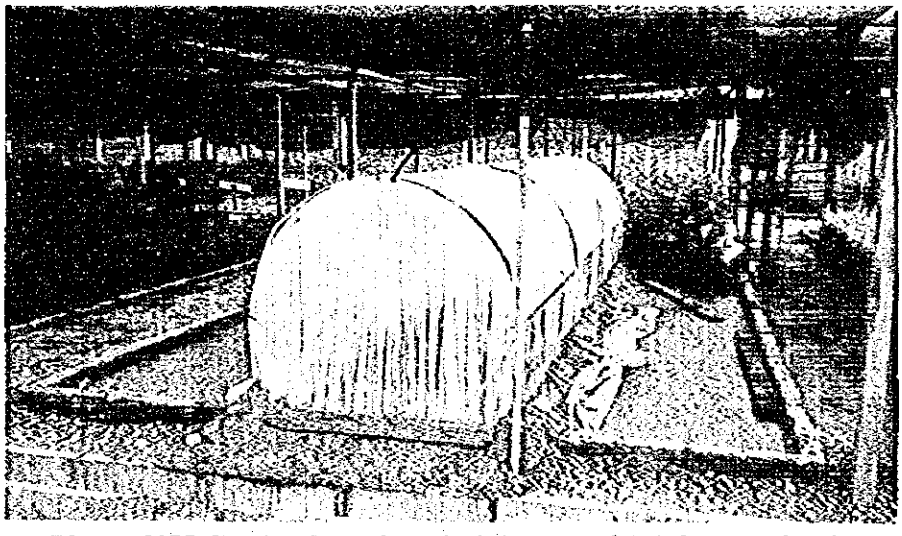


**Photo.-N55 Cutting by using airtight tunnel (*Shorea talura*)**

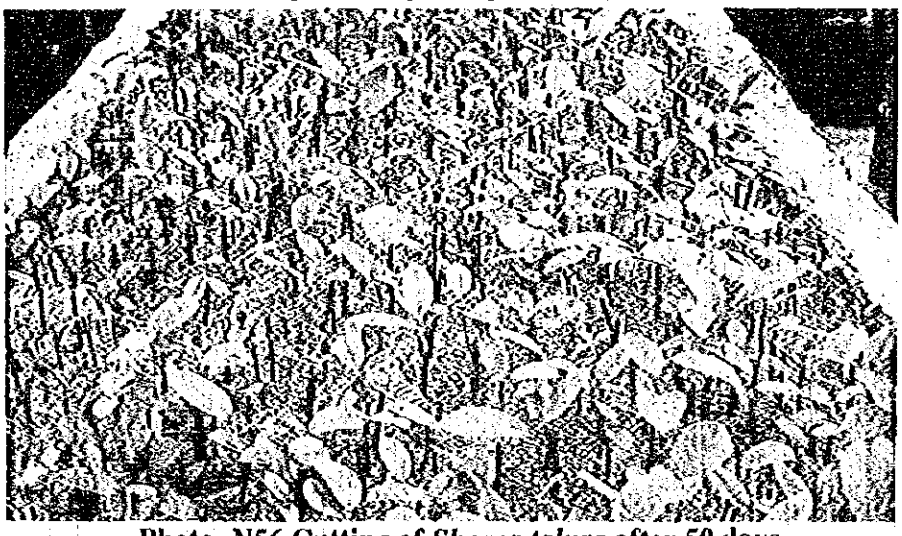


**Photo.-N56 Cutting of *Shorea talura* after 50 days**

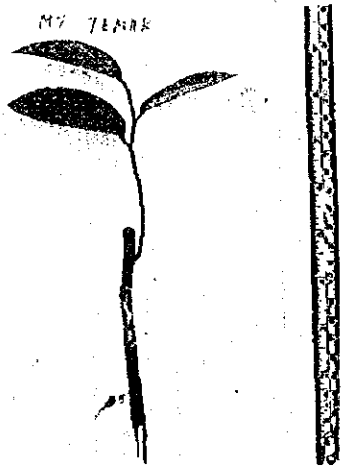


**Photo.-N57 Root condition after 50 days**

**Photo.-N58 Cutting of *Shorea talura* after 1 year 4 months transplanting into pots**

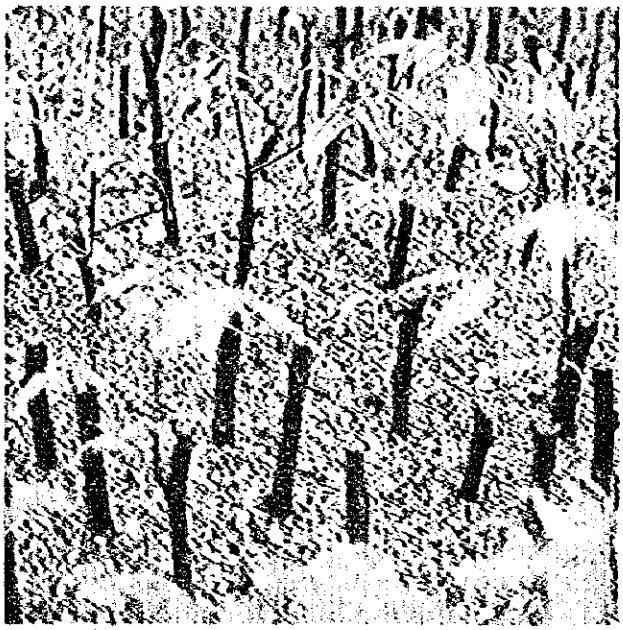


**Photo.-N59 Cutting of *Azadirachta excelsa* after 40 days**

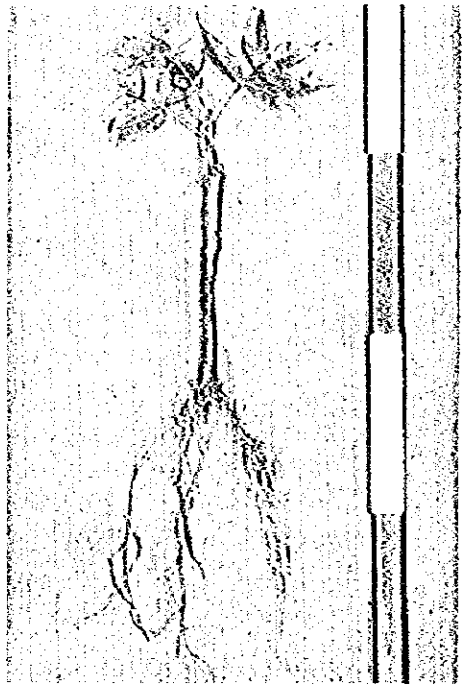


**Photo.-N60 Root condition after 4 months (*Azadirachta excelsa*)**

**c) Process of Cutting**

The cutting experiment so far only secured success for certain species. The project has optimized that with a little bit of refinement this method for producing seedling has a great potential in the future.

**c)-1 Preparation of Cutting Bed**

Cutting beds are made from river sand (which have been disinfected by burning) and they are separated according to their size and arranged in particular order as in Fig.-N30 for good drainage.

Drainage holes which are located at the base of the cutting beds need to be made before they are covered by the sand.

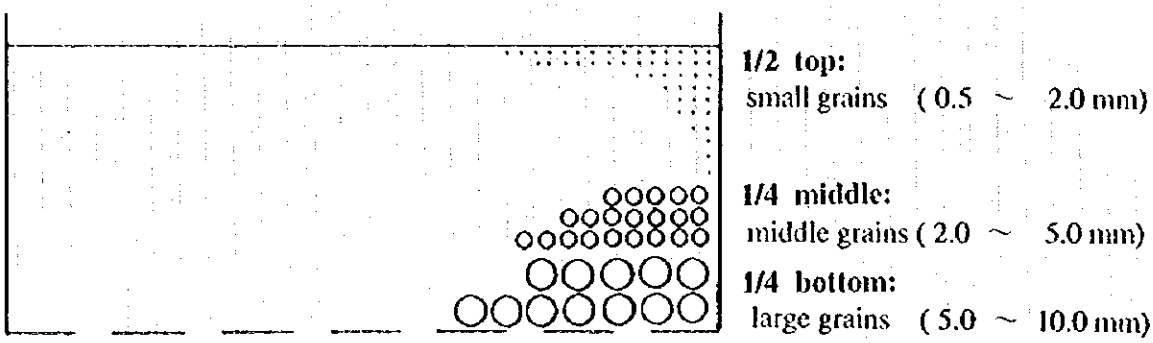



**Fig.-N30 Prepare Cutting Bed**

**c)-2 Prepare Scion**

In order to have a good survival rate, scion should be taken from young seedlings or from branches of a big tree.

Average size is between 10 to 15 cm long and having between one or two leaves.

Cut the top of part of the scion as in Fig.-N31.

Trim the leaf to one-third or one-quarter of it's original size for the purpose of reducing evaporation.

The base of the scion is prepared by using a sharp knife as in Fig.-N33.

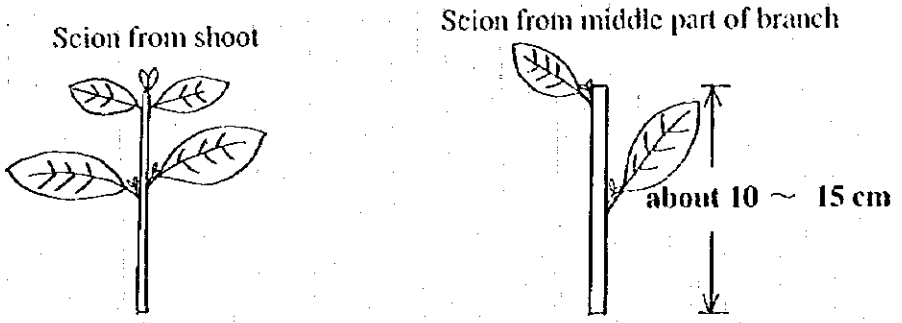



**Fig.-N31 The type of the scion**

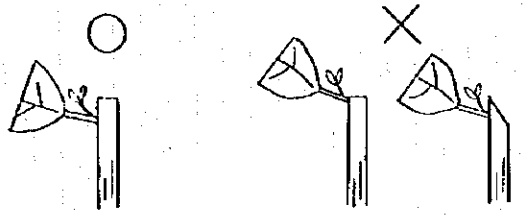


**Fig.-N32 The correct technique for preparing scion from middle branches**

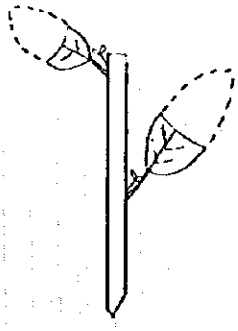


**Fig.-N33 Leaf of scion and scion base**

**c)-3 Method of Cutting**

The bottom part of the cutting is dipped into a chemical hormone before planting in the cutting bed. This aims at promoting rooting. The chemical hormones used were I.B.A ( Indole

butyric acid ) and S.E.R (SEREDIX) powder.

Holes were then made on the cutting bed using a guide stick so as not to damage the base of the scion during planting.

Insert the scion in the hole slowly to prevent from damaging the cambium. Each scion is firmly planted in the cutting bed by pressing the sand with finger.(To obtain close contact between the base of the scion and cutting bed medium.)

One-third to one-half scion length should be imbedded into the cutting bed medium.

Cover the cutting bed with the sun shade to filter about 50 % sunlight.

It is necessary to keep all cuttings at a proper temperature and humidity. The temperature should be around 25 to 30 degrees Celsius while the humidity at 100 percent.

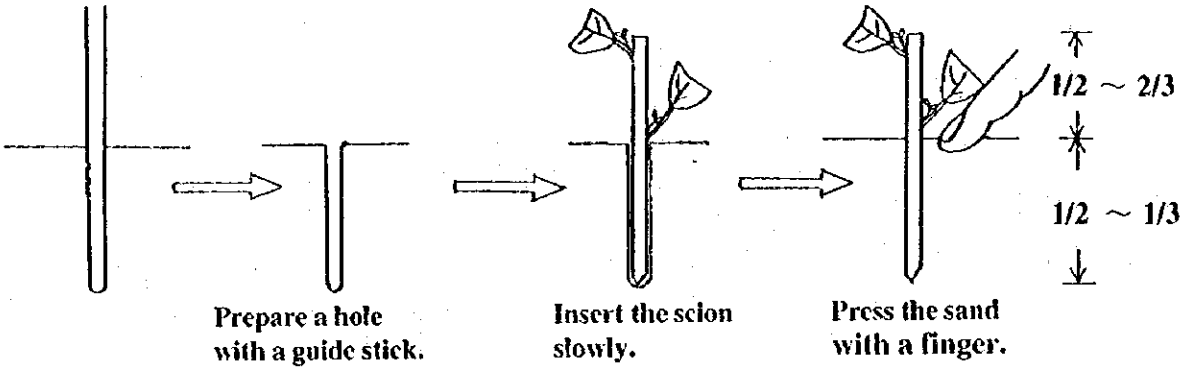



**Fig.-N34 Method of preparation scion**

**d) Cost Analysis of Cutting**

Cost analysis on raising seedling through cutting (large-scale) had been carried out by the Project. For *Shorea talura* the cost is RM 0.27 / cutting. Among factors that have been taken into consideration during the calculation are shown in Table-N40.

**Table-N40 Calculating cost for cutting**

| Types of Expenses | Expenses | No. of cutting | Price/ cutting |
|---|---|---|---|
| 1. Labor wages<br>a) Preparation of scion - 2 workers<br>b) To do cutting - 2 workers<br>c) Sowing of cutting - 1 worker<br>d) Treating hormone - 2 workers<br>e) Transferring of cutting to pot - 2 workers | 135.00<br>(30.00)<br>(30.00)<br>(15.00)<br>(30.00)<br>(30.00) | | |
| 2. Price of hormone<br>a) SREDIX ( 3 )<br>b) IBA ( 1 ) | 40.00<br>(30.00)<br>(10.00) | | |
| 3. Price of plastic | 20.00 | | |
| 4. Price of river sand | 25.00 | | |
| 5. Cutting scissors ( 2 ) | 46.00 | | |
| 6. Price of pot | 61.00 | | |
| **TOTAL** | **327.00** | **1,244** | **RM 0.27** |

**(4) Experiment on Promoting Flowering/Fruiting to Mother Tree**

**a) Purpose and Method**

Japanese larches in the past only flower/fruit once every seven years. Since then after a series of experiments and research, a method has been found to induce the particular tree to flower every year. Based on this success the Project has embarked on an experiment to promote regular flowering to indigenous tree species especially Dipterocarps. 2 methods have been introduced in this experiment and they are as follow:-

i ) Stripping away the bark of the mother tree/inflict injury to the mother tree.

ii) Injecting chemical hormone to the trunk and root of the mother tree.

These methods of treatment are illustrated in Fig-N35, 36.

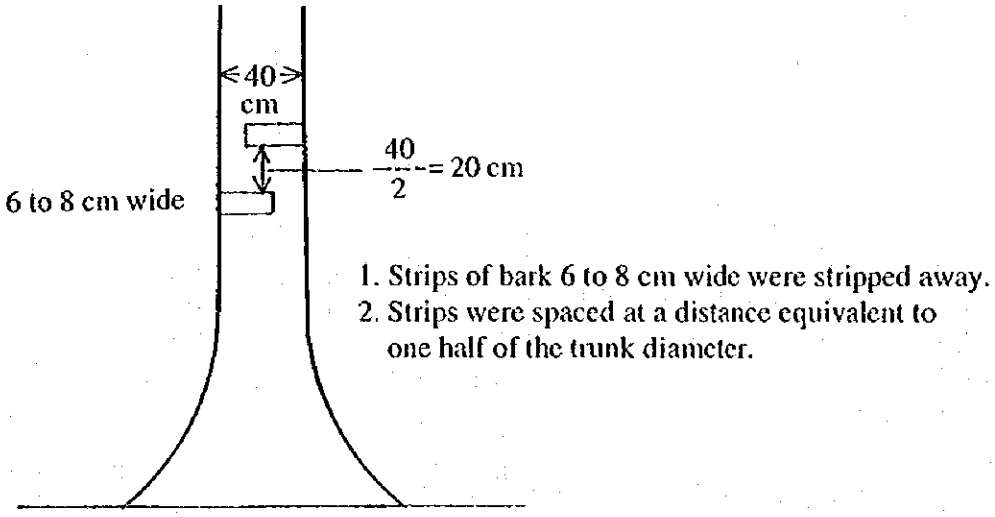
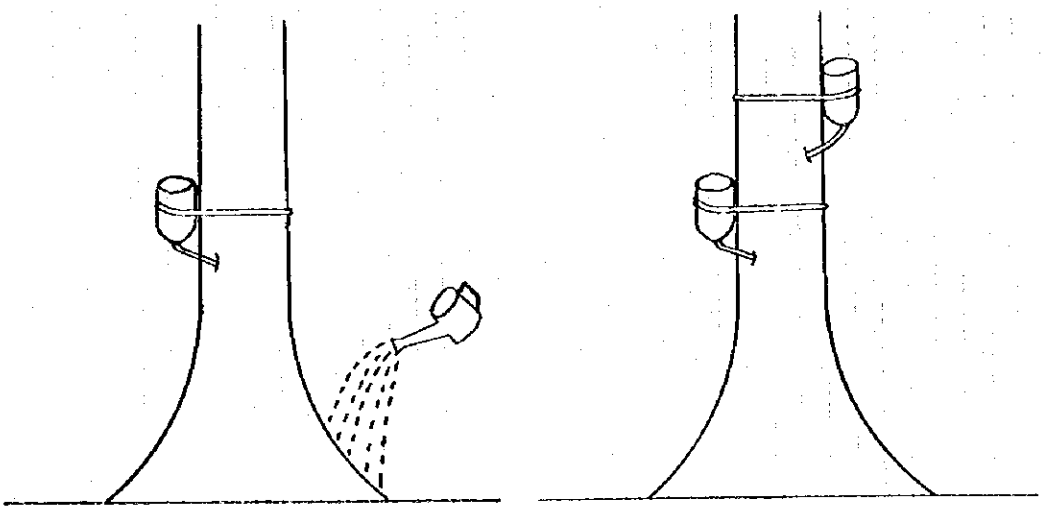



**Fig.-N35 The method of promoting flowering by stripping away bark**



A. Simultaneous hormone injection and root infusion B. 2-litre hormone injection

**Fig.-N36 The method of Promoting flowering by injecting hormones**

**b) Result and Consideration**

The results of this experiment (both stripping the bark and injecting hormone to trunk/root of the mother tree) are shown in Table-N41,42.

Result from first method that is stripping away the bark of the mother tree as at December 1995, did not show any response (flowering/fruiting did not occur) from the experimented tree. The Project will continue monitoring these trees in the future. On the other hand, the trees which were injected with a chemical hormone have been observed to flower in October 1994 but we could not ascertain the flowering was caused by the chemical hormone because at that particular time most of the other Diptrocarps species in the area (Chikus Forest Reserves) were also flowering and fruiting.

**Table-N41 Experiment on promoting flowering by stripping away bark**

| Observation tree No. | Species | Diameter (cm) | Hight (m) | Date of treatment | Result of observation | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Jun.94 | Dec.94 | Jun.95 | Dec.95 | Mar.96 |
| No.5 | *Shorea leprosula* | 40 | 28 | Mar.93 | × | × | × | × | × |
| No.6 | *Shorea leprosula* | 40 | 34 | Mar.93 | × | × | × | × | × |
| No.7 | *Shorea parvifolia* | 42 | 30 | Mar.93 | × | × | × | × | × |
| No.8 | *Shorea parvifolia* | 42 | 28 | Mar.93 | × | × | × | × | × |
| No.9 | *Neobalanocarpus heimii* | 66 | 32 | Mar.93 | × | × | × | × | × |
| No.10 | *Neobalanocarpus heimii* | 26 | 18 | Mar.93 | × | × | × | × | × |

Note: ○=Flowering or fruiting
×=There is no flowering or fruiting

**Table-N42 Experiment on promoting flowering by injecting hormones**

| Observation tree No. | Species | Diameter (cm) | Hight (m) | Date of treatment | Result of observation | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Jun.94 | Nov.94 | Jun.95 | Dec.95 | Mar.96 |
| No.16 | *Shorea parvifolia* | 48 | 32 | Mar.93<br>Jun. 95 | × | ○ | × | × | × |
| No.20 | *Shorea leprosula* | 50 | 35 | Mar.93<br>Jun. 95 | × | ○ | × | × | × |

Note: ○=Flowering or fruiting
×=There is no flowering or fruiting
* In June 1995, the same treatment was performed on the same tree to confirm the effect of the previous experiment.

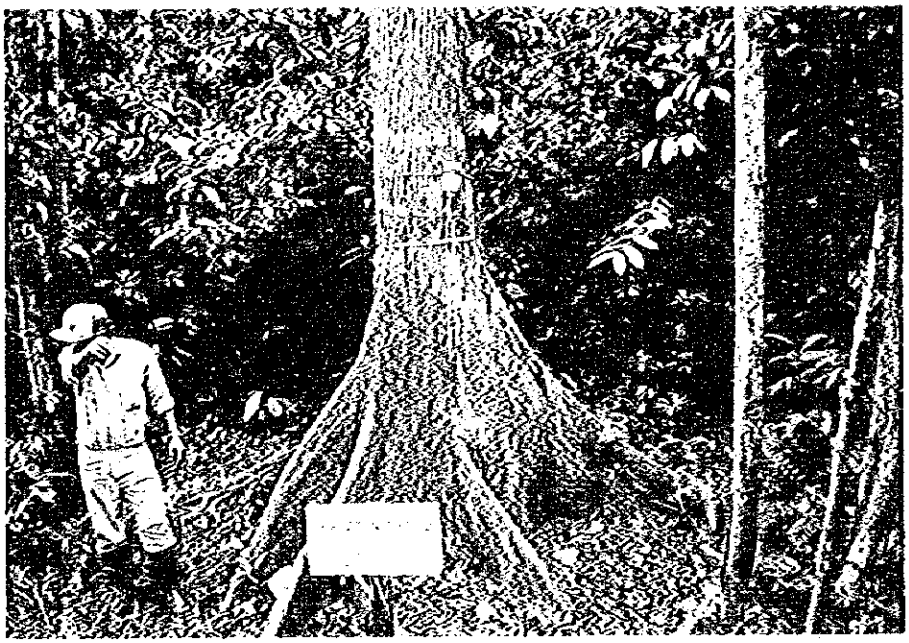


**Photo.-N61 Promoting flowering by stripping away bark (*Neobalanocarpus heimii*)**

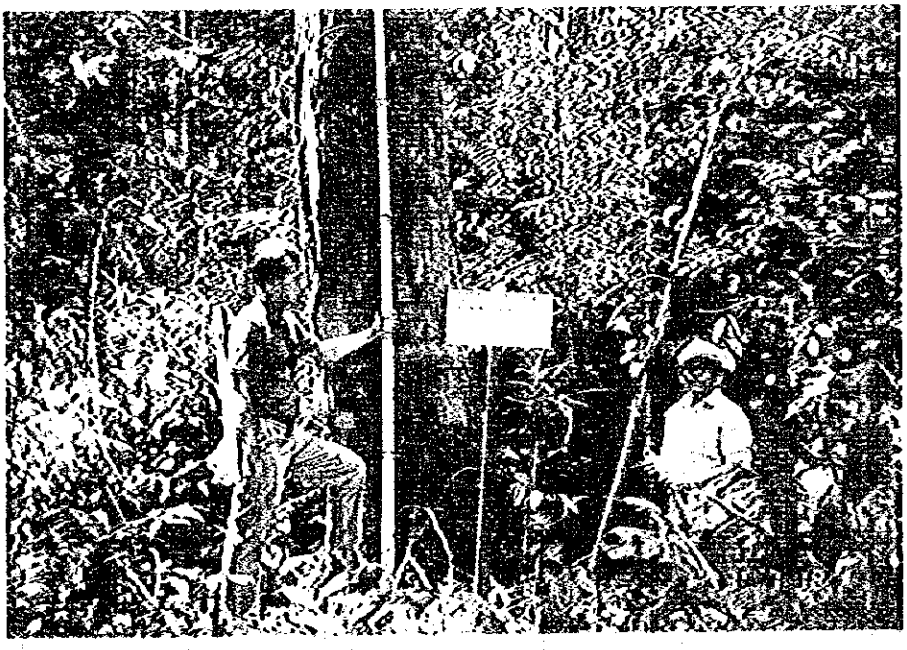


**Photo.-N62 Promoting flowering by injecting hormones (*Shorea leprosula*)**

Annex 2

Details on

# SILVICULTURE

# CONTENTS

# 1. INTRODUCTION

The objective of silviculture field in this project is to formulate proper and practical silviculture technique for the establishment of Multi-Storied Forest Management System through demonstrative plantings with various site conditions and species.

The light condition is one of the most important factors for the growth of plants. Two silviculture methods have been implemented in this Project which include Underplanting and Openplanting.. Underplanting method involve the planting of seedlings (especially indigenous species) under the influence of surrounding canopy. It was used for the conversion of existing forest (logged-over natural forest and fast growing forest plantation) into MSF. On the other hand, Openplanting involved the planting of both fast growing species and indigenous species in an open area.

Two sites were allocated to this project. One is in Chikus Forest Reserve which can be further divided into two, namely Block-A (Open area) with total area of 300 ha. and Block-B which is an *Acacia mangium* plantation with the acarage of 200 ha.. Another site is the Bukit Kinta Forest Reserve which consists of the logged-over natural hill forest with an Area of 500 ha.

Experiments on the establishment of MSF by underplanting method were conducted in Chikus F.R. Block B between 1992 to 1995 whereby 19 indigenous species was successfully planted under *Acasia mangium* plantation within an area of 182 ha. The total number of experimental plots established were 128. Strip planting was used for underplanting of indigenous species where *Acacia mangium* tree was felled in rows with five different strip widths; namely A-type (1:1, one row retain one row cut), B-type (2:2), C-type (4:4), D-type (8:8), and E-type (16:16). Two different planting directions were also chosen for these experiment i.e. East-West and North-South.

Openplanting method was carried out in Block A Chikus Forest Reserve. Both fast growing species and indigenous species were planted at the sametime. It was anticipated that Fast Growing species will outgrown the indigenous species to form upper storey and provide the necessary shade for the growth of indigenous species. Same planting design as in Block B was used here (Openplanting), such as 1:1, 2:2, 4:4, 8:8, 16:16. From 1993 to 1994, an area of 110 ha which made-up of 60 experimental plots were planted with 12 different indigenous species and 2 fast growing species. Due to several factors such as unsuitable local climatic condition, poor soil, seedling quality and damage cause by enroaching animal (cattle & water buffalo), the survival and growth both fast growing species and indigenous species were very poor.

Consequently Openplanting experiments in Block-A were modified into underplanting experiments in secondary forest (Belukar). Belukar consisting of pioneer species with the mean height of 8 m were used as nurse tree. In 1995, three different width of strip planting; 10m, 20m and 40m, were established over an area of 65 ha. This area was divided into 57 experimental plots and later planted with 15 indigenous species. The results after one year of establishment using this approach showed better survival and growth as compare to openplanting method.

Currently, only the Line Planting method is applied to logged over forests in Malaysia for enrichment planting under the Selective Management System (SMS) (Synonymous 1978). However, other planting methods have been suggested such as Patch Planting/Gap Planting in terms of controlling the light condition (Sasaki 1982, Ochiai *et al.* 1994).

In Line Planting, inter-line distance and intra-line distance are introduced as 10 m and 3m respectively, at the same time a clearing of 1m - 2m width is applied to each planting line (Synonymous 1978). Generally coverage by the forest vegetation such as palm, bamboo, wild banana, wild ginger, and tree species occupy a diameter of more than 2m each. Therefore a clearing of 2m wide may be easily covered by surrounding vegetation which intercept the sunlight vigorously. As a result, especially under SMS which used to have a lot of residuals after logging, the illuminance seems to be inadequate for planted seedlings/saplings though dense shade from the upper vegetation creates a high survival rate in its initial stage. In this context, Multi-Storied Forest Management Project (MSFM project) is looking into the Gap Planting method as an another option for the enrichment planting.

The growth performance of 7 dipterocarp species planted in Bukit Kinta Forest Reserve under different canopy opening is analysed to clarify the suitable planting design for the species. The purpose of this experiment is to obtain basic data for the further study which aims to detect the suitable planting specifications with consideration to operational aspects as well as economic aspects.

Bukit Kinta consists of natural hill forest after logging by the way of SMS. 1994-1996 7 species were planted in target area 50ha. Species planted in Bukit Kinta are mainly selected among Dipterocarps which are dominant and commercially high value and popular regenerating tree species in Bukit Kinta Forest Reserve. 17 planting Blocks were set up in 50ha which have 268 plots.

Planting methods taken in Bukit Kinta are gap planting and line planting in area which is logged-over hill forest. Gap planting is also set up for area ex-burning cultivation besides gaps made by logging. Thus gaps which are various sizes and are under various conditions have been experimented.

Gap planting can be divided into two types as GP-1,GP-2. : GP-1; gap planting in random shape made by logging. GP-2; gap planting in square shape made by artificial means with 5m×5m, 10m×10m, 20m×20m, 30m×30m. Line planting ; planting in line made artificially with 2m,10m,20m width and with length 120-160m. Consequently three types of planting methods have been testing. From the results in 1 - 2 years after planting Gap sizes and Growth, Species and Growth, Light condition and growth are mainly described as main factors in this 5-year report.

In the future there are some articles to be looked into to ensure introducing MSF by gap planting

1) Even though gap planting methods show superiority than existing planting methods, optimum gap sizes are not specified. Further study should make it clear from the both points of cost analysis and observing growth performance.

2) Gap planting methods implemented in Bukit Kinta site took excessive costs due to site preparation in recovered vegetation considerably, it would be a main theme to reduce costs of

setting up gap planting as well as costs of site preparation.

3) Light condition & Growth results showed over exposure is less risky than excessive shading in S. parvifolia within 18 months after planting. Hereafter, light conditions of other species also need to be looked into and other factors( soil condition, micro climate in forest and so on) affecting tree growth need to be taken into consideration.

4) In early stage tending has been implemented 3-4times in first year and 2 times in second year as a standard, in future optimum frequency and duration of weeding treatment need to be clarified including factors of topography, light condition and vegetation.

Establishing Arboretum in Chikus Block-A was also planned as one of the activity under silviculture field. This was aimed initially to collect growth data for various species through the intensive care for the planted seedlings. From 1992 to 1994, 31 species were planted in 18 ha and 34 plots were set-up. But for the same reasons as in openplanting in Chikus Block-A, survival and growth of planted trees were very poor. Only *Hopea odorata*, *Tectona grandis*, and *Cinnamomum* sp. showed better survival and growth.

# 2. Overview

## 2.1. Objectives

The objective of silviculture field in this project is to formulate proper and practical silviculture technique for Multi-Storied Forest Management System through demonstrative plantings with various site conditions and with various species. This project aims not only for experiments but proper practical basis/scale operation

## 2.2. Concept

There is a lot of options for establishing MSF. Among these options, two approaches were taken in this project. One is the conversion of existing forest, such as *Acacia mangium* plantation, logged-over natural forest, and pioneer species secondary forest (Belukar), into Multi-storied forest. And the another is to establish MSF in bare land through mix and coexistent planting both with FGS and indigenous species. Table S1 shows the concept taken in this project.

Planting methods are mainly divided into two types, Underplanting and Openplanting. Underplanting means a method of planting trees under the influence of surrounding existing canopy. This method is to convert existing forest into MSF, whereas openplanting means a method of planting trees in the area without existing canopy. This method is adopted for bare land in establishing MSF (Photos S1, S2).

Planting sites are mainly divided into two, existing forest and bare land, and existing forests

**Table S1 Concept of Silviculture Experiments in This Project**

| Experiment | Site | | Underplanting | Openplanting |
|---|---|---|---|---|
| Multi-Storied Forest | Chikus | *Acacia mangium* plantation | Strip planting; A (1:1), B (2:2), C (4:4), D (8:8), and E (16:16) type | - |
| | | Pioneer species secondary forest (Belukar) | Strip planting; F (10m), G (20m), H (40m)type | - |
| | | Bare land | - | Mixed & Coexistent planting; A (1:1), B (2:2), C (4:4), D (8:8), and E (16:16) type |
| | B.K. | Logged-over Natural forest | Gap planting; GP-1(Random shape), GP-2 (Square shape, 5m, 10m, 20m, 30m) | - |
| | | | Strip planting; (2m, 10m, 20m) | - |
| Arboretum | Chikus | Bare land | - | Monoculture planting |

Photo S1 Openplanting

are further divided into *Acacia mangium* plantation, logged-over natural forest, and Belukar. Planting sites can be classified in terms of location, one is the Chikus site of lowland forest, and the Bukit Kinta site of hill forest.

Planting Design taken in this project is divided into two, one is a strip planting and another is gap planting.

Various kinds of planting species were chosen to determine some promising high quality indigenous tree species for Multi-Storied Forest establishment.

Beside establishing demonstration forest of Multi-Storied Forest, establishing Arboretum is the other activity. This was aimed initially to collect growth data for various species through the intensive care for the planted seedlings. So far 32 species were planted with monoculture planting.

Photo S2 Underplanting

Planting methods are mainly divided into two types, underplanting and openplanting. Underplanting means planting trees under certain area where influence of surrounding canopy exists. This method is taken for the conversion of existing forest into MSF. Whereas Openplanting means planting trees under certain area where influence of this method is taken in bareland for establishing MSF.

Planting sites are mainly divided into two, existing forest and bare land, and further divided into Acasia mangium plantation and logged -over natural forest. Planting sites can be classified in terms of location, one is Chikus of lowland forest, and Bukit Kinta of hill forest.

Planting design taken in this project is divided into two, one is Line planting and another is Gap planting.

## 2.3. Background

### 2.3.1. Location

Malaysia is a tropical country located North of the Equator within the latitudes 1° to 7° North and longitudes 100°and 119°East. The total land area is approximately 32.9 million ha with 13.2 million ha in Peninsular Malaysia, 7.4 million ha in Sabah and 12.3 million ha in Sarawak. Peninsular Malaysia that is located between latitudes 1°20' to 6°45' North, and extending from longi-

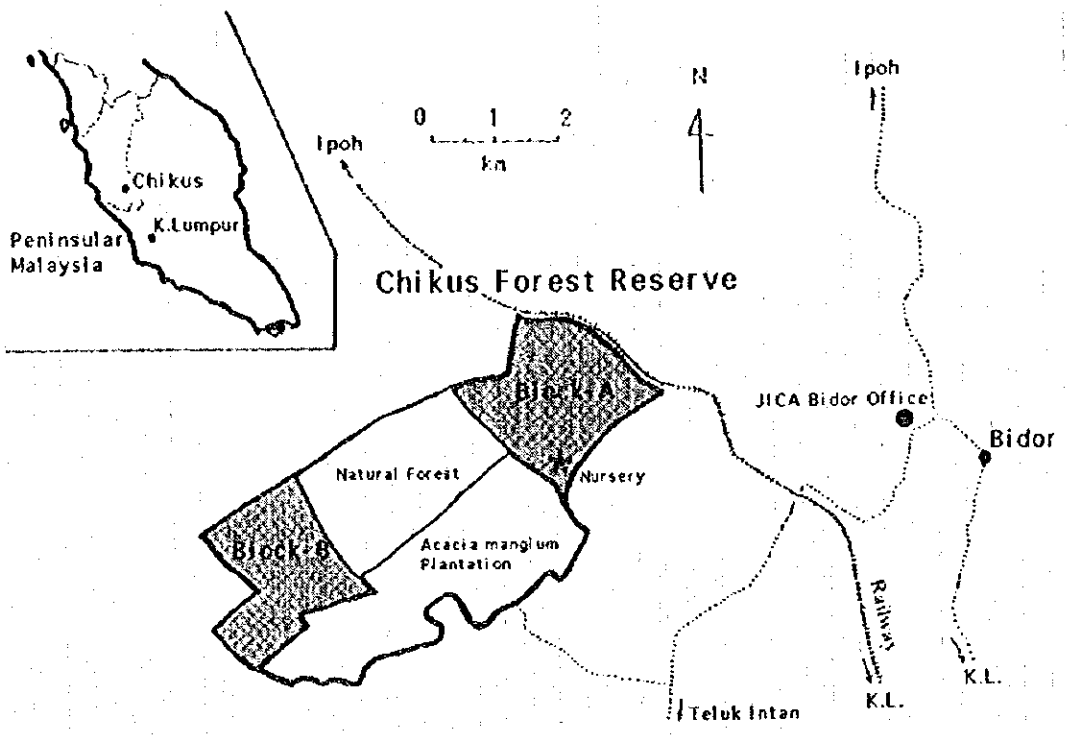



Fig S1. Location of Chikus Site

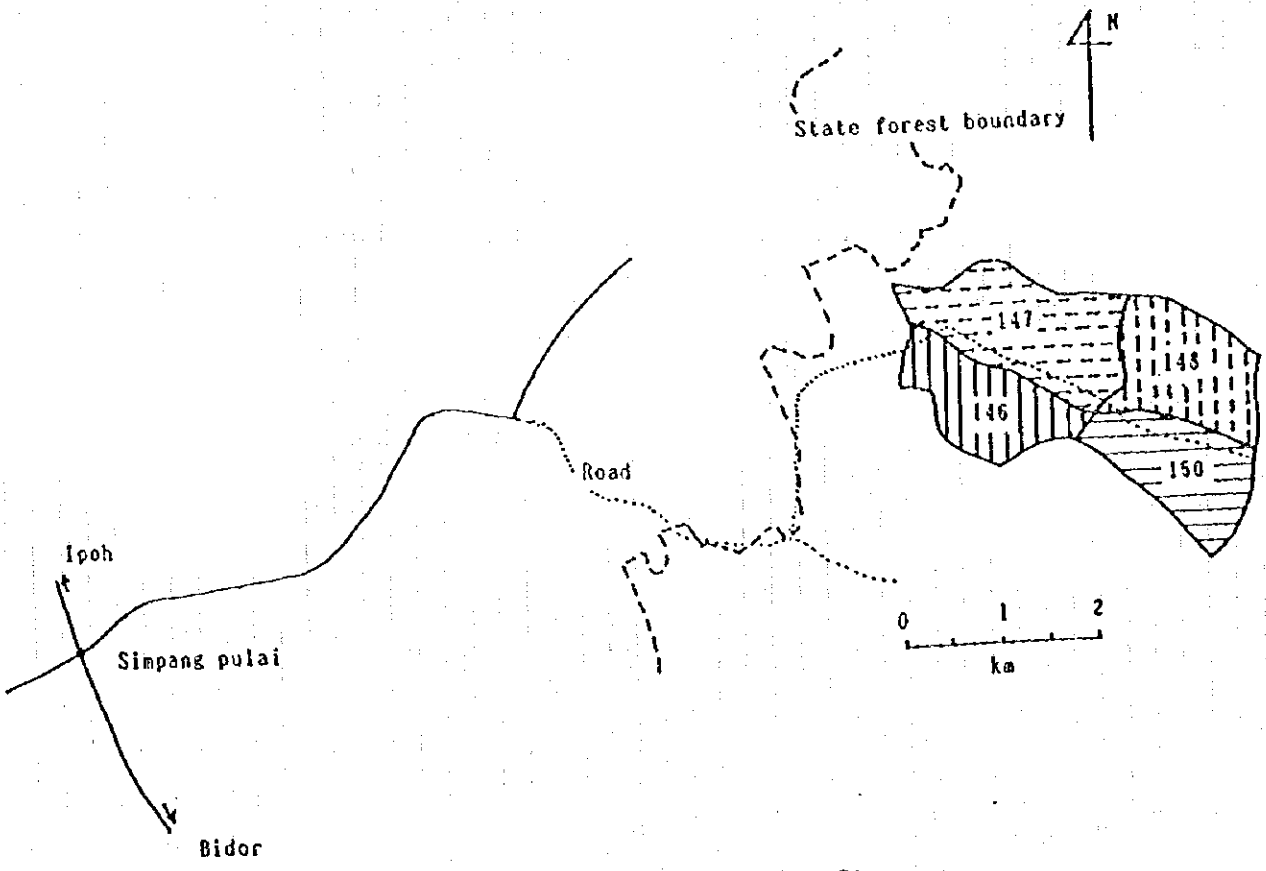



Fig. S2. Location of Bukit Kinta Site

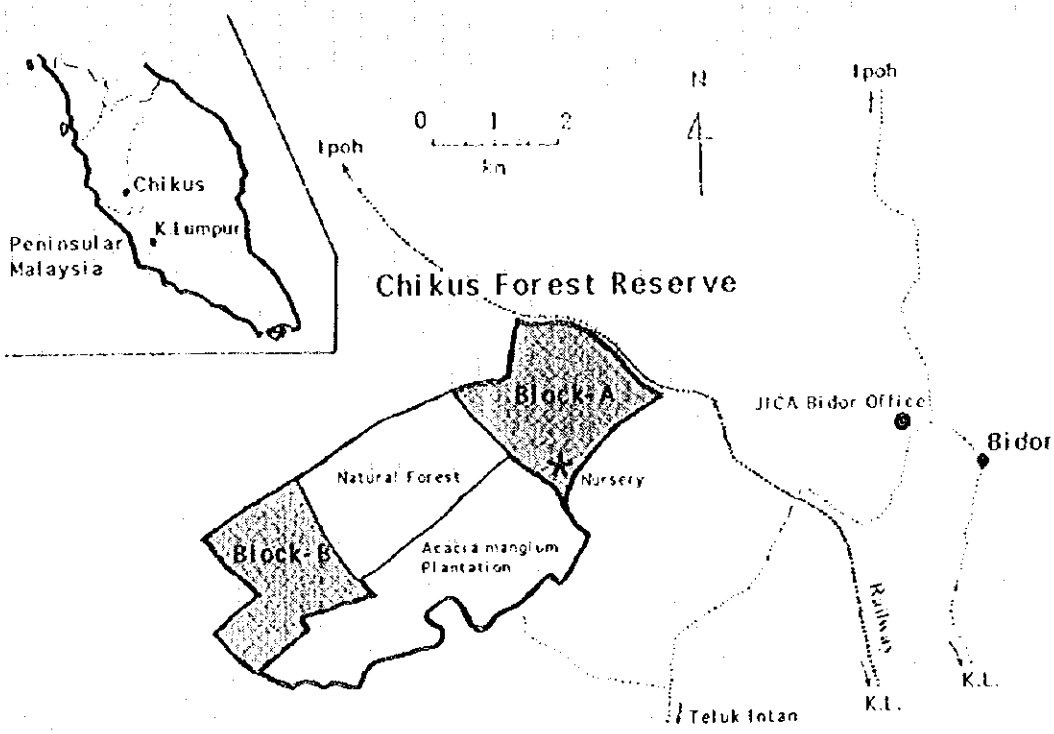



Fig S1. Location of Chikus Site

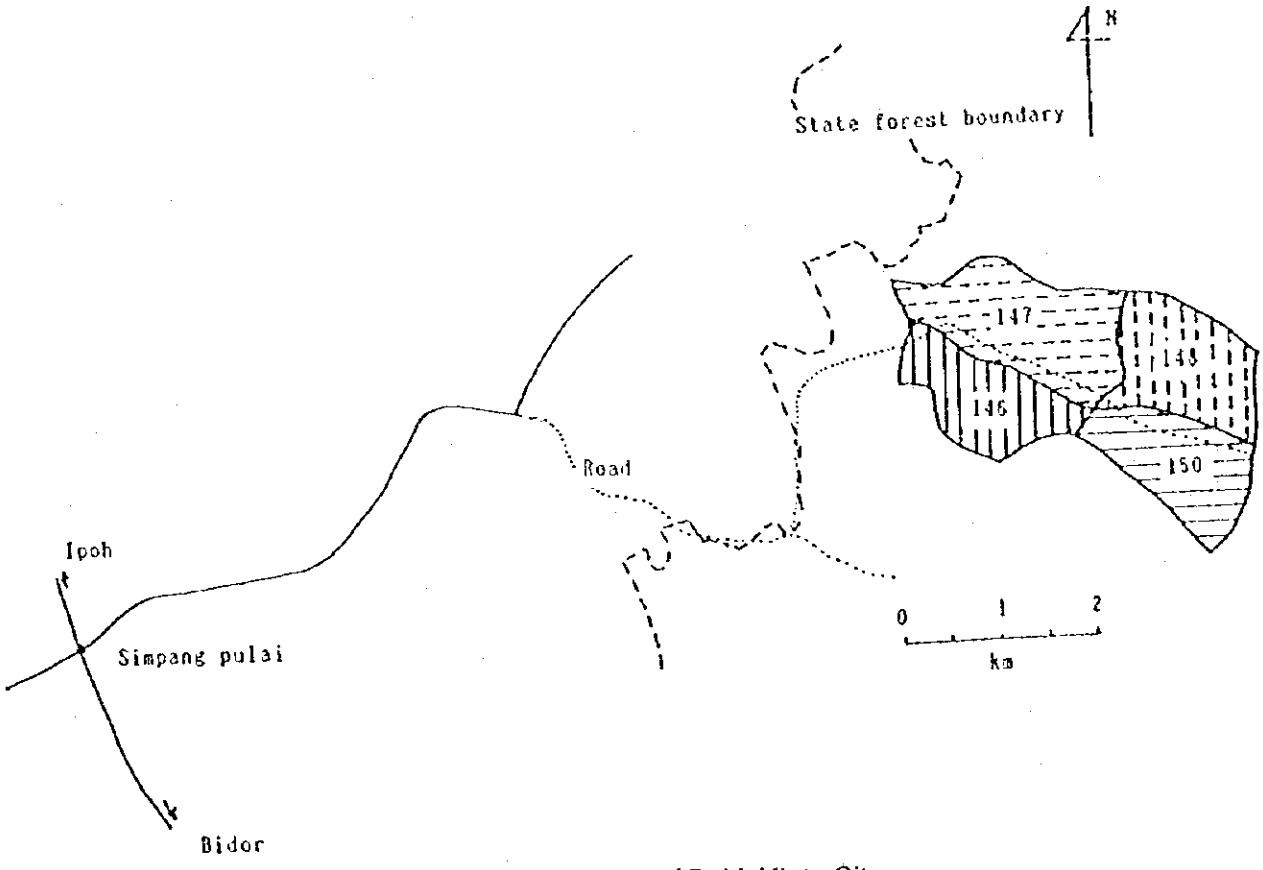



Fig. S2. Location of Bukit Kinta Site

tudes 99°40' and 104°20' East is separated from Sabah and Sarawak by 720 km of the South China Sea, giving the country a coastline of almost 4,830 km. Peninsular Malaysia is characterized topographically by a series of mountain ranges which dominate the northern and central portion of the country. The main mountain range, which extends from Thailand in the North, to the state of Negri Sembilan in the South, contains a number of peaks having heights of between 1,829 m and 2,171 m. It is drained by three major river systems. Two of these, the Sungai Kelantan, and the Sungai Pahang, drain eastwards into the South China Sea while the only major river draining into the Straits of Malacca in the West, is the Sungai Perak.

Two sites were allocated in the state of Perak in the western part of the Peninsular Malaysia. One is the Chikus site in the Chikus Forest Reserve, which is under the jurisdiction of the South Perak District Forest Office of the Perak State Forestry Department, located 80 km south of Ipoh (Fig.S1). The Chikus site consists of two blocks, namely Block-A and -B, the former is 300 hectares of bare land, and the other is 200 hectares of the *Acacia mangium* plantation.

The other is the Bukit Kinta, consisting of approximately 500 hectares of logged-over natural forest in compartments 146, 147, 148 and 150 in Bukit Kinta Forest Reserve (Fig.S2), which is under the jurisdiction of the Kinta and Manjung District Forest Office of the Perak State Forestry Department, located at approximately 25km east of Ipoh (4° 36' N, 101° 44' E).

### 2.3.2. Climate

The climate of Peninsular Malaysia is typically humid tropical or wet equatorial and is characterized by high temperature and no shortage of rain throughout the year. Under Köppen's meteorological classifications, the area is classified as a tropical rainforest climate.

According to the report of the Tapah weather station, 10 km north of Chikus site, an annual average precipitation is 3,313 mm, an annual average temperature is 27.6 °C, an annual average low temperature is 21.7 °C. an annual average high temperature is 33.3 °C. and an annual average number of rainfall days is 168. According to the report of the Ipoh weather station, 10 km east of the Bukit Kinta site, an annual average precipitation is 2,417 mm, an annual average temperature is 26.9 °C, an annual average low temperature is 20.1 °C. an annual average high temperature is 36.1 °C. and an annual average number of rainfall days is 192. According to meteorological record measured at Bukit Kinta site (Nov. 94 - Oct. 95), annual rainfall, annual average temperature, and annual average humidity are 2,864 mm, 24.5°C, and 90.4 %, respectively.

### 2.3.3. Topography, Geology and Soil

The Chikus site, has an overall elevation of 10 to 30 meters, with little undulation, and geographically can be divided into two areas: the northeast part (where Block-A is located), which has somewhat extensive undulation, relatively deep valleys, and a relative difference between valleys and forest slope ends of roughly 5 meters; and the southwest part (where Block-B is located), which has little undulation, marshes around the valleys, and a relative difference between valleys and forest slopes of 0.5 to 1 meter. Geologically, the northeast consists of sedimentary and meta-

morphic rock from the Silurian to Devonian periods, while the southwest is comprised of unconsolidated sediment from the Tertiary period. Soil is classified as acrisols under FAO/UNESCO classifications.

The Bukit Kinta site is situated on a steep mountain 300 to 600 meters in elevation and consisting of steep dales and ridges. Geologically, it consists of granite, with some distinct exposed rocks in some dales and other areas, although overall weathering is extensive, with considerable clay formation. Some quartz dikes also exist. The area around the experimental site is an overall steep mountainous region ,having gradients of 20 to 45 degrees. According to "Geological Map Of Peninsula Malaysia 8th Edition ,1985 ", geology of this area is acid intrusives. According to "Soil Map Of The world " (FAO-Unesco, 1979), soils in this site are Acrisols.

### 2.3.4. Forest Types

The tropical rain forest of Peninsular Malaysia is one of the most complex ecosystems in the world. It has a unique natural heritage which has evolved over million of years, and is rich and varied in plant and animal life, There are over 8,000 species of flowering plants, of which 2,500 are tree species; well over 200 species of mammals; 600 species of birds; 140 species of snakes; 80 species of lizards and more than 26,000 species of insects. It has been estimated that 890 of the 2,500 tree species reach harvestable sizes of at least 45 cm. diameter at breast height (DBH). Of these 890 species, a total of 408 have been introduced at one time or another to the international markets under the Malaysian Grading Rules.

The forests of Peninsular Malaysia can be divided into the following seven forest types according to species and elevation .

| | |
|---|---|
| (1) Montane ericaceous forest ; | Elevation over 1,500 meters |
| (2) Montane oak forest ; | 1,200 - 1,500 meters |
| (3) Upper dipterocarp forest; | 750 - 1,200 meters |
| (4) Hill dipterocarp forest; | 300 - 750 meters |
| (5) Lowland dipterocarp forest; | 0 - 300 meters |
| (6) Peat & fresh water swamp forest; | 0 - 15 meters |
| (7) Mangrove forest | |

The Chikus site is classified as in Lowland dipterocarp forest, and the Bukit Kinta site is as Hill dipterocarp forest.

### 2.3.5. History of the Sites

#### 2.3.5.1. Chikus site

The Chikus Forest Reserves with the total area of 2,000 ha, was originally classified as lowland dipterocarp forest. In 1988, part of the forest reserve (1,500 ha.) has been identified as suitable for compensatory forest plantation project with the primary objectives of converting marginally poor forest into forest plantation of fast growing species to meet the future timber demand. During the establishment of the plantation i.e. between 1988 to 1989, this area was subjected to site preparation which involved operations such as clear cutting of the existing trees and later the remains

were stacked and burnt. The remaining 500 ha of Chikus Forest Reserve on the otherhand was left intact as natural forest.

As mentioned earlier, Chikus Forest Reserves which was allocated for the MSFM Project can be further divided into 2 blocks, namely Block A and Block B. The brief background of the two blocks were as follows:-

a) Block A

The block made up part of the area identified for Compensatory Forest Plantation Project which was planned to be established in 1989. The implementation of the Project was by contract basis where land/site preparation which include felling, stacking and burning were sucessfully carried out . Shortly after site preparation, the appointed contractor faced management problems and had to abandon the Project without carrying out any planting work. Since nothing was done to the area between 1989 to September 1992, the area regenarated into secondary forest (Belukar) with predominant pioneer species such as *Macaranga* spp., *Mallotus* spp., etc.

b) Block B

The area was planted with Acacia mangium under the compensatory forest plantation project in 1988. The planting distance chosen was 3 x 3.7 metres which resulted in planting density of 900 trees per hectare. Prior to MSFM Project implementation i.e. 1988 to November 1991, the *Acacia mangium* plantation was subjected to prescribed forest plantation treatments such as:

a) Treatment I.

The first treatment of the Acacia mangium plantation was carried out between 4 to 6 months after planting. It involved operation such as weeding and prunning of the planted seedling.

b) Treatment II.

This treatment was carried out at 1 year after planting which involved slashing/clearing of weeds and grasses to the height of 30 cm. above the ground level. This activity aims at eliminating competition and to ensure better growth of the planted seedlings. Prunning of each individual tree was also done during this treatment whereby the branches on the lower 50 % of the height of the trees were removed.

c) Treatment III.

Treatment III was carried out when the Acacia mangium tree reached 2 years old. The operations involve 1; slashing/clearing of weeds and grasses, and 2; prunning of tree that have been identified for final felling. The branches of the lower 50 % of the height of the tree were removed. If the height of the trees were 12 meter or above, prunning was done to all the branches up to 7.4 meters above the ground level.

c) First Thinning.

30 % from the original number of trees planted were felled during this operation leaving 600 tree per hectare.

### 2.3.5.2. Bukit Kinta site

The Bukit Kinta site is categorized as hill dipterocarp forest and has consisted of large number of *Shorea curtisii* (especially on riges), *Shorea parvifolia*, *Shorea leprosula*, and other species. Although the area have been inhabited with *Orang Asli* for long time and their activities such as shifting cultivation and plantation of banana, durian, and *Petai (Parkia speciosa)* might have existed, their effct to the forest would be negligible.

Trees in the compartments 146,147,148 and 150 were logged in 1990-1993 by method of the Selective Management System (SMS). Compartments 146 and 147 were logged during Apr. 1990 - Nov. 1990, and compartments 148 and 150 were logged during Jul. 1991 - Jan. 1993. This is the only record of logging history in this area. Before this time target area for logging was limited to the area less than 1500 feet, however, under present forest law, limitation for the elevation was removed and the target was changed to the area less than 40 degrees of slope.

This felling resulted in many large and small gaps, and within the 2-3 year period, by the commencement of afforestation in January 1994, dense shrubs consisting of bamboo, ferns, palms and other tree species had regenerated to a considerable degree. Height of bamboo reached over 10 meters and that of the secondary trees reached 4-5 meters. According to Post-Felling inventory carried out in compartment 146 in 1993, it was found that there were a few remaining high quality species. There were only 4 trees/ha of dipterocarp specis exceeding 15 cm in DBH. More than 90 % of young trees (5 cm < DBH < 15 cm) had some damages or injury in felling and extraction of timber. RS (Regeneration Sampling) species, which were nominated by Forestry Department, were found only 34 trees/ha in the area.

History of the Chikus and Bukit Kinta sites are summarized in Table S2.

**Table S2 History of the Project Sites**

| Year | Chikus | | B.K. |
|---|---|---|---|
| | Block-A | Block-B | |
| Originally | Lowland dipterocarp forest | | Hill forest |
| Jun. 1988 - Mar. 1989 | Clear cutting for compensatory planting project | | |
| Apr. 1989 | Slash burning twice for the site preparation of planting *Acacia mangium* | | |
| Nov. 1989 | Area was left over and | Planting of *Acacia mangium* | |
| Dec. 1989 - Apr. 1990 | Belukar regenerated | Weeding twice & Climber cutting once | |
| Jul. 1990 | | Pruning of *Acacia mangium* | |
| Apr. 1990 - Nov. 1990 | | | Selective cutting by SMS in compartments 146, 147 |
| Oct. 1991 | Area was allocated as JICA project site | | |
| Jul. 1991 - Jan. 1993 | | | Selective cutting by SMS in compartments 148, 150 |
| Feb. 1993 | | | Area was allocated as JICA project site |

# 3. ACHIEVEMENT OF WORK PLAN

## 3.1. Five Year Plan and Achievement

The main objective of silviculture work is to establish demonstration multi-storied forests and an arboretum with practical large scale operation basis not with small scale experiment basis.

### 3.1.1. Chikus site

Five year work plan was formulated at the beginning of the project. Table S3 shows the initial plan and its progress. The figure of this table was summarized on Japanese fiscal year (JFY) basis, which begins in April and ends in March. Almost all of these silviculture works were carried out by local contractors.

Establishing multi-storied forest by underplanting in *Acacia mangium* plantation, with openplanting in bare land, and with underplanting in logged-over natural forest were planned for the area of 200 ha, 280 ha, 50 ha, respectively, and establishing arboretum was planned for the area of 20 ha. The progress of these plans were for the area of 182 ha (progress rate of 91%), 110 ha (39%), 50 ha (100%), and 18 ha (90%), respectively.

Since the survival and growth of the seedlings planted in bare land were quite poor due to harsh environment and inadequate seedlings qualities, the planting design was changed from openplanting into underplanting in secondary forest (Belukar). Thus openplanting in bare land was terminated by 1993 with the progress of 110 ha. Remaining area of 65 ha in Chikus Block-A was planted with this new design in 1994.

Total area of 425 ha, which falls on 77% of initial plan of 550 ha, of MSF and Arboretum were established. The unsuitable site conditions, such as swampy area, forest fire, inaccessibility, etc., prevented attaining the initial planned acreage.

Large amount of supplementary planting was required especially in Chikus Block-A. Harsh environment and other factors caused poor survival and growth of seedlings planted. Planting design has been changed and also supplementary planting was planned to solve this problem. In 1995 and 1996, we have concentrated on supplementary planting. In Chikus, totally 131 ha, which consists of 91 ha of Openplanting plots, 27 ha of underplanting in *Acacia mangium* plots, and 13 ha of arboretum, were replanted with different species.

### 3.1.2. Bukit Kinta site

Initial planting work was started in February 1994 and finished March 1996. The original schedule of planting work was delayed due to the conditions of forest roads and collapse of a bridge along forest road by torrential rainfall in 1993. However, the 5-year work plan was achieved without considerable alteration.

**Table S3 Five Year Silviculture Work Plan and Its Achievement**

| Type | Design | Site | 1992 | 1993 | 1994 | 1995 | 1996 | Total |
|---|---|---|---|---|---|---|---|---|
| Multi-Storied Forest | Underplanting in *Acacia mangium* plantation | Chikus Block-B | *50*<br>42<br><84%> | *50*<br>80<br><160%> | *50*<br>60<br><120%> | *50*<br>- | - | *200*<br>182<br><91%> |
| | Openplanting in bare land | Chikus Block-A | *50*<br>38<br><76%> | *80*<br>72<br><90%> | *100*<br>- | *50*<br>- | - | *280*<br>110<br><39%> |
| | Underplanting in Secondary forest (Belukar) | Chikus Block-A | -<br>- | -<br>- | -<br>65<br><-%> | -<br>- | - | -<br>65<br><-%> |
| | Underplanting in Logged-over Natural forest | Bukit Kinta | -<br>- | *6*<br>3<br><50%> | *14*<br>21<br><150%> | *20*<br>26<br><130%> | *10*<br>- | *50*<br>50<br><100%> |
| Arboretum | Openplanting | Chikus Block-A | -<br>8<br><-%> | *10*<br>8<br><80%> | *10*<br>2<br><20%> | -<br>- | - | *20*<br>18<br><90%> |
| Total | | | *100*<br>88<br><88%> | *146*<br>163<br><112%> | *174*<br>148<br><85%> | *120*<br>26<br><22%> | *10*<br>- | *550*<br>425<br><77%> |

| Type | Site | 1992 | 1993 | 1994 | 1995 | 1996 | Total |
|---|---|---|---|---|---|---|---|
| Supplemental planting | Chikus | - | - | - | 10 | 121 | 131 |
| | Bukit Kinta | - | - | 0.3 | - | - | 0.3 |

Note; Italic figures indicate initial plan

Most of the silvicultural works have been conducted by local contractor based on recommendation from FD.

## 3.2. Planted Species

Table S4 shows the list of species planted in this project. In Chikus site, 19 of dipterocarp species, 25 of non-dipterocarp indigenous species (including one non-wood species (*Calamus manan*), two fast growing species for openplanting (*Acacia mangium* and *Hevea brasiliensis*)) were planted in the experimental plots. In Bukit Kinta site, seven dipterocarp species were planted.

## Table-S4 Species planted in Project Site

| | | Multi-Storied Forest | | | | Arboretum |
|---|---|---|---|---|---|---|
| | Block | Block-B | Block-A | | Bukit Kinta | Block-A |
| | Planting method | Underplanting | Openplanting | Underplanting | Underplanting | Openplanting |
| | Forest type | L. manglum plantatior | Bareland | Secondary Forest | Hill Forest | Bareland |
| | Design | 5 type (A-E) | 6 type (A-E) | 3 type (F-H) | 8 type | - |
| | Direction | 2 type (EW & NS) | EW | EW | - | - |
| | SPECIES | | | | | |
| 1 | *Dipterocarpus cornutus* | X | | | | X |
| 2 | *Dipterocarpus baudii* | | | | X | |
| 3 | *Dryobalanops aromatic* | X | X | | | X |
| 4 | *Hopea odorata* | X | X | | | X |
| 5 | *Hopea pubescens* | X | | | | |
| 6 | *Neobalanocarpus heimi* | X | X | X | | X |
| 7 | *Parashorea densiflora* | X | | | | |
| 8 | *Shorea acuminata* | X | X | X | | X |
| 9 | *Shorea assamica* | X | | | | |
| 10 | *Shorea bracteolata* | | X | X | | X |
| 11 | *Shorea curtisii* | | | | X | |
| 12 | *Shorea gibbosa* | | | X | | |
| 13 | *Shorea glauca* | X | | X | | |
| 14 | *Shorea leprosula* | X | X | X | X | X |
| 15 | *Shorea macroptera* | X | | | X | X |
| 16 | *Shorea multiflora* | | | X | | X |
| 17 | *Shorea ovalis* | X | | X | | X |
| 18 | *Shorea ovata* | X | | X | X | |
| 19 | *Shorea parvifolia* | X | X | X | X | X |
| 20 | *Shorea panciflora* | X | | X | X | |
| 21 | *Shorea talura* | | | X | | X |
| 22 | *Acacia mangium* | | (X) | | | |
| 23 | *Agathis borneensis* | | | | | X |
| 24 | *Alstonia sp.* | | | | | X |
| 25 | *Azadirachta excelsa* | | | | | X |
| 26 | *Calophyllum sp.* | | X | | | X |
| 27 | *Cinnamomum sp.* | | | | | X |
| 28 | *Dacryodes sp.* | | | | | X |
| 29 | *Dialium sp.* | | | X | | |
| 30 | *Durio sp.* | | | | | X |
| 31 | *Endospermum malaccense* | | X | | | X |
| 32 | *Gonystylus sp.* | | | X | | |
| 33 | *Heritiera sp.* | | | | | X |
| 34 | *Hevea brasiliensis* | | (X) | | | X |
| 35 | *Intsia palembanica* | X | | | | X |
| 36 | *Koompassia malaccensis* | | | | | X |
| 37 | *Palaquium gutta* | X | | | | X |
| 38 | *Parkia sp.* | | | | | X |
| 39 | *Pentaspadon motleyi* | X | X | | | X |
| 40 | *Pouteria malaccensis* | | X | | | |
| 41 | *Scaphium macropodum* | | X | | | X |
| 42 | *Sindora sp.* | | | X | | |
| 43 | *Swietenia macrophylla* | | | | | X |
| 44 | *Tectona grandis* | | | | | X |
| 45 | *Toona sureni* | | | | | X |
| 46 | *Calamus manan* | X | | | | |
| | | 19 | 14 | 15 | 7 | 31 |

Note : (X) means the species which was planted as Fast Growing Species

# 4. SILVICULTURE METHODS IMPLEMENTED IN THIS PROJECT

Silviculture methods taken in this project are stated in this section. This section must be finalized as a silviculture manual for establishing Multi-Storied Forest in the future. During initial five years, necessary activities for establishing Multi-Storied Forest, such as over-story felling, subsequent plantings, thinning, etc., could not have been carried out in a large scale. After conducting these activities, silviculture manual should be compiled.

## 4.1. Chikus Site

### 4.1.1. Multi-Storied Forest by Underplanting in *Acacia manglum* Plantation

#### 4.1.1.1. Demarcation of experimental plots

The Block-B was divided into three sub blocks and three years from 1992 to 1994 were spent for establishing of Multi-Storied Forest in the area. The three sub blocks were named based on the year of contract, namely Block-B(1992), Block-B(1993), and Block-B(1994).

Experimental plots were set-up to demonstrate different planting designs for different species. Each plot has an area of approximately one hectare, with one silvicultural design planted with one species. Arrangement of plots are shown in Figs. S3, S4, and S5.

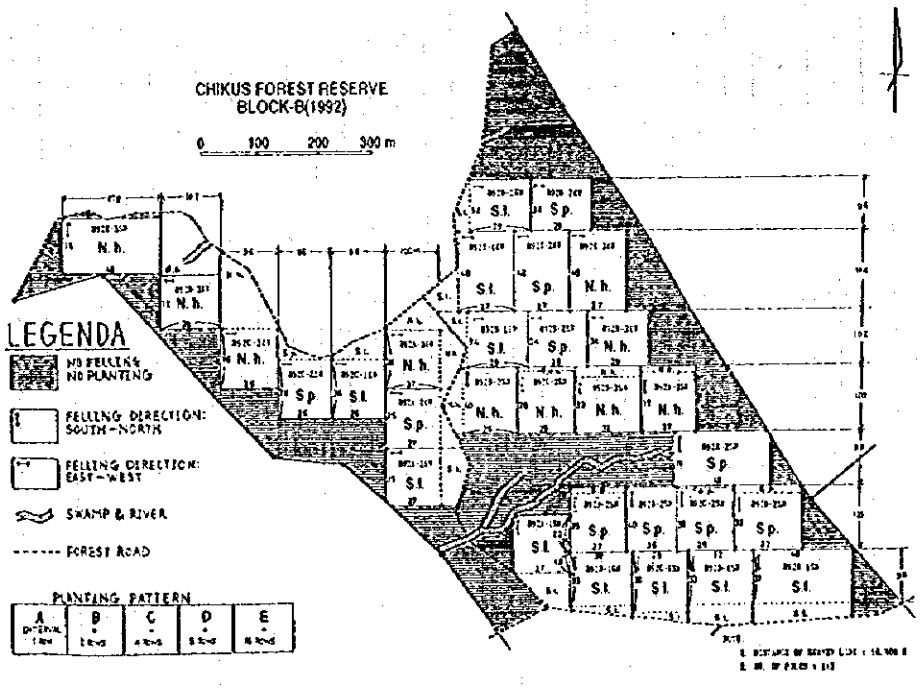



Fig. S3 Arrangement s of experimental plots in block B(1992)

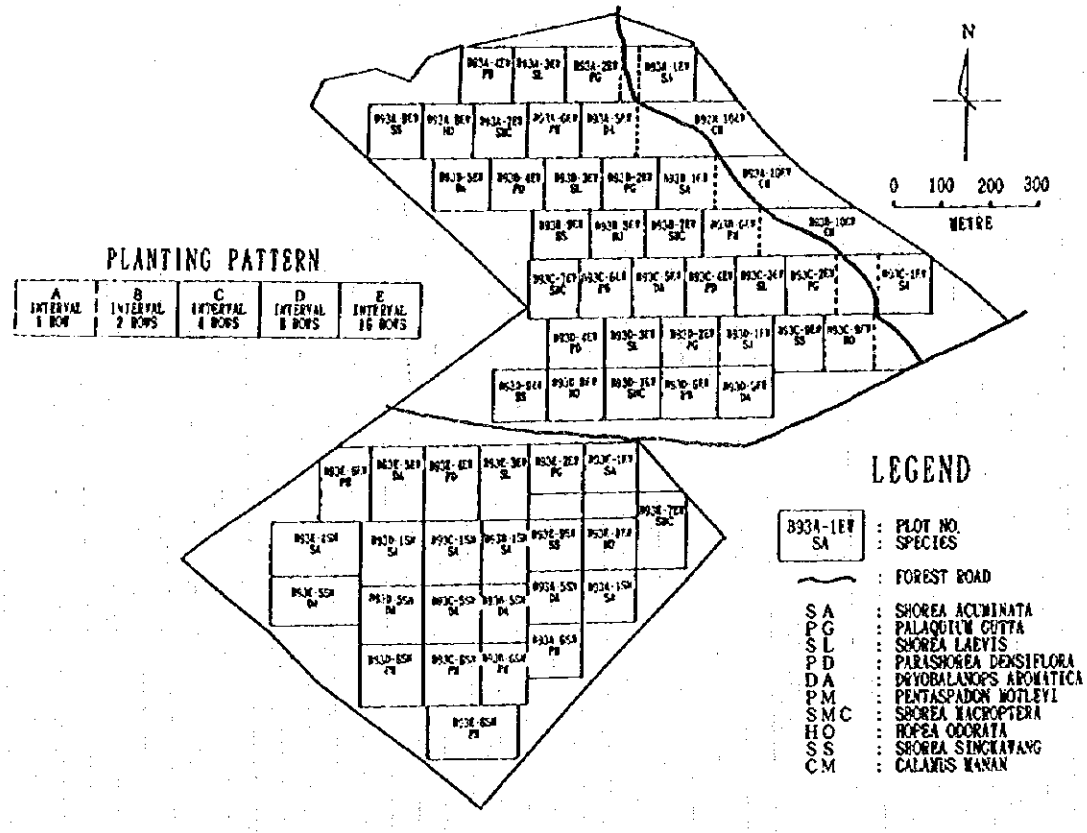



Fig. S4 Arrangement s of experimental plots in block B(1993)

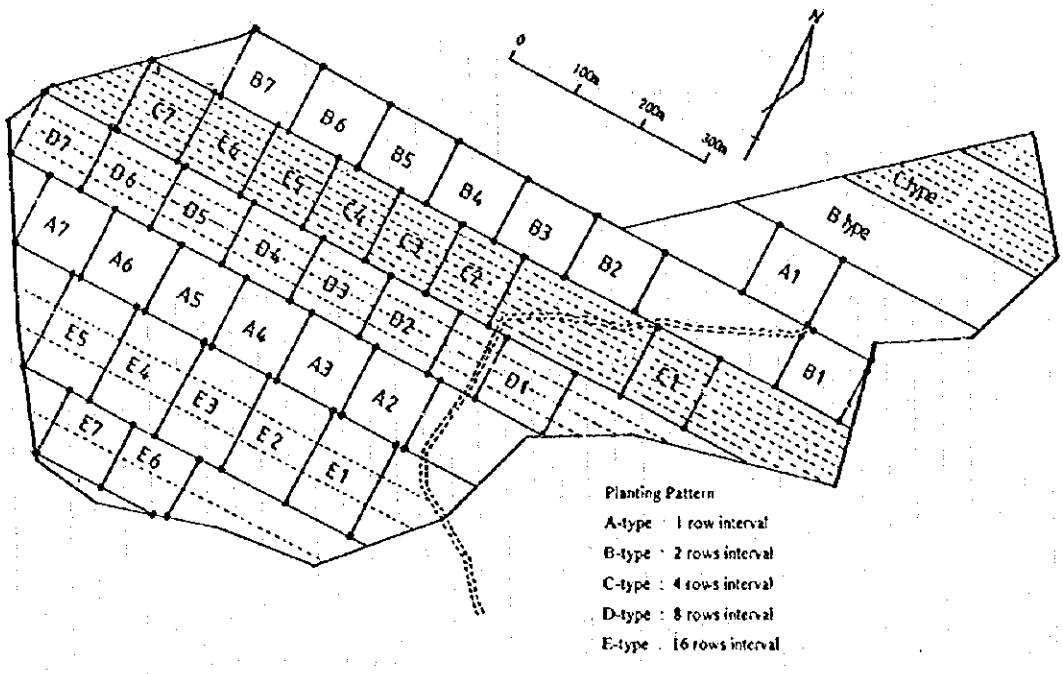



Fig. S5 Arrangement s of experimental plots in block B(1994)

Photo S3 Planting strip of EW-A type

*Acacia mangium* was designed to be felled in 5 different strip widths and 2 different directions in order to manipulate the light condition . Felled rows and retained rows were arranged alternately of the same number, A-type (one row felled & one row retained, 1:1), B-type (2:2), C- type (4:4), D- type (8:8), and E-type (16:16), so as to attain 50 % of the felling rate in number of *Acacia* trees (Photos 3,4,5). The felling direction of rows were taken in two ways, East to West (EW), and North to South (NS). Thus ten designs were taken, namely EW-A, EW-B, EW-C, EW-D, EW-E, NS-A, NS-B, NS-C, NS-D, and NS-E. *Acacia mangium* trees were planted in the spacing of 3.0 m x 3.7 m, so that actual width of planting strips were differed in EW plots and NS plots. Table S5 and Fig. S6 shows the design and planting widths.

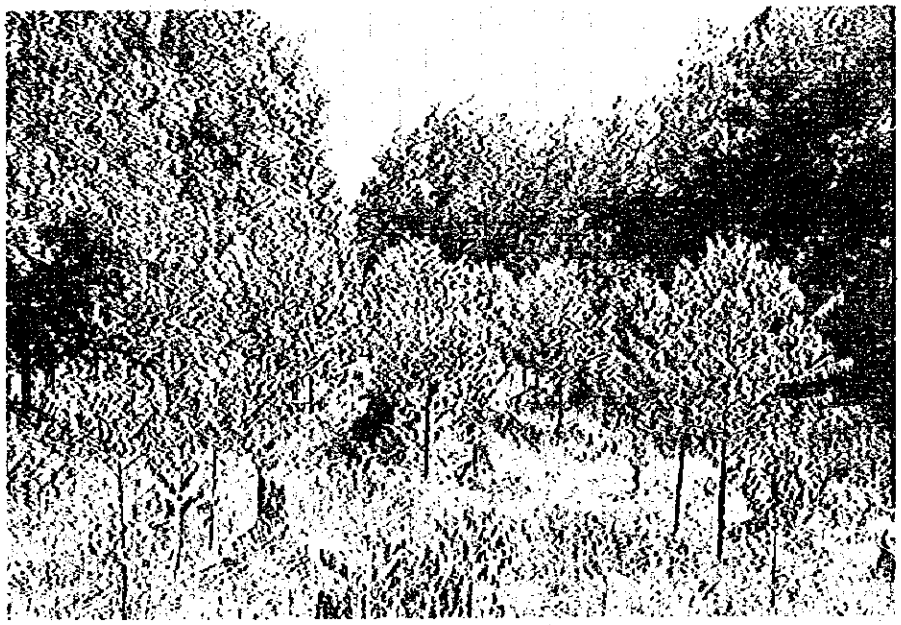
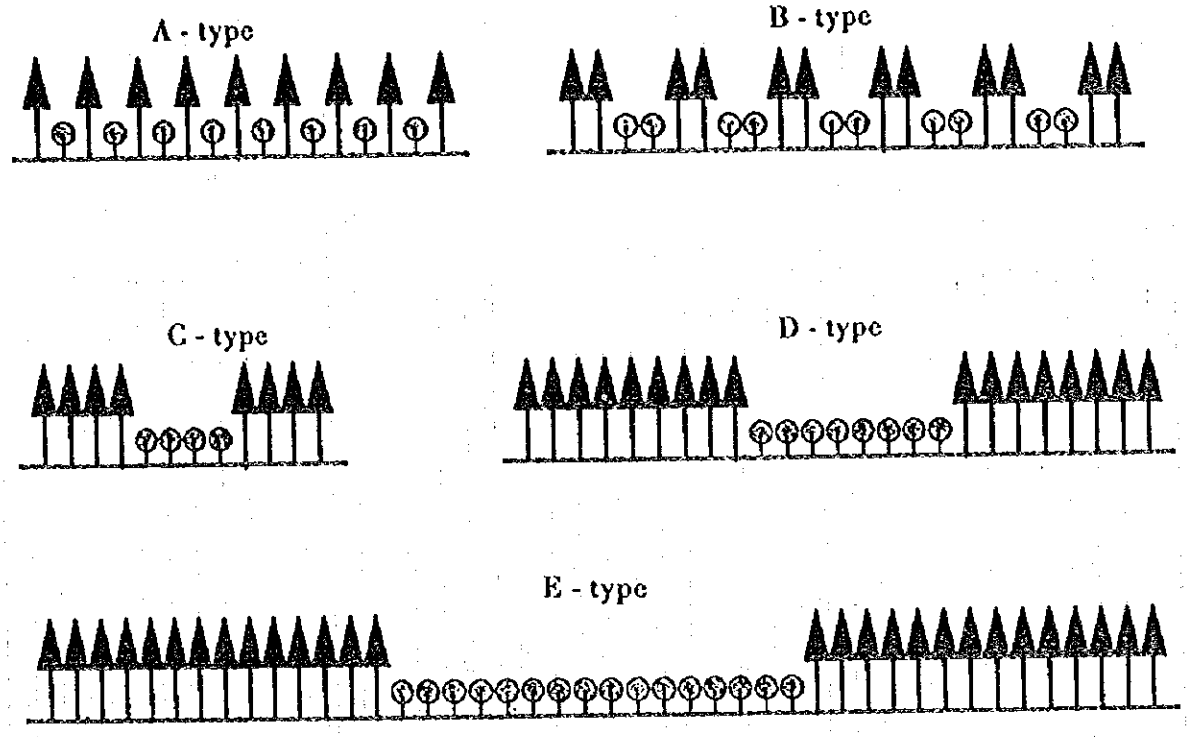


Photo S4 Planting strip of NS-D type

Photo S5 Planting strip of EW-E type

**Table S5 Design and Planting Strip Width**

| Type | A | B | C | D | E |
|---|---|---|---|---|---|
| Felled Rows: Retained Rows | 1:1 | 2:2 | 4:4 | 8:8 | 16:16 |
| East to West (EW) | 6.0m | 9.0m | 15.0m | 27.0m | 51.0m |
| North to South (NS) | 7.4m | 11.1m | 18.5m | 33.3m | 62.9m |




Remarks 1. indicates Fast Growing Species (Ex. Acacia mangium).
2. indicates High Quality Timber Species (Ex. Dipterocarpaceae).
3. Planting distance : 3.0m x 3.7m.
4. Acacia mangium in site-B were planted in Sept. - Dec. 1989.

Fig. S6. Design of Multi-storied forest by underplanting in Acacia mangium plantation

4.1.1.2. Site preparation

In Block-B(1992), *Acacia mangium* was felled in strips from July to September 1992 when *Acacia mangium* had an average height of 13 m and an average DBH (diameter at breast height) of 14 cm. In Block-B(1993), *Acacia mangium* was felled from October to December 1993 when *Acacia mangium* had an average height of 15.4 m and an average DBH of 16.7 cm. In Block-B(1994), *Acacia mangium* was felled from October 1994 to January 1995 when *Acacia mangium* had an average height of 17.0 m and an average DBH of 17.3 cm..

*Acacia* trees were felled with chainsaws and pruned on the spot, with branches cut at the point where the diameter is approximately 5 cm. This process was normally done by one worker. All felled trees were collected in tree length timber, and extracted by a farming tractor. The work team normally consists of one loader and one unloader for each farming tractor. Although a bull-

dozer could be used for extracting timber in wide planting gaps, a farming tractor (wheel-type) was used to avoid compacting the soil. Most of the logs were extracted from strips, and then compiled along the forest roads.

After the removal of *Acacia mangium* trees, remaining branches from felled trees, regenerated plants, and weeds were clared. These processes were mainly done by hands. A long hatchet (50 - 60 cm long) called "parang" in Malay was used for weeding. Branches were cut and accumulated towards the side of remaining *Acacia mangium* trees. The weeding width was 2 m along the planting line (i.e., 1 meter on each side of the position of planting). Because of the considerable regenerative capabilities of *Acacia mangium*, Escort 60DF was applied on all remaining stumps to stop sprouting. The soil was not cultivated. Fertilizer was not applied. Site preparation record in block B is shown in Table S6

**Table S6 History of Chikus Block-B**

| Year | Block-B (1992) | Block-B (1993) | Block-B (1994) |
|---|---|---|---|
| Nov. 1989 | Planting of *Acacia mangium* | | |
| Dec. 1989 - Apr. 1990 | Weeding twice & Climber cutting once | | |
| Jul. 1990 | Pruning of *Acacia mangium* | | |
| Jul. 1992 - Sep. 1992 | Felling & Extracting of *Acacia mangium* | | |
| Sep. 1992 - Oct. 1992 | Site preparation | | |
| Oct. 1992 - Nov. 1992 | Underplanting of indigenous species | | |
| Oct. 1993 - Dec. 1993 | | Felling & Extracting of *Acacia mangium* | |
| Jan. 1994 - Mar. 1994 | | Site preparation | |
| Feb. 1994 - May 1994 | | Underplanting of indigenous species | |
| Oct. 1994 - Jan. 1995 | | | Felling & Extracting of *Acacia mangium* |
| Dec. 1994 - Feb. 1995 | | | Site preparation |
| Feb. 1995 - Mar. 1995 | | | Underplanting of indigenous species |

### 4.1.1.3. Selection of planting species

One of our main objectives is to determine promising high quality timber species for establishing Multi-Storied Forest. These species were selected from "Pocket Check List of Timber Trees" (Malayan Forest Records No. 17). Species naturally distributed in lowland dipterocarp forest were chosen for Chikus sites mainly. Although we have tried to collect as many indigenous species as possible, the irregular flowering and fruiting patterns of many indigenous species and the lack of an organized system for seedlings production made it impossible to get enough amount of seedlings regularly. These problems forced us to rely on a passive system for seedlings selection. Planting species were selected based on the species available on the time of planting seasons. Species planted and their origin in these experimental plots are shown in Table S4 and Table S7.

Table S7 Planting Species in Underplanting in Acacia mangium plantation

| BLOCK | YEAR | TYPE | DIRECTION | SPP | Date Planted | Seed/Wilding | Name of Place | State | JICA / FD / Private nursery | Date acquired |
|---|---|---|---|---|---|---|---|---|---|---|
| B | 94 | A E | EW | Dipterocarpus cornutus | Mar 95 | Seed | Gauda | Perak | JICA | Aug. Sep. 93 |
| B | 93 | A E | EW, NS | Dryobalanops aromatica | Feb.-May 94 | Seed & Wilding | Kanching | Selangor | Private | May. Jul. 93 |
| B | 93 | A,C,D,E | EW | Hopea odorata | Mar 94 | Wilding | Kuala Berang | Terengganu | Private | Aug 92 |
| B | 93 | A,B,C,E | EW | Hopea odorata | Mar 94 | Wilding | Pagang | Perak | FD (Pagang) | Sep 93 |
| B | 94 | A E | EW | Hopea pubescens | Feb.-Mar. 95 | Wilding | Chikus | Perak | JICA | Nov 92 |
| B | 94 | A E | EW | Intsia palembanica | Feb.-Mar. 95 | Seed | Bauding | Perak | JICA | Sep 93 |
| B | 92 | A E | EW, NS | Koodersiocarpus ferrea | Oct.-Nov. 92 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug. Sep. 92 |
| B | 93 | A E | EW | Palaquium gutta | Feb.-Apr. 94 | Wilding | Tanjoh | Perak | JICA | Jun 93 |
| B | 93 | A E | EW | Parashorea tomentella | Mar.-Apr. 94 | Wilding | Bauding | Perak | JICA | Aug 93 |
| B | 93 | A E | EW, NS | Pentaspadon motleyi | Feb.-May 94 | Wilding | Chikus | Perak | JICA | Nov 92,Jan. 93 |
| B | 92 | A E | EW, NS | Shorea acuminata | Feb.-May 94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug 93 |
| B | 94 | A E | EW | Shorea assamica | Feb. Mar. 95 | Wilding | Bubu | Perak | JICA | Jan 94 |
| B | 93 | A,C,D,E | EW | Shorea glauca | Feb.94 | Wilding | Kota Setar | Kedah | Private (Kota Setar) | May 93 |
| B | 92 | A E | EW, NS | Shorea leprosula | Oct.-Nov. 92 | Wilding | Manong | Perak | FD (Manong) | Aug 92 |
| B | 94 | C | EW | Shorea leprosula | Feb 95 | Seed | Bauding | Perak | JICA | Aug 93 |
| B | 93 | A E | EW | Shorea macroptera | Feb.-May 94 | Wilding | Bauding | Perak | JICA | Sep 93 |
| B | 94 | C | EW | Shorea macroptera | Feb 95 | Seed | Bauding | Perak | JICA | Sep 93 |
| B | 94 | A E | EW | Shorea ovalis | Feb. Mar. 95 | Seed | Bubu | Perak | JICA | Mar 94 |
| B | 94 | A E | EW | Shorea ovata | Feb. Mar. 95 | Seed | Bauding | Perak | JICA | Sep 93 |
| B | 92 | A E | EW, NS | Shorea parvifolia | Oct.-Nov. 92 | Wilding | Manong | Perak | FD (Manong) | Aug 92 |
| B | 94 | A E | EW | Shorea pauciflora | Feb. Mar. 95 | Seed | Gauda | Perak | JICA | Aug 93 |
| B | 93 | A,B,N | EW | Calamus manan | Mar 94 | Wilding | Kota Setar | Kedah | Private | Oct 93 |

Four indigenous species were planted under *Acacia mangium* canopy from October to November 1992. Nine indigenous species were planted from February to May 1994. Nine indigenous species were planted from February to March 1995 (Photos 6, 7, 8, and 9).

Photo S6 *Shorea leprosula* planted in NS-B in Block-B(1992) at 30 months after planting

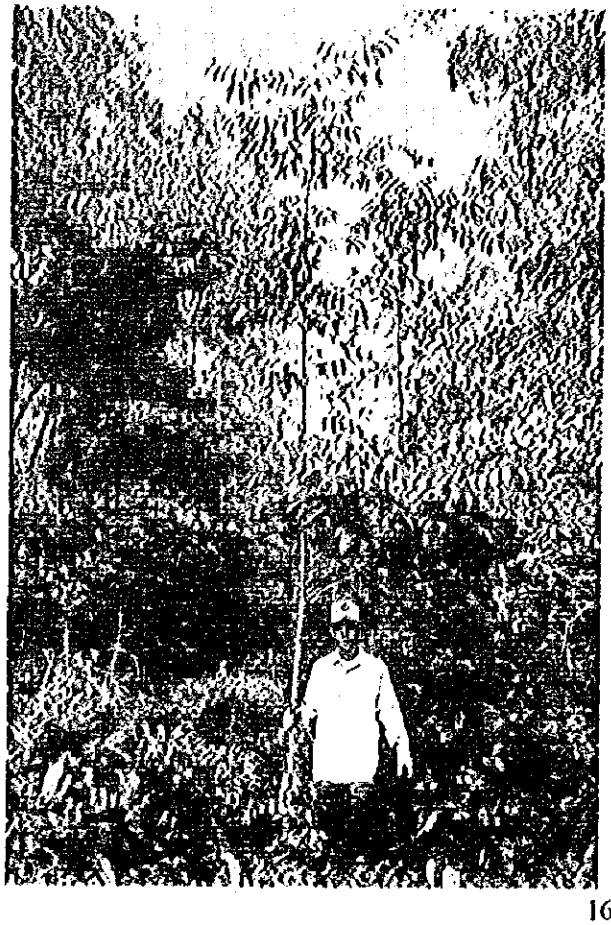


Photo S7(upper left) *Shorea acuminata* planted in EW-D in Block-B(1993) at 22 months after planting

Photo S8 (upper right) *Dryobalanops aromatica* planted in EW-A in Block-B(1992) at 30 months after planting

Photo S9 *Pentaspadon motleyi* planted in EW-A in Block-B(1992) at 23 months after planting

#### 4.1.1.4. Planting

Seedlings were planted between *Acacia mangium* stumps in the planting strips after felling of *Acacia mangium*. Thus the spacing was in accordance with that of *Acacia mangium*. The spacing of 3.7 m x 3.0 m makes the density of 900 trees per hectare (Fig. S7). The actual density of high quality timber species in project sites came to 450 trees per hectare as 50% of upper layer were designated for felling.

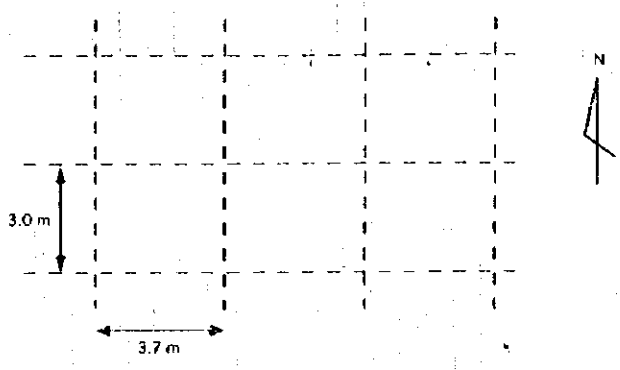



Fig. S7 Spacing in underplanting in *Acacia mangium* plantation

Before planting, Bamboo stakes were placed into the ground to mark the planting position (i.e., the hole where seedlings were to be planted). Staking was useful not only during planting time but also during subsequent weeding time for showing the position clearly.

Seedlings were transported from the nursery (in block A) to the site before 11:00 a.m. or after 5:00 p.m. This is to avoid the harsh sunlight and high temperature in daytime, which harm the seedlings. A covered truck was used for long-distance transport (i.e., more than 30 minutes drive). Generally planting was designated from sunrise to 11:00 a.m. or 4:00 p.m. to sunset. However in the narrower planting strips, such as A-, B-, and C-type plots, planting was allowed all day long because of their shady condition.

A planting hole is 20 cm in diameter and 20 cm depth, or slightly larger than the pot size. An instrument called "pengali" in Malay, which has a round blade with a 1.4 meter wooden handle, was used to dig these holes. Before planting, the plastic bags were removed from the potted seedlings to prevent the soil from crumbling. Seedlings were placed into the planting holes, then they were filled with soil. Weeded grass and shrub were put around the seedling as mulch. Removed bags were placed on the top of bamboo stakes to indicate planting position. These bags on bamboo stakes indicate that seedlings have actually been planted, and served as indicators for the seedlings planted during subsequent weeding.

A survival rate survey was carried out one month after planting. If it is determined that 20% or more of the seedlings had died, supplemental planting is carried out within the next two months.

#### 4.1.1.5. Tending

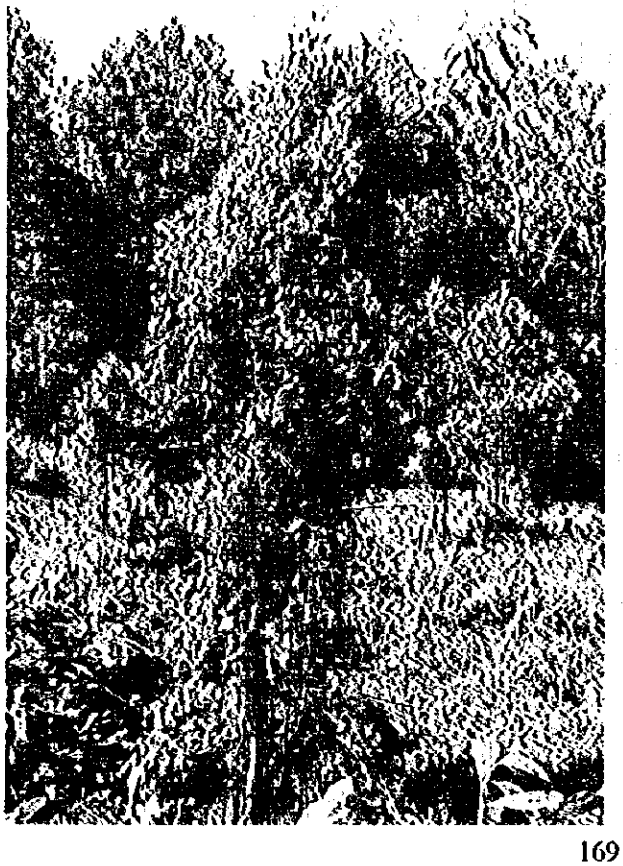
Weeding and climber cutting were carried out at the same time. While weeding and climber cutting should be carried out depends on the growth of the vegetation ideally, extensive weeding under a contract basis suited to the volume of vegetation was difficult because of the large scale of area and intricacy of preparation of contract work. Beside actual necessity of weeding and climber cutting, regular tending was needed for the smooth implementation for regularly measuring of the plots. The first weeding and climber cutting were carried out 3 - 4 months after planting. Afterward

they were carried out in every 3 - 5 months depending on the growth of undergrowth.

These works were mainly done with hatchets at the initial stage of project in order not to damage the seedlings. Weeding was carried out by line along the planting line, and the width was 2 m along the planting line (i.e., 1 meter on each side of the position of planting). Climbers on the seedlings were removed carefully by hand not to damage the seedling shoot. After second time of weeding, works were done by machine; bush cutter (Photo 10), because of the increase number of planting sites. Climber cutting was still done manually. Compared to manual weeding, machinery weeding had more problems with misweeding.

In Chikus Block-B, the growth of forest floor vegetation responds to the difference of the planting strip width. The following 5 species were main targets for weeding;

Photo S10 Weeding by bush cutter



1) *Perotis latifolia* (Malay name : Ekor kuching): This grass is the dominant species of weed in wider planting strips, i.e. D- and E-type, where received ample sunlight. It is hardly found in shaded areas, such as the narrower strips in A- and B-type.

2) *Mikania micrantha* (Common name : Mile-a-minute): This climber is quite common all over in Chikus-B, especially moist site. This species grows vigorously, so frequent removal was required (Photo 11).

Photo 11 *Mikania micrantha* on planted seedling

3) *Dioscorea* sp. (Malay name : Belokok) : This climber is found extensively in Block-B, can completely cover and kill planted seedlings if weeding is delayed. This climber can bend the shoot of seedlings and greatly retard the growth of *Shorea leprosula*, *Shorea parvifolia* and other species with extremely soft shoots. This climber is distributed largely all over Block-B, on moist soil, on dry soil, in wider strips, and in narrower strips as well.

4) *Ipomoea triloba* (Malay name : Selaput tunggul) : This climber is not so extensive as *Dioscorea* sp. but has thicker stems (2 - 3 mm diameter) and can bend seedlings' shoots and retard seedlings growth.

5) *Randia fasciculata* ( (Malay name : Duri) : This climber is less widely distributed, has even tougher and thicker stems (4 - 5 mm diameter) and can bend over and thus damage the entire seedling.

Beside these weeds, regeneration of *Acacia mangium* was outstanding especially in D- and E-type in Block-B(1994) area, while it was not observed so much in Block-B(1992) and Block-B(1993) area. This might be caused by mass fruiting of *Acacia* in Block-B(1994) after their strip felling. *Acacia mangium* was felled in Block-B(1992) from September to October when they were 2 years and 10 months old, in Block-B(1993) from October to December when they were 4 years old, in Block-B(1994) from September to October when they were 5 years and 2 months old. *Acacia mangium* is said to start their fruiting after 3 years of planting, and have its fruiting season all year around in tropic region. This may suggest that the age of *Acacia mangium* and the upper-story felling time should be considered carefully, otherwise undesired natural regeneration will be enhanced.

In this 5 year period, pruning for planted species was not carried out. Through the field observation, self-pruning of the planted species is slow. Observation should be continued.

**Table S8 Vegetation in Each Planting Design and Necessary Frequency of Weeding for Each Design**

| Type | Strip width | Vegetation | Mean height of vegetation | Frequency of weeding |
|---|---|---|---|---|
| A | 1-row | Herb and Fern | 1 m | 2 - 3 times per year |
| B | 2-row | Herb and Fern | 1 m | 2 - 3 times per year |
| C | 4-row | Herb and Grass | 1 m | 3 times per year |
| D | 8-row | Grass | 2 m | 3 - 4 times per year |
| E | 16-row | Grass | 2 m | 4 - 5 times per year |

### 4.1.1.6. Supplementary planting

Generally survival and growth of planted seedling were well in Block-B. Poor results were observed in E-type plots and in water logging area (Photo 19).

In 1994 and 1995, supplementary planting was conduced where the survival rate became less than 20 %. Different species than originally planted species were planted not to repeat the same problem and to try as many species as possible. Species planted with thier origin are shown in Table S9.

Table S9 Planting Species for Supplementary Planting in Underplanting in *Acacia mangium* plots

| BLOCK | YEAR | TYPE | DIRECTION | Rel. | SPP | Date Planted | Seed/Wilding | Name of Place | State | JICA / FD / Private nursery | Date acquired |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 92 | D | EW | 1 | Shorea parvifolia | 05-Nov-92 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| B | 92 | D | EW | 2 | Shorea curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 92 | E | EW | 1 | Shorea parvifolia | 10-Nov-92 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| B | 92 | E | EW | 2 | Shorea bracteolata <<Replant>> | 15-Feb-96 | Seed | Unknown | Kedah | Private | Oct-93 |
| B | 92 | E | EW | 1 | Neobalanocarpus heimii | 12-Nov-92 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug.-Sep-92 |
| B | 92 | E | EW | 2 | Shorea curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | A | SN | 1 | Shorea acuminata | 12-May-94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| B | 93 | A | SN | 2 | Dipterocarpus kerrii <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Dec-94 |
| B | 93 | D | SN | 1 | Shorea acuminata | 07-Apr-94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| B | 93 | D | SN | 2 | Dipterocarpus crinitus <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Jan-95 |
| B | 93 | E | EW | 1 | Shorea acuminata | 01-Apr-94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| B | 93 | E | EW | 2 | Anisoptera curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | D | EW | 1 | Palaquium gutta | 08-Mar-94 | Wilding | Teronoh | Perak | JICA | Jun-93 |
| B | 93 | D | EW | 2 | Shorea parvifolia <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Jan-95 |
| B | 93 | E | EW | 1 | Palaquium gutta | 01-Apr-94 | Wilding | Teronoh | Perak | JICA | Jun-93 |
| B | 93 | E | EW | 2 | Shorea glauca <<Replant>> | 15-Feb-96 | Wilding | Unknown | Kedah | Private | Nov-94 |
| B | 93 | B | EW | 1 | Dryobalanops aromatica | 22-Mar-94 | Seed & Wilding | Kanching | Selangor | Private | Mar-93 |
| B | 93 | B | EW | 2 | Shorea leprosula <<Replant>> | 15-Feb-96 | Seed | Ulu Slim | Perak | JICA | Sep-94 |
| B | 93 | C | EW | 1 | Shorea glauca | 04-Mar-94 | Wilding | Kota Setar | Kedah | Private (Kota Setar) | May-93 |
| B | 93 | C | EW | 2 | Shorea parvifolia <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Jan-95 |
| B | 93 | D | EW | 1 | Shorea glauca | 08-Mar-94 | Wilding | Kota Setar | Kedah | Private (Kota Setar) | May-93 |
| B | 93 | D | EW | 2 | Shorea leprosula <<Replant>> | 15-Feb-96 | Seed | Ulu Slim | Perak | JICA | Sep-94 |
| B | 93 | E | EW | 1 | Parashorea densiflora | 03-Apr-94 | Wilding | Bauding | Perak | JICA | Aug-93 |
| B | 93 | E | EW | 2 | Shorea curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | B | EW | 1 | Dryobalanops aromatica | 23-Mar-94 | Seed & Wilding | Kanching | Selangor | Private | Mar-93 |
| B | 93 | B | EW | 2 | Shorea parvifolia <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Jan-95 |
| B | 93 | D | EW | 1 | Dryobalanops aromatica | 06-Mar-94 | Seed & Wilding | Kanching | Selangor | Private | Mar-93 |
| B | 93 | D | EW | 2 | Dipterocarpus lagineus <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | D | SN | 1 | Dryobalanops aromatica | 09-Apr-94 | Seed & Wilding | Kanching | Selangor | Private | Jul-93 |
| B | 93 | D | SN | 2 | Dipterocarpus oblongifolius <<Replant>> | 15-Feb-96 | Seed | Ulu Kenas | Perak | JICA | Feb-95 |
| B | 93 | E | EW | 1 | Dryobalanops aromatica | 04-Apr-94 | Seed & Wilding | Kanching | Selangor | Private | Jul-93 |
| B | 93 | E | EW | 2 | Dipterocarpus cornutus <<Replant>> | 15-Feb-96 | Seed | Gauda | Perak | JICA | Jul-93 |
| B | 93 | E | SN | 1 | Dryobalanops aromatica | 07-Apr-94 | Seed & Wilding | Kanching | Selangor | Private | Jul-93 |
| B | 93 | E | SN | 2 | Terminalia catappa <<Replant>> | 15-Jul-95 | Wilding | Ulu Slim | Perak | JICA | Oct-94 |
| B | 93 | A | SN | 1 | Pentaspadon motleyi | 10-May-94 | Wilding | Chikus | Perak | JICA | Jan-93 |
| B | 93 | A | SN | 2 | Terminalia catappa <<Replant>> | 15-Jul-95 | wilding | Ulu Slim | Perak | JICA | Oct-94 |
| B | 93 | B | SN | 1 | Pentaspadon motleyi | 17-May-94 | Wilding | Chikus | Perak | JICA | Jan-93 |
| B | 93 | B | SN | 2 | Dipterocarpus lagineus <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | D | SN | 1 | Pentaspadon motleyi | 11-Apr-94 | Wilding | Chikus | Perak | JICA | Nov-92 |
| B | 93 | D | SN | 2 | Dipterocarpus kerrii <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Dec-94 |
| B | 93 | E | EW | 1 | Pentaspadon motleyi | 05-Apr-94 | Wilding | Chikus | Perak | JICA | Nov-92 |
| B | 93 | E | EW | 2 | Shorea leprosula <<Replant>> | 15-Feb-96 | Wilding | Batu Gajah | Perak | JICA | Jun-93 |
| B | 93 | E | SN | 1 | Pentaspadon motleyi | 10-May-94 | Wilding | Chikus | Perak | JICA | Jan-93 |
| B | 93 | E | SN | 2 | Terminalia catappa <<Replant>> | 15-Jul-95 | wilding | Ulu Slim | Perak | JICA | Oct-94 |
| B | 93 | C | EW | 1 | Shorea macroptera | 05-Apr-94 | Wilding | Bauding | Perak | JICA | Sep-93 |
| B | 93 | C | EW | 2 | Shorea assamica <<Replant>> | 15-Feb-96 | Wilding | Teronoh | Perak | JICA | Jun-94 |
| B | 93 | D | EW | 1 | Shorea macroptera | 27-Mar-94 | Wilding | Bauding | Perak | JICA | Sep-93 |
| B | 93 | D | EW | 2 | Shorea curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | E | EW | 1 | Shorea macroptera | 11-May-94 | Wilding | Bauding | Perak | JICA | Sep-93 |
| B | 93 | E | EW | 2 | Dipterocarpus lagineus <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| B | 93 | E | EW | 1 | Shorea glauca | 07-May-94 | Wilding | Kota Setar | Kedah | Private (Kota Setar) | May-93 |
| B | 93 | E | EW | 2 | Dipterocarpus oblongifolius <<Replant>> | 15-Feb-96 | Seed | Ulu Kenas | Perak | JICA | Feb-95 |

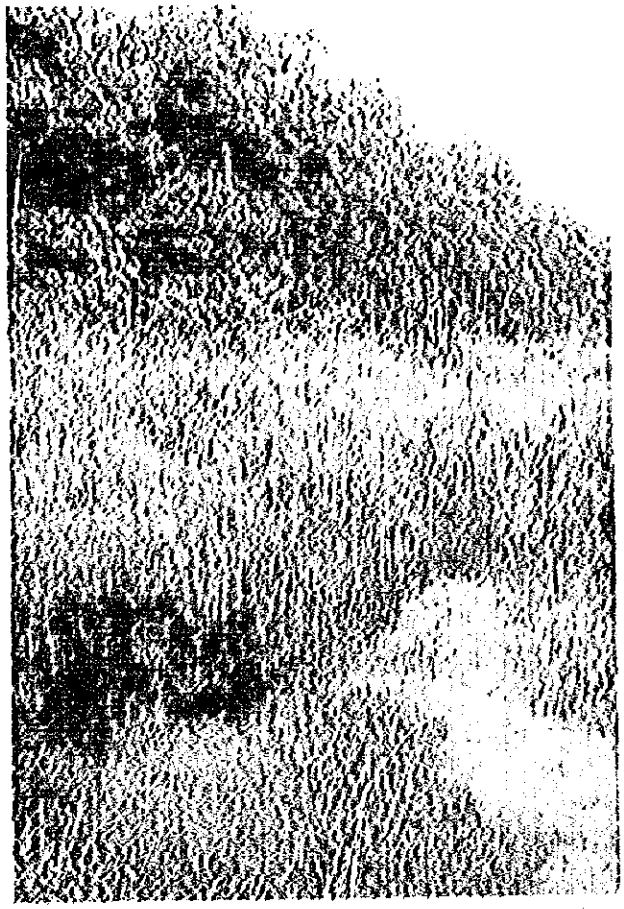


Photo 19 Waterlogging in experimental plot

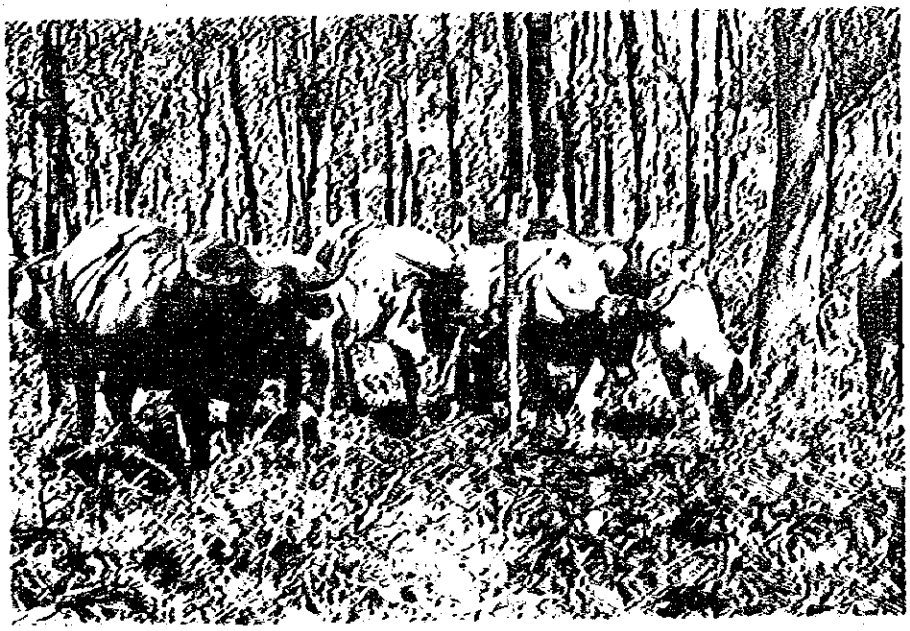


Photo 14 Water buffaloes encroaching in experimental plot

Photo 13 Trampled seedling (*Hopea odorata*)

#### 4.1.1.7. Pest and diseases

Because of the Chikus sites' flat terrain, numerous marshes and adjacency to extin mining area, where plants and other weeds are bountiful, water buffaloes and cattle were put to pasture here, and many entered the project sites to graze the vegetation that grew after weeding (Photo 14). They trampled some seedlings (Photo 13), and made some wound on the lower parts of the stems of planting seedlings with their body rubbing (Photo 12). Some fungi were found to invade from these wound especially of *Shorea leprosula*. Detail research on this matter was conducted by Dr. S. ITO, the short term expert.

Though we have asked the owners to graze their water buffaloes and cattle elsewhere, it had proven impossible to determine who were the actual owners of the animals responsible for the damage. For the prevention of cattle and water buffalo dam-

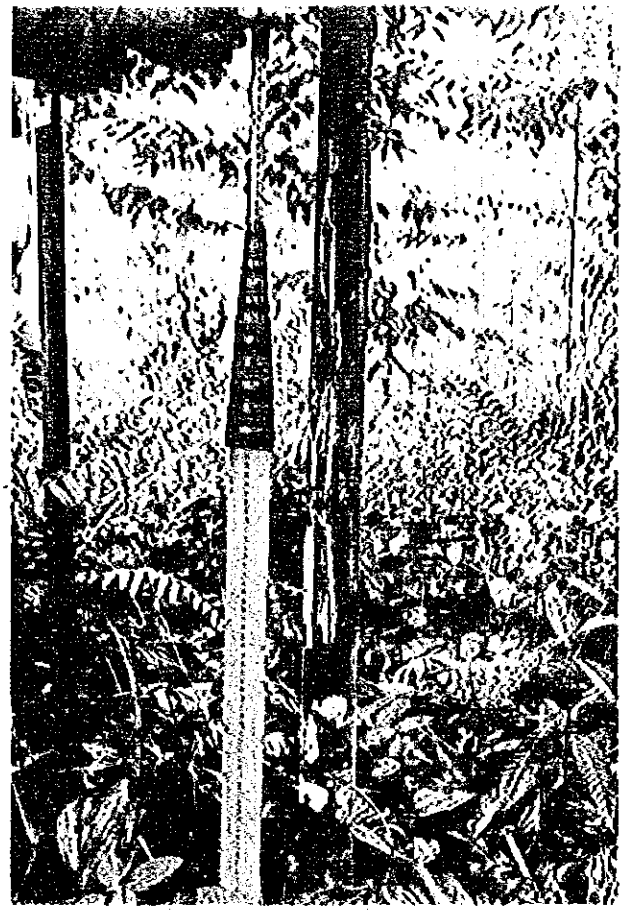


Photo 12 Canker on the stem of Shorea leprosula in block B

age, a fence was constructed around some plots. It was very effective, but other animal damage, maybe caused by wild boar still remained.

Same stem wound was also found on the naturally regenerated *Shorea leprosula* in Belukar in Block-A (Photo 15). It was found after the strip felling of Belukar. This wound might have been caused by some animal other than cattle or water buffalo.

Beside this phenomena, other wound on the upper part of the stem was also observed in 1995 (Photo 16). This wound might be caused by squirrels. This damages were found also on *Acacia mangium* stems (Photo 17). In 1996, some of the wound trees were found to be broken on the point of the wound. Further observation and study is required.

Many dipterocarps suffered from some damage by leaf-eating insects, while they were

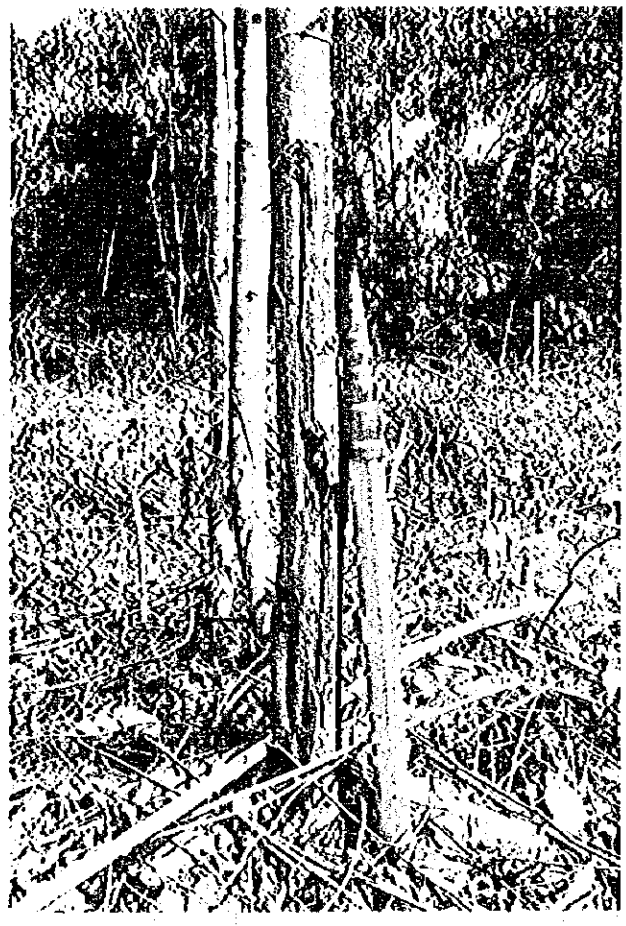


Photo 15 Stem wound on the stem of *Shorea leprosula* in Belukar in Block A

Photo 16 Stem wound on the upper part of stem of *Shorea leprosula* in Block B

not so serious. *Neobalanocarpus heimii* suffered from the shoot sucking insect (*Mintis longicornis*, *Coreidae* family, *Hemiptera* order). After the attack by this insect, multiple leader formation was observed on this species. Beside from this species, *Neobalanocarpus heimii* was suffered from the leaves eating insect, such as pest in group order *Coleoptera*, order *Lepidoptera* and order *Orthorptera*. ( Reported by Dr. Yaacop abd Wahab / UPM)

After September 1995, Some *Acacia mangium* were found dead in a group (Photo 18). According to Dr. Lee Sue See at FRIM, this might be caused by some fungi in the soil. She suggested to dig a drain surrounding damaged trees to prevent the spread of damage. In Block-B(1994) plots, this was found extensively.

Photo 17 Stem wound on the upper part of stem of *Acacia mangium* in Block-B

Photo 18 *Acacia mangium* trees dead in a group

### 4.1.2. Multi-Storied Forest by Open Planting

#### 4.1.2.1. Demarcation of experimental plots

Multi-Storied Forest by open planting was established in Chikus Block-A. The block was divided into two sub blocks and two years from 1992 to 1993 were spent for establishing of Multi-Storied Forest in the area. The two sub blocks were named based on the year of contract, namely Block-A(1992), Block-A(1993). Experimental plots were set-up to demonstrate different planting designs with different species. Each plot has an area of approximately one hectare, with one silvicultural design planted with one species. Arrangement of plots are shown in Fig. S8 and Fig. S9.

#### 4.1.2.2. Site preparation

Belukar was removed by a backhoe. Slash were left for several weeks to dry, after which they were heaped and burned. Heaping involved using a D6 class bulldozer to stack them at appropriate intervals. When heaping trees with the bulldozer, care had been taken to move topsoil as little

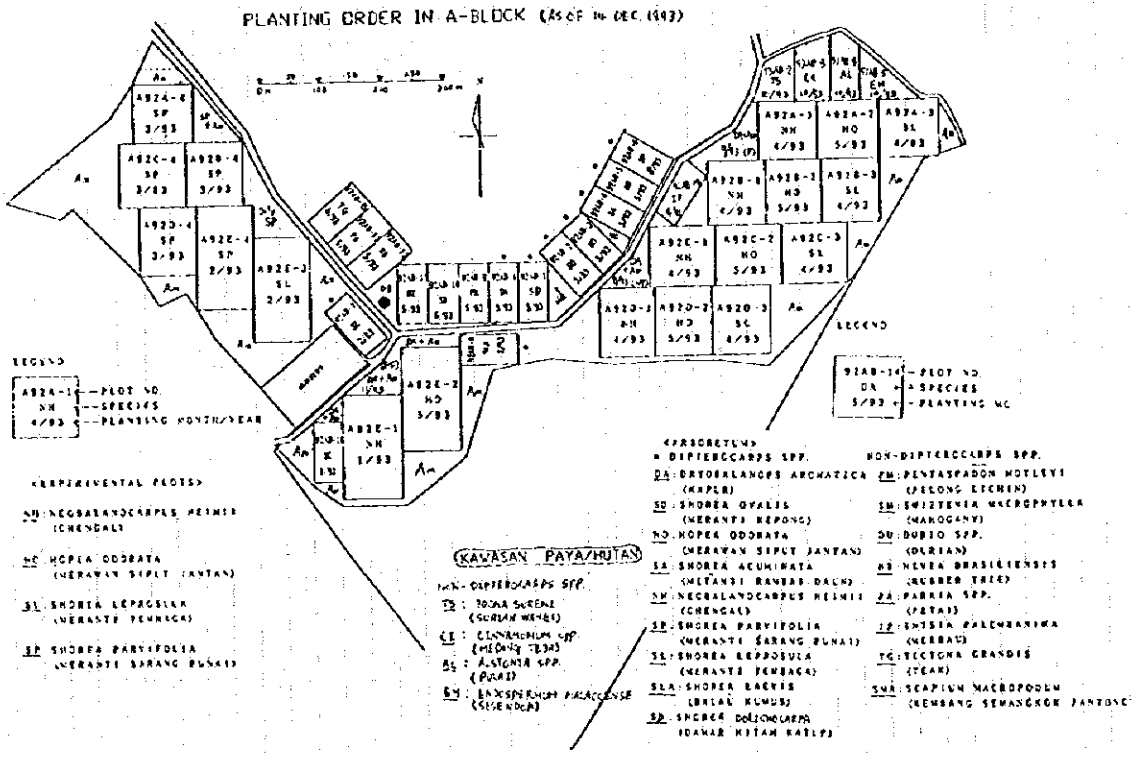



Fig. S8 Arrangements of experimental plots in Block A(1992)

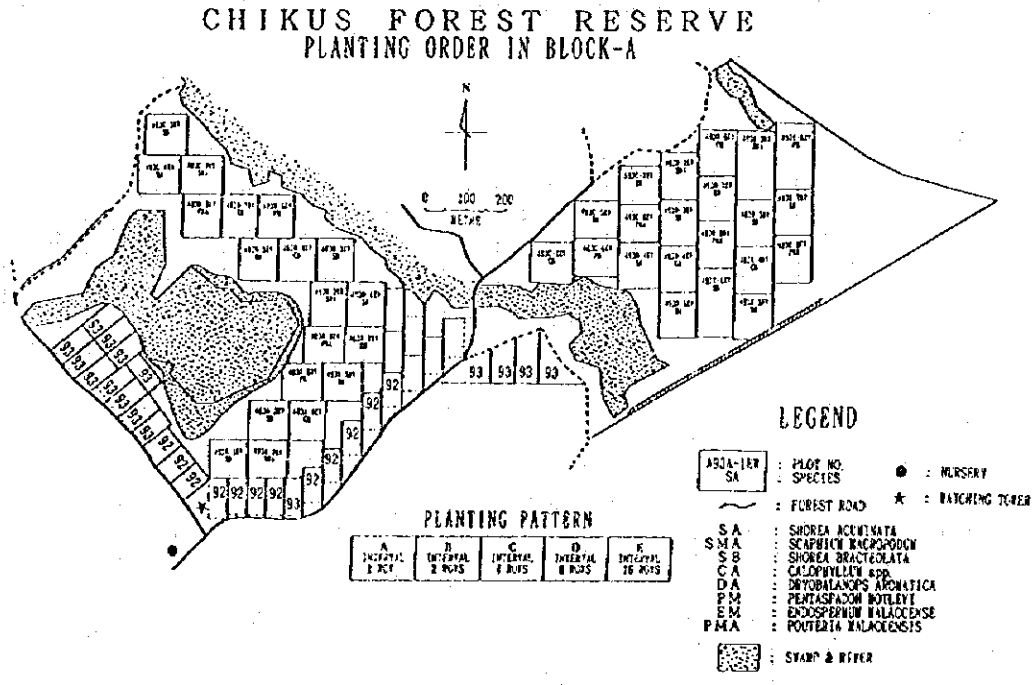



Fig. S9 Arrangements of experimental plots in Block A(1993)

as possible. Approval for slash burning was given by the Environmental Agency. After slash burning, the debris was again heaped and burned. Consequently burning was carried out twice. This was the ordinary process of site preparation for *Acacia mangium*. The site was not cultivated.

In Block-A(1992), Belukar was removed from October 1992 to January 1993, when it was two and a half years old and 2-3 meter of hight. Although the initial plan called for the completion of site preparation by November 1992, the poor performance of the contractor resulted in a two-month delay. The area was planted from January to May 1993. In Block-A(1993), Belukar was removed from September 1993 to February 1994 when it was 4-5 meters of hight. The area was planted from March to May 1994.

Because of time constraints to follow the working schedule, we were obliged to rely on the heavy duty machinery for the site preparation, while soil compacting was anticipated, it was not certain how the soil compacting would affect the growth of trees subsequently planted. If the time allowed, manual clearing should have been taken. The record of site preparation is shown in Table S10.

**Table S10 History of Chikus Block-A**

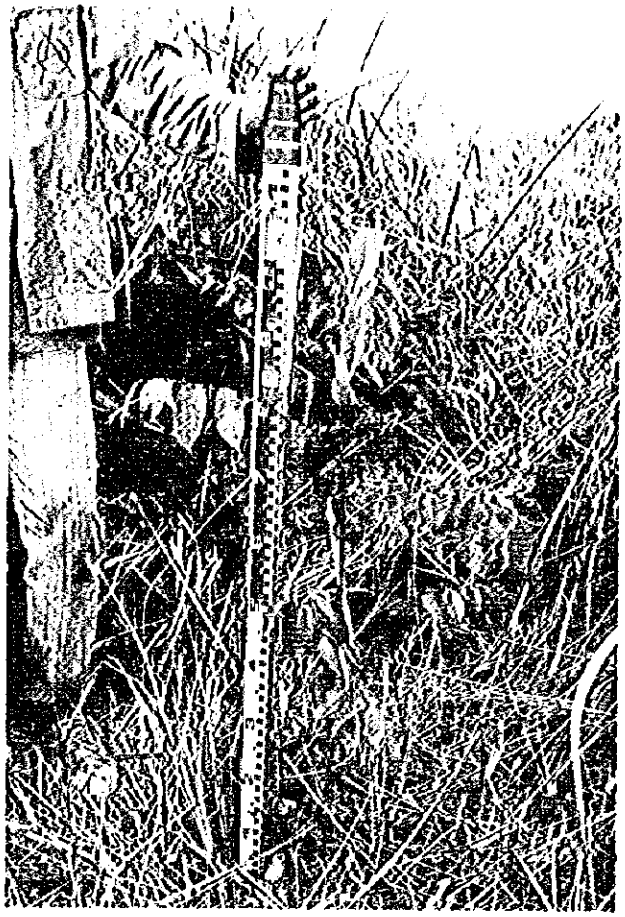
| Year | Block-A (1992) | Block-A (1993) |
|---|---|---|
| Originally | Lowland dipterocarp forest | |
| Jun. 1988 - Mar. 1989 | Clear cutting for compensatory planting | |
| Apr. 1989 | Slash burning twice for the site preparation of planting *Acacia mangium* | |
| | Area was left over without planting *Acacia mangium* and Belukar regenerated | |
| Oct. 1992 - Jan. 1993 | Removal of Belukar and slash burning | |
| Jan. 1993 - May 1993 | Mix and coexistent planting of both FGS and HQS | |
| Sep. 1993 - Feb. 1994 | | Removal of Belukar and slash burning |
| Mar. 1994 - May 1994 | | Mix and coexistent planting of both FGS and HQS |

## 4.1.2.3. Planting

The most important prerequisite for the selection of planting species is the ability to withstand harsh sunlight in this experiment. *Acacia mangium* was chosen as the fast growing timber species (FGTS) in Block-A(1992), and *Acacia mangium* and *Hevea brasiliensis* were chosen as the FGTS in Block-A(1993). The clone for the timber harvest of *Hevea brasiliensis*; PB260 was planted. Species planted and thier origin in this experimental plots are as shown in Table S11 (Photos S20, S21, S22, S23).

Table S11 Planting Species in Openplanting

| BLOCK | YEAR | TYPE | DIRECTION | SPP | Date Planted | Seed/Wilding | Name of Place | State | JICA / FD / Private nursery | Date acquired |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 92 | A-E | EW | Hopea odorata | May-93 | Wilding | Kuala Berang | Terengganu | Private | Aug-92 |
| A | 92 | A-E | EW | Neobalanocarpus heimii | Jan.-Apr. 93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug -Sep-92 |
| A | 92 | A-E | EW | Shorea leprosula | Feb.-Apr. 93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | A-E | EW | Shorea parvifolia | Feb.-Mar. 93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 93 | A-E | EW | Calophyllum sp. | Apr.-May 94 | Wilding | Besaut | Perak | JICA | Apr-93 |
| A | 93 | A-E | EW | Dryobalanops aromatica | Apr.-May 94 | Seed & Wilding | Kanching | Selangor | Private | Jul-93 |
| A | 93 | A-E | EW | Endospermum malaccense | Apr.-May 94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| A | 93 | A-E | EW | Pentaspadon motleyi | Apr.-Jun. 94 | Wilding | Chikus | Perak | JICA | Nov.92-Jan.93 |
| A | 93 | A-E | EW | Pouteria malaccensis | Apr.-May 94 | Wilding | Teronoh | Perak | JICA | Jun-93 |
| A | 93 | A-E | EW | Scaphium macropodum | Apr.-May 94 | Milding | Kota Setar | Kedah | Private (Kota Setar) | Oct-93 |
| A | 93 | A-E | EW | Shorea acuminata | Apr.-May 94 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| A | 93 | A-E | EW | Shorea bracteolata | Apr.-May 94 | Seed | Kota Setar | Kedah | Private (Kota Setar) | Oct-93 |

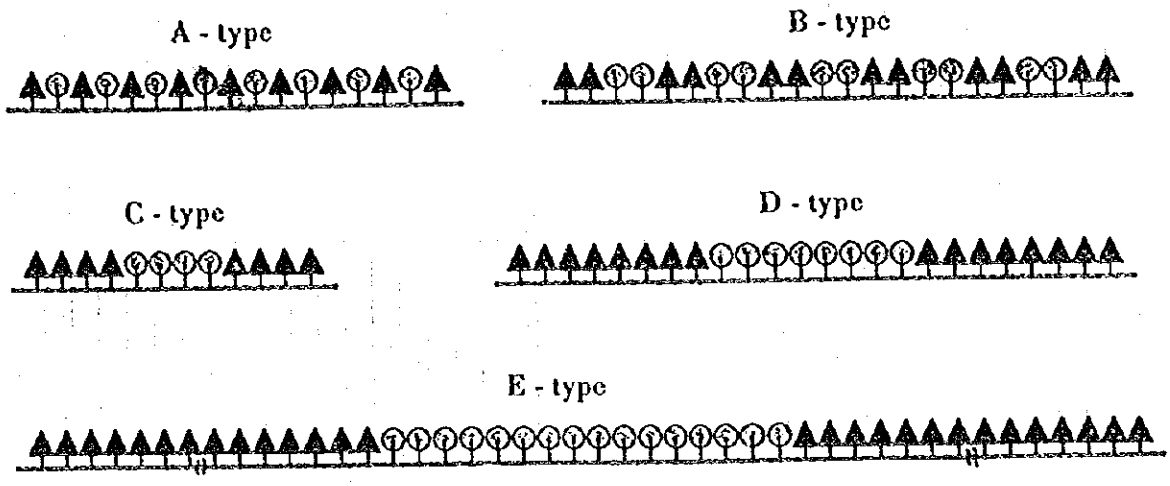


Same planting design and methods were taken as that of Multi-Storied Forest by under planting in *Acacia mangium* plantation for the purpose of comparison. Fast growing species (FGTS) and high quality timber species (HQTS) were mix planted at the same time. FGTS were expected to grow faster than HQTS and provide shade over them. FGTS and HQTS were planted in alternate rows of the same number, i.e. A-type (one row of FGTS, one row of HQTS, 1:1), B-type (2:2), C-type (4:4), D-type (8:8), E-type (16:16). Only East-West planting direction was taken (Fig. S10).

Seedlings were planted in 3.7 m x 3.0 m in accordance with the spacing of *Acacia mangium* plantation (Fig. S11). This results in a density of 900 trees per hectare. Since FGTS and HQTS were planted alternately

Photo S20 *Shorea parvifolia* planted in block A(1992) at 24 months after planting

Photo S21 *Shorea bracteolata* planted in block A(1993) at 20 months after planting




Remarks 1. ▲ indicates Fast Growing Species (Ex. Acacia mangium).

2. ⚲ indicates High Quality Timber Species (Ex. Dipterocarpaceae).

3. Planting distance : 3.0m x 3.7m.

Fig. S10 Planting design of multi-storied forest by openplanting

in the same number of rows, the densities were 450 trees per hectare for each. Contrary to the spacing in Block-B, planting rows were spaced 3.7 m apart and individual seedlings 3 m apart. Planting methods were the same as those of underplanting in *Acacia* plantation. Staking was done before planting as the same manner as in under planting in *Acacia* plantation.

#### 4.1.2.4. Tending

Weeding and climber cutting were carried out at the same time. While weeding and climber cutting should be carried out depended on the growth of the vegetation ideally, extensive weeding under a contract basis suited to the volume of vegetation was difficult because of the large scale of area and intricacy of preparation of contract work. Beside actual necessity of weeding and climber cutting, regular tending was needed for the smooth implementation for regularly

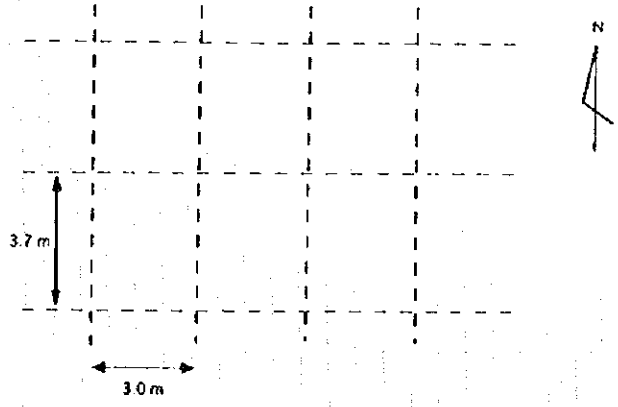
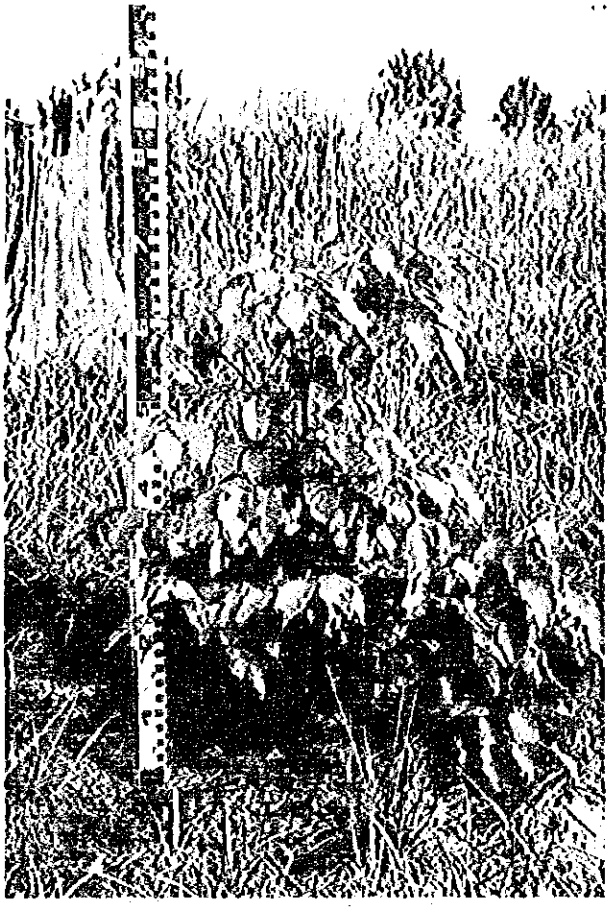



Fig. S11 Spacing in openplanting



measuring the plots. The first weeding and climber cutting were carried out 2 - 3 months after planting. Afterward they were carried out in every 2 - 4 months depending on the growth of undergrowth. This frequency was 1 - 2 times more than that in Block-B. Climbers on the seedlings were removed carefully by hand not to damage the seedling shoot. Climber cutting was continued manually.

Circle weeding was taken at the initial stage of project. Vegetation around a seedling was weeded with the diameter of 1 m. In this method vegetation recovered very quickly within one month after weeding. And it was very difficult to investigate the accomplishment of work. Afterward circle weeding manually was changed into line weeding by machine; a bush cutter with gasoline engine, because of the increase of planting site. Weed-

Photo S22 *Hopea odorata* planted in blockA(1992) at 21 months after planting

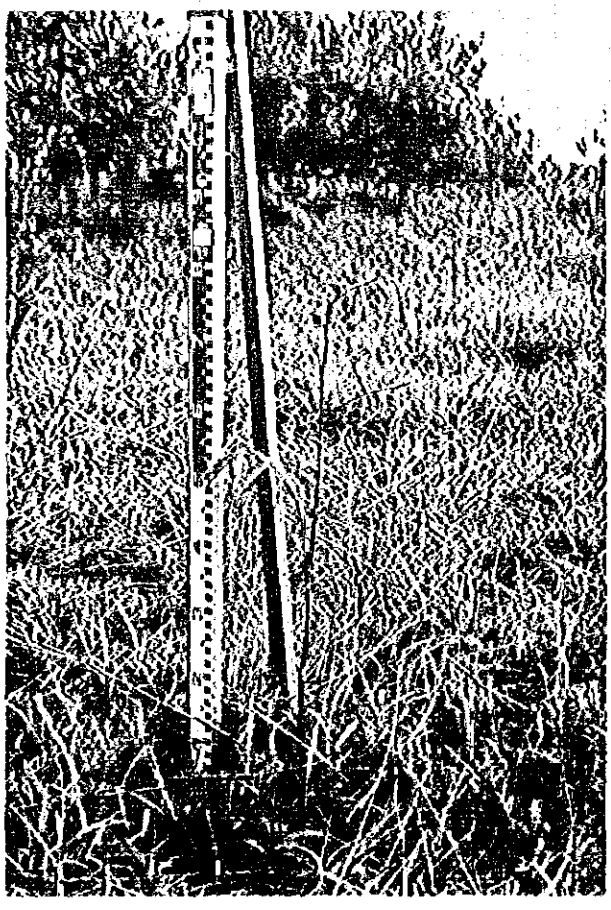


Photo S23 *Neobalanocarpus heimii* planted in blockA(1992) at 22 months after planting

ing was carried out by line along the planting line, and the width was 2 m along the planting line (i.e., 1 meter on each side of the position of planting). Compared to manual weeding, machinery weeding had more problems with misweeding.

*Perotis latifolia* (Malay name : Ekor kuching) was the dominant species in Chikus Block-A. This grass grew vigorously with the mean heights of 2 to 3 meters. Some shrub, such as *Trema* sp. and *Melastoma malabathricum*, was found on the ground with thicker surface soil layer. Climbers were not vigorous, but under the shrub *Mikania micrantha* was found.

In this 5 year period, pruning for both FGTS and HQTS was not carried out. According to silviculture manual for compensatory planting project for *Acacia mangium*, *Acacia mangium* is needed to prune at three years old. In Chikus Block-A, *Acacia mangium* is not considered to be pruned for serving as a shade tree since the growth of *Acacia* is so bad.

#### 4.1.2.5. Supplementary planting

In the open planting plots in Chikus block A, survival and growth of planted seedlings including FGTS were very poor (Photos S24-S28). The reasons of this poor growth will be discussed later. Since better growth was not expected if we re-plant seedlings of indigenous species in the same way, different planting method was introduced in the area planted in 1993. The area was divided into two sites as shown in Fig. S12, and *Acacia mangium* was chosen for main replant species for quick recovery of the site.

In one site, only *Acacia mangium* was planted in rows from January to February 1996. In order to clarify the provenance, *Acacia mangium* seeds were imported directly from Australia, and carefully raised in JICA Chikus Nursery. After the establishment of *Acacia mangium* forest in a few years, indigenous species will be planted between the rows of *Acacia mangium* (Fig.S13).

The other site was weeded in lines from February to March 1996. Retained grass and shrub were expected to provide shade on cleared line. HQTS and *Acacia mangium* were planted in cleared

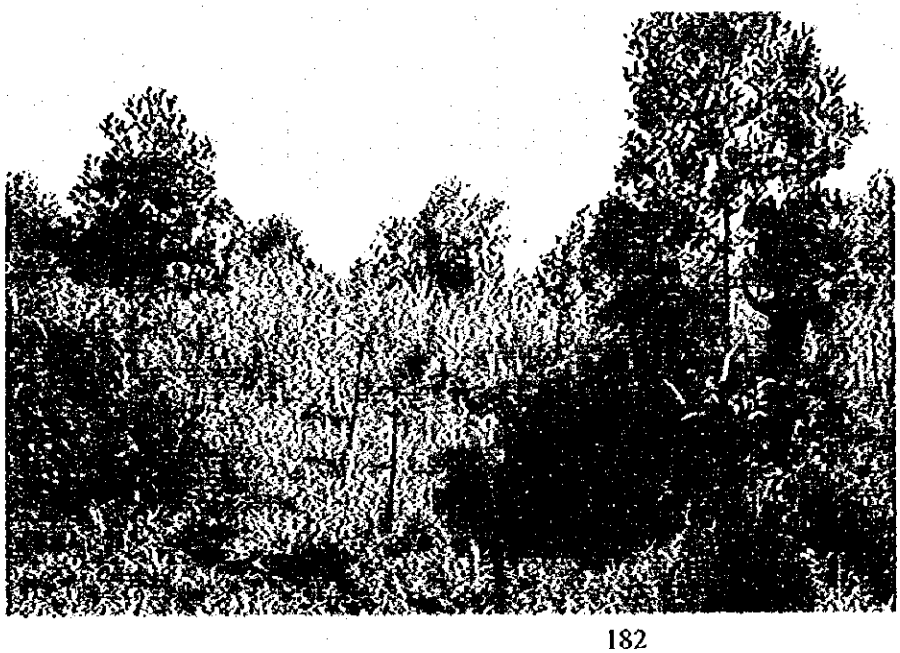


Photo S24 Insufficient growth of *Acacia mangium* and poor survival of *Neobalanocarpus heimii* in A type in block A(1992) at 32 months after planting

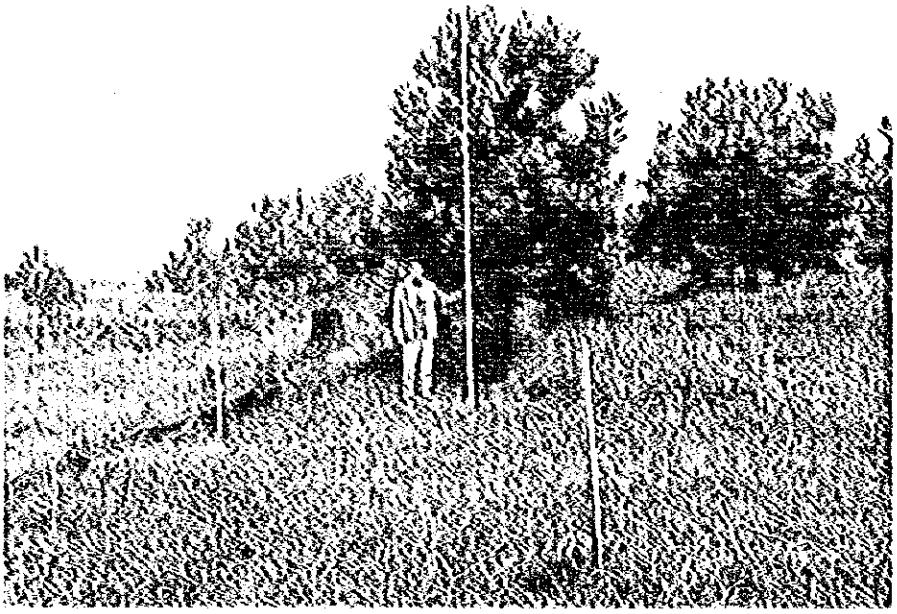


Photo S25 Insufficient growth of *Acacia mangium* and poor survival of *Neobalanocarpus heimii* in D type in block A(1992) at 22 months after planting

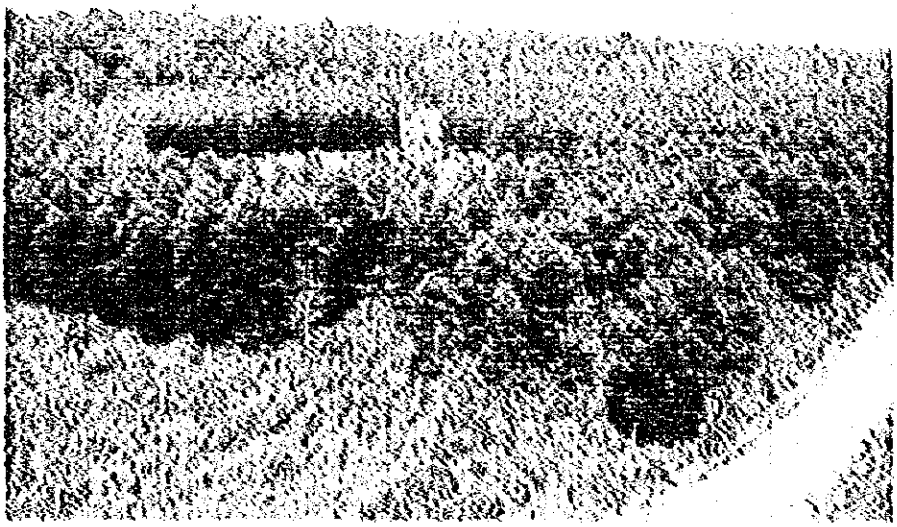


Photo S26 Poor survival of *Shorea leprosula* in E type in block A(1992) at 32 months after planting

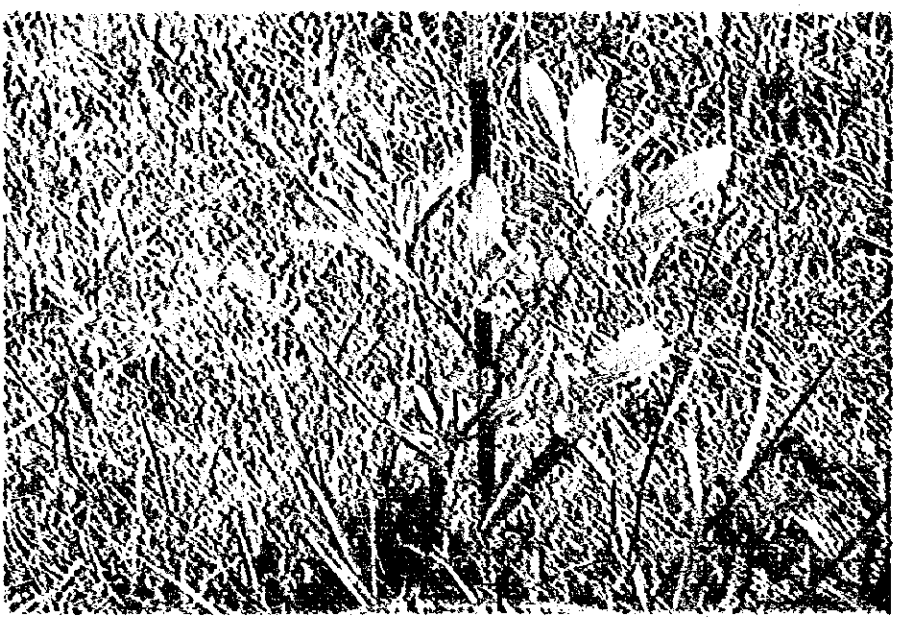


Photo S27 Poor growth of *Acacia mangium* in block A(1993) at 16 months after planting

Photo S28 Poor growth of *Hevea brasiliensis* (Rubber) inblock A(1993)

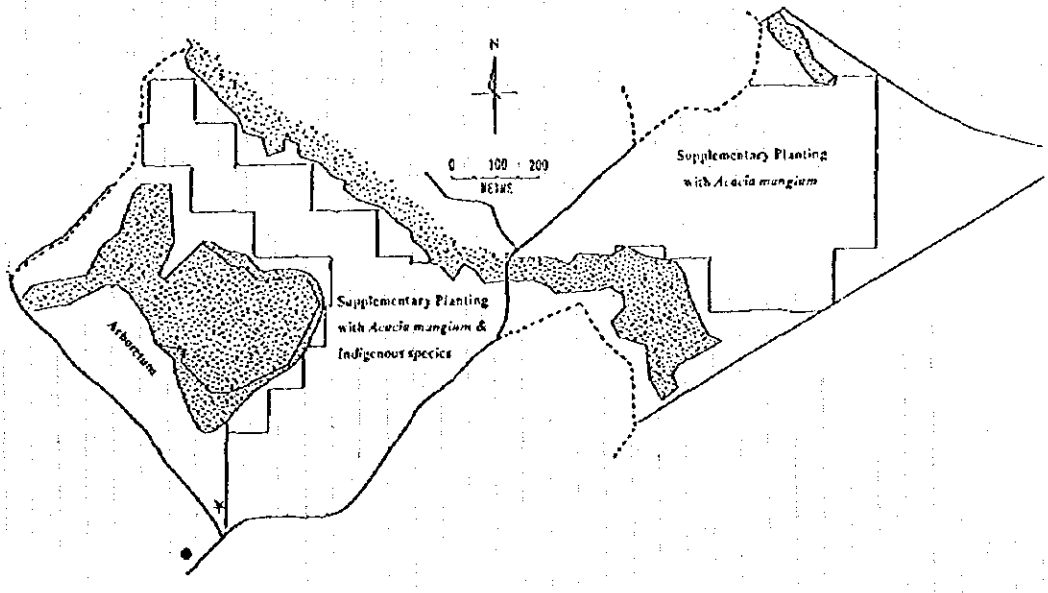



Fig. S12 Arrangements of experimental plots for supplementary planting in Block A

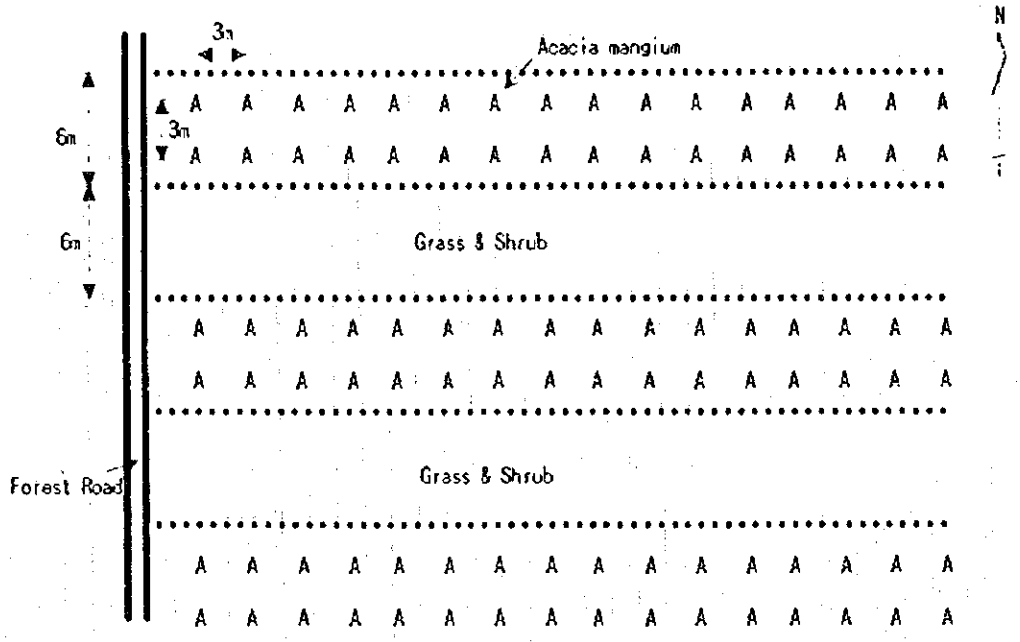



Fig. S13 Design of supplementary planting

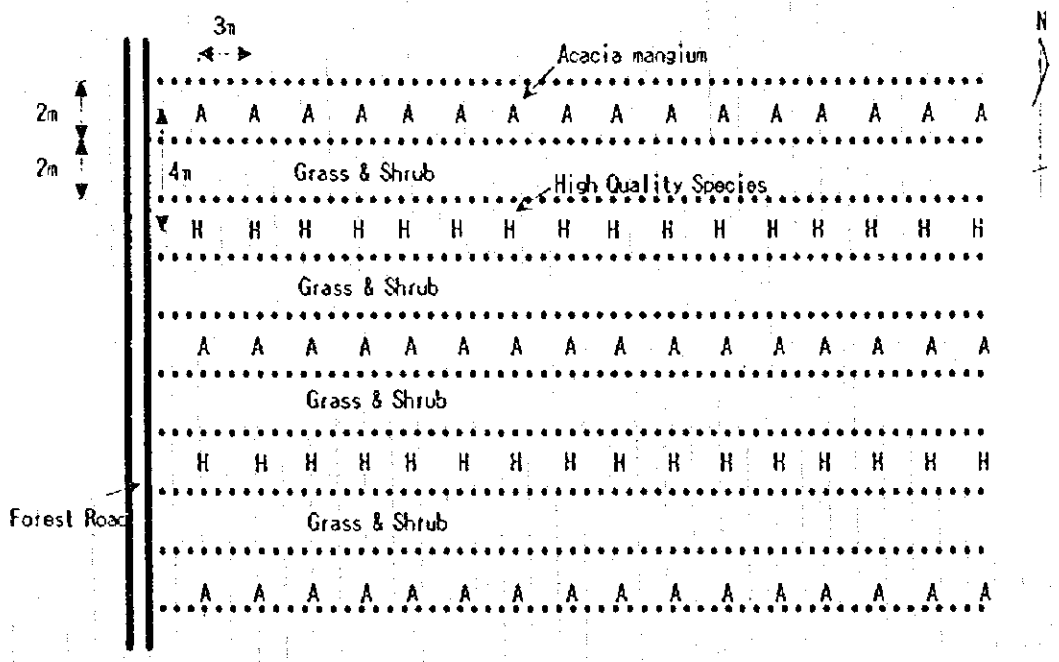



Fig. S14 Design of supplementary planting

lines in February 1996, and planting lines were arranged one by one alternately (Fig. S14). Species planted and thier origin are shown in Table S12.

The seedlings of HQTS were treated with hardening. They were exposed to full sunlight one week before planting. All leaves were cut in half in order to reduce excess transpiration (Photo 29).

Mulching was applied around the planted seedlings to get rid of high surface soil temperture and dryness. Coconuts husk, oil palm leaves, and oil palm bunches were used as multing materials (Photo 30-32).

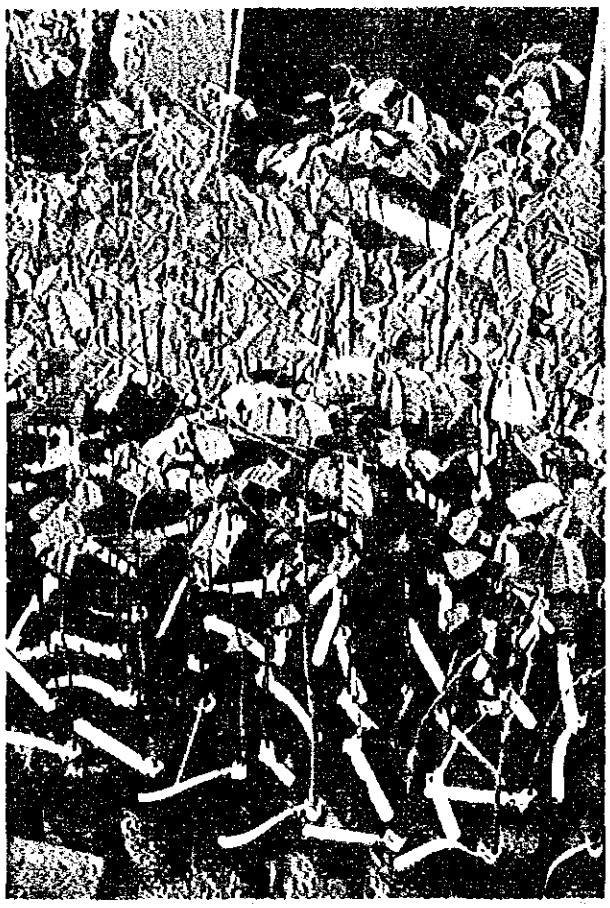


Photo S29 Seedlings of *Shorea leprosula* cut their leaves in half length in order to reduce excess evaporation.

## Table S12 Planting Species for Supplementary Planting in Openplanting Site

| BLOCK | YEAR | TYPE | DIRECTION | Ref. | SPP | Date Planted | Seed/Wilding | Name of Place | State | JICA / FD / Private nursery | Date acquired |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 92 | A | EW | 1 | Neobalanocarpus heimii | 21-Apr-93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | A | EW | 2 | Neobalanocarpus heimii <<Replant>> | 18-Jan-94 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | B | EW | 1 | Neobalanocarpus heimii | 21-Apr-93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | B | EW | 2 | Neobalanocarpus heimii <<Replant>> | 18-Jan-94 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | C | EW | 1 | Neobalanocarpus heimii | 22-Apr-93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | C | EW | 2 | Neobalanocarpus heimii <<Replant>> | 18-Jan-94 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | D | EW | 1 | Neobalanocarpus heimii | 22-Apr-93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | D | EW | 2 | Neobalanocarpus heimii <<Replant>> | 18-Jan-94 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | E | EW | 1 | Neobalanocarpus heimii | 18-Jan-93 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | E | EW | 2 | Neobalanocarpus heimii <<Replant>> | 18-Jan-94 | Seed & Wilding | Kuala Berang | Terengganu | Private (Kuala Berang) | Aug-Sep-92 |
| A | 92 | E | EW | 2 | Shorea macroptera & Rubber <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | E | EW | 1 | Hopea odorata | 16-May-93 | Wilding | Kuala Berang | Terengganu | Private | Aug-92 |
| A | 92 | E | EW | 2 | Shorea macroptera & Rubber <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | A | EW | 1 | Shorea leprosula | 19-Apr-93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | A | EW | 2 | Shorea leprosula <<Replant>> | 31-Dec-95 | Seed | Bauding | Perak | JICA | Aug-93 |
| A | 92 | B | EW | 1 | Shorea leprosula | 19-Apr-93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | B | EW | 2 | Shorea leprosula <<Replant>> | 31-Dec-95 | Seed | Bauding | Perak | JICA | Aug-93 |
| A | 92 | C | EW | 1 | Shorea leprosula | 19-Apr-93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | C | EW | 2 | Shorea leprosula <<Replant>> | 31-Dec-95 | Seed | Bauding | Perak | JICA | Aug-93 |
| A | 92 | D | EW | 1 | Shorea leprosula | 20-Apr-93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | D | EW | 2 | Shorea leprosula <<Replant>> | 31-Dec-95 | Seed | Bauding | Perak | JICA | Aug-93 |
| A | 92 | E | EW | 1 | Shorea leprosula | 20-Feb-93 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 92 | E | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | A | EW | 1 | Shorea parvifolia | 24-Mar-93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 92 | A | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | B | EW | 1 | Shorea parvifolia | 24-Mar-93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 92 | B | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | C | EW | 1 | Shorea parvifolia | 25-Mar-93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 92 | C | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | D | EW | 1 | Shorea parvifolia | 25-Mar-93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 92 | D | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 92 | E | EW | 1 | Shorea parvifolia | 20-Feb-93 | Wilding | Manong | Perak | FD (Manong) | Aug-92 |
| A | 92 | E | EW | 2 | Shorea macroptera <<Replant>> | 15-Mar-95 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 95 | X | EW | 2 | Shorea leprosula <<Replant>> | 15-Feb-96 | Seed | Ulu Slim | Perak | JICA | Sep-94 |
| A | 95 | X | EW | 2 | Shorea parvifolia <<Replant>> | 15-Feb-96 | Seed | Chikus | Perak | JICA | Jan-95 |
| A | 95 | X | EW | 2 | Neobalanocarpus heimii <<Replant>> | 15-Feb-96 | Seed | Unknown | Terengganu | Private | Sep-92 |
| A | 95 | X | EW | 2 | Azadirachta excelsa <<Replant>> | 15-Feb-96 | Unknown | Unknown | Perak | FD (Manong) | x-93 |
| A | 95 | X | EW | 2 | Peritassadon motleyi <<Replant>> | 15-Feb-96 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 95 | X | EW | 2 | Shorea acuminata <<Replant>> | 15-Feb-96 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| A | 95 | X | EW | 2 | Hopea pubescens <<Replant>> | 15-Feb-96 | Wilding | Chikus | Perak | JICA | Nov-92 |
| A | 95 | X | EW | 2 | Palaquium sp. <<Replant>> | 15-Feb-96 | Wilding | Bubu | Perak | JICA | Apr-94 |
| A | 95 | X | EW | 2 | Shorea glauca <<Replant>> | 15-Feb-96 | Wilding | Unknown | Kedah | Private | Nov-94 |
| A | 95 | X | EW | 2 | Parashorea densiflora <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Aug-93 |
| A | 95 | X | EW | 2 | Dryobalanops aromatica <<Replant>> | 15-Feb-96 | Seed & Wilding | Kanching | Selangor | Private | Jul-93 |
| A | 95 | X | EW | 2 | Endospermum malaccense <<Replant>> | 15-Feb-96 | Wilding | Mantin | Sembilan | FD (Mantin) | Aug-93 |
| A | 95 | X | EW | 2 | Dipterocarpus kerrii <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Aug-94 |
| A | 95 | X | EW | 2 | Shorea macroptera <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 95 | X | EW | 2 | Calophyllum sp. <<Replant>> | 15-Feb-96 | Wilding | Bukit Tapah | Perak | JICA | May-93 |
| A | 95 | X | EW | 2 | Heritiera sp. <<Replant>> | 15-Feb-96 | Wilding | x | Sembilan | FD (Mantin) | Aug-93 |
| A | 95 | X | EW | 2 | Dipterocarpus cornutus <<Replant>> | 15-Feb-96 | Seed | Bukit Kinta | Perak | JICA | Sep-95 |
| A | 95 | X | EW | 2 | Gonystylus affine <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Aug-94 |
| A | 95 | X | EW | 2 | Terminalia calappa <<Replant>> | 15-Feb-96 | Wilding | Ulu Slim | Perak | JICA | Nov-94 |
| A | 95 | X | EW | 2 | Knompassia malaccensis <<Replant>> | 15-Feb-96 | Wilding | Chikus | Perak | JICA | Oct-92 |
| A | 95 | X | EW | 2 | Pometia pinnata <<Replant>> | 15-Feb-96 | Wilding | Chikus | Perak | JICA | Oct-92 |
| A | 95 | X | EW | 2 | Elateriospermum tapos <<Replant>> | 15-Feb-96 | Seed | Bukit Kinta | Perak | JICA | Jan-94 |
| A | 95 | X | EW | 2 | Shorea parvifolia <<Replant>> | 15-Feb-96 | Seed | Gauda | Perak | JICA | Aug-93 |
| A | 95 | X | EW | 2 | Shorea ovata <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Sep-93 |
| A | 95 | X | EW | 2 | Sindora coriacea <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Oct-93 |
| A | 95 | X | EW | 2 | Scaphium macropodum <<Replant>> | 15-Feb-96 | Wilding | Ulu Slim | Perak | JICA | Nov-94 |
| A | 95 | X | EW | 2 | Shorea lelura <<Replant>> | 15-Feb-96 | Wilding | Batu Gajah | Perak | JICA | Jun-93 |
| A | 95 | X | EW | 2 | Dialium platysepalum <<Replant>> | 15-Feb-96 | Seed | Bauding | Perak | JICA | Oct-93 |
| A | 95 | X | EW | 2 | Shorea curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Shorea assamica <<Replant>> | 15-Feb-96 | Wilding | Bubu | Perak | JICA | Jan-94 |
| A | 95 | X | EW | 2 | Shorea ovalis <<Replant>> | 15-Feb-96 | Seed | Bubu | Perak | JICA | Mar-94 |
| A | 95 | X | EW | 2 | Shorea multiflora <<Replant>> | 15-Feb-96 | Wilding | Bubu | Perak | JICA | Mar-94 |
| A | 95 | X | EW | 2 | Hopea nervosa <<Replant>> | 15-Feb-96 | Wilding | C 67 Bubu | Perak | JICA | Jan-94 |
| A | 95 | X | EW | 2 | Shorea platycarpa <<Replant>> | 15-Feb-96 | Seed | Bikam | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Burseraceae sp. <<Replant>> | 15-Feb-96 | Wilding | Bukit Tapah | Perak | JICA | May-93 |
| A | 95 | X | EW | 2 | Shorea dasyphylla <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Anisoptera curtisii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Dipterocarpus fagineus <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Swintonia schwenkii <<Replant>> | 15-Feb-96 | Seed | Bukit Larut | Perak | JICA | Feb-95 |
| A | 95 | X | EW | 2 | Dipterocarpus oblongifolius <<Replant>> | 15-Feb-96 | Seed | Ulu Kenas | Perak | JICA | Feb-95 |

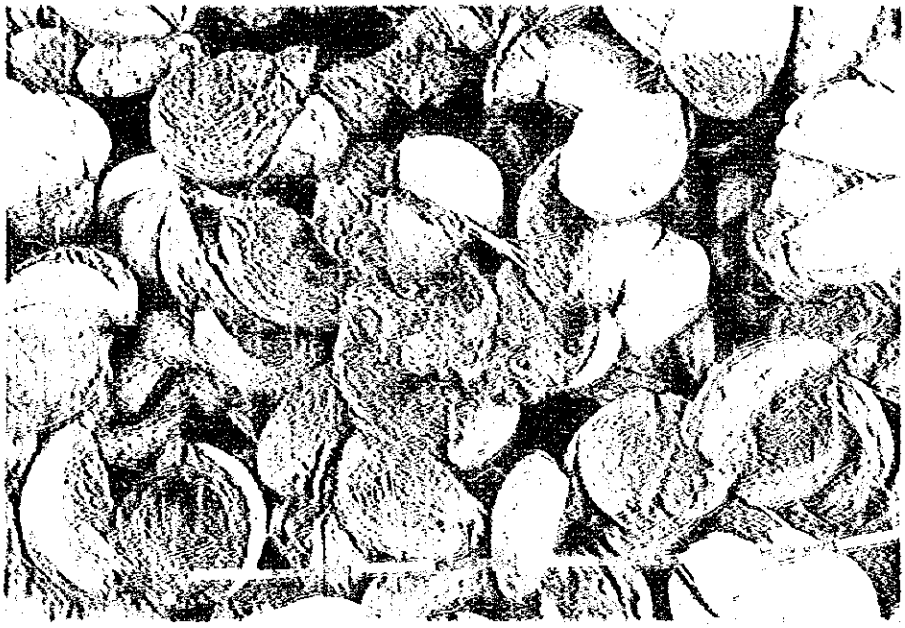


Photo S30 Mulling material (Coconut Husks)

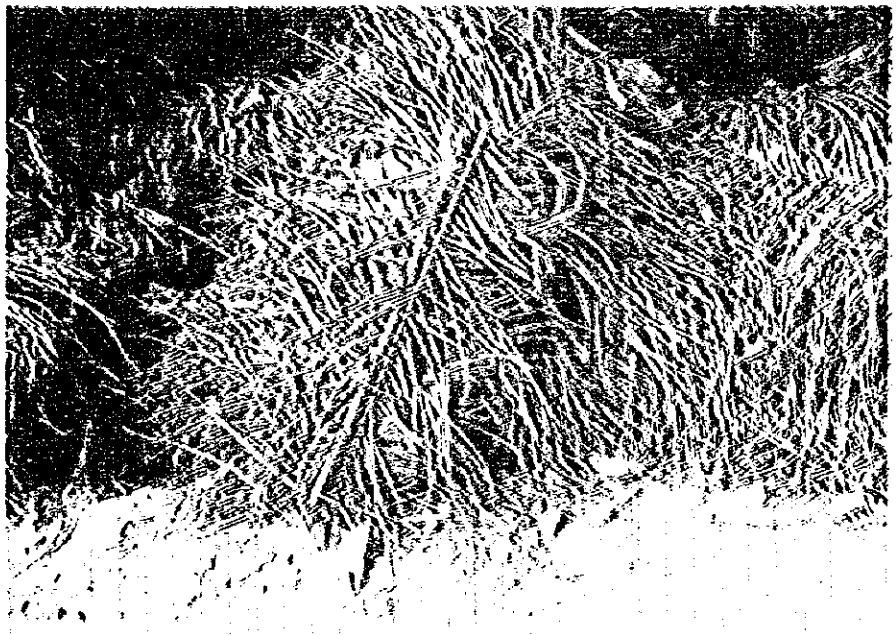


Photo S31 Mulling material (Oil Palm Leaves)