous shape
inflorescence column = the first inflorescence type in same line is male flower, the second one is female flower

Table 3.1 Numbers and percentages of *Xylocopa* sp. and *Trigona apicalis* visited *Shorea siamensis*'s flowers within a day (4 days, and 40 h of observation in total)

Time / Day	9 Feb 2002		10 Feb 2002		16 Feb 2002		17 Feb 2002		Total		Percent Total	
	X	T	X	T	X	T	X	T	X	T	X	T
7.00	23	11	32	6	0	2	4	1	59	20	4	8
8.00	28	3	70	3	15	3	11	4	124	13	10	5
9.00	45	17	120	12	33	2	43	1	241	32	19	13
10.00	20	7	166	6	43	6	53	7	282	26	22	11
11.00	13	13	81	10	54	8	65	6	213	37	16	15
12.00	22	22	24	18	41	4	53	8	140	52	11	22
13.00	9	4	18	17	38	4	39	4	104	29	8	12
14.00	5	4	11	5	20	2	23	3	59	14	4	6
15.00	8	2	3	3	24	2	15	4	50	11	4	5
16.00	6	2	2	1	6	0	4	1	18	4	1	2
17.00	4	0	0	0	4	2	2	1	10	3	1	1
Total	183	85	527	81	278	35	312	40	1,300	241	100	100

Note : X = *Xylocopa* sp.

T = *Trigona apicalis*

Table 3.2 Numbers and percentages of *Xylocopa* sp. and *Trigona apicalis* visited *Ellipanthus tomentosus*'s flowers within a day (4 days, and 40 h of observation in total)

Time / Day	8 Feb 2000		10 Feb 2000		18 Feb 2000		4 Mar 2000		Total		Percent Total	
	X	T	X	T	X	T	X	T	X	T	X	T
7.00	1	0	3	0	0	0	0	0	4	0	2	0
8.00	2	1	1	1	0	0	0	2	3	4	1	6
9.00	6	1	3	0	3	2	1	1	13	4	6	6
10.00	14	2	13	6	5	1	1	0	33	9	15	14
11.00	10	2	7	2	4	5	1	0	22	9	10	14
12.00	15	7	15	2	4	5	2	0	36	14	17	22
13.00	17	2	11	2	6	3	0	0	34	7	16	11
14.00	6	4	11	0	7	4	2	0	26	8	12	12
15.00	2	0	6	2	3	4	2	0	13	6	6	9
16.00	7	1	5	2	3	0	2	1	17	4	8	6
17.00	4	0	3	0	7	0	0	0	14	0	7	0
Total	84	20	78	17	42	24	11	4	215	65	100	100

Note : X = *Xylocopa* sp.
T = *Trigona apicalis*

Table 3.3 Numbers and percentages of *Xylocopa* sp. and *Trigona apicalis* visited *Xylia xylocarpa*'s flowers within a day (4 days, and 40 h of observation in total)

Time / Day	8 Feb 2000		10 Feb 2000		18 Feb 2000		4 Mar 2000		Total		Percent Total	
	X	T	X	T	X	T	X	T	X	T	X	T
7.00	1	3	0	0	0	0	0	0	1	3	2	2
8.00	1	2	1	1	1	4	0	4	3	11	7	8
9.00	0	2	2	2	0	4	0	2	2	10	5	7
10.00	1	12	5	8	1	2	0	2	7	24	16	17
11.00	3	8	10	6	3	6	0	6	16	26	36	19
12.00	2	10	1	1	2	3	0	2	5	16	11	11
13.00	0	2	3	6	3	2	0	0	6	10	14	7
14.00	0	7	0	4	1	4	0	2	1	17	2	12
15.00	0	3	0	0	1	5	0	4	1	12	2	9
16.00	1	3	0	2	1	3	0	3	2	11	5	8
17.00	0	0	0	0	0	0	0	0	0	0	0	0
Total	9	52	22	30	13	33	0	25	44	140	100	100

Note : X = *Xylocopa* sp.
T = *Trigona apicalis*

Table 3.4 Numbers and percentages of *Xylocopa* sp. and *Trigona apicalis* visited *Sindora siamensis*'s flowers within a day (4 days, and 40 h of observation in total).

Time / Day	28 Apr 2000		29 Apr 2000		13 May 2000		14 May 2000		Total		Percent Total	
	X	T	X	T	X	T	X	T	X	T	X	T
7.00	7	1	2	0	10	7	10	5	29	13	5	4
8.00	11	2	10	28	11	6	17	4	49	40	9	13
9.00	14	10	14	42	12	6	23	6	63	64	12	21
10.00	10	9	11	30	4	9	17	7	42	55	8	18
11.00	9	8	14	20	18	9	20	2	61	39	11	13
12.00	9	5	14	9	27	0	14	2	64	16	12	5
13.00	7	6	10	12	14	0	17	3	48	21	9	7
14.00	9	4	12	14	20	2	22	2	63	22	12	7
15.00	5	3	12	11	18	4	28	2	63	20	12	7
16.00	4	2	10	4	15	3	11	0	40	9	7	3
17.00	2	3	4	0	10	0	2	2	18	5	3	2
Total	87	53	113	170	159	46	181	35	540	304	100	100

Note : X = *Xylocopa* sp.
T = *Trigona apicalis*

Table 4 List of other pollinators which were present in dry dipterocarp forest at Nong Rawiang

Family	Scientific name
1. Acraeidae	1. *Acraea violae*
2. Danaidae	2. *Danaus chrysippus*
	3. *Danaus genutia*
	4. *Euplea core*
	5. *Parantica agleoide*
	6. *Tirumala septentrionis*
3. Hypsidae	7. *Euplocia membliaria*
	8. *Peridrome orbicularis*
4. Lycaenidae	9. *Arhopala amantes*
	10. *Euchrysops cnejus*
5. Nymphalidae	11. *Cethosia cyane*
	12. *Hypolimnas misippus*
	13. *Junonia almana*
	14. *Junonia atlites*
	15. *Junonia lemonias*
	16. *Junonia orithya*
	17. *Neptis hylas*
6. Papilionidae	18. *Graphium agamemnon*
	19. *Pachliopta aristolochiae*
	20. *Papilio demoleus*
	21. *Troides aeacus*
7. Pieridae	22. *Catopsilia pomosa* f. *crocale*
	23. *Catopsilia pomosa* f. *pomosa*
	24. *Delias descombesi*
	25. *Delias hyparete*
	26. *Delias pasithoe*
	27. *Eurema hecabe*
8. Sphingidae	28. *Daphnis nerii*

Note : Collected and identified the pollinators by Mr. Luis E. Garcia, RIT-NEC

APPENDIX III

POLLEN EFFICIENCY

Brewbaker's pollen germination medium

Brewbaker's stock solution (100 ml)

Boric acid [H_3BO_3] :	100	mg
Calcium nitrate [$Ca(NO_3)_2$- $4H_2O$] :	300	mg
Magnesium sulphate [$MgSO_4$ - $7H_2O$] :	200	mg
Potassium nitrate [KNO_3] :	100	mg

Dissolve all ingredients in deionized water and make to 100 ml

Brewbaker's working solution in 10 % sucrose (100 ml)

Add 10 gm sucrose and 10 ml of Brewbaker's stock solution and make to 100 ml with deionized water. One or two drops placed on a clean microscope slide works well for most pollen.

Agar medium

Add 0.5 gm agar to the 100 ml of Brewbaker's working solution in 10 % sucrose. Gently heat the solution to boiling point and cool until warm but still liquid. Pour 3-4 ml of solution into clean (preferably sterile) 35 mm petri dishes and cover. After the agar has cooled to room temperature it is ready for pollen to be added. For slide preparation, dip clean microscope slides into the warm agar medium and stand slides upright to allow the medium to solidify.

(Brewbaker and Kwack, 1963)

Table 1 Air temperature while collected pollen tree species in the year 2000

Species	Air Temperature (°C)	Species	Air Temperature (°C)
1. *Buchanania lanzan*	32	20. *Cratoxylum formosum*	30
2 *Lannea coromandelica*	30	21. *Irvingia malayana*	27
3. *Wrightia arborea*	32	22. *Vitex pinnata*	29
4. *Canarium subulatum*	25	23. *Careya sphaerica*	27
5. *Bauhinia racemosa* *	33	24. *Lagerstroemia floribunda*	31
6. *Erythrophleum succirubrum*	30	25. *Memecylon edule*	31
7. *Senna garrettiana*	29	26. *Chukrasia tabularis*	30
8. *Sindora siamensis* v. *siamensis*	29	27. *Albizia lebbeck*	31
9. *Sindora siamensis* v. *maritima*	29	28. *Xylia xylocarpa*	27
10. *Ellipanthus tomentosus*	30	29. *Artocarpus lacucha*	27
11. *Dipterocarpus intricatus*	27	30. *Ochna integerrima*	27
12. *Shorea obtusa* *	26	31. *Pterocarpus macrocarpus*	29
13. *Shorea roxburghii*	25	32. *Gardenia sootepensis*	25
14. *Shorea siamensis*	30	33. *Haldina cordifolia*	31
15. *Diospyros ehretioides*	30	34. *Morinda coreia*	34
16. *Aporosa villosa*	31	35. *Morinda elliptica*	34
17. *Bridelia retusa*	32	36. *Rothmannia wittii*	30
18. *Phyllanthus emblica*	27	37. *Schleichera oleosa*	32
19. *Cratoxylum cochinchinense*	31	38. *Strychnos nux-vomica*	31

Note : * flowers in the year 2001

APPENDIX IV

SEED PRODUCTION AND SEED DISPERSAL

Table 1.1 Accumulation number of fallen flowers/**young fruits** from parent tree *Shorea siamensis* No. 1 in traps of 50 x 50 cm at each time and each distance.

Distance from parent tree (m)	Number of flowers/ collected day				Total
	10 Feb	24 Feb	10 Mar	24 Mar	
2	539.12/ -	460.12/**234.12**	70.87/**229.62**	- /**1.37**	1,070.11/ **465.11**
4	259.62/ -	308.12/ **98.87**	54.62/**137.00**	- /**1.25**	622.36/ **237.12**
6	93.50/ -	164.75/ **32.87**	34.50/ **49.62**	- /**0.62**	292.75/ **83.11**
8	24.00/ -	50.25/ **9.62**	3.25/ **4.25**	- /**0.12**	77.50/ **13.99**
Total	916.24/ -	983.24/**375.48**	163.24/**420.49**	- /**3.36**	2,062.72/ **799.33**

Table 1.2 Accumulation number of fallen flowers/**young fruits** from parent tree *Shorea siamensis* No. 2 in traps of 50 x 50 cm at each time and each distance.

Distance from parent tree (m)	Number of flowers/ collected day				Total
	10 Feb	24 Feb	10 Mar	24 Mar	
2	70.12/ -	365.62/ **36.12**	38.25/ **59.25**	- /**2.37**	473.99/ **97.74**
4	206.75/ -	319.25/ **56.87**	22.00/ **50.37**	- /**2.62**	548.00/**109.86**
6	47.50/**3.62**	80.37/ **12.62**	8.87/ **11.87**	- /**1.00**	136.74/ **29.11**
8	6.50/ -	15.00/ **2.00**	2.50/ **1.25**	- /**0.12**	24.00/ **3.37**
Total	330.87/**3.62**	780.24/**107.61**	71.62/**122.74**	- /**6.11**	1,182.73/**240.08**

Table 1.3 Accumulation number of fallen flowers/**young fruits** from parent tree *Shorea siamensis* No. 3 in traps of 50 x 50 cm at each time and each distance.

Distance from parent tree (m)	Number of flowers/ collected day				Total
	10 Feb	24 Feb	10 Mar	24 Mar	
2	100.75/ -	72.37/ **53.75**	2.87/ **2.25**	- / -	175.99/ **56.00**
4	86.25/**2.75**	45.00/ **16.00**	8.62/ **2.75**	- / **0.87**	139.87/ **22.37**
6	12.75/ -	12.75/ **3.25**	8.25/ **2.87**	- / **0.50**	33.75/ **6.62**
8	- / -	- / -	- / -	- / -	- / -
Total	199.75/**2.75**	130.12/ **73.00**	19.74/ **7.87**	- / **1.37**	349.61/ **84.99**

Table 1.4 Accumulation number of fallen flowers/**young fruits** from parent tree *Shorea siamensis* No. 4 in traps of 50 x 50 cm at each time and each distance.

Distance from parent tree (m)	Number of flowers/ collected day				Total
	10 Feb	24 Feb	10 Mar	24 Mar	
2	166.00/**1.00**	501.37/**158.12**	283.12/**229.62**	- /**12.00**	950.49/ **470.37**
4	122.12/**0.75**	295.50/ **67.37**	166.62/**116.12**	- / **5.87**	584.24/ **190.11**
6	45.87/**1.25**	122.25/ **31.62**	75.25/ **56.75**	- / **6.12**	243.37/ **95.74**
8	74.50/**1.37**	57.87/ **15.25**	32.62/ **28.00**	- / **2.87**	164.99/ **47.49**
Total	408.49/**4.37**	976.99/**272.36**	557.61/**500.12**	- /**26.86**	1,943.09/ **803.71**

Table 1.5 Accumulation number of fallen flowers of *Shorea siamensis* at each distance from parent tree in the year 2002.

	Area depends on radius at each distance from parent tree				Total
Distance (m)	0 – 2	2 – 4	4 – 6	6 – 8	
Area (m^2)	12.57	37.71	62.86	88.00	
Parent tree No.1	53,805	93,877	73,609 *	27,280	248,571
2	23,832	82,660	34,382 *	8,448	149,322
3	8,849	21,098 *	8,486	-	38,433
4	47,791	88,127	61,193	58,076 *	255,187
Mean	33,569	71,440	44,418	23,451	172,878

Note : * crown cover area

Table 1.6 Accumulation number of fallen young fruits of *Shorea siamensis* at each distance from parent tree in the year 2002.

	Area depends on radius at each distance from parent tree				Total
Distance (m)	0 – 2	2 – 4	4 – 6	6 – 8	
Area (m^2)	12.57	37.71	62.86	88.00	
Parent tree No.1	23,386	35,767	20,897 *	4,924	84,974
2	4,914	16,571	7,319 *	1,186	29,990
3	2,816	3,374 *	1,664	-	7,854
4	23,650	28,676	24,073	16,716 *	93,115
Mean	13,692	21,097	13,488	5,706	53,983

Note : * crown cover area

Table 1.7 Accumulation number of fallen mature fruits of *Shorea siamensis* at each distance from parent tree in the year 2002.

	Area depends on radius at each distance from parent tree							
Distance (m)	0 – 2	2 – 8	8 – 14	14 – 20	20 – 26	26 – 32	32 – 38	Total
Area (m^2)	12.57	188.57	414.86	641.14	867.57	1,093.29	1,320.00	
Parent tree No.1	534	3,394 *	3,103	2,231	1,284	525	-	11,071
2	232	1,033 *	1,245	949	868	-	-	4,327
3	182	1,033 *	830	641	-	-	-	2,686
4	1,213	4,714	4,563 *	4,155	3,470	2,187	634	20,936
Mean	540	2,544	2,435	1,994	1,406	678	158	9,755

Note : * crown cover area

Table 1.8 The correlation value (r) of *Shorea siamensis* crown cover and number of fallen flowers and fruits.

Parent trees	Diameter of crown cover (m)	Number of fallen flowers	Number of fallen young fruits	Number of fallen mature fruits
No. 4	11.00	255,187	93,115	20,936
No. 2	8.50	149,322	29,990	4,327
No. 1	7.75	248,571	84,974	11,071
No. 3	7.00	38,433	7,854	2,686
r		0.66^{ns}	0.66^{ns}	0.87^{ns}

ns = non significant

Table 1.9 The correlation value (r) of *Shorea siamensis* DBH and number of fallen flowers and fruits.

Parent trees	DBH (cm)	Number of fallen flowers	Number of fallen young fruits	Number of fallen mature fruits
No. 2	43.27	149,322	29,990	4,327
No. 4	41.05	255,187	93,115	20,936
No. 1	32.45	248,571	84,974	11,071
No. 3	23.23	38,433	7,854	2,686
r		0.61 ^{ns}	0.44 ^{ns}	0.45 ^{ns}

ns = non significant

Table 1.10 The correlation value (r) of *Shorea siamensis* height and fruits dispersal distance.

Parent trees	Height (m)	Fruits dispersal distance (m)
No. 2	22.30	26
No. 1	20.70	32
No. 4	19.70	38
No. 3	19.00	20
r		0.04 ^{ns}

ns = non significant

Table 1.11 Accumulation number of fallen mature fruits from parent tree *Shorea siamensis* No. 1 in traps of 50 x 50 cm and size, quality of fruits at each distance.

Categories	Distance from parent tree (m)					
	2	8	14	20	26	32
Number of mature fruits	10.62	4.50	1.87	0.87	0.37	0.12
Fruits size [1] (cm)						
Width	1.41	1.21	0.97	0.95	0.94	0.93
Length	2.51	2.30	2.08	1.99	1.67	1.42
Wings size [1] (cm)						
Width	1.16	1.14	1.21	1.21	1.19	1.20
Length	5.35	6.89	6.88	7.06	6.71	5.80
Fruits weight [1] (g)	2.32	1.51	0.77	0.65	0.53	0.39
Fruits appearance [2]						
Percentage of normal fruits	16.27	24.65	22.10	26.85	33.33	50.00
Percentage of damaged fruits	83.73	75.35	77.90	73.15	66.67	50.00
Percentage of incomplete wings [2]	18.82	11.11	13.33	14.29	0	0

Table 1.12 Accumulation number of fallen mature fruits from parent tree *Shorea siamensis* No. 2 in traps of 50 x 50 cm and size, quality of fruits at each distance.

Categories	Distance from parent tree (m)				
	2	8	14	20	26
Number of mature fruits	4.62	1.37	0.75	0.37	0.25
Fruits size [1] (cm)					
Width	1.22	1.21	1.02	1.00	0.91
Length	2.19	2.16	1.78	1.74	1.62
Wings size [1] (cm)					
Width	1.33	1.35	1.29	1.17	1.27
Length	7.19	6.19	7.03	7.43	7.04
Fruits weight [1] (g)	1.20	1.09	0.84	0.72	0.41
Fruits appearance [2]					
Percentage of normal fruits	13.85	27.08	26.50	22.16	33.33
Percentage of damaged fruits	86.15	72.92	73.50	77.84	66.67
Percentage of incomplete wings [2]	21.62	9.09	16.67	33.33	0

Note : [1] = mean approximate from 2 – 8 fruits
[2] = mean approximate from 2 – 20 fruits

Table 1.13 Accumulation number of fallen mature fruits from parent tree *Shorea siamensis* No. 3 in traps of 50 x 50 cm and size, quality of fruits at each distance.

Categories	Distance from parent tree (m)			
	2	8	14	20
Number of mature fruits	3.62	1.37	0.50	0.25
Fruits size [1] (cm)				
Width	1.29	1.28	1.25	1.20
Length	2.65	2.45	2.40	2.24
Wings size [1] (cm)				
Width	1.49	1.50	1.29	1.65
Length	7.01	6.68	6.81	7.09
Fruits weight [1] (g)	2.15	2.00	1.60	1.07
Fruits appearance [2]				
Percentage of normal fruits	15.26	18.14	24.00	22.38
Percentage of damaged fruits	84.74	81.86	76.00	77.62
Percentage of incomplete wings [2]	20.69	18.18	25.00	0

Table 1.14 Accumulation number of fallen mature fruits from parent tree *Shorea siamensis* No. 4 in traps of 50 x 50 cm and size, quality of fruits at each distance.

Categories	Distance from parent tree (m)						
	2	8	14	20	26	32	38
Number of mature fruits	24.12	6.25	2.75	1.62	1.00	0.50	0.12
Fruits size [1] (cm)							
Width	1.19	1.17	1.03	0.97	0.89	0.83	0.81
Length	2.07	1.98	1.96	1.87	1.65	1.52	1.52
Wings size [1] (cm)							
Width	1.39	1.48	1.53	1.47	1.28	1.28	1.32
Length	5.84	6.73	7.03	6.96	6.71	6.55	7.05
Fruits weight [1] (g)	1.26	1.15	0.99	0.62	0.49	0.37	0.37
Fruits appearance [2]							
Percentage of normal fruits	11.57	21.60	25.15	26.36	28.57	50.00	100
Percentage of damaged fruits	88.43	78.40	74.85	73.64	71.43	50.00	0.00
Percentage of incomplete wings [2]	19.69	18.00	9.09	7.69	12.50	0	0

Note : [1] = mean approximate from 2 – 8 fruits
[2] = mean approximate from 2 – 20 fruits

Table 2.1 The correlation value (r) of *Xylia xylocarpa* crown cover group 1 and number of fallen inflorescences, mature fruits, and seeds.

Parent trees	Diameter of crown cover (m)	Number of fallen inflorescences	Number of mature fruits	Number of seeds
No. 4	10.85	8,257	32	174
No. 3	10.50	9,934	52	282
No. 2	10.15	12,812	575	4,065
No. 1	9.00	1,944	10	57
r		0.71 ns	0.07 ns	0.06 ns

ns = non significant

Table 2.2 The correlation value (r) of *Xylia xylocarpa* DBH group 1 and number of fallen inflorescences, mature fruits, and seeds.

Parent trees	DBH (cm)	Number of fallen inflorescences	Number of mature fruits	Number of seeds
No. 4	43.27	8,257	32	174
No. 2	33.73	12,812	575	4,065
No. 3	31.82	9,934	52	282
No. 1	24.98	1,944	10	57
r		0.50 ns	0.05 ns	0.04 ns

ns = non significant

Table 2.3 The correlation value (r) of *Xylia xylocarpa* height group 1 and number of fallen inflorescences, mature fruits, and seeds.

Parent trees	Height (m)	Number of fallen inflorescences	Number of mature fruits	Number of seeds
No. 3	17.75	9,934	52	282
No. 2	15.90	12,812	575	4,065
No. 1	14.70	1,944	10	57
No. 4	12.30	8,257	32	174
r		0.34 ^{ns}	0.25 ^{ns}	0.24 ^{ns}

ns = non significant

Table 2.4 Accumulation number of fallen inflorescences, mature fruits and quality of fruits from parent tree *Xylia xylocarpa* No. 1 in the year 2000-2001.

Collected day	Inflo-rescences	Mature fruits	Normal fruits	Damaged fruits	Fully developed seeds	Aborted seeds	Insect - damaged seeds	Fungal - damaged seeds
5 Mar 00	191							
10 Mar 00	304							
15 Mar 00	1,092							
20 Mar 00	357							
6 Mar 01		10	-	10	36	19	2	9
Total	1,944							

Table 2.5 Accumulation number of fallen inflorescences, mature fruits and quality of fruits from parent tree *Xylia xylocarpa* No. 2 in the year 2000-2001.

Collected day	Inflo-rescences	Mature fruits	Normal fruits	Damaged fruits	Fully developed seeds	Aborted seeds	Insect - damaged seeds	Fungal - damaged seeds
5 Mar 00	572							
10 Mar 00	778							
15 Mar 00	4,267							
20 Mar 00	4,512							
25 Mar 00	2,388							
30 Mar 00	295							
6 Mar 01		575	191	384	3,341	679	45	308
Total	12,812							

Table 2.6 Accumulation number of fallen inflorescences, mature fruits and quality of fruits from parent tree *Xylia xylocarpa* No. 3 in the year 2000-2001.

Collected day	Inflo-rescences	Mature fruits	Normal fruits	Damaged fruits	Fully developed seeds	Aborted seeds	Insect - damaged seeds	Fungal - damaged seeds
10 Mar 00	1,856							
15 Mar 00	1,964							
20 Mar 00	2,796							
25 Mar 00	2,851							
30 Mar 00	467							
6 Mar 01		52	13	39	214	68	-	77
Total	9,934							

Table 2.7 Accumulation number of fallen inflorescences, mature fruits and quality of fruits from parent tree *Xylia xylocarpa* No. 4 in the year 2000-2001.

Collected day	Inflo-rescences	Mature fruits	Normal fruits	Damaged fruits	Fully developed seeds	Aborted seeds	Insect - damaged seeds	Fungal - damaged seeds
28 Feb 00	879							
5 Mar 00	1,096							
10 Mar 00	1,227							
15 Mar 00	1,807							
20 Mar 00	1,442							
25 Mar 00	1,041							
30 Mar 00	765							
6 Mar 01		32	7	25	129	42	3	50
Total	8,257							

Table 2.8 The correlation value (r) of *Xylia xylocarpa* fruits weight and dispersal distance.

Distance from parent tree (m)	Fruits weight [1] (gm)			
	No. 1	No. 2	No. 3	No. 4
2	53.22	35.13	21.97	22.95
4	51.05	35.01	22.98	28.97
6	41.12	42.71	27.97	29.08
8	37.08	43.37	30.45	29.50
10	42.77	32.61	23.12	22.54
12	49.02	40.60	25.41	
14	51.57			
16	52.52			
18	54.75			
r	0.32 [ns]	0.24 [ns]	0.32 [ns]	- 0.01 [ns]

[1] mean approximate from 2 – 8 fruits, [ns] non significant

Table 3.1 The correlation value (r) of *Ellipanthus tomentosus* crown cover and number of flowers and fallen fruits.

Parent trees	Diameter of crown cover (m)	Number of total produced flowers	Number of fallen young fruits	Number of fallen mature fruits
No. 1	7.65	18,497	3,154	12,116
No. 3	7.35	17,092	4,170	9,316
No. 4	6.65	19,095	6,559	9,846
No. 2	5.65	17,708	5,451	9,583
r		0.04 ^{ns}	- 0.70 ^{ns}	0.56 ^{ns}

ns = non significant

Table 3.2 The correlation value (r) of *Ellipanthus tomentosus* DBH and number of flowers and fallen fruits.

Parent trees	DBH (cm)	Number of total produced flowers	Number of fallen young fruits	Number of fallen mature fruits
No. 1	30.23	18,497	3,154	12,116
No. 4	24.50	19,095	6,559	9,846
No. 3	18.45	17,092	4,170	9,316
No. 2	15.75	17,708	5,451	9,583
r		0.69 ^{ns}	- 0.38 ^{ns}	0.88 ^{ns}

ns = non significant

Table 3.3 The correlation value (r) of *Ellipanthus tomentosus* height and number of flowers and fallen fruits.

Parent trees	Height (m)	Number of total produced flowers	Number of fallen young fruits	Number of fallen mature fruits
No. 4	15.90	19,095	6,559	9,846
No. 1	14.70	18,497	3,154	12,116
No. 2	10.85	17,708	5,451	9,583
No. 3	10.70	17,092	4,170	9,316
r		0.96 *	0.20 ^{ns}	0.55 ^{ns}

ns = non significant

* = significant difference at the 0.05 confidence level

Table 3.4 Accumulation number of fallen flowers, young fruits, mature fruits and quality of seeds from parent tree *Ellipanthus tomentosus* No. 1 in the year 2000.

Collected day	Flowers	Young fruits	Mature fruits	Normal seeds	Damaged seeds	Empty seeds	Type of worm in seeds A	B	C
15 Jan	554								
30 Jan	928								
15 Feb	1,112								
29 Feb	633								
15 Mar		1,782							
30 Mar		918							
15 Apr		367							
30 Apr		75							
15 May		12	315	182	133	-	-	133	-
30 May			652	317	316	19	-	311	5
15 Jun			6,564	2,269	4,236	59	-	4,191	45
30 Jun			4,329	1,472	2,831	26	11	2,804	16
20 Jul			256	15	234	7	-	234	-
Total	3,227	3,154	12,116	4,255	7,750	111	11	7,673	66

Note : A = long worm (Unknown sp.)
B = yellow worm (*Araecerus* sp.)
C = big worm (*Deadorix epijarbus*)

Table 3.5 Accumulation number of fallen flowers, young fruits, mature fruits and quality of seeds from parent tree *Ellipanthus tomentosus* No. 2 in the year 2000.

Collected day	Flowers	Young fruits	Mature fruits	Normal seeds	Damaged seeds	Empty seeds	Type of worm in seeds A	B	C
15 Jan	403								
30 Jan	630								
15 Feb	983								
29 Feb	658								
15 Mar		3,159							
30 Mar		1,882							
15 Apr		358							
30 Apr		52							
15 May			119	77	42	-	-	42	-
30 May			899	586	291	22	-	277	14
15 Jun			3,319	1,386	1,845	88	-	1,806	39
30 Jun			4,422	1,157	3,232	33	-	3,205	27
20 Jul			824	524	288	12	22	247	19
Total	2,674	5,451	9,583	3,730	5,698	155	22	5,577	99

Table 3.6 Accumulation number of fallen flowers, young fruits, mature fruits and quality of seeds from parent tree *Ellipanthus tomentosus* No. 3 in the year 2000.

Collected day	Flowers	Young fruits	Mature fruits	Normal seeds	Damaged seeds	Empty seeds	Type of worm in seeds A	B	C
15 Jan	661								
30 Jan	932								
15 Feb	1,233								
29 Feb	780								
15 Mar		1,200							
30 Mar		2,254							
15 Apr		624							
30 Apr		92							
15 May			22	19	3	-	-	3	-
30 May			842	567	258	17	1	242	15
15 Jun			4,098	904	3,111	83	-	3,068	43
30 Jun			3,818	604	3,145	69	-	3,116	29
20 Jul			536	237	284	15	-	262	22
Total	3,606	4,170	9,316	2,331	6,801	184	1	6,691	109

Note : A = long worm (Unknown sp.)
B = yellow worm (*Araecerus* sp.)
C = big worm (*Deadorix epijarbus*)

Table 3.7 Accumulation number of fallen flowers, young fruits, mature fruits and quality of seeds from parent tree *Ellipanthus tomentosus* No. 4 in the year 2000.

Collected day	Flowers	Young fruits	Mature fruits	Normal seeds	Damaged seeds	Empty seeds	Type of worm in seeds A	B	C
15 Jan	434								
30 Jan	682								
15 Feb	921								
29 Feb	653								
15 Mar		1,620							
30 Mar		3,830							
15 Apr		1,109							
30 Apr		-							
15 May			470	310	160	-	-	160	-
30 May			1,503	510	947	46	-	899	48
15 Jun			4,236	871	3,303	62	-	3,241	62
30 Jun			2,921	817	2,074	30	-	2,030	44
20 Jul			716	169	520	27	-	487	33
Total	2,690	6,559	9,846	2,677	7,004	165	-	6,817	187

Note : A = long worm (Unknown sp.)
B = yellow worm (*Araecerus* sp.)
C = big worm (*Deadorix epijarbus*)

Table 4.1 The correlation value (r) of *Sindora siamensis* crown cover and number of fallen flowers and fruits.

Parent trees	Diameter of crown cover (m)	Number of total flowers production	Number of fallen mature fruits	Number of seeds
No. 2	15.75	146,230	5,367	3,860
No. 4	14.25	41,870	1,935	1,839
No. 3	11.60	98,643	963	933
No. 1	8.65	92,380	870	1,058
r		0.20^{ns}	0.81^{ns}	0.82^{ns}

ns = non significant

Table 4.2 The correlation value (r) of *Sindora siamensis* DBH and number of fallen flowers and fruits.

Parent trees	DBH (cm)	Number of total flowers production	Number of fallen mature fruits	Number of seeds
No. 2	79.55	146,230	5,367	3,860
No. 1	32.45	92,380	870	1,058
No. 4	30.12	41,870	1,935	1,839
No. 3	28.00	98,643	963	933
r		0.80 ^{ns}	0.97 *	0.96 *

ns = non significant
* = significant difference at the 0.05 confidence level

Table 4.3 The correlation value (r) of *Sindora siamensis* height and number of fallen flowers and fruits.

Parent trees	Height (m)	Number of total flowers production	Number of fallen mature fruits	Number of seeds
No. 2	21.05	146,230	5,367	3,860
No. 4	15.90	41,870	1,935	1,839
No. 1	15.25	92,380	870	1,058
No. 3	13.50	98,643	963	933
r		0.62 ^{ns}	0.97 *	0.98 *

ns = non significant
* = significant difference at the 0.05 confidence level

Table 4.4 Accumulation number of fallen flowers, mature fruits and quality of fruits from parent tree *Sindora siamensis* No. 1 in the year 2000.

Collected day	Flowers	Mature fruits	Normal fruits	Aborted fruits	Fully developed seeds	Aborted seeds	Type of damaged seeds		
							A	B	C
14 May 00	2,548								
4 Jun 00	11,235								
25 Jun 00	4,693								
3 Sep 00		103	67	36	94	-	-	11	-
1 Oct 00		435	397	38	279	4	-	189	59
29 Oct 00		214	208	6	124	1	8	120	23
26 Nov 00		95	95	-	51	5	-	52	3
10 Dec 00		23	23	-	13	4	-	18	-
Total	18,476	870	790	80	561	14	8	390	85

Table 4.5 Accumulation number of fallen flowers, mature fruits and quality of fruits from parent tree *Sindora siamensis* No. 2 in the year 2000-2001.

Collected day	Flowers	Mature fruits	Normal fruits	Aborted fruits	Fully developed seeds	Aborted seeds	Type of damaged seeds		
							A	B	C
14 May 00	3,186								
4 Jun 00	17,364								
25 Jun 00	8,696								
3 Sep 00		75	41	34	52	-	-	4	-
1 Oct 00		1,052	803	249	217	180	52	351	92
29 Oct 00		2,548	2,475	73	290	471	38	1,134	51
26 Nov 00		1,140	1,126	14	83	147	23	306	28
24 Dec 00		303	302	1	27	31	-	105	2
28 Jan 01		249	246	3	34	28	-	105	9
Total	29,246	5,367	4,993	374	703	857	113	2,005	182

Note : A = rotten seeds
B = insect-damaged seeds
C = broke coat seeds

Table 4.6 Accumulation number of fallen flowers, mature fruits and quality of fruits from parent tree *Sindora siamensis* No. 3 in the year 2000.

Collected day	Flowers	Mature fruits	Normal fruits	Aborted fruits	Fully developed seeds	Aborted seeds	Type of damaged seeds		
							A	B	C
14 May 00	6,937								
4 Jun 00	9,243								
25 Jun 00	3,549								
3 Sep 00		249	191	58	124	-	-	6	-
1 Oct 00		632	526	106	358	81	-	176	86
29 Oct 00		54	46	8	40	1	-	15	7
19 Nov 00		28	27	1	26	2	-	11	-
Total	19,729	963	790	173	548	84	-	208	93

Table 4.7 Accumulation number of fallen flowers, mature fruits and quality of fruits from parent tree *Sindora siamensis* No. 4 in the year 2000.

Collected day	Flowers	Mature fruits	Normal fruits	Aborted fruits	Fully developed seeds	Aborted seeds	Type of damaged seeds		
							A	B	C
14 May 00	854								
4 Jun 00	5,732								
25 Jun 00	1,788								
3 Sep 00		10	1	9	1	-	-	-	-
1 Oct 00		367	196	171	252	-	3	17	11
29 Oct 00		869	813	56	671	40	-	102	46
26 Nov 00		447	437	10	299	21	-	101	7
24 Dec 00		242	237	5	178	14	-	73	3
Total	8,374	1,935	1,684	251	1,401	75	3	293	67

Note : A = rotten seeds
B = insect-damaged seeds
C = broke coat seeds

APPENDIX V

SEED QUALITY

Table 1 Example of germination test and germination index sheet

Species : ***Buchanania lanzan***

Date collected : 09/04/2000

Date sown : 19/04/2000

Date completed : 07/05/2000

Germination test | **Germination index**

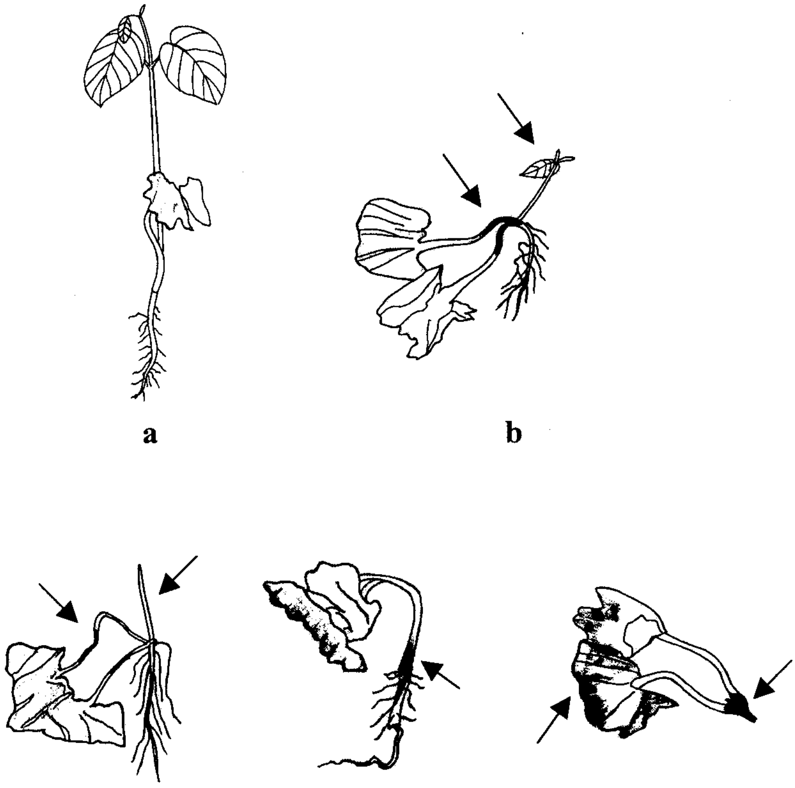
Day after sowing	**Seed emergence**				**Normal seedling in each day**				
	1	**2**	**3**	**4**	**Sub-sample***	**1**	**2**	**3**	**4**
1	-	-	-	-					
-	-	-	-						
8	-	-	-	-					
9	2	-	1	-		2	-	1	-
10	5	2	1	6		3	2	-	6
11	5	2	2	6		-	-	1	-
12	8	3	2	10		3	1	-	4
13	9	4	3	10		1	1	1	-
14	9	4	3	10		-	-	-	-
15	9	4	3	10		-	-	-	-
16	9	5	4	11		-	1	1	1
17	9	6	5	11		-	1	1	-
18	9	7	6	11		-	1	1	-
					Average**				
Imbibed seed	18	17	15	14	32 ± 3.65				
Dead seed	23	25	28	25	50 ± 4.12				
Empty seed	-	-	-	-					
Abnormal seed	-	1	1	-	1 ± 1.15				
% Germination	9	7	6	11	17 ± 4.43				

* sub-sample for 4 replication x 50 seeds

** compared with 100 seeds

Figure 1 The characteristics of dominant tree species germinants occurred in the present study.

1. ***Shorea siamensis***

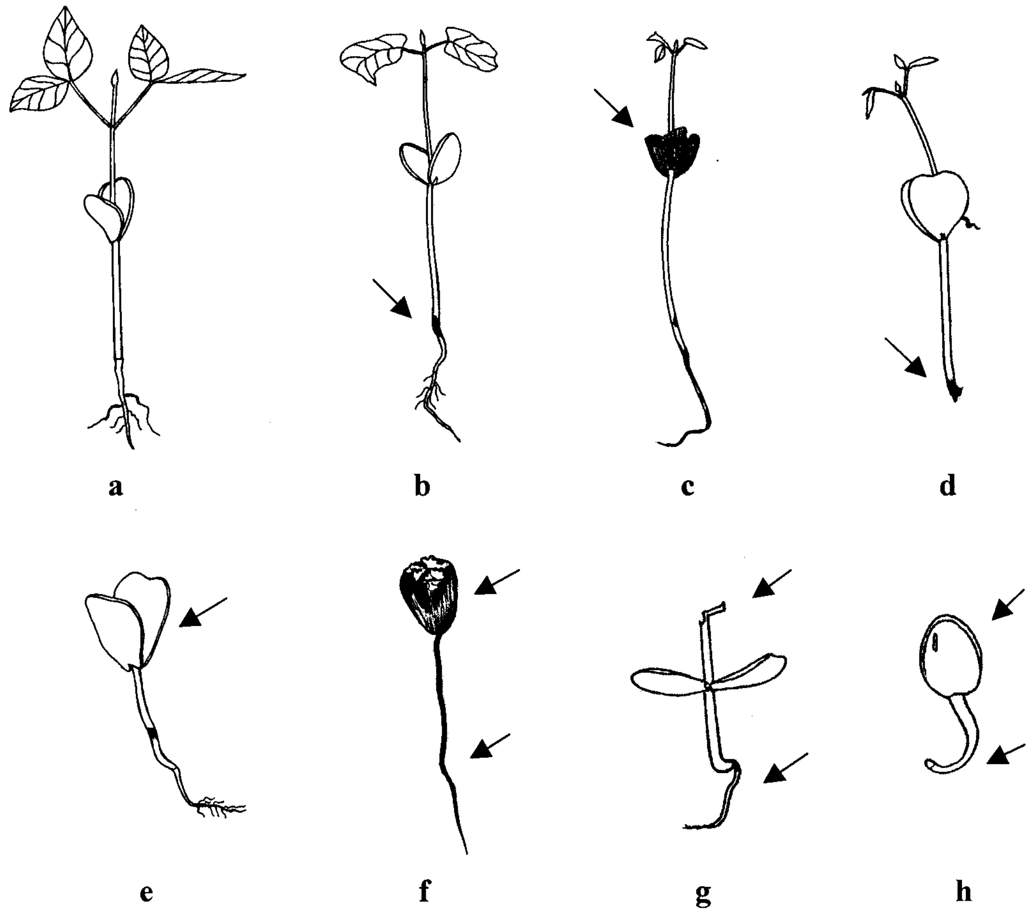


a b

c d e

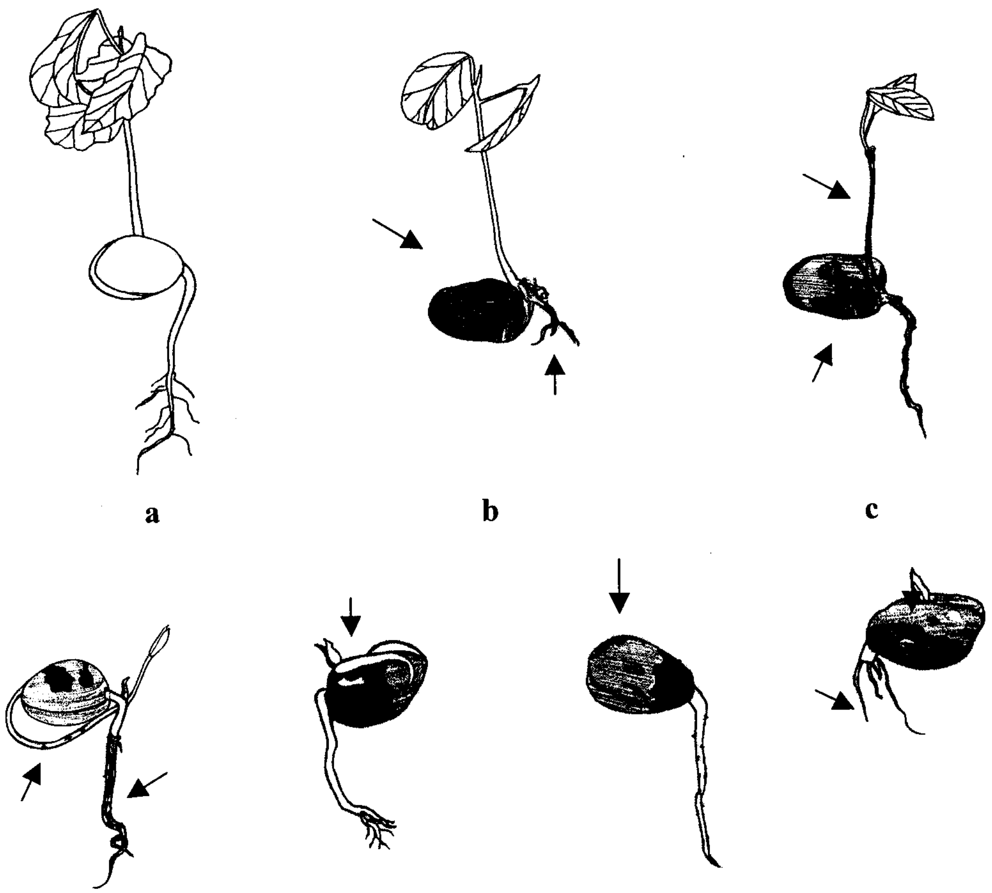
a. normal seedling; **normal weak seedling : b.** partial decay of hypocotyl and only one normal primary leaf; **abnormal seedling : c.** partial decay of hypocotyl and primary leaves missing, **d.** hypocotyl deeply cracked, **e.** partial decay of cotyledon and primary root missing.

2. ***Xylia xylocarpa***



a. normal seedling; **normal weak seedling : b.** partial decay of hypocotyl, **c.** cotyledons decayed as a result of secondary infection and less than a half of cotyledons missing; **abnormal seedling : d.** primary root missing, **e.** epicotyl missing, **f.** cotyledons and hypocotyl decayed as a result of primary infection, **g.** primary leaves missing and primary root decayed, **h.** primary root stubby and epicotyl missing.

3. ***Ellipanthus tomentosus***

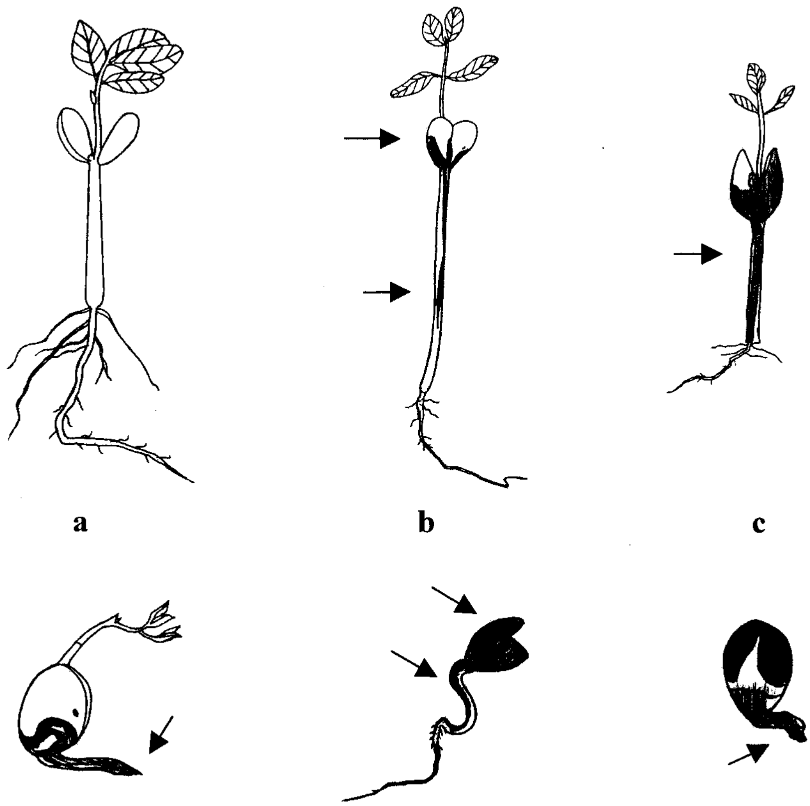


a b c

d e f g

a. normal seedling; **normal weak seedling :** **b.** cotyledons decayed as a result of secondary infection and primary root slight growth retardation, **c.** partial decay of cotyledons and epicotyl; **abnormal seedling :** **d.** epicotyl forming a loop and hypocotyl decayed as a result of primary infection, **e.** primary leaves missing, **f.** epicotyl missing, **g.** primary root stunted and primary leaves missing.

4. *Sindora siamensis* var. *siamensis*

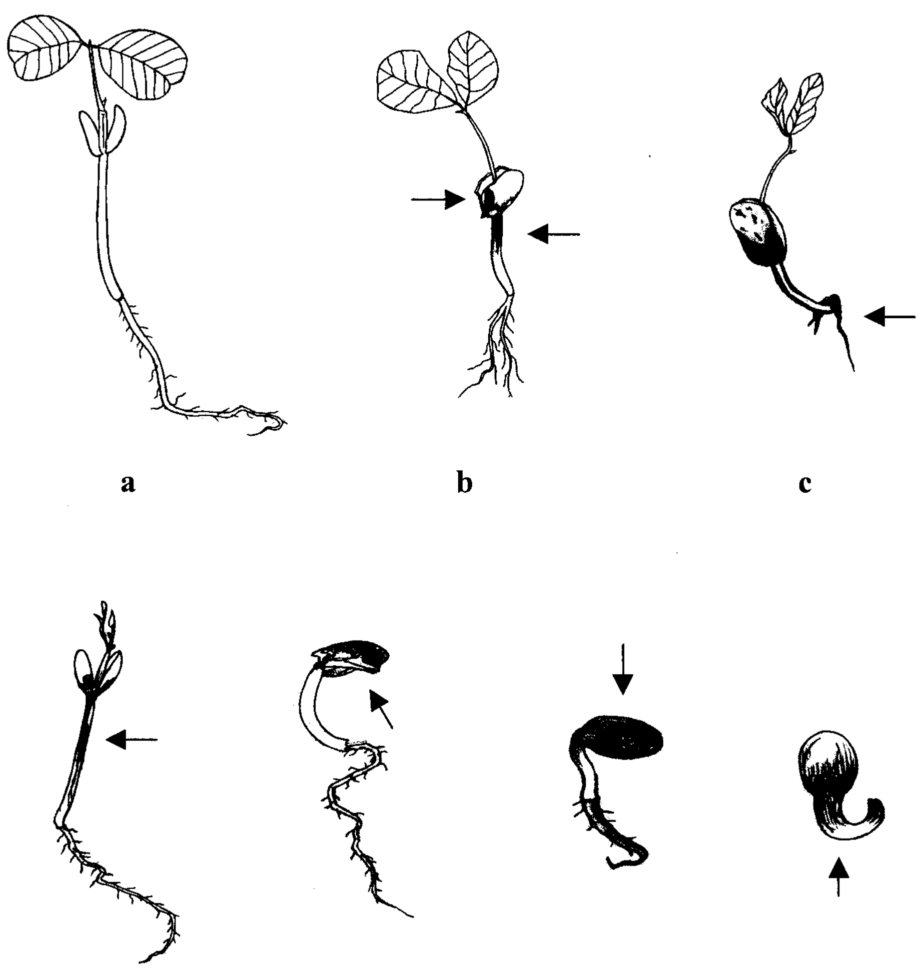


a b c

d e f

a. normal seedling; **normal weak seedling : b.** partial decay of cotyledons and hypocotyl; **abnormal seedling : c.** hypocotyl deeply cracked, **d.** primary root missing, **e.** cotyledons and hypocotyl decayed as a result of primary infection, **f.** hypocotyl short and thick and primary root missing.

5. *Sindora siamensis* var. *maritima*



a b c

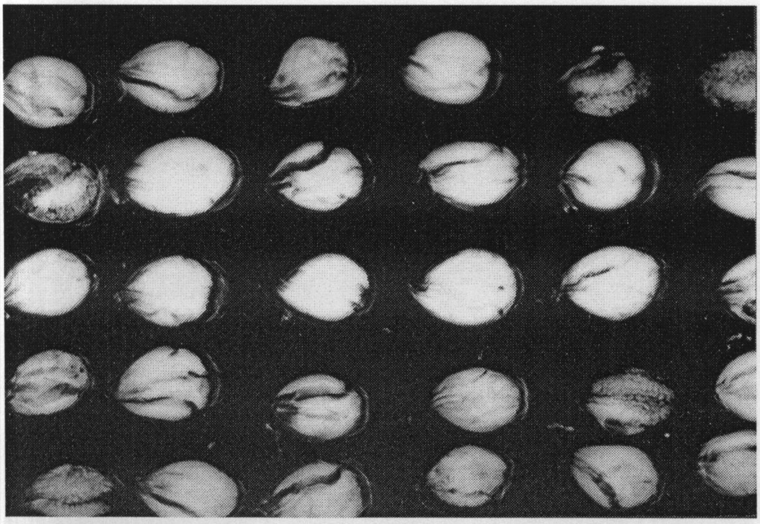
d e f g

a. normal seedling; **normal weak seedling : b.** partial decay of cotyledons and hypocotyl, **c.** primary root slight growth retardation, **d.** hypocotyl with limited damage; **abnormal seedling : e.** primary leaves missing, **f.** cotyledons decayed as a result of primary infection, **g.** primary root stubby.

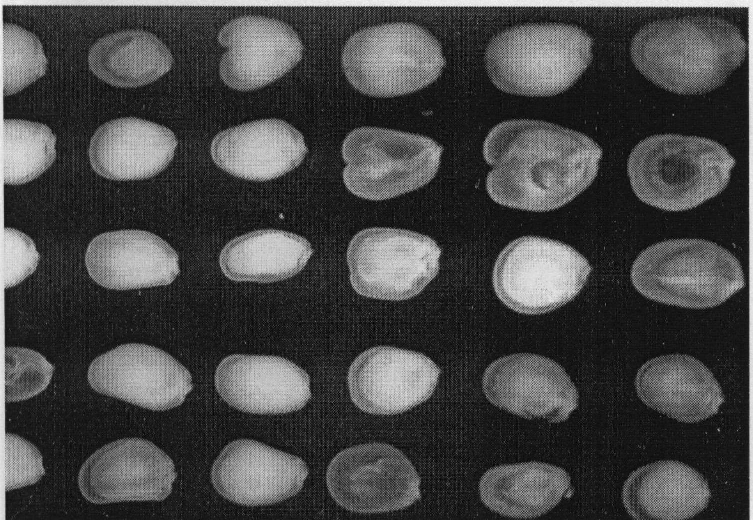
Table 2 List of exposure conditions for seed of 30 tree species radiographed

Species	Subject position	Seed thickness (mm)	Exposure time (seconds)
1. *Lannea coromandelica*	Flat	4.675 ± 0.549	7
2. *Wrightia arborea*	Flat	1.638 ± 0.164	7
3. *Canarium subulatum*	Flat	3.167 ± 0.319	15
4. *Erythrophleum succirubrum*	Flat	4.693 ± 0.337	35
5. *Senna garrettiana*	Flat	1.201 ± 0.272	8
6. *Sindora siamensis* var. *siamensis*	Flat	10.751 ± 1.226	35
7. *Sindora siamensis* var. *maritima*	Flat	9.266 ± 0.914	35
8. *Ellipanthus tomentosus*	Flat	11.784 ± 0.441	20
9. *Dipterocarpus intricatus*	Flat	8.033 ± 0.524	30
10. *Shorea siamemsis* (Y-Y)	Flat	12.289 ± 0.807	35
11. *Shorea siamemsis* (R-R)	Flat	11.008 ± 0.774	35
12. *Shorea siamemsis* (Y-R)	Flat	11.200 ± 1.023	35
13. *Aporosa villosa*	Flat	4.498 ± 0.670	7
14. *Bridelia retusa* (fruit)	Vertical	7.063 ± 0.266	15
15. *Phyllanthus emblica*	Flat	2.914 ± 0.297	10
16. *Cratoxylum cochinchinense*	Flat	0.531 ± 0.141	5
17. *Cratoxylum formosum*	Flat	0.507 ± 0.105	6
18. *Irvingia malayana*	Flat	7.998 ± 1.228	25
19. *Vitex pinnata*	Flat	5.318 ± 0.310	20
20. *Careya sphaerica*	Flat	5.762 ± 0.492	20
21. *Lagerstroemia floribunda*	Flat	1.886 ± 0.292	7
22. *Memecylon edule*	Flat	5.696 ± 0.414	15
23. *Chukrasia tabularis*	Flat	0.623 ± 0.165	8
24. *Albizia lebbeck*	Flat	2.409 ± 0.234	18
25. *Xylia xylocarpa*	Flat	2.733 ± 0.433	10
26. *Artocarpus lacucha*	Flat	7.029 ± 0.500	8
27. *Ochna integerrima*	Flat	5.819 ± 0.345	25
28. *Pterocarpus macrocarpus*	Flat	2.428 ± 0.179	8
29. *Gardenia sootepensis*	Flat	0.797 ± 0.110	8
30. *Rothmannia wittii*	Flat	3.101 ± 0.420	12
31. *Schleichera oleosa*	Flat	9.704 ± 0.985	35
32. *Strychnos nux-vomica*	Flat	7.213 ± 1.252	18

Figure 2 Results of X-radiography test of dominant tree species

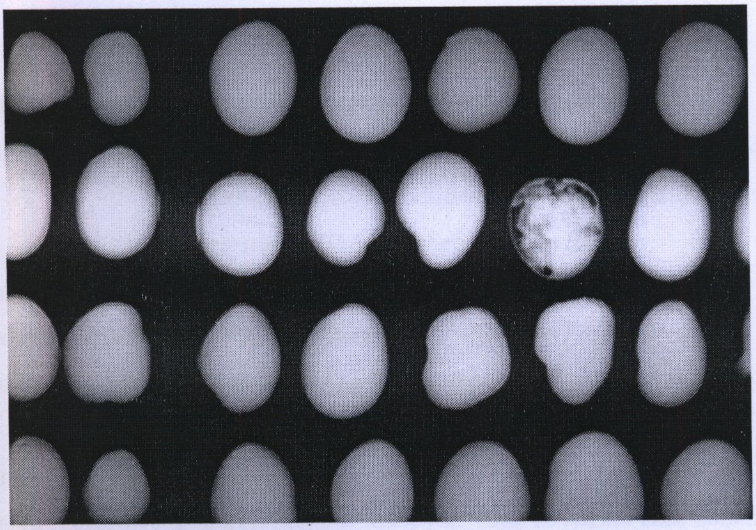


1. Seed viability evaluation by X-ray testing of *Shorea siamensis*



2. Seed viability evaluation by X-ray testing of *Xylia xylocarpa*

3. Seed viability evaluation by X-ray testing of *Ellipanthus tomentosus*



4. Seed viability evaluation by X-ray testing of *Sindora siamensis*

APPENDIX VI

MORPHOLOGICAL DATABASE OF FRUITS AND SEEDS

Table 1 Species list of fruit class and fruit type in dry dipterocarp forest

Fruit class & Fruit type	Tree species
1. Fleshy fruit	
1.1 berry	*Diospyros ehretioides, Careya sphaerica, Gardenia sootepensis, Rothmannia wittii, Strychnos nux-vomica*
1.2 drupe	*Buchanania lanzan, Lannea coromandelica, Canarium subulatum Bridelia retusa, Phyllanthus emblica, Irvingia malayana, Vitex pinnata, Memecylon edule, Ochna integerrima, Schleichera oleosa*
2. Dry fruit	
2.1 dehiscent	
2.1.1 follicle	*Wrightia arborea, Ellipanthus tomentosus,*
2.1.2 pod	*Bauhinia racemosa, Erythrophleum succirubrum, Senna garrettiana, Sindora siamensis* v. *siamensis, Sindora siamensis* v. *maritima, Albizia lebbec, Xylia xylocarpa.*
2.1.3 capsule	*Haldina cordifolia*
2.1.4 septicidal capsule	*Aporosa villosa,*
2.1.5 loculicidal capsule	*Cratoxylum cochinchinense, Cratoxylum formosum, Lagerstroemia floribunda, Chukrasia tabularis.*
2.2 indehiscent	
2.2.1 samara	*Dipterocarpus intricatus, Shorea roxburghii, Shorea siamensis, Shorea obtusa, Pterocarpus macrocarpus*
3. Fleshy multiple	*Artocarpus lacucha, Morinda elliptica*

Table 2 List of tree species in fleshy fruits and dry fruits for each month

Month	Fleshy fruits	Dry fruits
Jan	*Phyllanthus emblica, Strychnos nux-vomica*	*Bauhinia racemosa, Dipterocarpus intricatus, Senna garrettiana, Lagerstroemia floribunda*
Feb	*Phyllanthus emblica, Strychnos nux-vomica*	*Bauhinia racemosa, Dipterocarpus intricatus, Senna garrettiana, Lagerstroemia floribunda, Albizia lebbec, Pterocarpus macrocarpus*
Mar	*Buchanania lanzan, Lannea coromandelica, Memecylon edule, Rothmannia wittii, Strychnos nux-vomica*	*Wrightia arborea, Erythrophleum succirubrum, Ellipanthus tomentosus, Dipterocarpus intricatus, Shorea roxburghii, Shorea siamensis, Cratoxylum cochinchinense, Lagerstroemia floribunda, Albizia lebbeck, Xylia xylocarpa, Pterocarpus macrocarpus*
Apl	*Buchanania lanzan, Lannea coromandelica, Careya sphaerica, Memecylon edule, Artocarpus lacucha, Ochna integerrima, Rothmannia wittii*	*Erythrophleum succirubrum, Ellipanthus tomentosus, Aporosa villosa, Dipterocarpus intricatus, Shorea obtusa, Cratoxylum cochinchinense, Albizia lebbeck, Xylia xylocarpa, Pterocarpus macrocarpus*
May	*Memecylon edule, Ochna integerrima, Rothmannia wittii*	*Ellipanthus tomentosus, Aporosa villosa, Cratoxylum cochinchinense*
Jun	*Memecylon edule, Schleichera oleosa*	*Ellipanthus tomentosus, Cratoxylum formosum, Haldina cordifolia*
Jul	*Canarium subulatum, Irvingia malayana Morinda elliptica*	*Cratoxylum formosum, Haldina cordifolia*
Aug	*Canarium subulatum, Irvingia malayana Morinda elliptica, Diospyros ehretioides,*	*Sindora siamensis* v. *siamensis, Cratoxylum formosum, Haldina cordifolia*
Sep	*Canarium subulatum, Irvingia malayana Morinda elliptica, Diospyros ehretioides, Phyllanthus emblica, Vitex pinnata,*	*Sindora siamensis* v. *siamensis, Sindora siamensis* v. *maritima, Cratoxylum formosum*

Table 2 (cont.)

Month	Fleshy fruits	Dry fruits
Oct	*Diospyros ehretioides, Bridelia retusa, Phyllanthus emblica, Vitex pinnata, Gardenia sootepensis*	*Sindora siamensis* v. *siamensis, Sindora siamensis* v. *maritima, Pterocarpus macrocarpus, Lagerstroemia floribunda, Chukrasia tabularis*
Nov	*Bridelia retusa, Phyllanthus emblica, Gardenia sootepensis*	*Bauhinia racemosa, Senna garrettiana, Sindora siamensis* v. *siamensis, Sindora siamensis* v. *maritima, Pterocarpus macrocarpus, Lagerstroemia floribunda, Chukrasia tabularis*
Dec	*Bridelia retusa, Phyllanthus emblica, Gardenia sootepensis*	*Bauhinia racemosa, Erythrophleum succirubrum, Senna garrettiana, Sindora siamensis* v. *maritima, Pterocarpus macrocarpus, Lagerstroemia floribunda, Chukrasia tabularis*

Table 3 Fruiting phenology at Nong Rawiang DDF in the year 2000.

Species	Months during which fruits were observed											
	J	F	M	A	M	J	J	A	S	O	N	D
1. *Buchanania lanzan*			+	+								
2. *Lannea coromandelica*			+	+								
3. *Wrightia arborea*			+									
4. *Canarium subulatum*							+	+	+			
5. *Bauhinia racemosa*	+	+									+	+
6. *Erythrophleum succirubrum*			+	+								+
7. *Senna garrettiana*	+	+									+	+
8. *Sindora siamensis* v. *siamensis*								+	+	+	+	
9. *Sindora siamensis* v. *maritima*									+	+	+	+
10. *Ellipanthus tomentosus*			+	+	+	+						
11. *Dipterocarpus intricatus*	+	+	+	+								
12. *Shorea obtusa*				+								

Table 3 (cont.)

Species	Months during which fruits were observed											
	J	F	M	A	M	J	J	A	S	O	N	D
13. *Shorea roxburghii*			+									
14. *Shorea siamensis*			+									
15. *Diospyros ehretioides*								+	+	+		
16. *Aporosa villosa*				+	+							
17. *Bridelia retusa*										+	+	+
18. *Phyllanthus emblica*	+	+							+	+	+	+
19. *Cratoxylum cochichinense*			+	+	+							
20. *Cratoxylum formosum*						+	+	+	+			
21. *Irvingia malayana*							+	+	+			
22. *Vitex pinnata*									+	+		
23. *Careya sphaerica*				+								
24. *Lagerstroemia floribunda*	+	+	+							+	+	+
25. *Memecylon edule*			+	+	+	+						
26. *Chukrasia tabularis*										+	+	+
27. *Albizia lebbeck*		+	+	+								
28. *Xylia xylocarpa*			+	+								
29. *Artocarpus lacucha*				+								
30. *Ochna integerrima*				+	+							
31. *Pterocarpus macrocarpus*		+	+	+						+	+	+
32. *Gardenia sootepensis*										+	+	+
33. *Haldina cordifolia*						+	+	+				
34. *Morinda elliptica*							+	+	+			
35. *Rothmannia wittii*			+	+	+							
36. *Schleichera oleosa*						+						
37. *Strychnos nux-vomica*	+	+	+									
No. of species in fruit	6	8	16	16	6	5	5	7	9	10	10	10

\+ = fruits observed

Table 4 List of tree species in wind-dispersed species for each month

Month	Wind-dispersed species
Jan	*Dipterocarpus intricatus, Lagerstroemia floribunda*
Feb	*Dipterocarpus intricatus, Lagerstroemia floribunda, Pterocarpus macrocarpus*
Mar	*Dipterocarpus intricatus, Shorea roxburghii, Shorea siamensis, Wrightia arborea Cratoxylum cochinchinense, Lagerstroemia floribunda, Pterocarpus macrocarpus,*
Apl	*Dipterocarpus intricatus, Shorea obtusa, Cratoxylum cochinchinense, Pterocarpus macrocarpus*
May	*Cratoxylum cochinchinense*
Jun	*Cratoxylum formosum, Haldina cordifolia*
Jul	*Cratoxylum formosum, Haldina cordifolia*
Aug	*Cratoxylum formosum, Haldina cordifolia*
Sep	*Cratoxylum formosum*
Oct	*Lagerstroemia floribunda, Chukrasia tabularis, Pterocarpus macrocarpus*
Nov	*Lagerstroemia floribunda, Chukrasia tabularis, Pterocarpus macrocarpus*
Dec	*Lagerstroemia floribunda, Chukrasia tabularis, Pterocarpus macrocarpus*

Table 5 List of tree species in bright color fruits for each month

Month	Bright color fruits
Jan	*Phyllanthus emblica, Strychnos nux-vomica*
Feb	*Phyllanthus emblica, Strychnos nux-vomica*
Mar	*Buchanania lanzan, Lannea coromandelica, Wrightia arborea, Ellipanthus tomentosus, Memecylon edule, Strychnos nux-vomica*
Apl	*Buchanania lanzan, Lannea coromandelica, Ellipanthus tomentosus, Aporosa villosa, Careya sphaerica, Memecylon edule, Artocarpus lacucha*
May	*Ellipanthus tomentosus, Aporosa villosa, Memecylon edule*
Jun	*Ellipanthus tomentosus, Memecylon edule, Schleichera oleosa*
Jul	*Canarium subulatum, Irvingia malayana*
Aug	*Canarium subulatum, Irvingia malayana, Diospyros ehretioides*
Sep	*Canarium subulatum, Irvingia malayana, Diospyros ehretioides, Phyllanthus emblica, Vitex pinnata*
Oct	*Diospyros ehretioides, Phyllanthus emblica, Vitex pinnata*
Nov	*Phyllanthus emblica*
Dec	*Phyllanthus emblica*

Table 6 List of tree species in arillate seeds for each month

Month	Arillate seeds
Jan	-
Feb	-
Mar	*Ellipanthus tomentosus*
Apl	*Ellipanthus tomentosus, Aporosa villosa*
May	*Ellipanthus tomentosus, Aporosa villosa*
Jun	*Ellipanthus tomentosus, Schleichera oleosa*
Jul	-
Aug	*Sindora siamensis* v. *siamensis*
Sep	*Sindora siamensis* v. *siamensis*, *Sindora siamensis* v. *maritima*
Oct	*Sindora siamensis* v. *siamensis*, *Sindora siamensis* v. *maritima*
Nov	*Sindora siamensis* v. *siamensis*, *Sindora siamensis* v. *maritima*
Dec	*Sindora siamensis* v. *maritima*

Table 7 List of tree species in each seed moisture content for each month

Seed moisture content (%)	Tree species
0 – 10	*Wrightia arborea, Canarium subulatum, Erythrophleum succirubrum Senna garrettiana, Gardenia sootepensis, Irvingia malayana, Albizia lebbeck, Pterocarpus macrocarpus*
10 – 20	*Buchanania lanzan, Lannea coromandelica, Bauhinia racemos, Sindora siamensis* v. *siamensis*, *Sindora siamensis* v. *maritima*, *Bridelia retusa, Phyllanthus emblica, Cratoxylum formosum, Vitex pinnata, Lagerstroemia floribunda, Chukrasia tabularis, Xylia xylocarpa, Haldina cordifolia, Morinda elliptica, Rothmannia wittii, Strychnos nux-vomica*
20 – 30	*Cratoxylum cochinchinense, Schleichera oleosa*
30 – 40	*Dipterocarpus intricatus, Diospyros ehretioides, Artocarpus lacucha, Ochna integerrima*
40 – 50	*Shorea obtusa, Shorea roxburghii, Careya sphaerica, Memecylon edule*
50 – 60	*Aporosa villosa, Shorea siamensis*
60 – 70	-
70 – 80	*Ellipanthus tomentosus*
80 – 90	-
90 – 100	-

CURRICULUM VITAE

Mr. Surasak Ratree was born on August 30, 1957 and finished high school from Benchama Maharat School, Ubon Ratchathani. In 1980, he got a Bachelor of Science degree from the Department of Plant Science, Faculty of Agriculture, Khon Kaen University. After his graduation, he worked at Agronomy Research Station Ubon Ratchathani and Pha Tai Hospital, Nakhon Ratchasima. He became a teacher at Northeastern Technical College, Nakhon Ratchasima in 1981. He studied Plant Production for his Master of Science Degree at the Faculty of Agriculture, Khon Kaen University and finished in 1990. He was a number of staff of the Royal Initiated Project for the Conversation of Plant Genetic Resources under Her Royal Highness Princess Maha Chakri Sirindhorn at Nong Rawiang Forest and Tap Lan National Park, Nakhon Ratchasima for more than 4 years. This project induced him to apply for a Doctoral degree in the field of Environmental Biology, School of Science, Institute of Science, Suranaree University of Technology in 1998. He completed his Ph.D. in 2003.

Currently, he is still an instructor at Rajamangala Institute of Technology, Northeastern Campus Nakhon Ratchasima.