# Report on the Forest Research in Negara Brunei Darussalam from 1984 through 1986

by Isamu YAMADA

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Japan International Cooperation Agency

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## Forward

Negara Brunei Darussalam is located at the north western coast of Borneo (114°23'E - 115°23'E, 4°N - 5°5'N) facing the south China sea with population of twenty-two hundred thousand on the area of 5765 km . After the discovery of oil and natural gas, she is one of the most prosperous country in Asia and the relationships with Japan is quite tight mainly by exporting natural gas.

Since attaining independence from U.K., she has been seeking alternative industries in place of oil related ones. In the fifth five year planning, the development of non-oil sectors were given priority. Under these circumstances, the activities of Forest Department become more and more important in the economy of the nation, because the forest products are thought to be one of the most potential resources next to oil.

Although the forest resources was not conspicuous because of the major products of oil and natural gas, the high quality of forests have been recognized from the beginning of this century and several studies were carried out mainly by British; such as Browne, Anderson and Ashton, whose contributions to understanding Bruneian forest were fundamental and valuable. It is, however, regrettable that no institutional research center was established during that time.

On independence, the Brunei Government established a forest research center at Sungai Liang, located at a convenient distance to the major forested area in Brunei.

Taking this opportunity, the forest research center project was planned between Brunei and Japanese government to promote forest research necessary for the future development of the center. The Record of Discussion was signed on the 1st of October 1985.

This report deals with the research items conducted during my stay in Brunei from April 1984 through July 1986. Many of the subjects of field survey are being continuously studied by the successors. Only the basic data and brief discussions are shown here.

## Summary

The following report will discuss in detail the following aspects of my research in Brunei from April 1984 to August 1986.

1) The research items carried out during my stay in Brunei from April 1984 to August 1986 has been fully documented here.
2) Eleven permanents plots were established and the floristic composition, DBH, height, height to the lowest living branch and annual increment of diameter were measured. Crown projection diagram was drawn.
3) Phenological study was conducted at four sites where biweekly observation of leafing, flowering and fruiting were carried out for 18 months.
4) Aluminum band type dendrometer was used for the micro diameter growth and the relationship between diameter growth and phenology was discussed.
5) Line planting was surveyed at Bt. Kukub and several points are mentioned for the improvement of the line planting method.
6) The population study of the seedlings in natural forest are briefly mentioned.

# I. Permanent Plot Study

## Introduction

The typical tropical forest types have been kept undisturbed and are in good condition and approach to the site of each forest types can be reached within one or two hours. These two factors are quite unique and not found in other part of tropical countries.

The aim of this study is to establish the permanent plot where the floristic composition, forest structure and diameter growth and so on are to be investigated and to continue observation of forest dynamics permanently.

The forest types of Brunei have been classified by Anderson & Marsden as follows:

1. Mangrove
2. Freshwater swamp forest
3. Peat swamp forest
   - 3.1 Mixed peat swamp
   - 3.2 Alan forest
   - 3.3 Alan bunga forest
   - 3.4 Padang Alan forest
   - 3.5 Padang forest
   - 3.6 Padang keruntum
4. Kerangas
5. Mixed dipterocarp forest
6. ( supposed to be lime stone forest but not existed in Brunei )
7. Montane forest
8. Secondary forest
9. Urban, cleared land & cultivation

Within these types, major important forest types, as mentioned below, were selected under the request of Forest Department. Mangrove, fresh water swamp forest and montane forest were not included mainly because of less importance for the timber utilization and due to difficult access.

Studies by Browne, Anderson and Ashton gave vast knowledge about floristic composition of the forest here. However, the establishment of permanent plots may give us more detailed data about the changing pattern of the vegetation, dynamics of forest ecosystem and growth pattern of the species if it is continuously studied.

## Methods of Survey

In the choosing and setting up of permanent plots, a general observation survey was conducted to examine widely the condition of the forest types. In order to do so, the forest type map made by Anderson & Marsden was consulted and the final point which seemed typical of the forest type was decided. (Fig. 1)

The basic area of the plot is 50m x 50m which is devided into 10m x 10m unit by using hand compass and measuring tapes, and the border line was marked by plastic tapes and poles. The size of each plot varied from 50m x 50m to 100m x 100m according to the tree height and the diversity of the species.

Diameter at DBH(1.3 m) of the trees of DBH 10cm and over were measured by the diameter tape and the height to the lowest living branch and total height were measured by Weize hypsometer. All the trees were numbered and the DBH measuring points were marked by the white paint for annual routine measurement. The location of the trees and crown projection diagram were drawn. Leaf samples for the identification of unknown species were taken. The half of the permanent plots at Alan bunga and Agathis plot were established in April 1983 and others were in 1984 to 1986.

I was assisted by several technical staffs to carry on this survey. The time needed to complete the survey was a few days to a few months depend on the site condition. The hardest was Alan bunga, Alan batu and Mixed swamp forests, all of which are peat swamp forest types of which forest floor was as worse as mangroves in Sumatra. Particularly troubles were Mengkuwan ( *Pandanas andersonii* ) and high buttresses of Alan which made the survey so difficult.

Technical assistants headed by Niga bin Nangkat were very diligent and after several trials at setting plots, they mastered how to work by themselves. Their ability is same as or more that those I know in other tropical countries. Especially the efforts made by Niga was worth mentioning.

## Agathis forest

### Location

This is located about ten minutes drive from Sungai Liang to the direction of Seria, left at Liquid Natural Gas Factory (LNG) and following unpaved road penetrating into Badas peat swamp forest for 20 minutes. Just

in front of the water pump station, we turn to the right over crossing the wooden bridge of water pipe and come into the kerangas forest. After few minutes drive we reach to the point of sign of VJR, where we park the jeep and walk three minutes to the plot site.

The road condition reaching this site was in poor condition. Initially it took more than an hour to reach, but since the renovation of water pump site was started, the road was well maintained and the side ditch was excavated regularly so that the swampy water does not overflood on the road.

The road along the water pipe was just crossing the Badas peat swamp forest. At both side of the road, we can see the pure Alan forest with the typical pale greyish colour of crown of Alan. The side ditch was full of almost dark tea colour peat water and the debris of dug up peat was seen. This area is the nearest site from Sungai Liang to be able to see the peat swamp forest. The Alan forest become smaller as we penetrated deeper in the forest. The trunks more or less crooked at the lower part of the crown and the small crown is seen on the top. The yellowish trunk of *Calophyllum* and reddish Rengas were also prominent from the road. Keruntum was dominant where the original forest was cut and opened. The edge of the forest was abundant with large *Nepenthes* and sporadical red palm (*Cyrtostachys lacca*) and big flowers of *Campnosperma* were also observed.

On the latter half of the road near Belait river, the land become a little bit higher and a white sandy small hill with very dense vegetation where Selunsor dominates occurred. Tree height is about 25m which is very low compared with Alan forest. After entering the kerangas forest, the road is covered with very whitish sand and *Sphagnum* grows on it. Mosses and epiphytic orchids are abundant in the forest. Gradually, the Agathis tree come to appear with approaching the plot site of which cylindrical, straight bole with scaly bark and white resin at the lower part of the trunk are the common features of the species. This species was formerly abundant in this area and Temburong, but because of the high demand of this good quality wood, almost all the trees were cut down and the remaining Agathis are found only here and several spots in Temburong.

The site dominated by Agathis showed very thick small root layer which is 20 to 30cm thick over the podosolic kerangas soil. This thick layer is only found on Agathis site and never on the non-Agathis kerangas type. The forest floor is rich with the seedlings of Agathis and many of the orchids,

epiphytic trees and ferns are abundant on the fallen trunks. The light intensity is reduced. The area exactly dominated by Agathis is not so wide that within several hundred meters, the vegetation change to the peat swamp forest. This drastic change of vegetation from kerangas to peat swamp is only seen in this point and this is worth seeing.

**Physiognomy**

The site where the permanent plot was established is the most abundantly Agathis growing spot around this area. The highest tree reaches 45 m high and 90 cm DBH which forms the first layer and successive vertical stratification continue to the lower layer, but it is difficult to divide into each layers. Agathis can be found at each layer with all size classes. The seedlings are also rich so the regeneration is quite stable in this plot. On the white podosolic soil a thick fine root layer cover the whole forest floor and the fallen small twigs and leaf litters were abundant on it. The number of fallen trees are not so abundant as in peat forest and rather smaller fallen trees are seen on the ground. The density of the tree is less than that of surrounding kerangas forest., but the portion where the Agathis does not grow is quite densely populated by other species. Epiphytic plants are not so rich as in the kerangas forest. The matured or immatured cones are abundant on the forest floor. Especially on the early part of the year, many of the female cones are found on the forest floor spreading one-winged seed nearby and many juvenile seedlings are growing. The area is flat but the edge of the plot is already declining to the peat swamp forest. Abnormal roots, especially buttressed and plop roots are not common here and only the flying buttress of Ru (*Casuarina*) is prominent.

According to Furukawa (1987) the soil condition here is as follows:

| | | | |
|---|---|---|---|
| 0-15 cm | F-H layer | 7.5 YR2/1 | Crumb |
| -35 cm | H layer | 7.5 YR2/1 | Many fine roots |
| -45 cm | A1 | 7.5 YR4/1 | LCS |
| -200 cm | A2 | 10 YR7/1 | LCS |

**Results**

The results of the survey are summarized in Table 1. In this plot a half of the plot was first established in 1983 (SP-1) where the number of Agathis tree counts 83 which is of course the most abundant species in the

plot. Resak durian is the second largest. These two species are the characteristic predominant species in the plot. Besides these species, Mang and Sempilau appear sporadically in the upper most layer. Agathis as well as Ubah and Mengilas become codominant and Ubah ribu is abundant in the third layer. On the ground vegetation, the seedling of Agathis are abundant especially at rather open spot under the large size Agathis. The seedlings cannot be found on the very dense forest floor where no big Agathis occur.

Near the edge of the second sub plot (SP-2), Alan is growing which indicate the beginning of peat swamp forest where Agathis is desappearing and come to the same number as Resak durian and Nyatoh(1). The number of Kayu malam, Alan, Rengas and Merpisang(1) are increasing.

Comparing two subplots, the total number of trees is large in the SP-2, but the basal area of SP-1 is bigger which is caused by large Agathis. The number of species counts 38 which indicate the condition of kerangas forest is not so suited for the growth of many species. In diameter distribution, 56% of trees are found in 10cm DBH class and gradually decreasing with L shape curve.

## Alan Batu forest

### Location

There is a saw mill called Hiap Hong at Kota Baru at the south eastern edge of Seria. The timbers of Alan are sawn here of which cut log was sent by loco from the inner part of this area. The loco run into the forest through Alan Batu forest first and then Alan Bunga forest at the end. There are two type of loco: one is the large size and very slow one carrying logs and the other is the small and very quick for sending labourers. By the small loco, we can reach to this site in 20 minutes.

The loco railway is unbelievably crooked and several times the truck is derailed on the way. The surroundings are very matured, old Alan forest which we refer to Alan Batu forest type. There are many fallen large size trees and uprooted big buttresses. Mengkuwang and Salak make the penetration difficult. At the damp points, *Hanguana malayana* is abundant and large type of *Nepenthes* are also dominant. Peat is soft and deep and the crossing root in the peat can catch ones feet. The wood used for lintes began to rot several months after construction which makes it more difficult to walk on. The large size Alan is commonly hollowed in the lower

part of the trunks.

**Physiognomy**

The plot was established at the typical Alan Batu forest type which is situated ca. 100m from the loco railway. The highest tree reaches 60m and there are many trees of which branches become old shaping like antler, but if it is complete, the large crown is overspread. This emergent layer is so prominent that the second layer below looks very low which is actually 20 to 30 m. Kayu malam and Menjalin are the main species at second layer of which average diameter is 30 cm. The third layer is not rich and the ground vegetation is covered by Mengkuwang, *Nepenthes* and Salak. *Hanguana malayana* grow at the damp location. The big pond is made after the large tree had fallen down. Epiphytic plants are scarce in the upper part of the trunks but mosses, fungi, small climbing plants ferns and orchids are rather abundant around the large buttress. The most striking features on the forest floor are the large number of fallen trees, large uprooted buttresses and the web of root system stretching from buttresses. The number of fallen trees are the largest among the forest surveyed and all the size class of fallen trees are seen. Of course if the big tree fall down, medium to small size trees are also fell simultaneously. I heard naturally fallen sound several times during the survey and also found the leaning tree which could not fell to the forest floor because of vines on the canopy so the lower part of the trunks were sinking in the peat.

The root system of Alan is peculiar. The buttress become as big as 4m high in the large size tree and stretch it's branched surface root to radial direction which sometimes reach beyond the end of the crown area. This web of root system make a pseudo-forest floor which catch the leaf or branch litters and decomposition occurred on this floor. On the other hand, the root directed below is coming down to the real forest floor which is some 30 to 100cm below the pseudo-forest floor. Some of the penetrating root reach to the soil layer through the peat. This root system seems to be the key factor to understand the dominancy of Alan in the peat swamp forest.

Once the tree falls, the buttress stand at vertical angle like a high wall below which large pond is made where the fishes are living. Since the peat swamp forest has no connection with river water, I could not understand this fish problem. But, this mystery was solved when I visited this forest at the middle of the rainy season. The forest floor was almost covered by

the water at the lower portion. Water flow from the higher portion to the lower depression. So, the fish in one pond which happened to be there by some reason can move to other pond during the rainy season. Most probably the original egg or fish come from the nearest river and changing its habitat one by one to come to the peat swamp.

**Result**

Nyatoh(l) and Medang(l) which are main medium to small size trees are largest in numbers. However, although the number of Alan is not so large, the total basal area is the biggest as 48%. At the second layer, Kayu malam, Jelutong and Ramin appear and at rather open area Nyatoh(l) and Medang occur. The second and third layer is difficult to distinguish. Under these layers, there appear ground vegetation covered by Menkuwang, Salak and *Nepenthes*. (Table 2)

The highest tree reaches to 60m which is the tallest in this survey and the diameter as well as buttress are also the greatest. Total species number as 24 shows simple floristic composition. The total number of trees are 522/ha, which is smaller than the Agathis plot, but the basal area is larger as 42.6 $m^2$/ha. According to Anderson, this forest can attain to 70m high, however, such a tall tree could not find in this area. The number of fallen trees are the largest and the layers of peat is fairly deep. On the profile at dug up site near higb _tzD obh qh;ob kv ;hto jhtegchq ok ih 3m and there is a white sand layer below it where the large root are found which come from the upper buttress.

This forest had a gregarious flowering on December through January in 1985-1986 and bore fruits after two to three months. The flower bud is red and small flowers pale yellowish when it bloom. The fruit colour changed from reddish to pale green. During the survey by helicopter, eighty to ninety percent of trees were full of floweres in Alan Batu forest and the percentage decreased in Alan Bunga forest.

**Alan Bunga forest**

**Location**

Passing through Alan Batu forest by loco, the loco railway comes to the regeneration area after logging where the small trees of 10m high grow densely at one side. Other side is a pure Alan forest where the tall Alan trees are predominant. Before reaching to the logging site, there is a very

fine Alan Bunga forest near the curve to the logging point. The distance from Hiap Hong saw mill to this point is 40 minutes by small loco but if on foot, it takes two hours which is equivalent to the time needed by the long log carrying loco. After taking off loco, we have to cut Mengkuwang and walk on the buttress of Alan. The density of Mengkuwang is the highest which attain 3m high in this locality and the spikes on the both side of leaves make the penetration very difficult. The permanent plot was established at 100m point from the railway. Unfortunately the rail was removed on April 1986, so that the routine work in the plot get into difficulty.

**Physiognomy**

Alan trees of which average height is ca. 50m are dominating the upper most layer only by this species, which is very peculiar in the tropics. If we look down this forest from the helicopter, the greyish green crown make a very flat and even canopy throughout the forest. While if we look up it from the forest floor, the crowns of each trees live very harmoniously with a little space around the crown. Because there are no other trees in this layer, this canopy structure is quite impressive. The trunk of Alan is straight at the lower portion and looks lanky at the canopy portion and usually the length from the lowest living branch to the leaf canopy is long and on that slender branches, the very small crowns are topped.

Under this layer, there are few trees, only occasionally, Ramin or Trentang occur at around 20 to 30m level. The small size tree of Mempening, Nyatoh(1) and Medang are common in the next layer sporadically which frequently damaged by the fallen branches of the upper trees.

On the ground layer, Mengkuwang is the most dominant species reaching 3m high densely covered the damp part of the plot. The root tubes are creeping on the ground like a snakes. Many of Rassau palms and small seedlings of small trees are found but only one seedling of Alan was found in the plot. The density of fallen trees are not so many as in Alan Batu. The size of buttress of Alan is not so big as Alan Batu, too, and the walking on the forest floor is not so difficult, but the pseudo-forest floor are present already. The colour of the peat is lighter brown and the pond is scarce. Epiphytic plants are rare only except for the gaps of fallen trees where the climbing fern is abundant. On the small tree there are one vine which always flowering regardless of season (*Timonius flavescens*).

The humidity and the heat is the same as in Alan Batu, but sometimes before the heavy rain, very strong wind blow and the crowns are shaken heavily causing the tree or branch fall.

**Results**

As shown in Table 3, the percentage of Alan dominate overwhelmingly as 44 % in number and 84 % of basal area, which is larger than Agathis tree in the Agathis plot. Ramin and Keruntum are the high trees nearly to Alan layer with *Calophyllum* but they are suppressed under Alan and many dead individuals were encountered. Other small trees are dominating the low layers. Because the second layer below Alan is lacking, the sun light reach to the forest floor promoting the massive growth of Mengkuwang. The total species number is 22 which is the same level as Alan Batu. The highest tree is lower than Alan Batu. The root rot or hollow in the trunks are not so common and the growth rate still looks very stable. Alan Batu may be called as over matured forest while Alan Bunga is well called as matured forest. Considering the successional stage of Alan, if the process from Alan Bunga to Alan Batu is a normal successional direction, we can make a hypothesis as below.

The tree called Alan which is very adaptive in the peat swamp area and so grow rapidly under such unfavorable conditions for other species occupy the first layer quickly and the gaps between Alan and other species are large as seen in Alan Bunga forest here. With time elapsed, the growth rate of Alan become slower which is indicated in a very hard sapwood in the present Alan Batu forest trees. The buttresses become larger and larger and the lower part of the trunks were decayed. During the time, the small tree come to grow occupying the empty space of second layer and grown up to medium trees as seen in Alan Batu forest. Because of these second layer trees, the light penetrating to the forest floor become less and less and Mengkuwang become scarce and other seedlings become dominant.

The regenerating seedlings of Alan is rare here and only one seedling and one sprout from the axillary bud were found. As already mentioned in Alan Batu, the gregarious flowering and fruiting occurred in March 1986 mainly in Alan Batu forest as well as in Alan Bunga which is smaller in the number of flowering trees. The seedlings established afterward were also few. Alan Batu seemed better to be regenerated by the seedlings of gregarious fruiting. It is said that the mass flowering of Alan occur 25

years interval in the Borneo rigion. If it is true, the overmatured Alan Batu leave their next generation in 1986 and the seedlings of the same age grow together and become a pure, even aged stand as seen in the present Alan Bunga stand. The process of seedling stage through sapling to matured trees are still missing link. For this purpose, it is necessary to carry out the field survey of the seedlings growth on the occasion of gregarious flowering.

## Padang Alan forest

### Location

The new road along the water pipe from Hiap Hong saw mill to the water pump station of Belait river is crossing the Alan forest. At the point of thirteen km from saw mill, a lintes was made to go into the forest to the south direction. Padang Alan plot was set about 10 minutes walk from the road.

Both side of the new road was covered by Alan forest of which northern part is conspicuous with antler shape crowns of old Alan which become smaller with approaching to the water pump station. While the southern part is first covered by Alan type and changed to Ulat Bulu type and again the Alan forest of which part was kerangas forest appear and finally Alan forest occur again.

At the site where we get off the jeep, there is a ditch with almost black peat water and the depth of the peat is several meters. After a few minutes walk in the secondary forest, we come to the Padang Alan forest. At the first time we made survey, the lintes was good condition but after one year it become decayed and hard to walk on. There is another pass reaching this point through pumping station but this route cannot be taken because of the construction of the site. If we take a route round from Seria, it takes 50 minutes from Sungai Liang.

### Physiognomy

At a first glance, this is a very similar forest to Alan Bunga, however, the forest is rather dark and the size of the crown of each tree is larger and forest floor is dry and the number of Mengkuwang is much scarce.

The first layer is dominated by Alan but the second layer consists of larger size trees than Alan bunga type. Ground vegetation is scarce and the

wet depressed portion is not so abundant and easy to walk. Fallen trees are not so many and epiphytic plants and climbing trees are scarce. According to the boring by Furukawa, the peat reaches to 7m deep. Total impression is rather xeric type of Alan forest.

**Results**

The percentage of the occupancy of Alan shows the highest among peat swamp forest as in Table 4. The number of Nyatoh also increase and with *Keruntum*, they predominate lower layer. *Ramin*, *Jelutong* and *Kayu malam* also occur. The number of species is 14 which is equivalent level to Alan Bunga forest. Compared to Alan Bunga forest, the percentage of middle layer tree is larger. The total basal area is the largest among the plots surveyed.

**Padan forest (Mixed species)**

**Location**

Walking through the kerangas forest about 300m from the Agathis plot, the land come to down about two meters and suddenly the peat swamp forest appear. This change from rather xeric kerangas type to swamp type is very drastic, although some of the species occurred at both localities.

Numerous knee root and loop root emerges on the forest floor and there are small water places here and there and the semi decayed litter covered the forest floor. The number of the fallen trees are quite abundant of its outer bark seems smooth but inner wood is always decayed. The mosses and lichens become wetter covering the lower half of the trunks. Epiphytic ferns and many swampy type palms come to appear and the dominant species change from Agathis to Alan and yellowish bark Bintangor. The humidity become almost saturated as in Alan Bunga forest type. This forest is a type of peat swamp forest distributed along the water pipe from pumping station to Lumut Liquid Natural Gas Factory. Although we can recognize several forest types along this road, Anderson & Marsden call all the types into one as Padang forest. Locally, they call the most densely grown mixed Alan forest as Padang Alan.

The plot is about 100m inside from the kerangas forest and 200m from the border of virgin jungle reserve. Another path directly meet to the road along the pipe line takes 20 minutes on foot.

**Physiognomy**

This is comopletely different from aforesaid Alan type that the height become much lower and all the trees are very densely growing, so to speak kerangas like peat swamp forest. The number of Alan decrease and other species become co-dominate and many species occupy the first layer. Each layer become less obvious and more or less continuous vertical layers are seen.

The epiphytic *Asplenium* is abundant on the trunks at about 1.5m above ground. Ground vegetation is covered by palms, nepentheses and zingers. Epiphytic ferns and mosses are numerous. Forest floor is walkable but many loop type roots and fallen medium size trees are seen. Fine root layer is developed just below the forest floor surface and the foot never sink in the peat. According to Furukawa, the peat covered up to 280cm deep.

**Results**

The number of trees is much larger than other plots which indicate the high density of the plot. The basal area is same as Agathis but the tree height is lower. The maximum diameter class is 60 cms. The number of Alan is less than half of Alan Bunga forest and the number of Ramin, Keruntum, and Bintangor come to the same level. Nyatoh dominates the middle to lower layers. High buttress of Ubah, flying buttress of Ru and various small loop type and knee type roots are prominent. The buttress of Alan is as small as 30cm high. The results are summarized in Table 5.

**Alan Padang forest**

**Location**

Following the lintes via Padang Alan plot to the end which is about 1.5 hours on foot, we can reach to the Alan Padang forest type site. At the middle of this route, there is a area of regeneration after damaged by Ulat Bulu, after which the tree size become gradually smaller and the peat is dry and very thick humus is accumulating on the forest floor. This plot is located at the most deepest part of the Badas peat swamp area.

**Physiognomy**

This type is quite different from other types of peat swamp, that is, the tree height become smaller and the slender medium to small size trees of Alan are growing densely and some of them are leaning. The sun light come

to the forest floor directly and the peat layer is thick and dry, accumulating a thick Ao layer especially at the basement of the trunks. When we walk in the forest, it looks like to be more in the dry thick litter than wet peat forest. The stratification is simple as Alan dominates first layer followed by other species in second layer and ground vegetation of which composition is by miscellaneous species except for Alan. Epiphytic or climbing plants are rare and there are no abnormal roots.

**Results**

The total number of trees are the second largest next to Padang forest but the total basal area is smaller than Agathis forest as shown in Table 6. The highest tree is 33m and the maximum diameter is 46cm that means this forest is the smallest in the plots surveyed. The species accounts for only ten species and more than half of the number of trees are dominated by Alan, followed by 20% of Mengilas, and other common species like Keruntum, Kandis and Medang tabak. The diameter class of Alan is between 14 to 46cm DBH and this distribution pattern is similar in other species, too. Occurrence of so many leaning trees may be due to the even-aged high density population. Crown size is small and more or less similar in all species that identification by outer look is quite difficult. Unfortunately Furukawa could not survey this plot. Since this is the most deepest portion of the Badas peat swamp, further detailed survey is required.

**Ulat Bulu forest**

**Location**

This plot is located at the middle part between Padang Alan and Alan Padang, about 40 minutes walk from Padang Alan plot. The site is once attacked by Ulat Bulu and the secondary regenerating forest appears. After passing from the under canopy of Padang Alan forest, the forest open suddenly and the small size tree grow densely which is very similar to the ordinary secondary forest of the dry land. This kind of portion in the peat swamp is seen in Badas and Sungai Damit area which looks like crater like large circle or oval shape of several kilometers diameter from the sky.

Ulat Bulu is a name of a caterpillar of which damage to Alan forest was first reported in Sarawak in the middle of this century and the similar cases were found in Brunei, too. The size and location of the attacked forest are clearly indicated in the Anderson & Marsden's map of basic forest

types.

**Physiognomy**

The inner part of the regeneration forest is very dark which is much darker than any other forest types. At the first glance, there appeared that only the straight boles with no branches and leaves up to several height were seen. The first layer is around 30m to 20m and the main canopy is found at 20m level. This is the only layer and no other layers below. The forest floor is scattered with fallen trunks and branches. The ground vegetation is completely absent. Peat surface is dry and easy to walk. The epiphytic or woody climbing plants do not exist. This forest is under the regenerating process with rather high speed.

**Results**

Because this is the regenerating forest, the total number of trees are extraordinarily large but the total basal area is small on the contrary, which indicate the small size trees grow densely in the plot. The highest tree is 30m and the maximum diameter is 46m, which is equivalent to Alan padang. The species number is 26 in which Nyatoh, Medang and Mempening are dominant and other species like Kayu malam, Ubah, Mengilas and Keruntum are appeared. Only one tree of Alan was found which seems normal judging from the regenerating condition under natural primary forest. The time of the damage cannot definitely identified but presumably it would be around 1950's consulting the accounts of Anderson. The results are summarized in Table 7.

**Mixed Peat Swamp forest (1)**

**Location**

The distance from Sungai Liang to Kuala Belait is about 30 minutes by car. Changing to motor boat and going up the Belait river for 15 minutes, there is a small stream at the southern coast. Getting off the boat further upstream, we penetrate into Nypa forest which fringe the river bank from the mouth of Belait river. The front of Nypa reaches 10m high and at the lower tide, boat can land on the bank itself, but at the high tide, the boat has to penetrate into the bush of Nypa. Nypa zone is only several meters and Salak palms are abundant behind of it. The riverin forest spread for a while and gradually changes to the peat swamp forest. The influence of

river water come to inner area of the forest where the forest floor is always damp and under foot is always muddy humus in which loop or knee type root are abundant. The plot is about 300m from the bank where there seemed no sign of river water influences.

**Physiognomy**

The plot is located at drier portion than nearer part to the river where there are no large crown trees and the tree height is relatively short and the size of the trees are from medium to small. Accordingly, this is not so characteristic forest, but the type of root system is quite interesting, including prop root, knee root, flying buttress and buttress.

The vertical structure of the forest is continuous from the upper layer to the lower layer and the ground vegetation is rich. The fallen trees and branches scattered abundantly on the forest floor. The vines are climbing the trees in the gap. Generally the epiphytic trees and climbers are scarce but large dense epiphytes are seen at the lower part of the crown of the large trees. This forest type is found on the shallowest peat which only distributed along Belait river.

**Results**

The highest tree reaches 36m high and largest tree diameter is 73 m, which indicates this type is a medium size forest and medium to small size trees dominate the forest. Total species number is larger as 41. The total number is the same as Padang forest and the total basal area is rather smaller as shown in Table 8.

The most abundant species in terms of number and basal area is Sepetir which is the representative species in the mixed peat swamp in Brunei and Sarawak. The group of *Shorea* also occurs a few number. The distinguished species in the root system are high buttress in Ubah and prop root in Menjalin and Nantungan. Totally more than 50% of trees in this plot have several types of abnormal root systems.

According to the Furukawa report, the peat in this plot is the shallowest as 150cm below which the element of mangrove appeared. This fact suggest the area is the most recently formed peat swamp forest.

## Mixed Peat Swamp forest (2)

### Location

This is almost the same location as above mentioned plot, but rather nearer to Kuala Belait. The landing point is the upper part of Dayak house at Rassau where the old lintes penetrate into the forest. Rassau palm grow on the river bank of the landing point and after passing through Salak zone, the swamp forests start at first with small size trees and gradually the larger size trees come to appear. About 500m walk from the landing point, we can see the large Jelutong tree which shows many cutting surface for exudation of resin. A plot was established in this area. Forest floor is waterlogged and sometimes the depth is more than knee depth and there are many roots in the surface peat. The forest is dark and semi-decomposed litter is abundant. Knee and prop roots are numerous as the former plot.

This location is reached by 20 minutes walk on lintes plus 20 minutes walk in the forest. During the rainy season, the black water flow with a rush from forest to the river. Alan appears in about 10 minutes walk inside from this plot.

### Physiognomy

According to Anderson, this type of peat swamp forest resembles the Mixed Dipterocarp forest. In fact, there are large size dipterocarp and the forest floor is not so bad as in Alan bunga or Alan batu. The species diversity is rich and the largest tree Kapur paya which attains 50m tall having large buttress takes rank with Kapur bukit in the Mixed Dipterocarp forest.

The vertical stratification is also similar which has emergent tops and the succeeding layers to the ground. There are many fallen trees and although the forest floor is originally flat, the rain water run through uneven surface during the rainy season. The knee root is abundant in the waterful place and there are so many prop root. Woody climbers are abundant at gaps, but the epiphytes are scarce. The major differences between the preceding plot and here is the existence of the large canopy trees in this plot.

### Results

Total number of trees are 645 and total basal area accounts for 33.9 which are rather small compared with other forest types. But the species

number is the largest as 58 in the peat swamp forest types. The highest tree is almost 50m and the largest tree reaches 140cm DBH which is the equivalent level to Mixed Dipterocarp forest.

The most abundant species Sepetir accounts for 12% to 13% which is quite different figure from Alan which occupied more than 50% in Alan forest types. Nantungan, Merpisang, Ubah, Kayu malam, Medang and Amat are codominant next to Sepetir. The small number of Kapur paya and Ramin which are both large size class in the forest are found. The Meranti group also appeared. All the data are summarized in Table 9.

## Mixed Dipterocarp forest

### Location

Driving five minutes on the Labi road from Sungai Liang to the south, there is a logging road on the left where the Kayu puteh tree change to *Acacia auricuraeformis* along the road side tree and the plantation of *Pinus caribeae* is seen. Going into this logging road along the border of the Andulau Forest Reserve, the virgin forest appears on the right. Riding on jeep, it takes 20 minutes up to here, but recently the road was so spoiled that we have to walk from the entrance which takes 40 minutes by foot. Walking a few minutes further, we can reach to the entrance of Virgin Jungle Reserve marked by red panel on the tree. The plot is about 200m from this point into Virgin Jungle Reserve. The approach to this plot was initially good but because there is no side ditches along the road, all the rain water flow on the road causing serious erosion which makes it difficult to go by jeep. If we can use jeep, this is the nearest plot from Sungai Liang.

### Physiognomy

This plot is a part of areas where Ashton has studied and as Virgin Jungle Reserve, the typical Mixed Dipterocarp forest is reserved. The emergent layer is around 50m under which the continuous layer are found successively. The straight boles on the medium to small trees and buttresses on the large trees are common. Climbers are rather abundant and epiphytic plants are at upper branching layers. On the forest floor, palms are predominant and seedlings of upper layer trees are sometimes occupy a small area densely. The sun penetrate into the ground through the canopy and the forest floor is not so dark and the litter layer is thick. The

abundance of fallen trees are similar to mixed peat swamp forest. Since the plot is located near the sea, the strong wind often blow especially before the heavy rain and the crowns are shaken strongly causing the fall of large branches and trunks. This phenomena have happened several times during our visit.

**Results**

As summarized in Table 10, the total number of trees is 736 which is a rank of Alan padang, but the total basal area is second largest among the plots surveyed. The highest tree is 50m and the maximum diameter is 114cm which is rather smaller level as Mixed Dipterocarp forest. The species number is the largest as 174.

The percentage of the occupancy of Dipterocarpaceae is higher and the species of this group are found at any layer from small size to large trees.

The characteristics of this forest is that there are no dominant species. There is no species which occupied more than 6 % in number and in basal area. Almost all species except Kapur bukit show several percentage.

Kapur Paya forest

**Location**

Located 15 minutes by car from Sungai Liang to Seria direction, we reach the Anduki Forest Reserve which, being situated at the side of main road, suffered from accidental fires quite often and the constant regeneration of forests occurs. This location is the border of the coastal sand area and the elements of mangrove such as *Acrostichuum aureum* and Rhizophoras are seen.

**Physiognomy**

This is a forest dominated by Kapur Paya of which conical crown and straight bole is easily recognized. The highest tree is 30m level and the first layer is almost completely covered by Kapur Paya. The second layer is scarce trees and ground layer is abundant with Salak palm. The litter and thin peat layer cover the sand layer. On the dry period this area dry up completely but there are small streams of rain water during the rainy season. Epiphytes and climbers are scarce.

Kapur Paya flowers almost every year on March. The year of 1986 was the gregarious flowering year of this species and almost all the trees of the first layer bore flower and fruits.

**Results**

As shown in Table 11, the number of trees are second to Ulat Bulu, both of which resemble a secondary forest type. Total basal area, maximum height and maximum diameter are smaller. Kapur Paya dominates overwhelmingly in terms of basal area and number as well. Other species figure are much smaller. The species number is as small as 28. The small size tree of Ubah, Kandis, Medang and Nyatoh appeared and Amat which is found in fresh water swamp or peat swamp forests and *Vatica* of Dipterocarps are found.

**Discussion**

The summarized figures in each plots are shown in Table 12.

Within 11 plots, swamp forest types were studied at 9 plots. This is because there has been limited study in swamp area except by Anderson. Furthermore, the importance of the swamps seems to be greater in the future from the point of the development of forest in Brunei. From the results, the swamp forests, although being scarce in species number, the standing crops show quite large amount comparable to Mixed Dipterocarp forest. This means if the disadvantage of inconvenient situation of locality is overcome, this area is still a big potential resources. The scarcity of the species number is more advantageous for the forest development. The problem is how to promote the regeneration of swamp forest, otherwise the only unvalued secondary forest remain after the extraction of good timbers. The regeneration study of logged over areas of Alan should be carefully designed and started as soon as possible. For this purpose, this kind of permanent plots are quite important as a control of the original condition. Although Alan is the most prominent species in the region, there are many other species which have potential value as Kapur Paya, Kayu malam, Sepetir and etc. The fundamental studies focusing on those specific species are required especially in the field of ecology, phenology and regeneration as well as timber utilization. I advise the collection of minor products from the forest like Jelutong as providing valuable material and information for chemical and pharmacological developments.

For these purposes, establishment of permanent logging system is necessary. The railway or logging road now existing in Brunei are all temporarily basis so the regeneration works cannot be performed with good condition. Although permanent plot were set up at convenient sites, it is advisable to establish more plots in the future so that at least the major remaining forest types can be studied on a sound basis. It is important to continue the study on a routine basis. Without frequent visit to the permanent plot, the border of the plot is easily lost and the marking poles decayed. Regular check by the researchers is the best way to protect the forest from any type of disturbances.

## II. Phenological Observation of Main Tree Species at Four Forest Sites

### Introduction

Biological activities of leaf flushing, flowering and fruiting of the tree species in the tropics are different from those in the temperate zone. The cycle of species differ each other and even in the same species, it change by individuals and often even by branches. These evidences have been studied in Indonesia, Malaysia and Singapore by Coster, Holttum, Koriba, Medway, Ng, Sasaki, Tamari, Chan and others, many of which were conducted out of Borneo island.

This study is the preliminary study on the phenology of the main tree species at four sites, i.e. two sites at Mixed Dipterocarp forest, one each at Agathis and Alan bunga forest. The purpose of this survey is to get basic information of phenology of main species and apply these results to the seed study and forest breeding study in the future.

### Methods

The best way to carry out phenological study may be to observe the tree activities from the high tower in the forest or traversing artificial hanging bridge between canopies as tried in Malaysia, however, there have been no such facilities and since it cannot be built up on time, the observation by binoculars from the ground was made. The survey was carried by two observers and one recorder on fortnight basis for almost two years. The activities to be checked are the presence of leaf bud, new leaf flushing, new leaf, old leaf, leaf fall for leaves, flower bud, half open, fully open and flower fall for flowers and young fruit, matured fruit and fruit fall for fruits. If the new and old leaves are mixed together, the degree of abundance was recorded.

### Study Sites

Four sites were selected for this survey considering the convenient approach from Sungai Liang and importance in forestry development and scientific research as well.

#### 1) Arboretum Andulau

This is the nearest site just in front of Forest Research Center where the original mixed dipterocarp forest has been reserved and the observation

paths were laid out throughout arboretum and many trees were named on the board. Totally 227 trees of 5cm DHB and over were chosen for the observation which were selected from all over layers in the forest.

**2) Compartment 7, Andulau Forest Reserve**

Along the road to the permanent plot in Compertment 7, there is a primary mixed dipterocarp forest which is equivalent to the forest in Abroretum. One hundred and twenty one trees of 5cm DBH and over were chosen for observation to compare the pattern of phenology with Arboretum.

**3) Agathis forest**

In the permanent plot of Agathis forest in Badas, one hundred and fourty-three trees of 10cm DBH and over in 50m x 50m plot were observed to see the phenological patterns of Agathis and associated Kerangas species.

**4) Alan Bunga forest**

Phenological survey was conducted at Alan Bunga forest permanent plot in Badas thinking of the importance of this forest type although it is rather far from Sungai Liang. Seventy-two trees of 10cm DBH and over were selected. The main object is focusing on the flowering of Alan which is said to have flowered at only 25 years intervals.

## Results

**1) Arboretum Andulau**

This site contains the largest number of trees of 227 which takes full one day or sometimes two days in case of many flowers to complete the observation. There still have been many unidentified species but only the major results are mentioned here.

Within 227 trees there are 53 trees which flowered once during the observation period and 5 trees twice, 3 trees thrice and one tree four times each made flowers. For the fruiting, 37 species bore fruits once, 5 trees twice and 2 trees thrice. As for leafing, complete leaf fall was observed once in 21 trees and twice in 4 trees. Families of which frequency of flowering is high are Dipterocarpaceae, Sapotaceae, Moraceae,Fagaceae and Anacardiaceae.

The time of flowering of once flowered species is, with the exception of Resak hitam(127), it occurred during 15 June 1985 through 2nd November,

especially during 27 July to 7 September there were 19 trees of flowering. But if all flowering trees are considered, the flowering can be seen throughout the year. In Fig. 2 shows all the one time flowering trees according to the height layer divided into 5m class, which clearly indicate the peak at the surrounding of August.

As for fruits, there are three types which 1) bears fruit while flowers remain on other branches of the tree, 2) fruit appear just after all the flowers over, and 3) fruit start some times after flowers over as shown in Fig. 3. These types may be attributed to the pattern of growth of each branches. Eighteen trees out of 30 species are starting fruits during flowers are still on the tree. This type of trees may have a tendency of manifold growth type as called by Koriba which more or less grow arbitrary at the different branches. The duration of fruiting is normally longer than flowering period and Berangan(2), Bintangor(84), Rengas(4, 27) and Pendarahan(42) are specially fruiting longer period. Trees which did not bear fruit despite setting flowers were 23 out of 53. This high percentage of non fruiting is noteworthy. Within the higher trees more than 30m tall, majority of the flowering trees belong to Dipterocarpaceae. Fifty six trees out of 227 trees are belonging to this family and 12 trees in 9 species flowered and 8 trees in 7 species bore fruits that is Binchaloi(72), Meranti laut puteh(53, 116), Meranti paya bersisik(227), Meranti saran punai bukit(110), Kapur bukit(145), Keruing buah bulat(147) and Resak hitam(127). Within these, except for Resak hitam which bore fruits during 22 September 1984 through 9 February 1985, all the trees produced fruits during 21 September 1985 through 22 February 1986 with slightly changing each peak period. This high concentration of flowering of Dipterocarpaceae is common in other part of Malaysian region.

The evidence described here is only the results of two years observation and not enough to conclude the phenological cycles, but tentatively we can say that the major flowering season occur around August and the fruiting succeed after this month to the end of the year. Because of the high mortality of seeds of tropical trees, it is advisable to sow seed as soon as the seeds are collected. For this purpose, the sufficient space of nursery should be prepared in advance, checking the approximate date of maturing of fruits. It is important to collect good seeds from better phenotype mother trees. The attitude of collection of seed is arbitrary in many countries causing a unstable seedling survival and

growth. The heredity of seeds should be most carefully studied during the course from collection to nursery practice. In this point, the first step is to find the better phenotype mother trees which grow with straight bole, high and small branching and good regeneration capacity. The quality of seed can be checked in the nursery.

Concerning to the leaf fall, eighteen trees fall leaves once and 5 trees twice. The period of leaf fall occurs during 9 March through 18 May 1985, which is rather dry period after the first rain of the early stage of the year, and the next is 25 August to 22 September 1984 and 24 August to 7 September 1986, both of which are the second dry period of the year. Generally the leaf fall occurs during these dry periods, but in wet season there also occurs a little leaf fall from November to December 1985. This phenomena is also quite often happened in the tropics. The species which fall leaf twice are Bintangor, Binchaloi, Meranti paya bersisik and Kempas.

**2) Compartment 7, Andulau Forest Reserve**

This observation area is located at 4.7 km east south east from aforesaid Arboretum. The results of phenological activities of 121trees are as follows.

As for flowering, non-Dipterocarp trees showed first peak between January to March 1986 and the second is from August to October 1985, which is only concerned to one time flowered. If trees of twice or thrice flowering added, the flowering occurred almost through the year. Dipterocarp trees which flowered once shows main peak at August to December 1985, April to May 1986 and September to December 1984. If the trees flowered more than twice are added, the peak become October to November 1985 and July to September 1984, which indicate that this group flowers at the driest part of the year.

As for fruiting of non-dipterocarps, it occurred after the flowering season one by one and especially during October 1985 to May 1986. The fruiting season of Dipterocarps is divided into two seasons, one is September 1985 to January 1986 and the other is from May 1986 on.(Fig. 4)

On the leaf fall, the two main peaks are recognized that is in July 1984 and from November to December 1985. There are another period as in September 1984, June and July 1985.

The species which start to bear fruit during the flowering time are

Meranti paya, Bintangor, Jelutong, Medang, Mempening and Bantas. Species start to bear fruits just after the flowering are Kapur bukit, Keruing buah bulat, Keruing mempelas and Kedondong. Kedondong(56), Ubah and Geronggan have some intervals between the period of flowering and fruiting. (Fig. 5)

Compared the results with Arboretum, nearly the same flowering and fruiting pattern can be seen in Dipterocarps. In non-Dipterocarps, however, the flowering and fruiting occur at different period of the year besides of the peak period and this tendency is also seen in the leaf falling. The phenological activities in both area are summarized in Table 13. Although the site is not so far apart from each other, the differences may be attributed to the difference of habit, stratification, and age and strain in some species and of course the differences of species composition as well as an ecological situation on both site.

**3) Agathis forest**

In this forest, the flowering and fruiting activities are recognized in 12 trees out of 113 Agathis trees and 16 trees out of 20 of Resak durian only and no other species showed any sign of these phenomena and also no complete leaf fall occurred.

In Agathis, six trees bore male cones once and ten trees bore female cones once, and two twice. In Resak durian, six trees flowered once, nine trees twice and one tree thrice. Two tree bore fruits once. The male cone of Agathis concentrated during 17 August through the end of September 1985. The female cone can be seen throughout the year. There are two peaks in the flowering season of Resak Durian, that is from July to end of September 1984 and January to March 1986, the former is in the dry season and the latter is in the rainy season. The fruit occurred only on two trees in October to November 1984 and February to March 1985.

In Agathis, the reproductive activities occur in only a large size trees. In the smaller trees between 10 to 30 cm, almost all the trees show same tendency and cones are not produced. The reproductive organs are only produced over 40cm DBH trees. The frequency in each diameter class is as follows. (Fig. 6)

40 cm - Four trees out of 11 trees bore cone of which period are divergent and the longest was 38 weeks from August 1984 to January 1986. Male cones were observed during August to

October and November to December 1985.

50 cm - Three trees out of 6 trees bore cones. The longest period was 40 weeks from July 1984 to January 1986. Male cones were found on August to September 1984.

60 cm - One tree out of two bore cones. Male cones were from August to September 1985 and the female cones were seen from that period to January 1986 for 12 weeks.

70 cm - Two trees out of three bore cones, which were continuously observed throughout the year.

90 cm - Both two trees bore cones one of which was observed during 32 weeks from October 1984 to January 1986 and the other was found in two separate phase, that was 6 weeks from February to March 1985 and September to December 1985 for 16 weeks. Male cones occurred on August to September 1985.

From the above observations, a long time is needed for cone bearing and at least the time tree reaches to a certain height to be able to receive direct sunshine might be the age of maturation of cones, and the timing period of maturation seems also variable according to individuals. It is generally said in Brunei that the maturation of female cone is in March or April. The results of this survey almost support this generalization.

Agathis is monoecious and taxonomically not well revised yet, but Whitmore (1977) temporarily classified genus Agathis into 13 species and 3 varieties were found in Southeast Asia. The examples of the observation of phenology of Agathis is unexpectedly few and only in *Agathis robusta* the cycle was studied that the male cone come out in January of the 1st year and female cone appears in June/July and mates in August/ September. The fertilization occurs in September of the second year and at the 3rd year the seed fall which means eighteen months is necessary until the seed obtained. This is the case in south Queensland. In the plantation forest, the first year of appearance of the female cone is 15 years in east Java, 20 years in Queensland and 20, 18, 12, 13 and 10 years in West Java. But it is generally accepted that the only seed obtained from the trees of age of more than 25 years show good germination. The matured female cones occur once at regular intervals in any plantations and the period continue for two to three month.

In this survey, there might be mistake of identifying the axillary male cones which is very hard to recognize from ground but the growth of

terminal female cones and their falling time is precisely recorded. The male cone grow on dryer month of August/September and after several months the crossing may occur, and the 18 months later which is February/ March, the matured female cones shatter on the tree or fall on the ground. It is commonly said that the cone of Agathis shatter on the tree and in Brunei, the female cones were bagged and the seed were collected on the tree after shattering. But during the survey, many of the female cones were found on the ground spreading the seeds surroundings.

About the leafing, there are no signs of activity during March to June 1985. The leafing activity are found between October to March 1985, August 1985 to January 1986 and February to April 1986, which shows the intermittent growth type.

In Resak durian, the most prominent flowering occurred in June to August on the trees more than 20cm DBH and over and not on the smaller trees. Two trees defoliated completely and bore fruits. This species can be classified as deciduous types. The flowering in some trees occurred on July to September 1984 and the other on January to March 1985, but the majority is the former and once flowered, the same tree did not flower on the same month of the succeeding year. The fruiting in No. 14 occurred after a long flower period in November 1984 and in No. 121 bore fruit in February/March 1985. (Fig. 7)

Other smaller trees which mainly the components of lower layers, have never born flowers and fruits which indicate the very poor phenological activities of the lower trees in the Kerangas forest.

**4) Alan Bunga Forest**

Generally speaking the flowering intervals of Alan is not yet clearly known. Anderson mentioned it as 25 years interval but loggers in Brunei said it to be every 7 to 8 years and the officers of Forest Department recognized the red colourd tree crown from the helicopter quite often whenever he took on it. Anyway, we don't have a record of accurate time of flowering and fruiting.

Fortunately we could encounter the gregarious flowering and following fruiting in February to April 1986. Within 34 trees of Alan, as one was fallen down by wind, all of 33 trees flowered. The beginning of flower was noticed on 14th January 1986 of the fastest and others started on 11th February and ended 8th April. The fruiting of 32 trees started on 24th

March during which the flowering still occurred in some part of the trees and only one individual commenced fruiting on 8th April. The fruiting ended on 21st April for 25 trees, on 5th May for 7 trees and one tree are still bearing fruits on 19th May. Since all of the Alan tree dominated the upper most layer, this events can be truly called gregarious flowering. From the survey with helicopter, the flowering was most abundant in Alan Batu forest spreading to the inner part of Alan Bunga forest. Even in this Alan Bunga forest, the flowering occurs in such a large scale as mentioned above.

Besides Alan, Ubah flowered on January to February 1985 and bore fruits on the following March to June. The second flowering occurred in Apirl 1986. Two trees of Mempening had flower from September or October 1985 to January/February 1986 both of them are rainy season type. The fruiting occurred only once for one tree on non rainy July 1985. Two trees of Nyatoh and one Terentang had flower and fruit on August 1985. No deciduoue trees were observed.

Flowering season of Alan in February to April which is the successional period from the most wet to the dry period. On the same period, only one Ubah flowered on April 1986. But in 1985, 11 trees of Ubah flowered coincidely. These facts means this period may be one of the flowering season in Alan Bunga forest. (Fig. 8)

As to the flowering season of Dipterocarpaceae, almost all the trees flower on August and September 1985 with only exception of flowering in April in Arboretum. In Compartment 7 Andulau, flower centered on August to December 1985 and only two trees flowered on April 1986, and one tree on January to March 1985. Resak Durian in Agathis forest set flower on July and August 1985 and January to March 1986. Judging from these pattern, Alan Bunga does not coincide with the major phenological patterns of Dipterocarpaceae and rather tends to show the similar seasonality with minor groups.

## Discussion

Let us consider the phenological tendencies of each species with the rain fall pattern at Sungai Liang. As shown in Fig. 9 the months of smaller rainfall are March, June and August. February and March in 1983 had almost no rain because of the El Nino and severe drought have spread over Borneo which caused wide spread forest fires especially in east Kalimantan where

more than 3 million ha. of forest was burnt. Even in Brunei, the roadside forests were severely damaged and the kerangas forest along Labi road was most widely burnt by accidental fire. This drought, however, is a rare case in this area. The rainfall of the months of February, March and August amounts for ca.100 mm. The period from September to January in each year shows high precipitation rate.

In general, the flowering of major tropical tree species occur at the end of a rather long dry spell. Resak durian in Agathis forest and some of the species in the Mixed Dipterocarp Forest follow this tendency. But the flowering of Alan in the peat swamp forests differs as to have mass flowering in February 1986, which is the middle of the rainy season. Some of the dipterocarp species indicate the same cycle.

There have been a number of references of phenology in tropical Asia many of which were done in Singapore and Peninsula Malaysia. Major works are summarized as follows.

Holttum(1931), who has observed phenology of trees in the Singapore Botanical Garden from 1927 to 1931, found that the majority of the deciduous trees change leaf once a year mainly in February and some in August. Species which shed its leaves twice a year were observed in January and August. In other species, there are no significant tendencies of seasonality or fixed interval. But in some species, they changed leaf at a fixed interval and there are varieties in the individual trees of a species. Besides those, there is a species which shows very irregular cycles like *Havea brasiliensis*. The small change of climatic factors stimulate the flowering and connecting with inner factors, the leaf change may occur.

In the second paper in 1940, Holttum(1940) modified the initial article based on ten years observation and said that there are various species from the very sensitive to the totally independent to the climatological change. They are categorized into 1) Species which shed leaf once a year, 2) Species which have more than one year leaf period, 3) Species which have six to twelve months leaf period, and 4) Species with irregular leaf period. He reported details of the leaf shedding pattern of deciduous trees and also mentioned about the relationship between flowering and leafing of deciduous and evergreen trees. The stimulus for the change of leaf is the decrease of temperature (10 - 15°F) after a storm and cool days after a long hot days. In Singapore, the most drastic change

of climate occur in February and the defoliation occur most frequently in February to March and July to August which are the driest months of the year. *Koompassia malaccensis* keeps leaf more than a year (12.7 months). The species which have longer leaf period are *Heritiera elata* (20.5 months) and *Heritiera macrophylla* (32.0 months). *Sterculia* spp. show short leaf period between six to twelve months and *Dyera costulata* has irregular trend.

The flowering phenomena of deciduous trees occur at certain point of leaf cycle, however, it is not so in the evergreen trees and no connection with new shoot elongation. In evergreen trees, the growth of new leaf occur at the intervals of six months, one month or more and this interval is more irregular than the deciduous trees. Generally the old leaf does not drop even after the new leaf growth resulting in the longer life of old leaf. *Dyera costulata* shows the intermediate characters between evergreen and deciduous. The growth of new leaf of evergreen tree seems to be stimulated by the rain. *Koompassia mallaccensis* which grow in the Botanical Garden as a remainder of the original vegetation changes leaf in every September until 1931 but there was no leaf change in 1933 and changes occurred in March 1935, May 1936, July 1938, 1939 and May 1940. So the average leaf period is 12.7 months.

After these primary surveys, Koriba (1958) made a detailed study of the seasonality of the trees in the same Garden as well as in the Singapore Island classifying the pattern of shoot growth as 1) evergrowing, 2) manifold and 3) intermittent, and discussed the relationship to the flowering. This category was checked in the montane forest of Mt. Pangrango, West Java by Yamada (1976) to measure the litter fall dividing to species unit and he found the seasonality of flowering, fruiting and leafing and the differences of the evergrowing and intermittent types are depending on niche in the vertical stratification.

In Peninsular Malaysia, Medway (1972) made a phenological survey in Hill Dipterocarp Forest at Ulu Gombak F.R., Selangor (3°21'N, 101°47'E) on 61 canopy trees biweekly for 6 years from July 1963 to July 1969. The flowering occurred simultaneously in 5 species and only *Ficus sumatrana* (strangler) made flower throughout the year. Ten species have a tendency to flower regularly at the certain period of the year repeatedly. Other species have irregular intervals and often the flowering intervals exceeded one year. Ten species had flower every year during 1963 to 1969

and six species bore fruits. In total, minimum 20 species had flowers and 12 species bore fruits. There happened a severe drought in 1963 and 1968 when mass flowering occurred and many of them succeed to fruit. The most active season of flowering was February to July and the second was August to November. The most inactive periods were from December to January. Fruiting was prevailing between May to November and especially September to November is the best season. As a whole community, rather clear seasonality was observed.

Foliage activities were various as three species continuously grow, 21 species show same cycle every year and two active periods were observed. The irregular biannual activities were also noticed. Four species defoliated every year and another four species had irregular tendencies. At least six species correlated with the cycle of flowering clearly. Another five species has same cycle as annual flowering and the remainings were independent each other. As a whole, the foliage activity have two peaks one of which is higher in the less rainy period and the other is on the rainy season.

Ng (1977) has summarized the mass flowering of Dipterocarps. The flowering record of the Arboretum of Forest Research Institute at Kepong, showed mass flowering in 1976 when non-Dipterocarp species such as Euphorbiaceae, Polygalaceae, Moraceae, Bombacaceae also simultaneously flowered. Fifteen species out of 50 species have had first flowers in this year and the oldest tree was 45 years of age. The total 79 trees have flowered. The fertile seeds were obtained abundantly probably because of better chance of fertilization than usual. The peak period of flowering at Kepong was March to April. The stimulus of flowering was thought to be the increase of sunshine hours, because of the sudden increase of an average of two to several hours of sunshine hour which usually occurs in January, February and March, the mass flowering in 1957, 58, 63, 68, 70 and 76 might occur. He also stressed that to measure drought by rainfall amount is nonsense and drought should be recognized as the continuous hot days after cool period and this cannot be found in the rain record.

Sasaki et al (1979) consulting the flowering phenomena at several localities in Malaysia 1976, proved that the simultaneous flowering occurred only in certain species in certain region. The timing of flowering differed depending on the altitude, species localities, topography and climatic conditions. They recommended the need of wide

scale survey of several important species for the development of forest tree breeding study in the future.

Putz (1979) has studied phenology of 131 trees in one ha. plot near Kuala Lumpur for four years from March 1972 to February 1976. The observation bridges among which the longest was 75m were constructed across the crowns of major trees totaling 363.5m. He recorded several times a month of flowering, fruiting and leafing and analyzed seasonality by Spectral or Colwell methods. In the flower production, non-synchronism was recognized and the flowering period differed even in the same species, i.e., the male tree of *Knema stenophylla* flowered continuously and female flowers discontinuously. *Santiria laevigata* flowered none, once or twice a year and not synchronized. The average flowering period was one month. *Randia densiflora*, *Anisophyllea corneri*, and *Millettia atropurpurea* also indicated the unsynchronity. At a community level, an average of 15 species out of 62 had flowers every month which means at least some of the flowers are found in any time of the year and some of them flowered for a long time. Twelve species out of 62 species flowered more than 25 months. *Euodia glabra*, *Strombosia javanica* and *Millettia atropurpurea* have continuously flowered for more than 12 months. Regular seasonality was found in *Alangium ebenaceum*, *Actinodaphne oleifolia*, *Koompassia malaccensia*, *Intsia palembanica* and *Ormosia venosa* which flowered on the same month of every other year. Four species flowered regularly every year with a slight time lag. i.e., *Alstonia angustiloba* flowered on March and April of 1972, 74, 75 and 1976 but after the flowering on December 1972, there were no flowers in 1973, *Litsea castanea* flowered in August September and October every year also did at different time of the year, *Elatoriospermum tapos* have flowered every January and February, but sometimes it again flowered in July, August and September, and *Cryptocarya griffithii* flowered first three months of three years out of 4 years. Those species which flowered at regular month seems to respond to the inner rhizome, photoperiodicity or regular climatic cycles. However, total 66% of species have not flowered which makes difficult to show the general seasonality concerning to flowering. Wycherley (1973) suggested that the flowering occurred after dry season and it is well correlated with the small rainfall of two or three months before flowering. The sudden change of temperature by the rainy storm during or at the later part of dry period stimulate the flowering.

In regards to the fruits, average 20.6 species out of 62 bore fruits every months and although April to September is the most abundant fruit production period, the time needed for fruit production and the longevity of fruit on the branch varied very much. Species which retain fruits long time on the tree and poccess germinated seed are *Anisophyllea corneri*, *Barringtonia pendula*, *Canarium littorale* and *Millettia atropurpurea*, all of which have large fruits and animal pollination type except for the last species. There are many species which continue flowering and fruiting production for more than 12 months such as *Timmonius wallichianus*, *Nauclea subdia*, *Santiria leavigata*, *Dacryodes costata*, *Endospermum diadenun*, *Planchonella maingayi*, *Paropsia vareciformis*, *Grewia laurifolia*, *Litsea castanea* and *Myristica* sp. Besides these, all species bore fruits with some intervals some of which bore fruit more than once a year and others once more than a year. Twenty six species bore fruit at the intervals of more than a year and 19 species did for two to three times a year at different trees or branches and no fruits were set on 3 species. Species pollinated by wind are apt to fertilize on dry season. Ninety percent of upper trees is animal pollination type having fleshy fruits.

Concerning to the leaf, there are always leaf production without any time intervals and more than half species flush every month but no correlation with the climate was detected and no seasonality was recognized by Colwell & Spectral methods. There were no synchronism between individuals even in the same species. In the deciduous trees, there are no species of which leafless period is over two weeks. The complete deciduous species are *Ficus caulocarpa*, *Terminalia subspathulata*, *Intsia palembanica*, *Irvinga malayana* among which the first species defoliate in May to November and others in January to March. *Alstonia angustiloba*, *Dracontomelum mangiferum* and *Xanthophyllum obscurum* dropped almost all the leaf before new leaf come out and one tree out of three of *Barringtonia pendula* showed the same tendency. The frequency of flushing differ widely by species. Species with longer intervals are *Xanthophyllum griffithii* and *Diospyros pendula* which flush twice in 4 years. Evergrowing type which continuously flush are *Actinodaphne oleifolia*, *Knema stenophylla*, *Endospermum diadenum*, *Macaranga hypoleuca*, *Strombosia javanica*, *Nauclea subdita*, *Randia densiflora* and *Timmonius wallichianum*.

As a result, the seasonality at a community level is not so strong and the responsibility to the climatological change varied widely. The merit

of aseasonality contribute to the constant supply of flowers and fruits to pollinators and distributors. Moreover, the species which have no distinct periodic response organ get this benefits to the reaction of localized periodic or site condition. Compared with the work by Medway (1972), here are the scarceness of the one year or two years cycle species and the lack of synchronism between the species. The clear and repeat seasonal changes found in Medway which, as he mentioned "Even though there are varieties of seasonality by species, community as a whole regular seasonality was seen as one peak in flowers and fruits and two peaks of leaf production," may be due to the character of the dominant species which occur at the higher vertical layers in the stratification. Koelmeyer (1959) found aseasonality in Sri Lanka as a result of 9 years observation.

Chan (1980) has surveyed the fruiting activities and seedling dynamics of Dipterocarps in Pasoh, Malaysia where he found that many of the species which bear infertile fruits have flowered in the early stage. The fruits of Dipterocarps are wind distributed which drop vertically for the first several meters and spread wings to start circling so that the dropping speed decrease and flow to a short distance from the mother tree. If there is no wind, matured fruit is rotating to drop just beside the mother tree. In normal wind condition, the matured fruits are distributed to 50m from the mother tree but normally within 20 m, which is mainly due to the dense crown. In the case of slope or ridge, occasional gust blow fruits further. Burgess (1975) mentioned the distance of *Shorea curtisii* was within 80m but Kochumman & Ng (1977) measured 1/2 mile case. Janzen (1970) has proposed that the survivorship is better at some distance from the mother tree but the reverse results were observed by Liew & Wong (1973) and Daljeet Singh (1976).

Chan & Appanah (1980) have carried out a wide scale survey of Red Meranti Group (Muticae sect.) of Dipterocarps (*Shorea leprosula*, *S.Macroptra*, *S.acuminata*, *S.Lepidota*, *S.parvifolia* and *S.dasyphylla*) of total 100 trees at the occasion of mass flowering period in Pasoh, Malaysia. At first *Shorea macroptera* has flowered and succeedingly *Shorea desyphylla*, *S.lepidota*, *S.parvifolia*, *S.acuminata* and *S.leprosula* flowered. These flowering periods were overlapped at the latter half of the preflowered species with the beginning of the next species, and all the peaks do not coincide with each other. The flowering period is as short as two weeks in *Shorea macroptera*, *S.dasyphylla* and *S.lepidota* and 3.5 weeks

in *Shorea leprosula*. The later the flowering initiated, the longer the flowering period continued. In *Shorea leprosula*, the number of flowers in one tree were estimated to be 63,000 to 4,000,000.

Tamari & Jacaline (1984) have surveyed fruit distribution of *Shorea contorta* at Makiling forests, Los banos, the Philippines 1979 reporting that the distance of distributed fruits from mother trees normally within 30m if no special condition occur. In the phenological study of Dipterocarps in the Philippines by Tamari & Domingo (1979), the flowering period was from February to May and scarce in August to December. The fruits matured from May to October which coincide with rainy season in Makiling area. This area is rather dry area in the country but the phenological phenomena is similar to that of in the wet area. In whole country, the peak of flowering periods occur with rather wide range as in April at the dry area, May at intermediate area and May or June at wet area, which indicate the two or three months time lag at different sites for the maturation of the fruit. The flowering and fruiting time in the wet or intermediate regions are apt to be longer than the dry area.

In Malaysia, Tamari (1976), who studied phenology of Dipterocarps near Kuala Lumpur found that two flowering peaks occurred every year which coincide with rainy season though there were many variations by sudden storm or drought. Almost all the Dipterocarps shifted from flowering to fruiting in two to five month. But from the figures he drew, it is also possible to estimate that scarceness of rain in February and July seemed to stimulate the flowering two or three months later. Wong (1983), who examined phenology of undergrowth in natural as well as regenerated forest in Pasoh, found the reproductive activities are more active in natural forest but the seasonality is not so clearly found as in the trees of the upper layer.

Besides these references, there are many other publications on phenology throughout the world. In tropical Asia, there are Nicholson (1958), Burgess (1972), Cockburn (1975), Appanah & Chan (1982), Yap (1982) and Ng (1984). There also are many works in tropical America as Janzen (1970, 74), Daubenmire (1972), Frankie et al (1984 b), Gentry (1974), Croat (1975), Opler et al (1976), Opler et al (1980), Borchert (1980, 83), Reich & Borchert (1982), Mueller-Dombois, et al (1981), Fleming et al (1985). In mangrove, Wium-Anderson & Christensen (1978) in Thailand and Gill (1971) in America have reported on phenology. Shimizu (1983) in Japan and Hopkins

(1968) and Malaisse (1974) in Africa also deal with phenology. As a comprehensive issue, Lieth (1974) and Frankie et al (1974 a) are the examples. Concerning reproductive biology, Baker et al (1985) is a good review. Recently Okimori(1987) made a report on the relationship between phenology and diameter growth of the plantation trees in West Java.

After consulting major references, the conclusion is that the seasonality of Dipterocarps is more or less clear but not likely in other groups. Since Dipterocarps is the most important group in Southeast Asian forest, it is quite natural to have so many studies especially focusing on mass flowering. To make clear of the mechanism of mass flowering, whether Ng's hypothesis is true or not, the extensive as well as intensive survey on phenological phenomena with more accurate and localized climatic data must be necessary for the further analysis as Burgess suggested.

The tendency of seasonality in the upper tree layers and aseasonality in the lower strata species is understandable. Koriba said that outer factors as well as inner factors mutualy effect on the seasonality of the trees and the hormonic activities must be great as an inner factor. We don't know how the growth hormone or flower inducing hormone in the tropical trees have been studied but these items are not our concern. What we can do is to study the phenological phenomena as accurately as possible for a long term basis.

Although the Dipterocarps of Brunei has studied by Ashton in the field of taxonomy and ecology, the phenology and other characters of each species are still unknown. Since there are too many species in the tropics, we have to select some of the important species and to find each characteristics which will be important for the further study for silviculture and forest tree breeding.

In this study, major forest types were selected and significant species were chosen to observe the phenology which are Dipterocarps in the Mixed Dipterocarp forest, Alan in Alan Bunga forest and Agathis and Resak Durian in the Kerangas forest. The points which become clear in this study are 1) the Dipterocarps on the dry land differ of their phenological pattern to those on the peat swamp, 2) the Kerangas species show intermediate type and the phenological activities are very poor in the lower trees and 3) generally the lower trees are inactive in the phenological activities.

This is the first step in Brunei to have this kind of study, so a

deeper observation could be expected by the technical staff in Brunei in the future. Even in this preliminary stage, the results here are quite interesting. Especially, it was very fortune for us to encounter the mass flowering of Alan and found the flowering season at the middle of the rainy season which is completely different from dry land Dipterocarps. Anderson also noticed this fact but we don't know whether he saw the mass flowering of Alan. According to a counterpart in Brunei, this was his first experience to see Alan flower during his 28 years service in Forest Department.

The sites chosen for this study were located near to Sungai Liang, except for Alan Bunga forest. It is quite important to continue these observations at least until the phenological cycle of the important species is found.

In the practical procedure of forest tree breeding on the population genetics basis, it is advisable to select better phenotype trees and collect seeds from those better ones. There often occurs many fruits on the unsound trees and since it is convenient to collect seeds from such trees, there are many cases to collect undesirable seeds. Moreover, since the chance to encounter the same species is scarce, we are apt to gather seeds from the trees whatever we encounter. These are the cause of misleading the procedure.

There are considerable trees at least in Agathis and Alan for mother trees. Actually in Agathis, seeds or seedlings have been collecting from Badas stand. In Alan, because of the long span of flowering intervals, the propagation by cuttings are being done in mist box at Sungai Liang. This should be enlarged and improved using seedlings from 1,000 seeds taken by us from Badas, on the occasion of mass flowering. Concerning the Dipterocarps, based on the trees at Arboretum and Compartment 7 and 8, the important species are selected and several trees per species marked to collect seed and scions. As it is obvious that many of the species will have mass fruiting at some intervals, the sufficient space is to be prepared in nursery in advance so that those seeds can be sowed at one time. The trials to prolong seed storage are also to be investigated.

Whitmore (1977) mentioned in the book on Agathis the possibility of forest tree breeding. The wide ecological adaptability, wide range of distribution, high quality timber, to evaluate these characteristics and development of storing seed, vegetative propagation as well as a total

revision of taxonomy and survey of ecotypes are mentioned as future subjects. Smits (1983) tried leaf cutting propagation and Whitmore & Bowen (1983) made growth analysis and reported that the planting in the small gap was successful.

Judging from the Agathis in Badas for the probability of plantation by better clones from superior phenotypes, even the present population is small and far from desirable minimum population as 5,000 individuals as Whitmore suggested, the selection could be done in the population and plantation by better clones or seedlings will have better production. With conducting basic research, the necessary items for the tree breeding also should be practiced side by side.

## III. Micro Diameter Growth in Relation to Phenological Activities

### Introduction

Main functions of the establishment of permanent plots are to carry out routine works at regular intervals to observe the growth, mortality, phenology and regeneration conditions for long term basis. These data are especially scarce in the tropics which makes difficult to estimate growth rate of the tropical trees which have no annual rings. Here, besides the annual growth measurement by diameter tape, the micro diameter growth measurement was conducted by using aluminum band type dendrometer. In this chapter, the relationship of micro diameter growth to the phenological activities are discussed briefly.

### Method of survey

The instrument used here is originally proposed by Liming (1957) named aluminum band type dendrometer which have been widely used in tropical Southeast Asia, United States and Japan. The dendrometer was made in Japan and set at the position of upper part of white paint of 1.3m DBH. After setting, the coil and aluminum band were checked and after the stable fixation was recognized, the regular measurement was started on biweekly intervals at the same occasion of phenological survey.

### Survey sites

The survey sites are the same as phenological survey sites where several major trees were chosen to set the dendrometer.

### Results

#### 1) Arboretum Andulau

The dendrometers were set on 49 trees along the paths in the Arboretum but because of several reasons as unskillful installation, resin exudation, irregular bark or break by small animals and human disturbance, as many as 35 dendrometers could not work properly so that 14 trees showed good results half of which belong to Dipterocarps within which Meranti sarang punai bukit grow best as shown in Fig. 10. This tree is 19.3cm DBH and 17m high with 12.5m of the height to the lowest living branch. As indicated in the figure, the growth rate is more or less constant from September 1984 to February 1985. There is no growth in March, and again

gentle growth curve is seen and rapid growth is found in September, and again gentle curve start from October to March 1986, and at the latter half on March, the growth become faster again. Compared this figure to the phenological evidences, there is a period of non-activity in between frequent flushing as in August to November 1985 which means the species is categorized to intermittent growth type. The rapid growth in September 1985 and March 1986 may be coincide with pause period of new bud or leaf flushing.

In three Meranti kawang tikus, of which diameter are 13.4, 21.6 and 31.2cm all of which belong to the middle layer in the vertical stratification, total growth is not so large and No.200 and 8 show similar pattern of seasonal activity and there is a tendency that the growth is slightly larger during non-flushing period. In No.46, the tendency is not so vivid and frequency of flushing is high and in September 1985 or January to March 1986, the growth is rather rapid. (Fig. 11)

Kapur bukit shows evergrowing type so that the relationships between phenological activities are not so clear but at the small pausing period in May 1985, the growth rate looks high. Although Binchaloi (No.31) have only half data because of the break of coil, it shows the rapid growth after the development of leaves. But even there is a pause period in February to April in 1985, the growth is very slow. The growth of Sepetir (No.40) is rather slow on the flowering and fruiting occasion and the growth from July to September 1985 seems rather fast. (Fig. 12)

As a results concerning Dipterocarpaceae, it is not always the case, but bud, leaf flushing and flowering are active when diameter growth is small.

In non-Dipterocarp species, the diameter growth of Terap (No.81) is small at the time of flowering and fruiting but during the leaf pausing period in October 1984 or May 1985, the growth is rather high. In Medang (No.125), the good growth is observed during the non-active period of leaf in October 1985 on. There are two trees of Garu of which growth tends to be fast during non-active period. Rengas (No.210) is not so conspicuous but similar trend is observed. Bintangor (No.35) shows very clear new bud and leaf period and the growth is rapid at non-active period, too. The same tendency is found in Kempass. As conclusion, the same tendency as shown in Dipterocarps can also be recognized in non-Dipterocarps. (Fig. 13)

2) Compartment 7, Andulau Forest Reserve

The dendrometers were set on 40 trees in this plot but because of the same reason as in Arboretum, fourteen of them were spoiled. Consequently the good results obtained from five trees in Dipterocarps and 21 trees of non-Dipterocarps.

In Dipterocarps, Damar laut merah (No.2) grow fast at the non active period of flushing or leafing. Keruing mempelas (No.16) showed evergrowing type with rather high growth rate at the rest period of leafing but this is not so clear. Meranti paya (No.107) indicated the distinguished diameter growth at non new leafing period in January to April 1985 and March 1986. There were two trees of Meranti Kawan tikus which repeated leaf flushing frequently indicated the rapid diameter growth at the rest period of leafing. Therefore the same tendency as found in Arboretum was detected here. (Fig. 14)

Checking the relationship between diameter growth and phenological activities in 21 trees of non-Dipterocarp species, the results can be summarized as follows. (Fig. 15)

(1) Species which flowered and bore fruits during the survey period and displayed lower growth rate at the active period of flushing, flowering and fruiting and reversely exhibited good diameter growth at rest period.

Mempening (No.38, 15.9 cm DBH) (i.) intermittent type
Bintangor (No.55, 32.4 cm DBH) i.
Geronggan (No.10, 10.5 cm DBH) i.

(2) Species which flowered and bore fruits during the survey period but showed not so conspicuous a relationship with diameter growth

Pendarahan (No.73, 14.6 cm DBH) i.
" (No.116, 28.3 cm DBH) i.

(3) Species which exhibit good diameter growth at the rest period of flowering and leafing and not so on the active phenological period

Bangkoh (No.79, 17.1 cm DBH) c. (Evergrowing type)
Pulai (No.25, 15.9 cm DBH) i.
Kedondong (No.95, 15.8 cm DBH) i.

(4) Species of which relationships between phenological periodicity and diameter growth was not so conspicuous but the high growth rate could be seen at the certain time of resting period.

| | | | |
|---|---|---|---|
| Kempas | (No.85, 11.7 cm DBH) | d. | (Deciduous type) |
| Medang berunuk | (No.11, 12.6 cm DBH) | e. | |
| " " | (No.61, 12.6 cm DBH) | e. | |
| Bintangor | (No.104, 12.1 cm DBH) | i. | |
| Merpisang | (No.67, 24.4 cm DBH) | i. | |

(5) Species which have no relationship between leaf activities and diameter growth

| | | |
|---|---|---|
| Sireh sireh | (No.118, 15.9 cm DBH) | i. |
| Kembang semangkok | (No.41, 29.5 cm DBH) | i. |
| Pulai | (No.63, 16.0 cm DBH) | i. |
| Kedondong | (No.97, 12.4 cm DBH) | i. |
| Medang berunuk | (No.1, 16.1 cm DBH) | e. |
| Geronggang | (No.77, 12.2 cm DBH) | e. + i. |
| " | (No.78, 16.5 cm DBH) | e. + i. |
| " | (No.60, 13.7 cm DBH) | e. + i. |

Consequently there are several variations in the correlation of phenological activities and diameter growth so that the similar conclusion, as found in Dipterocarps, cannot be expected in non-Dipterocarps.

**3) Agathis Forest in Badas Kerangas Forest**

Although all Agathis trees in 50m x 50m plot with several other trees were set dendrometer, the diameter growth here is very small in this plot. This is supposed to be 1) ill fitting of dendrometer, 2) resin exudation, 3) real slow growth rate, each of which reason should be checked in the future but most probably the second and the last reasons are the most likely. In Agathis, examining the good growth trees of No.24, 29, 118 and 124, the similar correlation found in Dipterocarps in the Mixed Dipterocarp forest in Arboretum and Compartment 7 could not exhibited in this species. The diameter growth showed the same pattern in all trees and the phenological activities are very similar, but the relationships are quite different as the diameter growth was small at resting period. This tendency is generally found in other small Agathis trees. Namely, the diameter growth increase from August 1984 to February 1985 and the growth rate become slow after that up to August 1985 and again the growth speed become bigger continuing to April 1986. To consider this pattern, it is possible to interpret that the growth of Agathis come to slow at the low

precipitation period and the growth is promoted by flushing or leaf development at the rainy season. (Fig. 16)

Besides Agathis, Resak durian exhibited the most conspicuous flowering and fruiting activities, but there is no relation with this to diameter growth, but rather the growth is faster at the rainy period like in Agathis. The same tendency is found in Ubah (No.28) or Mang (No.35), although those growth is rather small and not so conspicuous. (Fig. 17)

**4) Alan Bunga**

The dendrometers were set on 12 trees of Alan and non Alan each and 9 of them each run well. In Alan, the tree No.8 showed the decrease in diameter increment at the leaf flushing period and sometimes even exhibited minus growth. The same trend was observed at the flowering and fruiting periods and after falling of fruits, the diameter growth increased. These phenomena was seen clearly only in this individual, but although not so vividly apparent, the similar tendency is seen in other trees. (Fig. 18)

In non-Alan species, Mempening and Ubah indicated the similar trend but the relationships with phenology is not so clear. Anyway, all the trees exhibited identical pattern and the diameter growth is larger at the less rainy season. (Fig. 19)

## Discussion

As mentioned above, there are several important matters to be discussed here, i.e., 1) the quality of dendrometer, 2) the relationship between phenological activities and diameter increment in the Dipterocarp species in the Mixed Dipterocarp forest and the character of non-Dipterocarp species, 3) the increment of diameter growth and leaf elongation in Agathis forest during rainy season, and 4) the better growth in the less rainy season in Alan forest.

**1) The quality of dendrometer**

The aluminum band type dendrometer used in this survey is originated in USA and now widely used by Japanese scientists in Japan and Southeast Asia. In the case of Sumatra and Bogor, all the attached instrument work in good condition except when small mammals disturb them. While in this survey, there are considerable cases which tape could not run properly. This is mainly because of the damage by small animals and human beings in

the case of Arboretum. Unskillful setting of coils especially in the small trees by the thinner aluminum is also the cause. Concerning to the large trees, the connected aluminum band tape works smoothly. The reason of many unworked tapes in Agathis was because of the exudation of resin when the bark surface was cut by knife and the tape was stuck to the bark. In the mixed Dipterocarp forest or in Alan bunga forest, there were several cases that the root of the climbers caught the aluminum tape. This happened when the thinner aluminum was used. The root elongation of epiphytic species are unexpectedly fast and resin exudation could be seen in many trees besides Agathis. We should be very careful the setting of this instrument so as not to cut the surface bark too much.

**2) The seasonality and growth of Dipterocarps and non-Dipterocarps**

The relationship between phenology and diameter increment has shown clear correlation as rapid growth at the pausing period of bud or leaf activities in the Dipterocarp trees. The similar trend is observed in some of the non-Dipterocarp trees while in other non-Dipterocarp, these trends could not be observed. The general feature of Dipterocarps which repeat mass flowering and fruiting at several years intervals may be a point of discussion. That is to say, the energy of flower initiation or leaf flushing may be enormous especially at the mass flowering of this group. The transfer of photosynthetic energy to the increment of diameter may also be large. The growth pattern is mainly intermittent type and at the instant of leafing activities, the photosynthetic substances may be transferred. This kind of inner movement must be similar in this group.

On the other hand in non-Dipterocarps, such characters could not be expected. This is mainly because that non-Dipterocarps are the mass of variety of species belonging to many families and their habitat as well as characters differ much. Therefore the result obtained here should be checked again by family basis. Important matter is the very homogeneous character of Dipterocarps.

**3) The good diameter growth in rainy season at Agathis**

The characteristics shown in Agathis which have a good growth rate at rainy season and also have a good leaf flushing may be considered from its habitat condition. The Kerangas forest Agathis growing is one of the peculiar type of forest which exhibit xeric type where the white sandy

podozol spread and the physiognomy looks so xeric that the rainfall is the limiting factor for the growth of trees. The period of low rainfall naturally limit the tree growth and production in any aspects. On the other hand, the vigorous leaf flushing occur in the rainy season and consequently the diameter growth is also stimulated at almost the same occasion. Inner mechanism may be different from that of Dipterocarps. The coniferous Agathis and broadleved Dipterocarps may have some different pattern in transferring the photosynthetic substances.

**4) Relationships of diameter growth with activities of leaf flushing, flowering and fruiting in Alan bunga forest**

The same pattern as in Dipterocarps in the Mixed Dipterocarp forest can be observed in Alan that the diameter growth decrease at the active period of leaf flushing, flowering and fruiting. The importance is that the diameter growth rate is fast at the time of small rain of which pattern is completely reverse to Agathis. The explanation of this phenomena may be possible to say that the Alan forest is always under the water saturated condition and the growth rate maintained at low level.

During a rather dry spell, the water saturated condition is relieved and the water condition become favorable for the tree growth, and the growth rate increases. Although this interpretation is only concerned the water regime, the pattern can be summarized tentatively as follows.

1) Optimal water condition --- Mixed Dipterocarp forest
   Upper layer and intermittent growth
      Clear tendency of low diameter growth at the active period of phenology --- Dipterocarps
   Middle to lower layer and evergrowing to intermittent growth type
      The relationships of diameter growth and phenological activities is not so clear --- non-Dipterocarps
2) Xeric condition --- Agathis
   Good diameter increment with the supply of water coincide with the phenological activities
3) Water saturated condition --- Alan
   Good growth in dry season because of the better preferable water condition

In the literature of phenology, Wong (1983) mentioned a seasonality of the trees in the lower strata which differs to the Dipterocarps in the upper strata. This seems, however, quite reasonable because the tree in the upper strata may have a very adaptive character to the climatic change while the lower strata tree which grow under the stable climatic condition are not so effected by the climatic change.

Now, I want to think over what kind of trees can be a upper most layer trees, based on the data of phenology and dendrometer conducted in this survey.

First of all we think about the growth type proposed by Koriba, who analyzed the deciduous trees in the tropics. The deciduous tree shed leaves to spend the dry season or winter season, while evergreen tree do not. In the tropics there seemed no such a severe climatic condition for the growth but this is not always true because there is a sudden decrease of temperature after storm which promote flowering or leaf falling in some case and the long sunny days after rain also effect considerably to the phenological activities. It is of course evergreen trees that are dominant in the tropics, but the existence of rather large amounts of deciduous trees means the sensitive tree species are abundant. These react to slight changes of climate under the stable tropical climates.

In regards to the growth type, the evergrowing and intermittent types can be distinguished in a broad sense. The former type has no pausing period whatever happens and the latter type has some resting period at certain intervals. The problem of which type has advantage is difficult to say according to the situation. But at least for the pioneer species, the evergrowing type seems advantageous to cover the ground quickly. These pioneers develop a very large fast cycling leaves to the certain size and seize the growth. In other cases, in the gaps of virgin forest, these evergrowing type can grow very rapid from the forest floor to the canopy to be a emergent tree. Of course it is up to the speed of growth whether the tree can grow to the top layer, so even the intermittent type if it is very fast growing, it can be a top group.

Now the character of intermittent type is to have a pausing period. Since the elongation of shoot seize for a certain time, the energy will be transferred to the other part of the organ, i.e., to the increment of diameter or to be reserved for the next leaf flushing or flowering, which means intermittent type has better preparation for the various potential

change of surrounding condition. That is to say, the intermittent type is superior to the evergrowing type in the sense of various tolerance.

Next, the conditions to become dominant in the forest should be considered. There may be several approaches but here I would like to raise the mass propagation at one time. The mass flowering in Dipterocarps has already been repeatedly mentioned and this characteristics must have dominant role in the lowland forest. The mass flowering means all the twigs bear flowers at almost one time and the process from flowering to fruiting run smoothly and the fertilized seeds can be spread widely on the ground and the seedlings can grow normally on the forest floor. To make this process successful, the large amount of propagative factors have advantage over than the smaller amount. Then, what is the relationships between mass flowering and growth type?

Most probably the evergrowing type may have frequent flowering and fruiting by elongation of new shoots timelessly, on the other hand, the intermittent type may have more character to be able to have mass flowering by reserving the energy for it. If it is true, this type can be a predominant oriented species. In the series of investigation by Koriba, *Dryobalanops* is the only evergrowing type in the Dipterocarpaceae I am sure that if only the dominant trees are checked, there must be much abundant intermittent types in the upper layer of the forest. Besides that, hormones are an important point. But we will not expand further in this matter.

The next important point is the size of the tree. How big the tree can grow on the same physical condition is the point. The absolute size and proportional speed of growth become important. Even in Dipterocarps, if it is not so large, this group could not be dominant in the forest. The growth speed from seedling to sapling and to matured tree is very important but unfortunately there have been no data so far to follow all these growing stages. But certainly there should be a wide range of differences of the growth speed and this speed is the key factor to it becoming dominant. Therefore, the growth stage from seedling to sapling is the second barrier. The dominancy is obtained by surviving under the critical site condition with severe competition with surrounding trees or allelopathy. After surviving these condition and continuing vigorous photosynthesis and repeat mass flowering are the conditions for the dominant species.

As mentioned in Koriba, all the trees must be an evergrowing type

originally and after thorough various physical conditions, the composition become such as we can see now in the tropics.

Besides these elements, the degree of tolerance to the dry and wet condition is important. In the relationship of rain and phenological activities in Alan and Agathis, we can see that these two species have the best tolerant character to those site condition, nevertheless those conditions are the limiting factor for their growth and once these conditions released, the activity of tree become more vigorous. Mixed Dipterocarp forest may be categorized in between these two extreme conditions.

Species number is another issue. The larger the limiting factor become, the smaller the species number become. If the species become scarce, the most vigorous species of which degree of tolerance is much bigger than others become much dominant. Alan in the peat swamp is a typical example. Alan has a characteristic of mass flowering at a long interval and the growth is rapid so that the crown is emergent from the canopy of other species. Moreover it has large buttress and its stretching root system which spread fine absorbing roots to wide area, and has two layers root stratification which contribute to support the dominant characteristics. The long penetrating root sometimes reach to the soil layer. In addition to these factors, Furukawa stated, the level of tide is not so large that the water logged condition is always prevailing. In such a condition the species like Alan which have large buttress has advantage. Of course the physical strength to support large trunk by buttress is important.

In Agathis, there is not such distinguishing characteristics, but the good regeneration of Agathis seemed to spread its occupancy little by little in the Kerangas forest and retrogress other species. The chemical components of Agathis may have allelopathy effects to the coexisting species. The thick root mat found only in Agathis may have a similar function for the dominancy of Agathis.

## IV. Line Planting

### Introduction

There are some small scale line planting trials in Brunei from 1970'. Although these trials are still in the experimental stage, line planting is important for the future reforestation. The primary survey was conducted to check the growth and survivorship of the trees planted.

### Survey site

The survey was conducted at Bt.Kukub, located in the northeast corner of Andulau forest reserve where Kapur bukit was planted. This is a part of shifting cultivation area on the ridge of yellow podozolic soil and frequent fire may have occurred in the past surroundings of this area where *Macaranga* and *Rantana* are dominant in the secondary forest. The altitude is 100m above sea level and the trial plantation by NPP is also carried out nearby stand. The planting site is originally a Mixed Dipterocarp forest stretching from Sungai Liang area. The site is frequently used as military practice.

### Planting methods

The species planted is Kapur bukit and the planting was carried out from December 1973 through February 1974. The line were set at 7.2m intervals along the bordering road on the ridge at the southern slope with 1.5m width into the forest reserve for several ten meters. The seedlings were planted at 3.6m intervals. A handful of synthetic chemical fertilizer was added at the time of planting. The seedlings were originally from the seeds of the mother trees in the virgin forest and cultivated in the nursery at Sungai Liang. The weeding and regular tending were carried out and the large trees were poison girdled. By the observation on March 1983, there was a tree of Kapur bukit of 60cm DBH and 30m high nearby line planting site covering the upper part of the planting tree crown. At the time of planting, it is said that the large remaining trees were killed by poison girdling and the useful timber trees were remained. Burning off is not used for the land preparation.

In 1983, the number plates were lost and white paint around DBH point was also vanished. The topography is very irregular with very steep ascents and descents and on entry, the coverage of surrounding original

trees become larger and the size of planting trees become smaller. The damage by termite is severe and the trees damaged by the falling of surrounding trees were also abundant.

## Survey method

The survey was carried out on 20 lines first in 1983 and it was added to 49 lines from 1984 on. The diameter at breast height(DBH), height and height to the lowest living branch were measured. DBH was measured annually by caliper or diameter tape and the both height were measured biannuary by the height measuring pole. The trees were numbered and the measuring point of DBH was marked by white paint.

## Results and Discussion

### 1) Survivorship

The year of 1983 is just ten years after planting. In 20 lines, the dead trees during the time were 136 trees out of 385. The survivorship is 64.7%. It appears that the mortality just after the planting might be great. In line 21 to 49, the survivorship deteriorated to 45%. But after 1983 on, the mortality is not so high and the survivorship is always more than 93% and this trend become improved with the years. The variation of survivorship between lines are great as 30.3% at the worst to 93.8% at the best. The reason of death in the first ten years are unknown but, after ten years, the most cases are death by termites. This damage occurred frequently at the trees under the coverage of other original large trees where the forest floor is dark and the growth of planting tree is extremely bad and damaged by the fallen branches of the upper trees. The termites attack through such damaged portion of trunks or branches.

### 2) Diameter growth

The diameter growth at the first 20 lines is 4.2cm in 10 years on an average and the growth afterward is not so good either. The value of total 49 lines is still worth as 3.3cm in 11 years and 1cm growth was attained in the recent two years. On the line basis, the largest growth is 7.0cm in ten years and there are several trees which grow almost 10cm in ten years. The worst growth was 1cm only in ten years. These data include all the trees even the regenerating ones, so if we discount these spoiled tree, the average value become better, but even though so, the growth is so small.

3) Height growth

The height growth for the first ten years in the 20 lines is 4.77m on an average and large growth can be seen after that which attained to 7.3m. The average height growth in 49 lines is 5.7m in 1985 which is smaller than the average value of 20 lines. (Table 14)

The data obtained here is by no means very bad results. Survivorship, diameter growth and height growth were all very poor. We have to think over the reason of these results.

First of all, the site condition should be considered. The location near the ridge covered by yellow podozolic soil is not so suited for the plantation of Kapur bukit. The tending of the surrounding trees is the second problem. As already mentioned, trees at the portion of no covering trees have good growth compared with the trees under the dense canopy. If the condition is good, diameter growth will be expected to be 10cm in 10 years with 10m height. Next problem is the origin of seed. The seed should be carefully collected from the good phenotype trees and even in such a good phenotype, there would be a inferior seed which is caused by self mating. These studies should be carried out at the state of nursery work.

In summary, silviculture is a practical procedure based on the total understanding of ecology and genetics. Unfortunately there are scarce examples in the tropics where the sound silvicultural system were established. For the better establishment of line planting, the following series of study will be necessary.

1) Phenological study of the major species in the typical forest types.
   (This survey have been conducted for two years and this should be continued for at least 10 years so that the phenological characteristics of each species can be obtained.)
2) Seed production and seed characteristic study of the major tree species.
   (On the occasion of the phenological survey, the seed from the fruiting trees are to be collected and the productivity of seed on the individual tree basis and germination rate and fertility are to be checked.)
3) Storage of seed.

(The viability of seed in tropical area is so short that large scale plantation by native seedlings are sometimes hard to practice. The storage of seed changing the atmospheric conditions and treatment are essential.)

4) Nursery experiment.

(Seedling morphology, abnormal seedling, growth rate under different light and density condition are important. After these comprehensive study, the line planting planning should be laid out.)

5) The ecological studies of the planting site, including topography, soil and vegetation to see the suitable species to be planted.

6) Design of line planting.

(The interval of lines, density of planting, weeding and poison girdling standard for the surrounding trees)

7) Routine survey of growth and pest.

These subjects are better to be conducted at the different site with small scale before the large scale plantation start.

## V. Seedling Survey

### Introduction

The population dynamics of the seedlings in the forest is a essential work besides of productivity, floristic composition, structure and phenology. There have been many studies in the temperate zone in these ten years, but it is few in the tropics. Series of work by Ng and Becker(1982) are the main contributions. In Borneo, few study was done in Kalimantan and new project will start in Sabah.

The purpose of this survey is how the seedling grow on the forest floor and how the regeneration is maintained in the natural forest. This survey need sufficient time and the data are still on the process of collecting. Only the methods and study sites are mentioned briefly.

### Survey methods

All the survey were conducted by setting several 1m x 1m quadrats on the forest floor and all the seedlings appeared in the quadrat were numbered and diameter at ground level, height and number of leaves were counted. The number of quadrats are 4 to 23 according to the population size and the routine measurement was conducted every two to three month.

### Survey site

1) **Damar hitam timbul**

There is a spot where the seedlings of this species are abundant just before the permanent plot in Compartment 7. The survey was started on July 1984. Twenty three quadrats were set at four direction of one mother tree and another five quadrats were set on the most dense portion under two mother trees. The survey was conducted in April, July, October 1985 and January and June 1986.

2) **Damar hitam bukit**

Abundant seedlings were found at 1 km inside from 1 ha. plot of Compartment 7. Eight quadrats were set and the survey was carried out on May, August 1985 and February 1986.

3) **Tismantok**

At the same site as in 2), seven quadrats were set in the dense seedling of this species. The survey was conducted in April, July, October 1985 and February 1986.

4) **Kapur bukit**

At nearly the same portion as in 3), the large amount of seedlings were seen under two mother trees. The number of quadrat is eight and the measurement was done in May, July 1985 and February 1986.

5) **Kapur paya**

In Anduki Forest Reserve, the mass flowering and fruiting occurred in March 1986. The fallen fruits were numbered and the seedlings in 25 quadrats are under investigation.

6) **Alan batu**

In Alan batu forest in Badas, the seedling after the gregarious flowering and fruiting have been studying in five quadrats.

7) **Agathis**

In Agathis plot in Badas, seedlings in 25 quadrats have been studying on routine basis.

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# Figure & Table

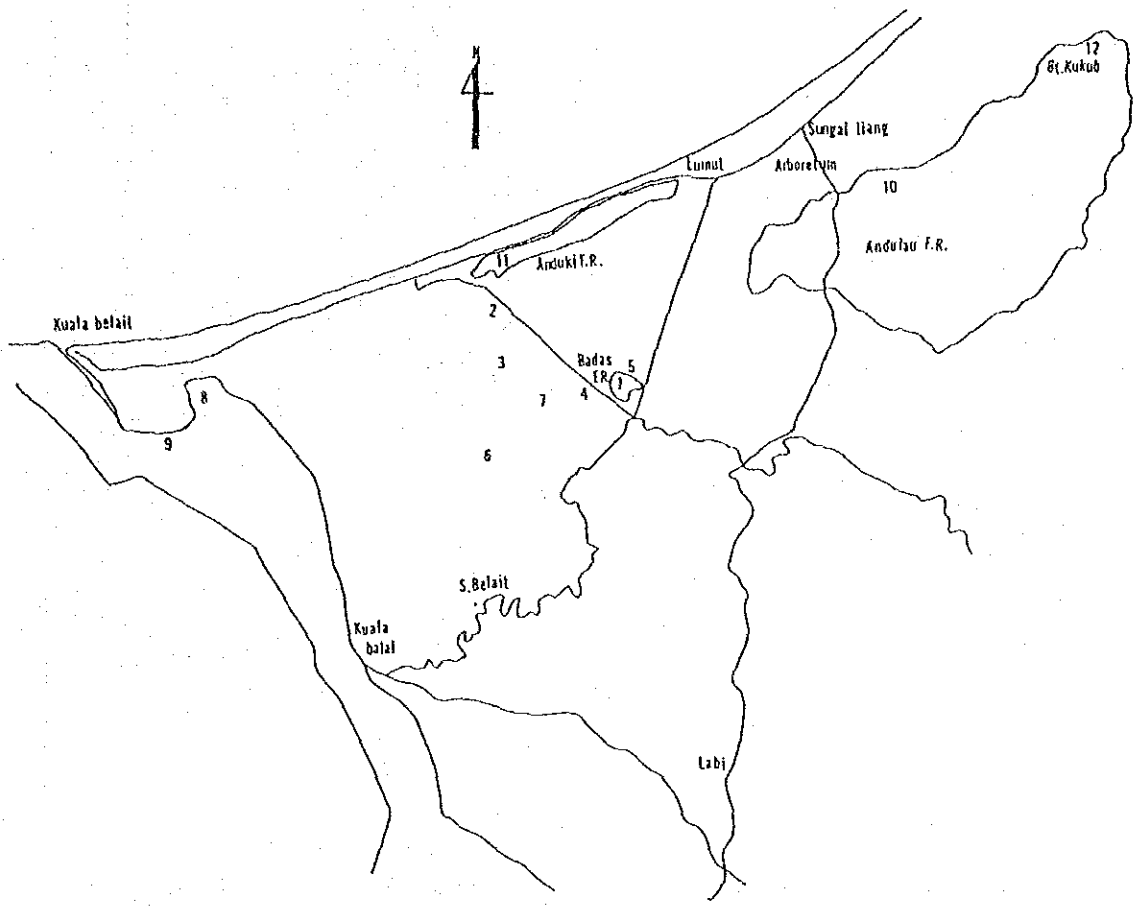


Fig.1 Map showing the location of permanent plots and line planting site.

1 Agathis, 2 Alan batu, 3 Alan bunga, 4 Padang alan, 5 Padang forest (Mixed species), 6 Alan padang, 7 Ulat bulu, 8 Mixed peat swamp (1), 9 Mixed peat swamp (2), 10 Mixed diperocarp, 11 Kapur paya, 12 Bukit Kukub line planting site.

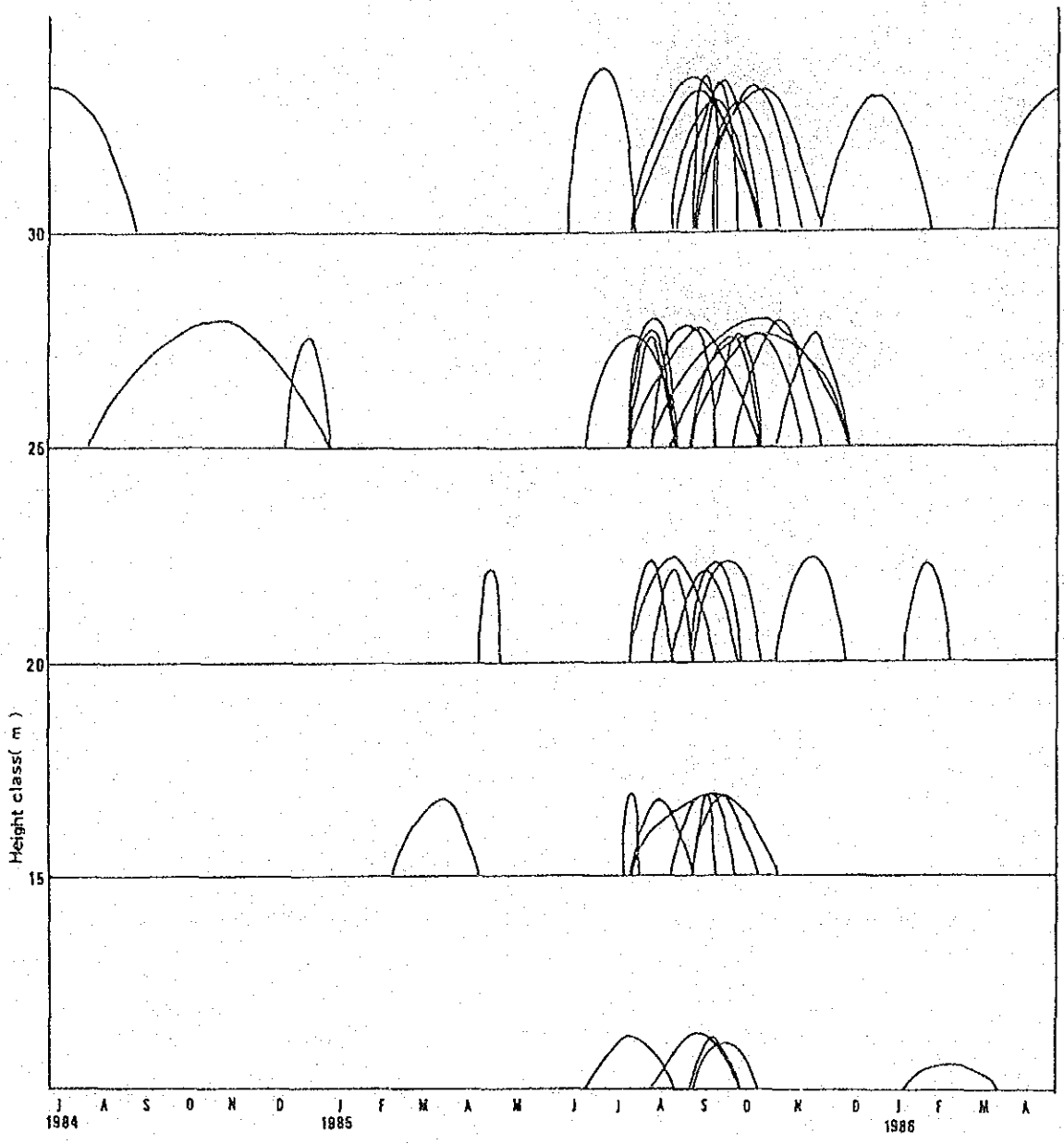


Fig.2 Trees once flowered during the survey period in Arboretum Andulau, divided into five height classes.

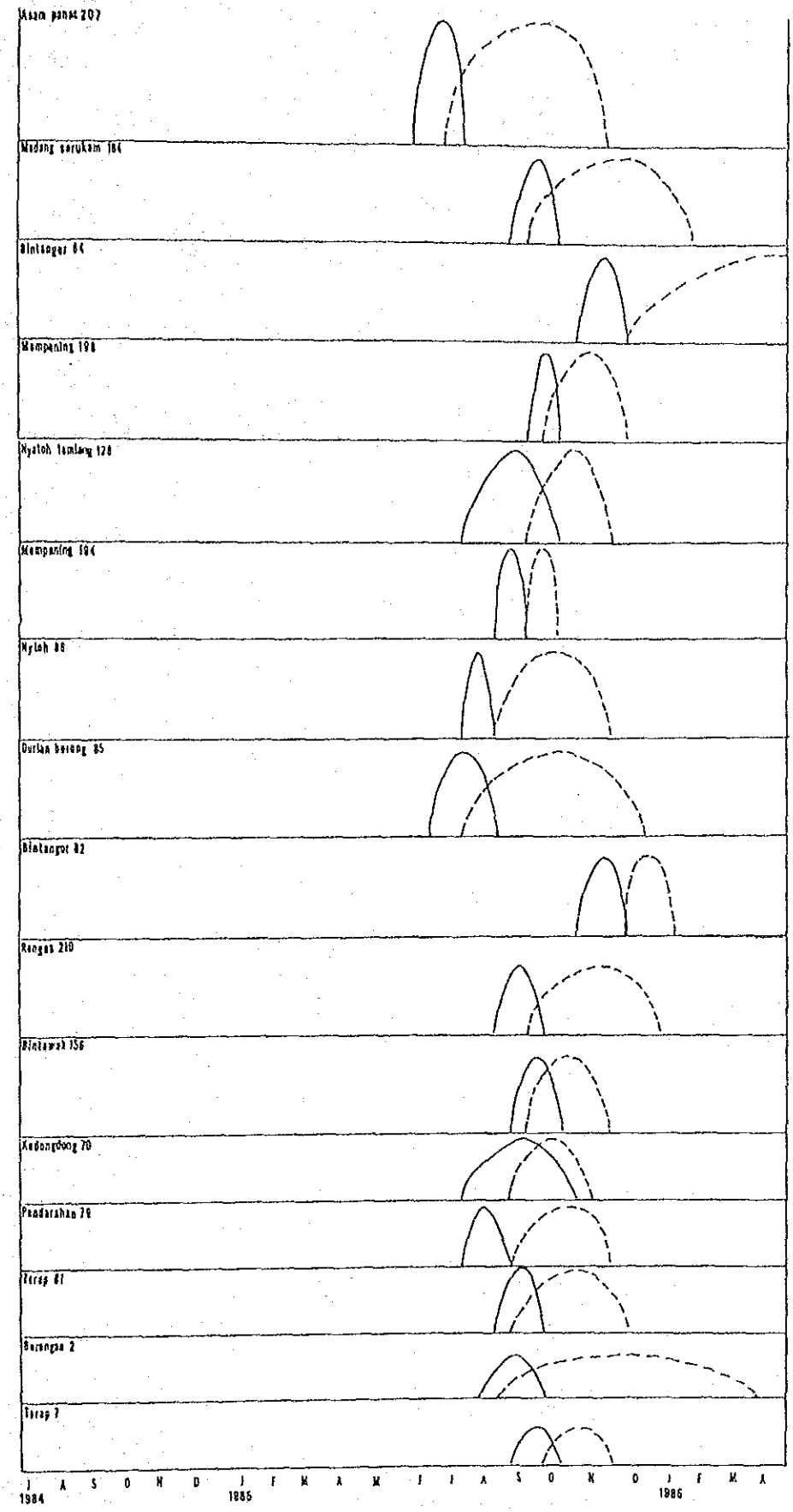


Fig.3 Relationship of flowering and fruiting intervals of trees in Arboretum Andulau. Solid line: flowering, Dotted line: fruiting.

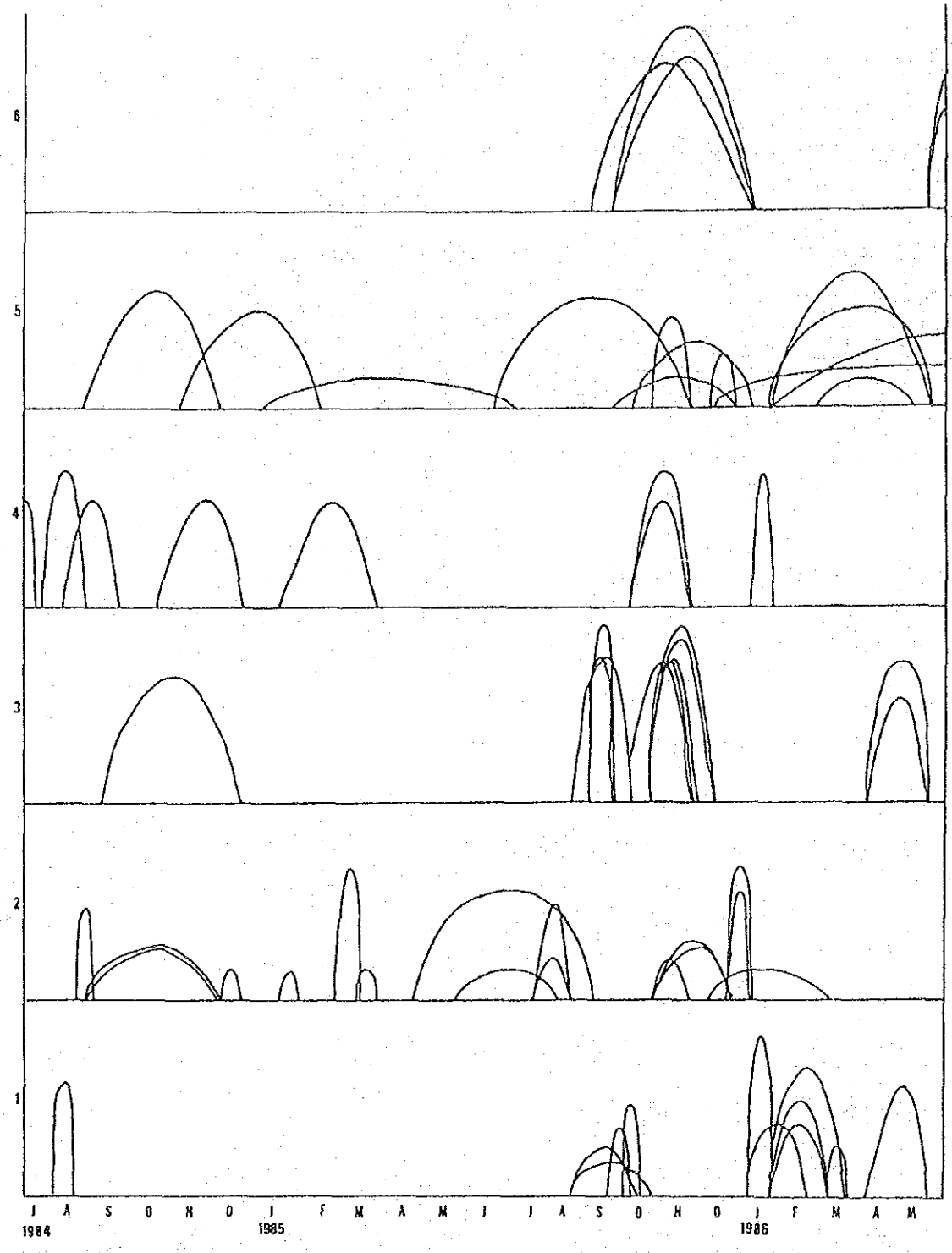


Fig.4 Phenological activities of the trees in Compartment 7, Andulau Forest Reserve. 1) Non-dipterocarps only trees flowered once during the survey period are shown. 2) Non-dipterocarps only trees flowered twice and thrice, 3) Dipterocarps only trees flowered once, 4) Dipterocarps only trees flowered more than twice, 5) Non-dipterocarps fruited once and twice, 6) Dipterocarps fruited.

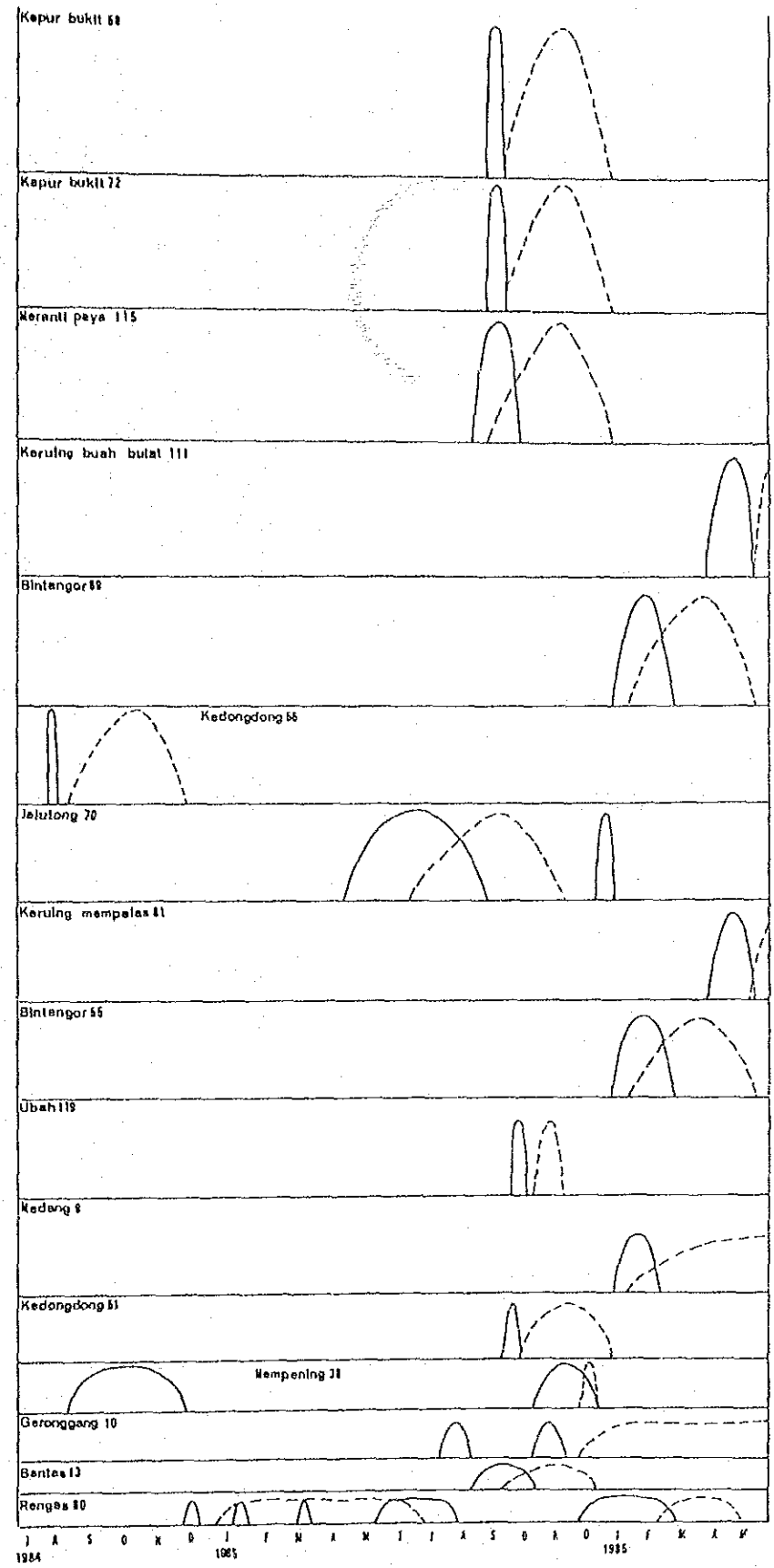


Fig.5 Relationship of the flowering and fruiting intervals of the trees in Compartment 7, Andulau Forest Reserve.
Solid line: flowering, Dotted line: fruiting

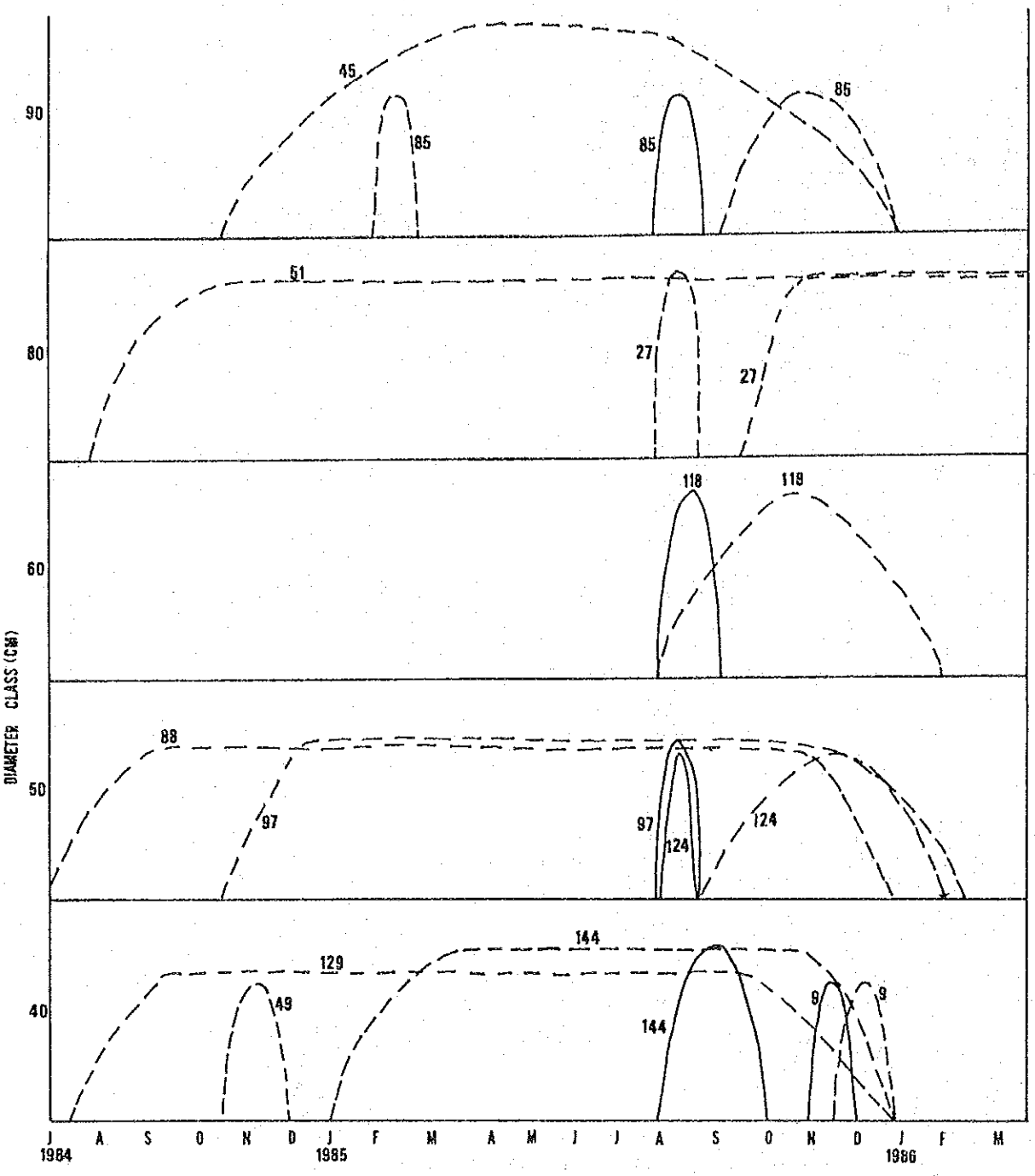


Fig.6 Phenological activities of Agathis trees in Agathis plot, divided into diameter class. Solid line: male cone, Dotted line: female cone

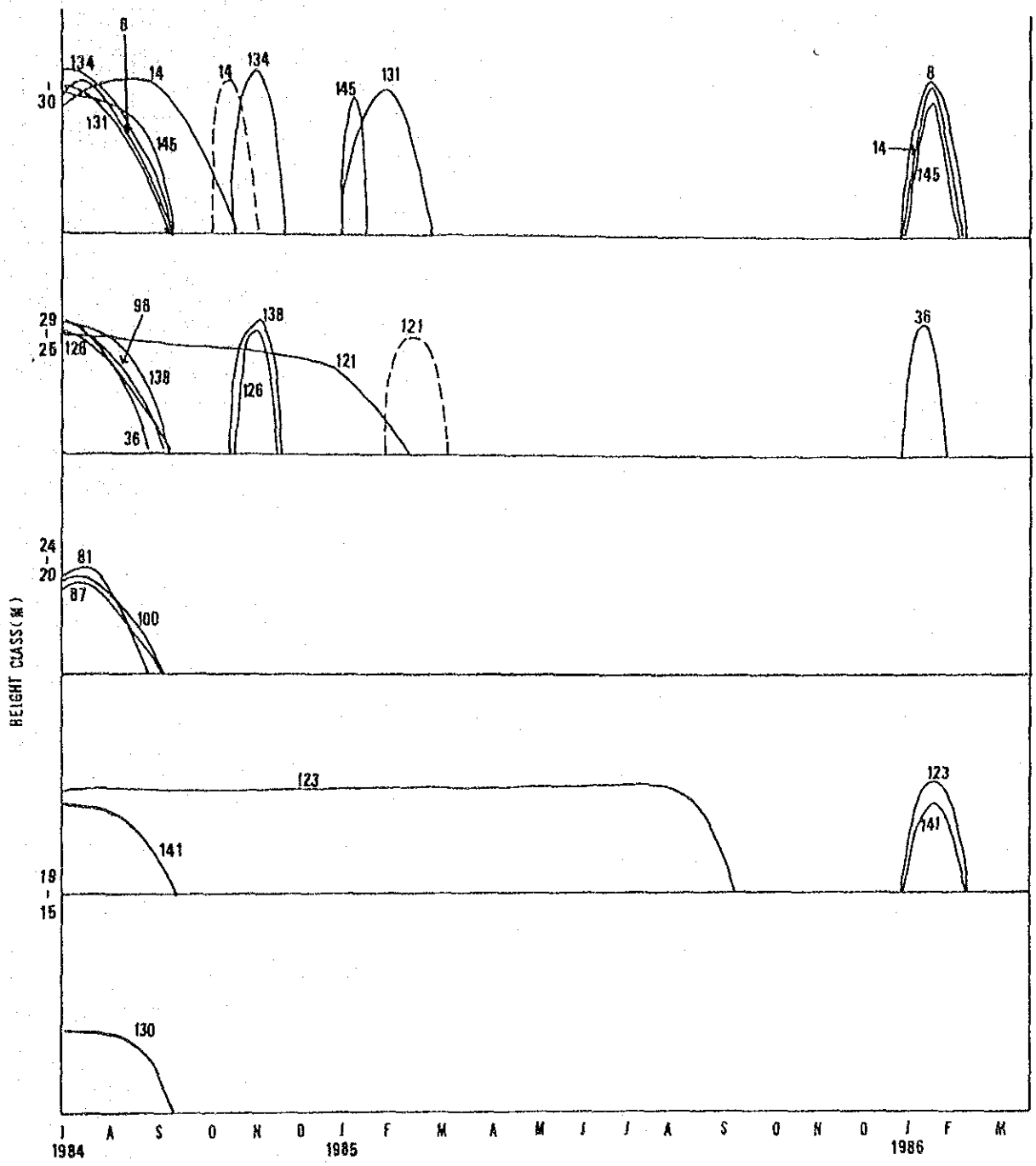


Fig.7 Phenological activities of Resak durian in Agathis plot, divided into height class.

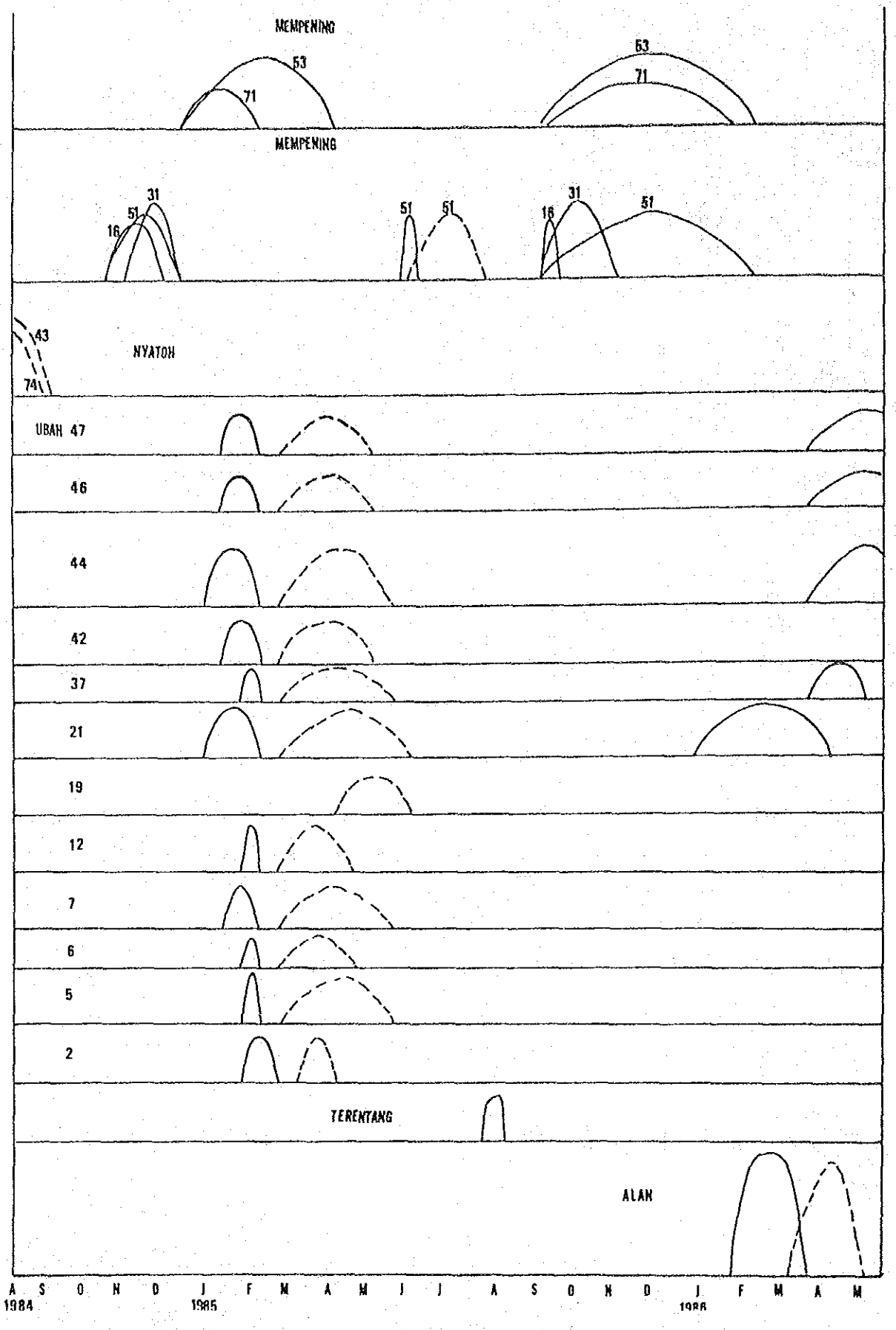


Fig.8 Phenological activities of the trees in Alan bunga forest. Solid line: flowering, Dotted line: fruiting

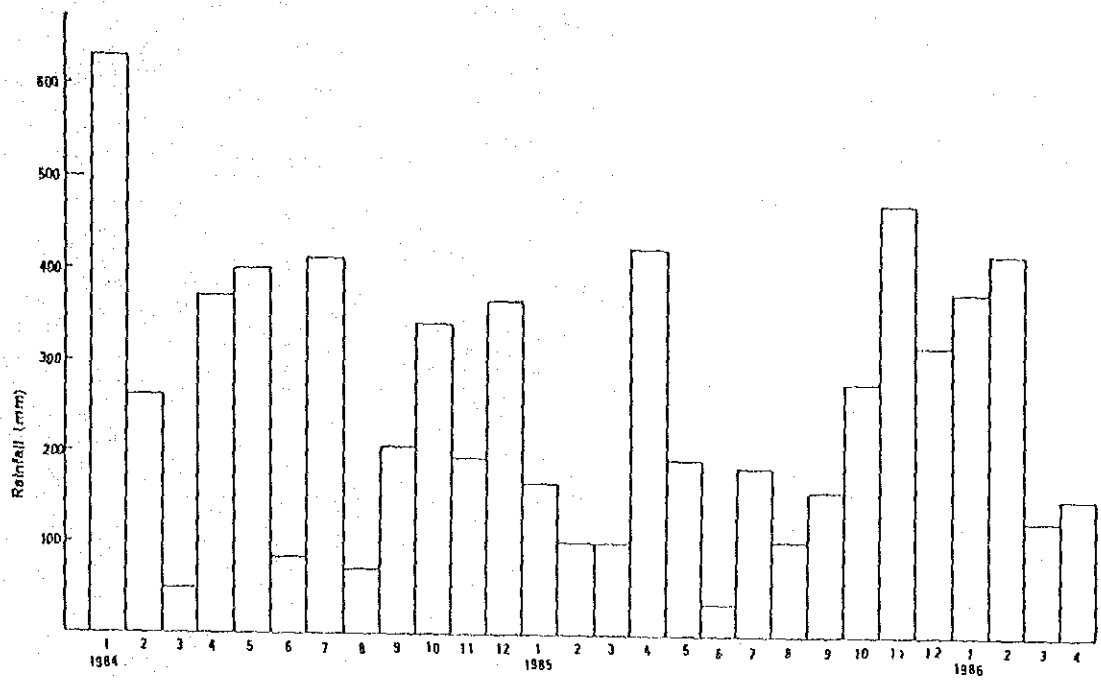


Fig.9 Rainfall at Sungai Liang from January 1984 to April 1986.

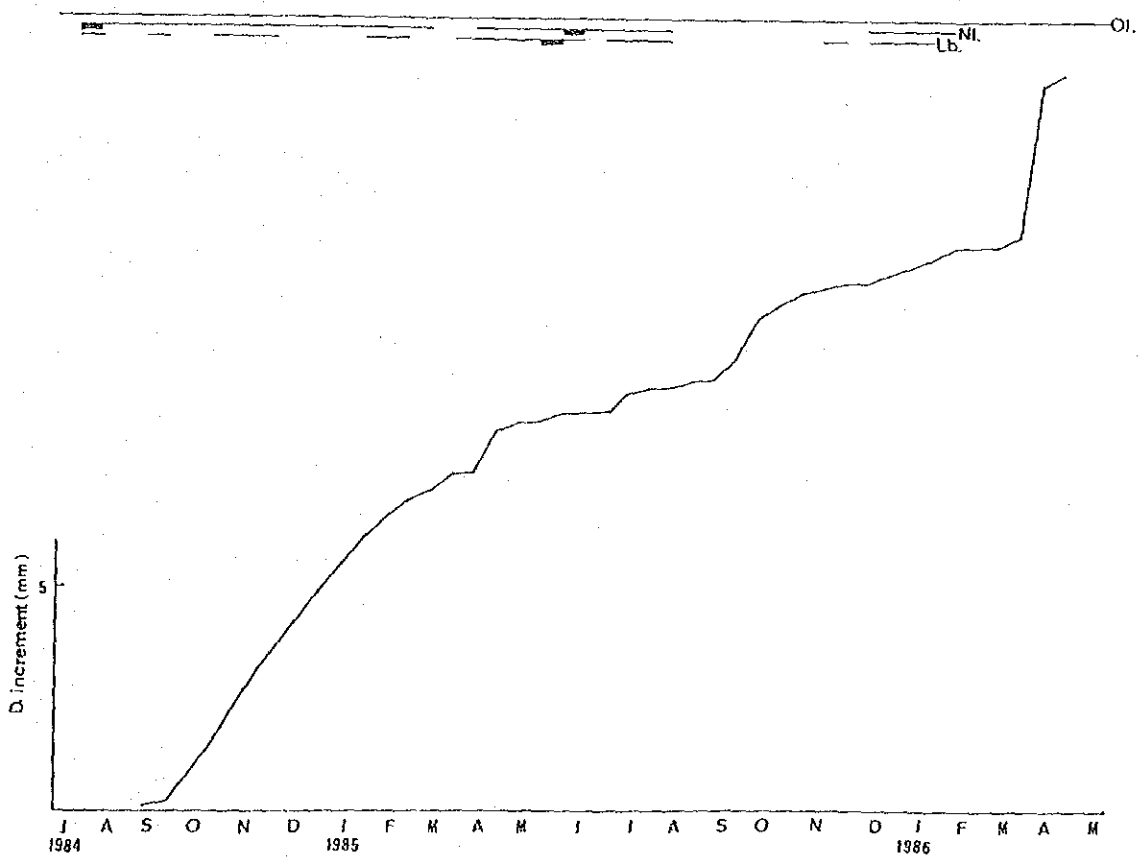


Fig.10 Relationship of micro diameter growth and phenological activities of Meranti sarang punai in Arboretum Andulau. Abbreviations for Fig.10-18 are: Lb: Leaf bud, Nl: New leaves, Ol: Old leaves, Fl: Flowering, Fr: Fruiting. Bold line means weeks of abundance.

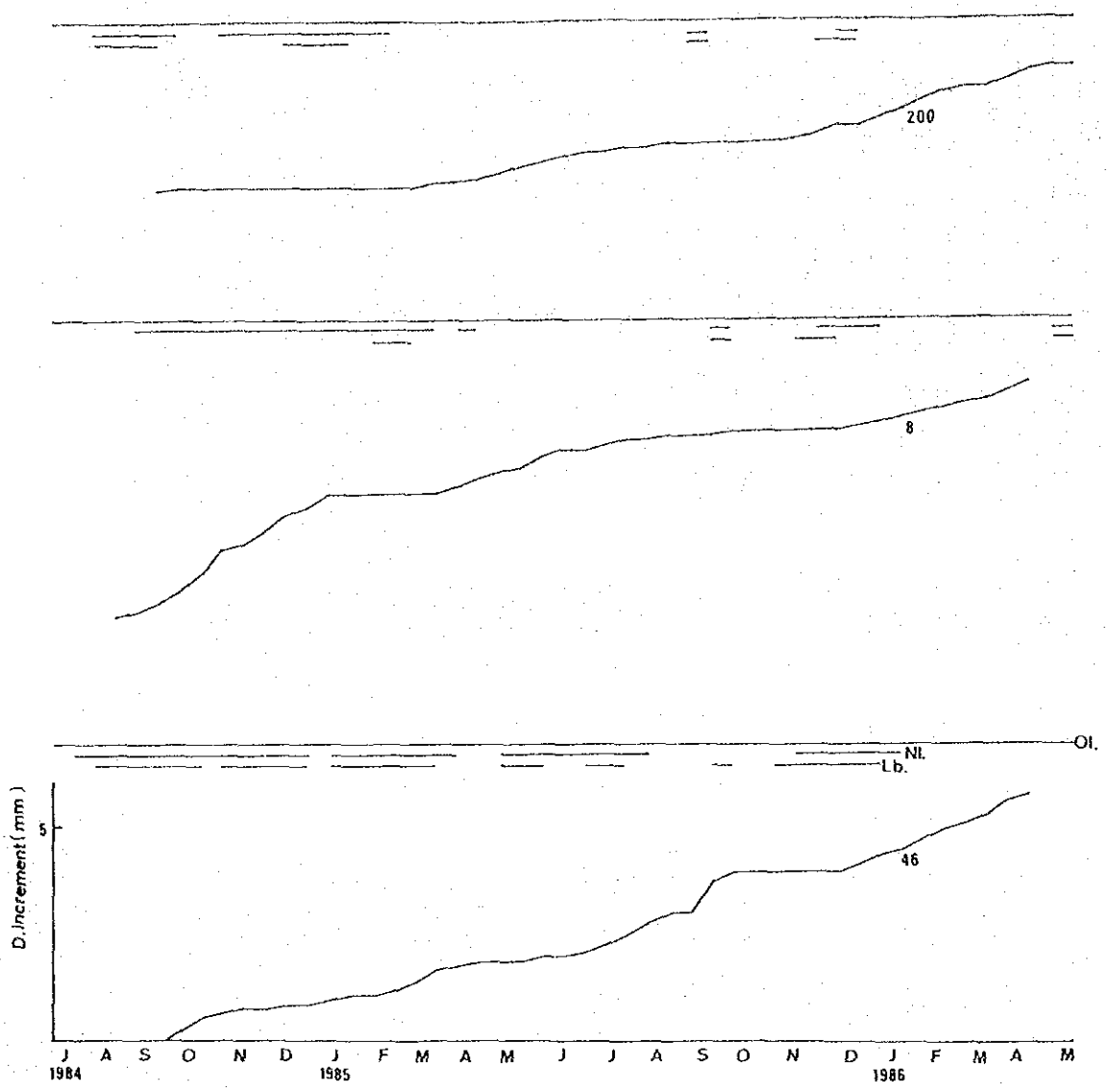


Fig.11 Relationship of micro diameter growth and phenological activities of Meranti kawang tikus in Arboretum Andulau.

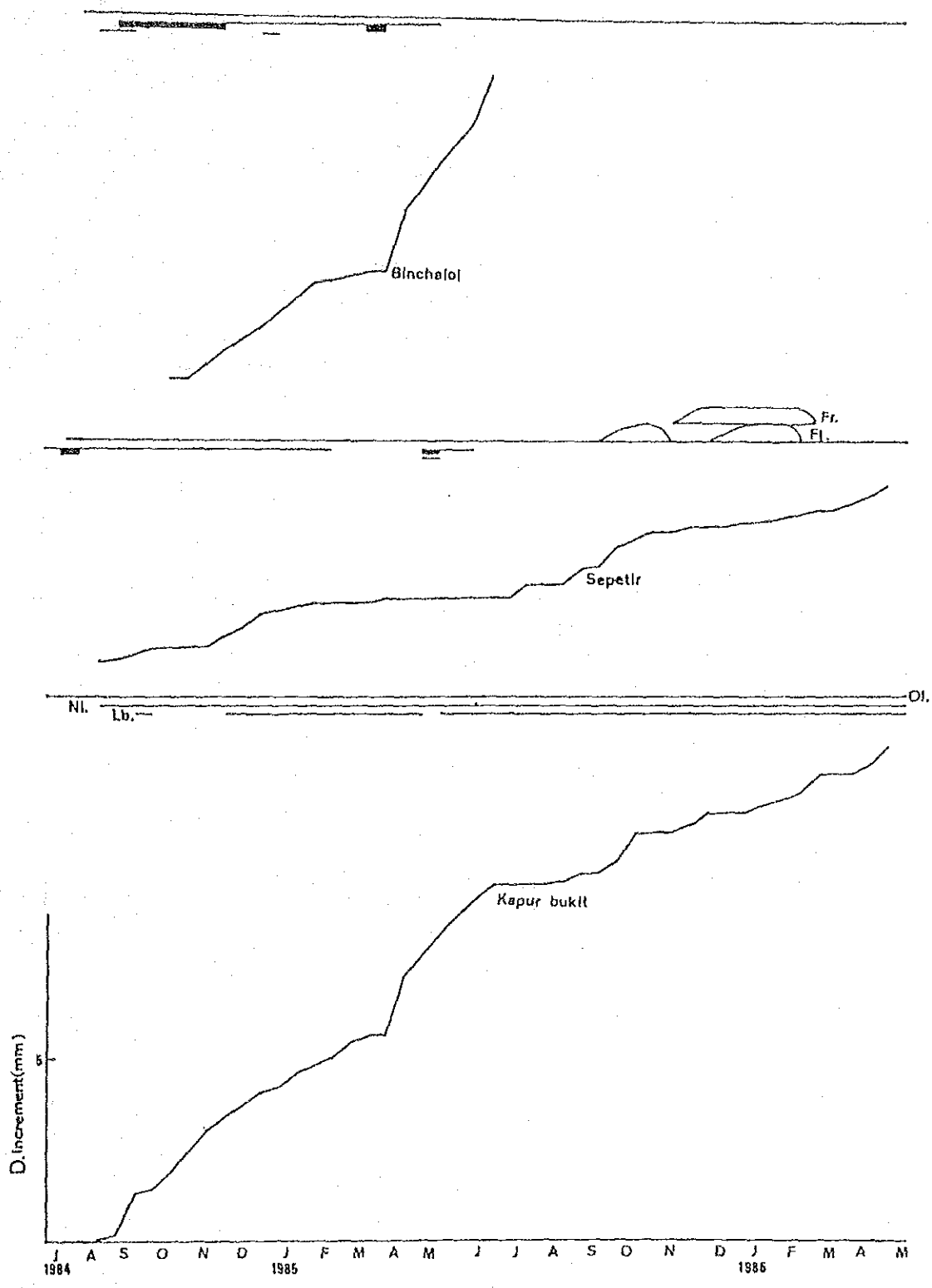


Fig.12 Relationship of micro diameter growth and phenological activities of Kapur bukit, Sepetir and Binchaloi in Arboretum Andulau.

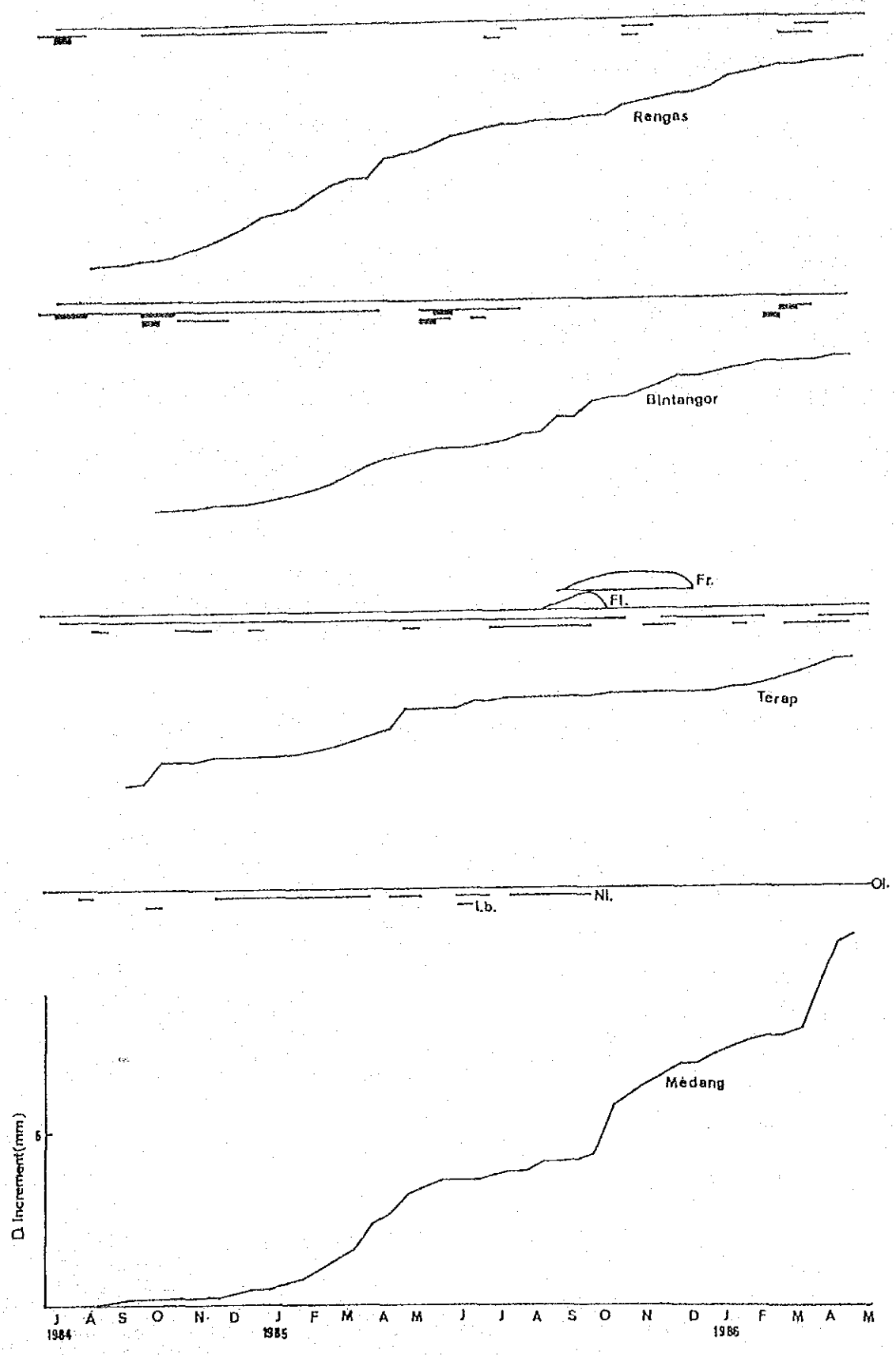


Fig.13 Relationship of micro diameter growth and phenological activities of Non-dipterocarps in Arboretum Andulau.

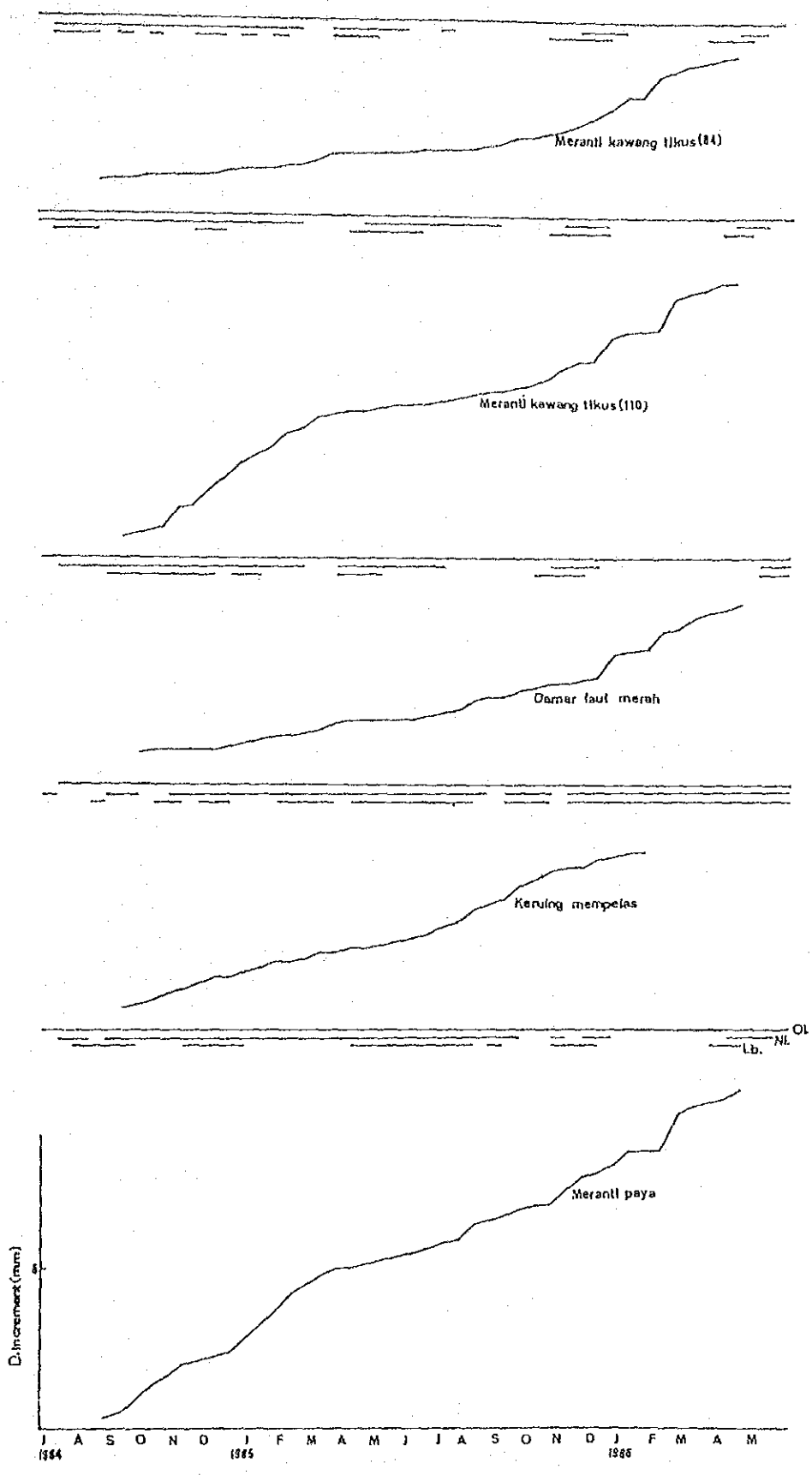


Fig.14 Relationship of micro diameter growth and phenological activities of Dipterocarps in Compartment 7, Andulau Forest Reserve.

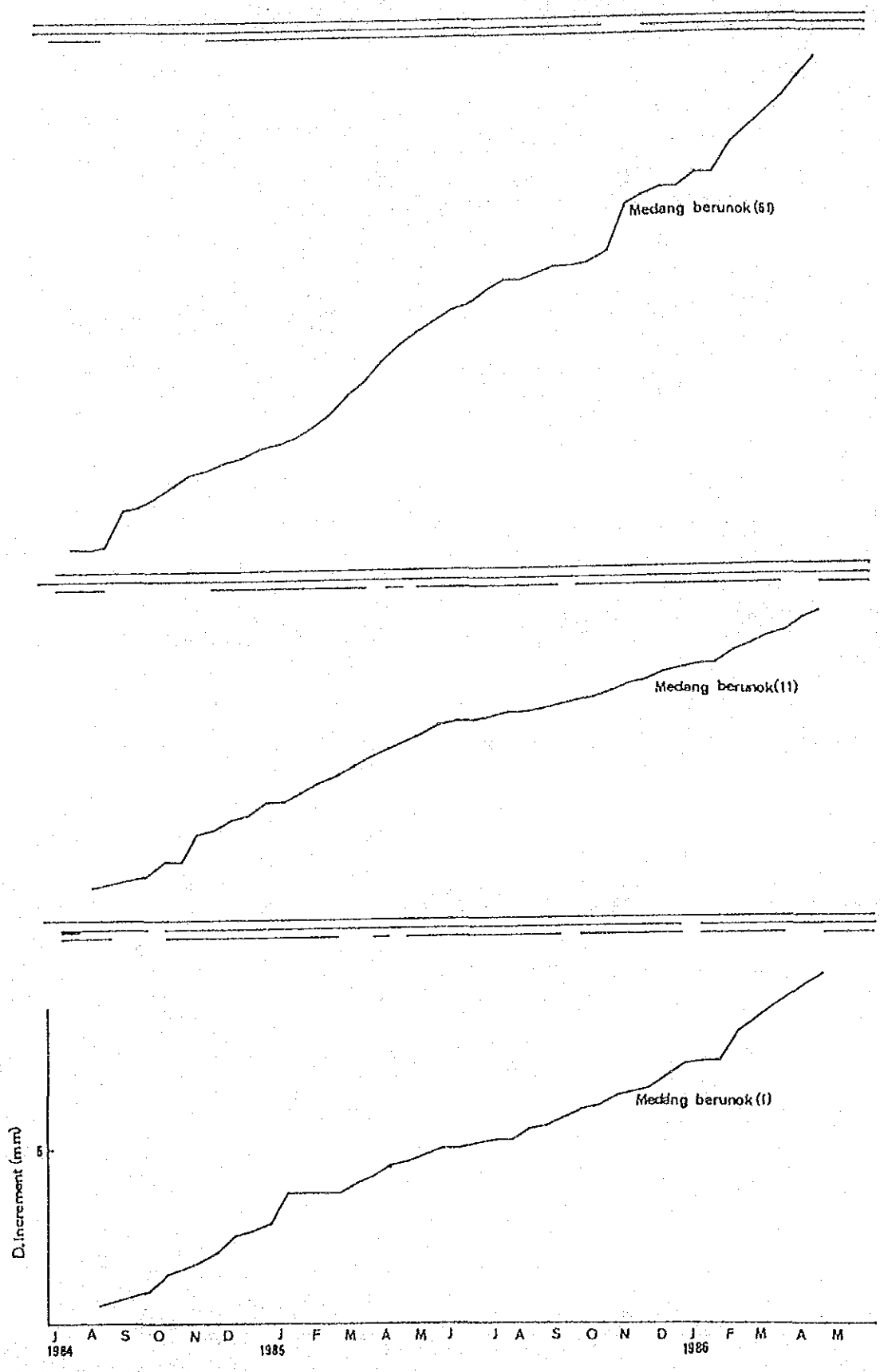


Fig.15 Relationship of micro diameter growth and phenological activities of Non-dipterocarps in Compartment 7, Andulau Forest Reserve.

1/6

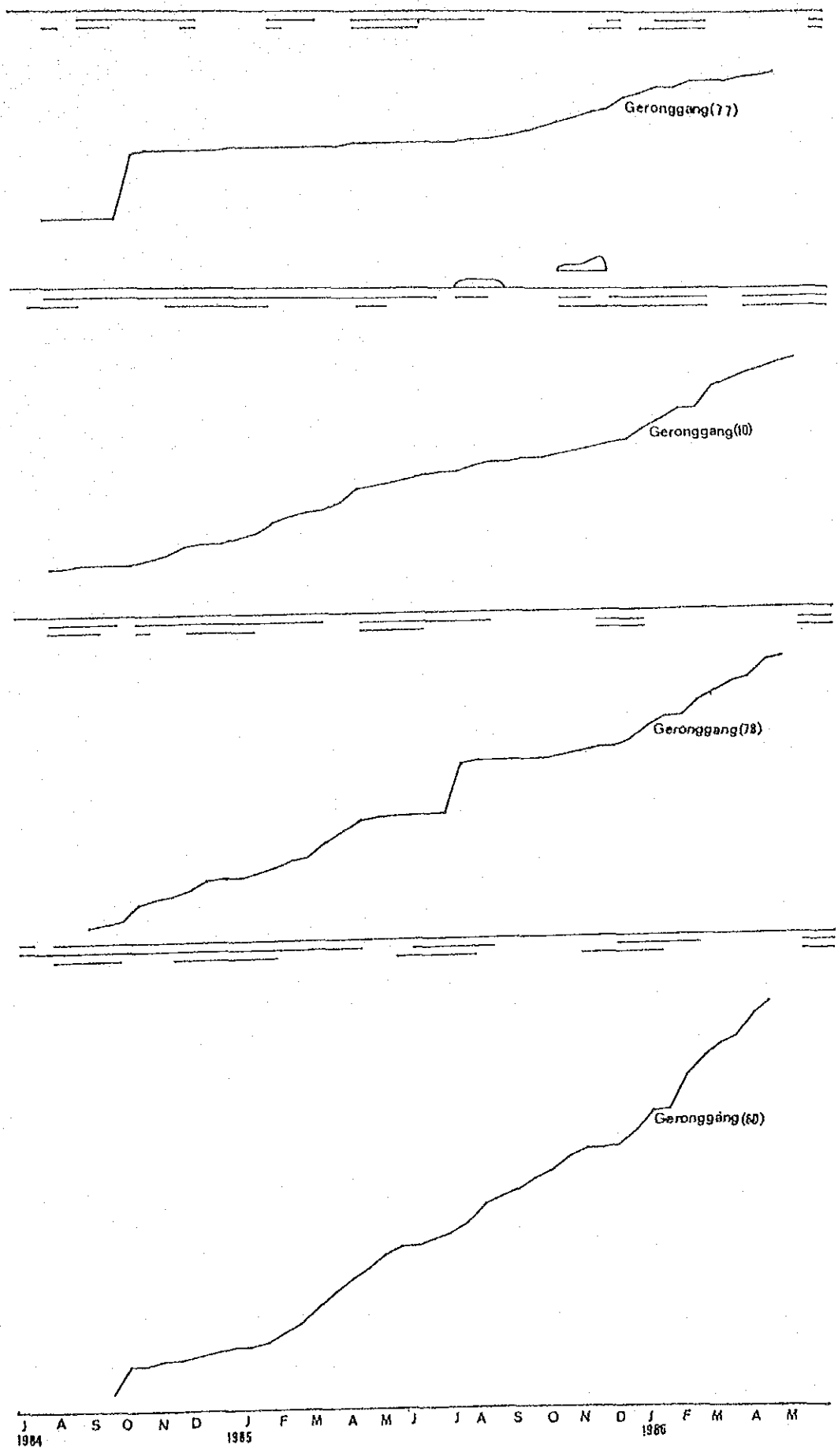
Geronggang(77)
Geronggang(10)
Geronggang(78)
Geronggang(80)
J A S O N D J F M A M J J A S O N D J F M A M
1984
1985
1986

Fig. 15 2/6

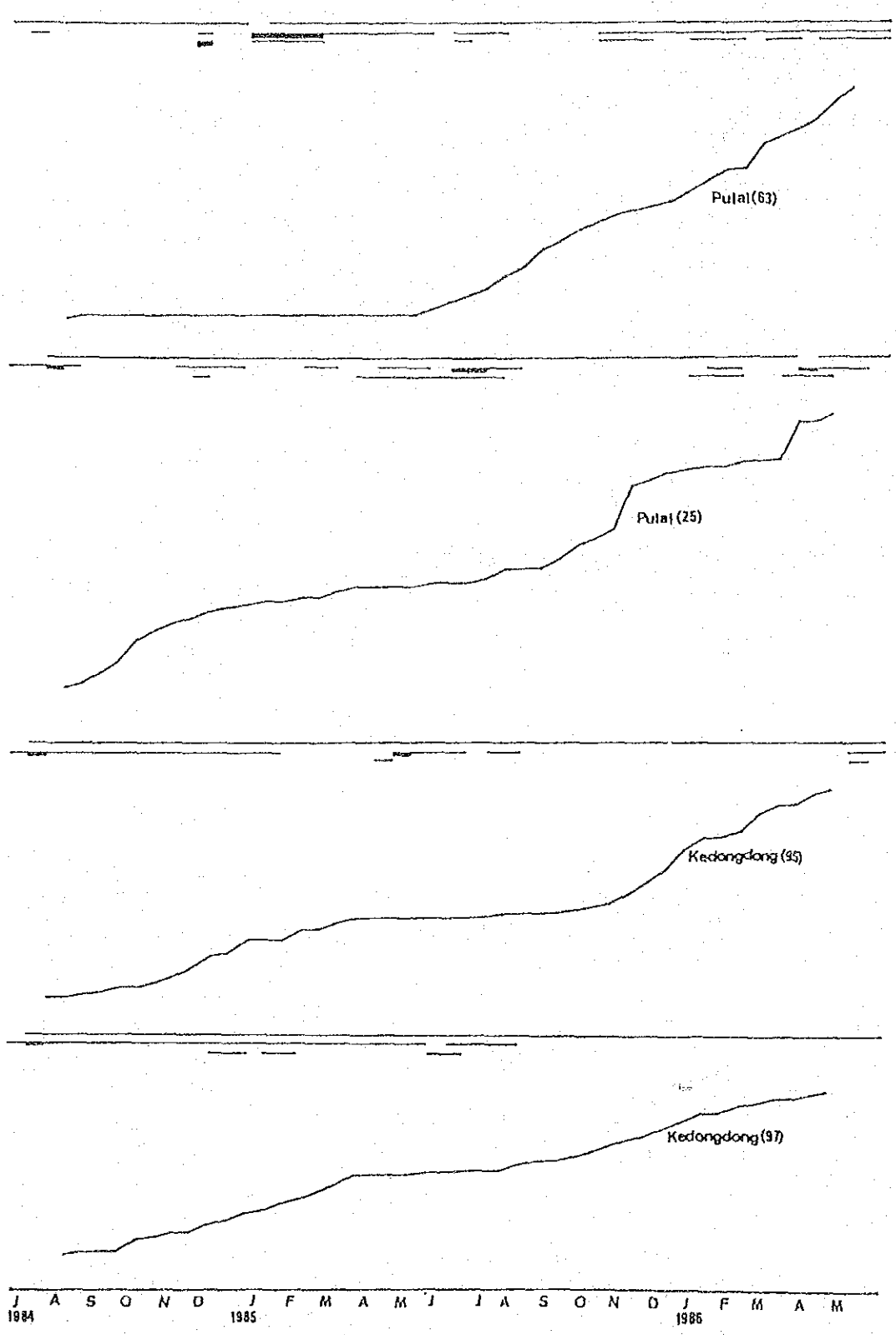
Pulai(63)
Pulai(25)
Kedongdong(95)
Kedongdong(97)
J A S O N D J F M A M J J A S O N D J F M A M
1984
1985
1986

Fig. 15 3／6

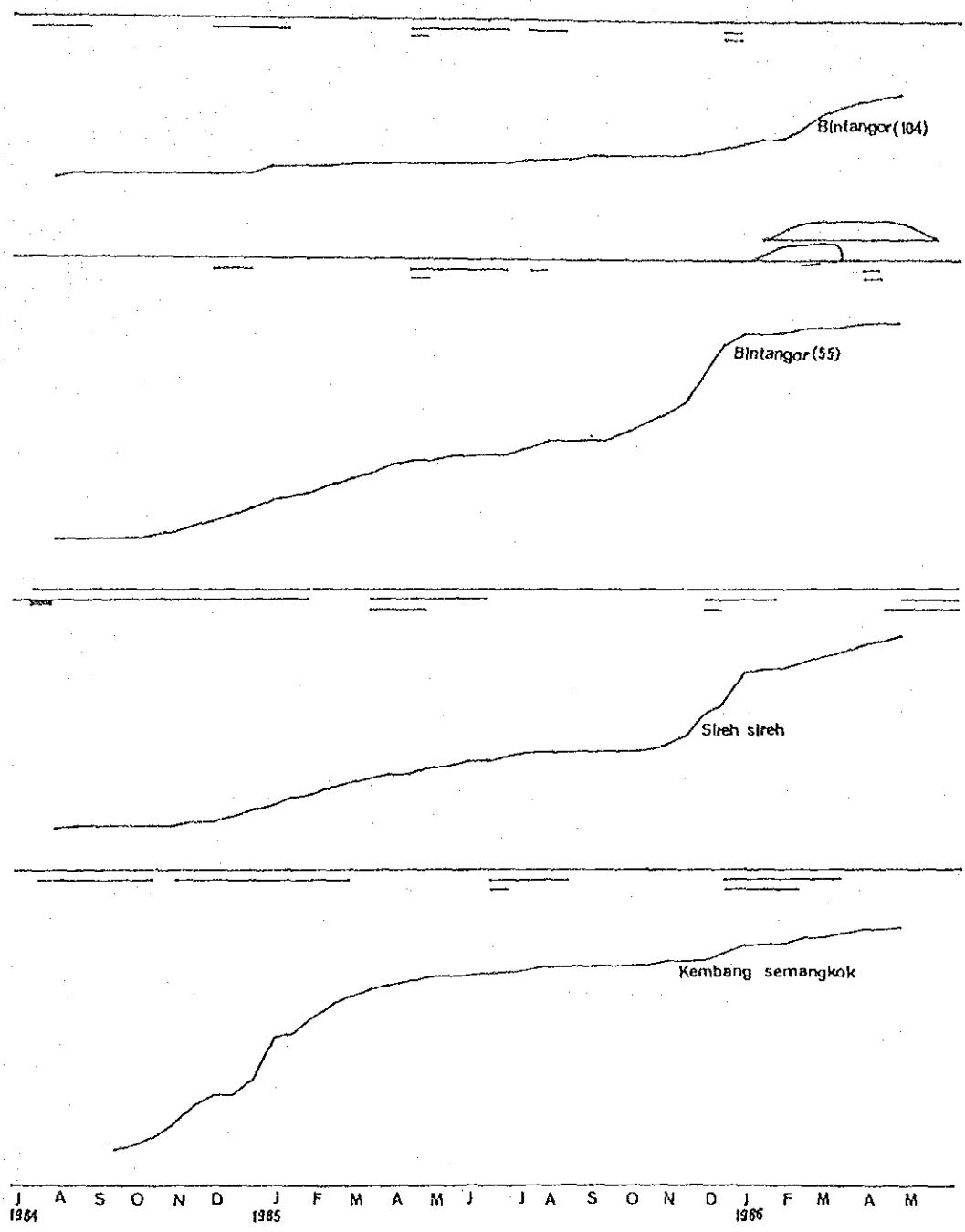
Bintangor(104)
Bintangor(55)
Sireh sireh
Kembang semangkok
J A S O N D J F M A M J J A S O N D J F M A M
1984
1985
1986

Fig. 15 4/6

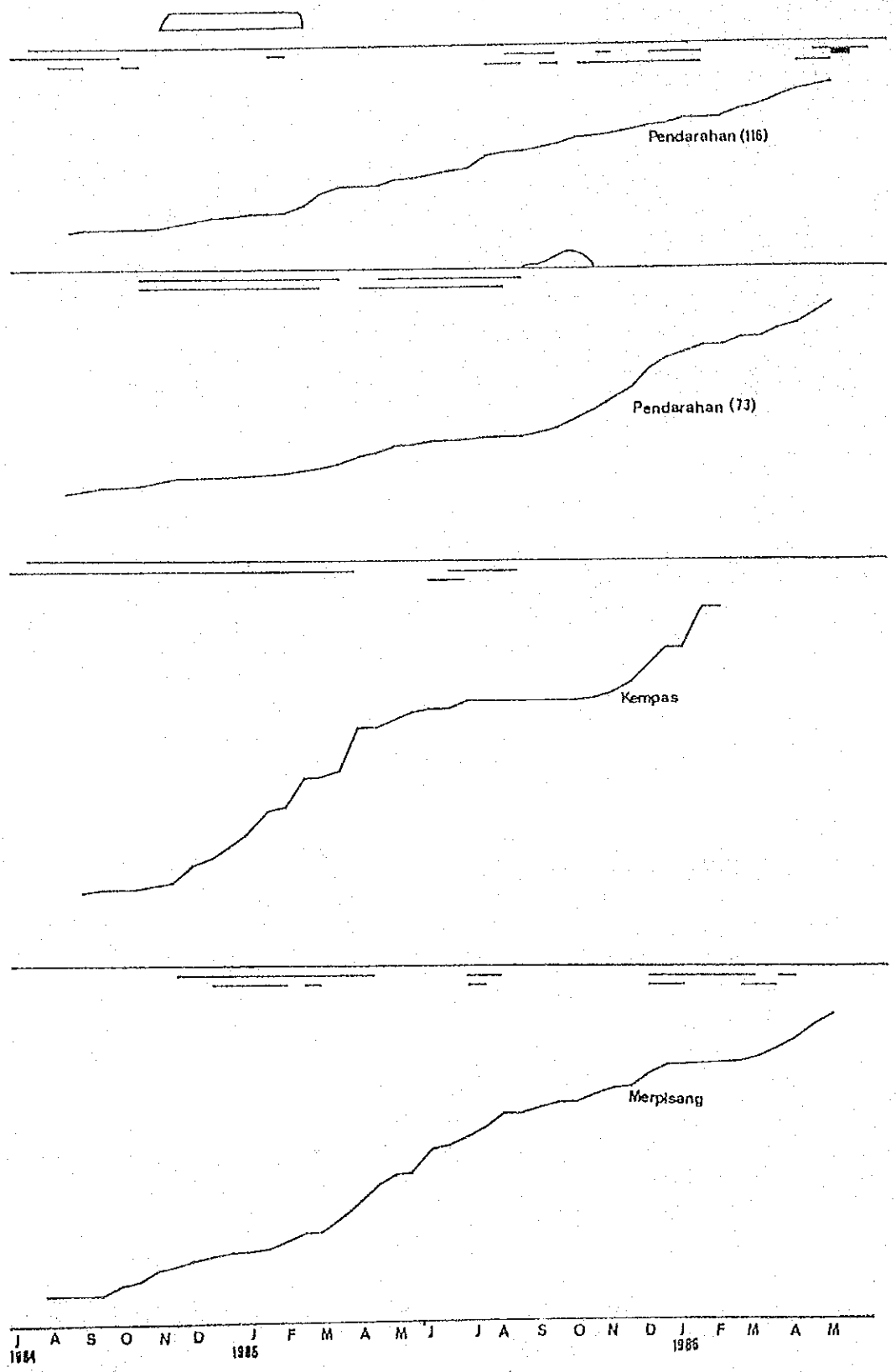
Pendarahan (116)
Pendarahan (73)
Kempas
Merpisang
J A S O N D J F M A M J J A S O N D J F M A M
1984
1985
1986

Fig. 15 5/6

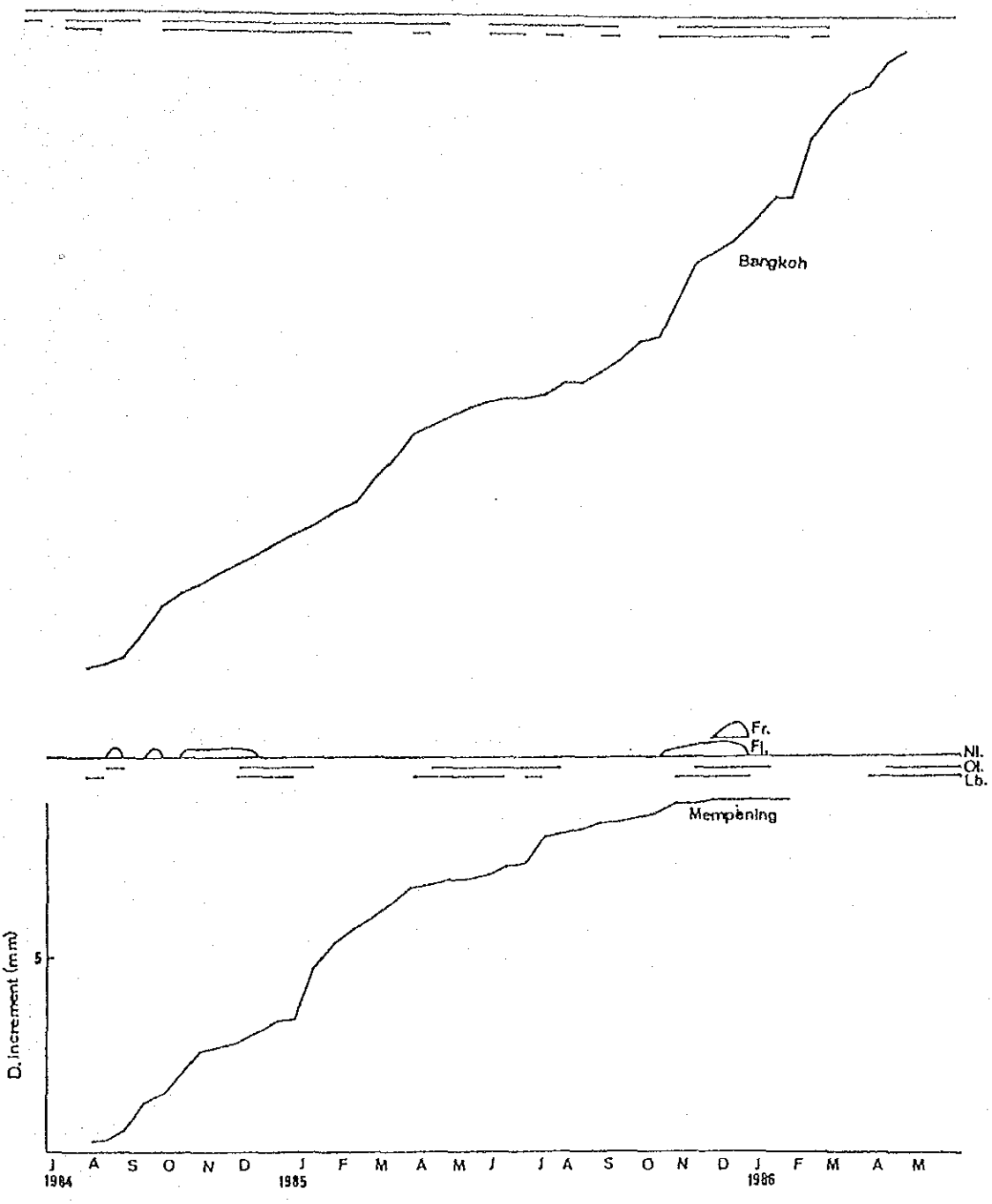
Bangkoh
Fr.
Fl.
Nl.
Ol.
Lb.
Mempèning
D. increment (mm)
5
J A S O N D J F M A M J J A S O N D J F M A M
1984
1985
1986

Fig. 15 6/6

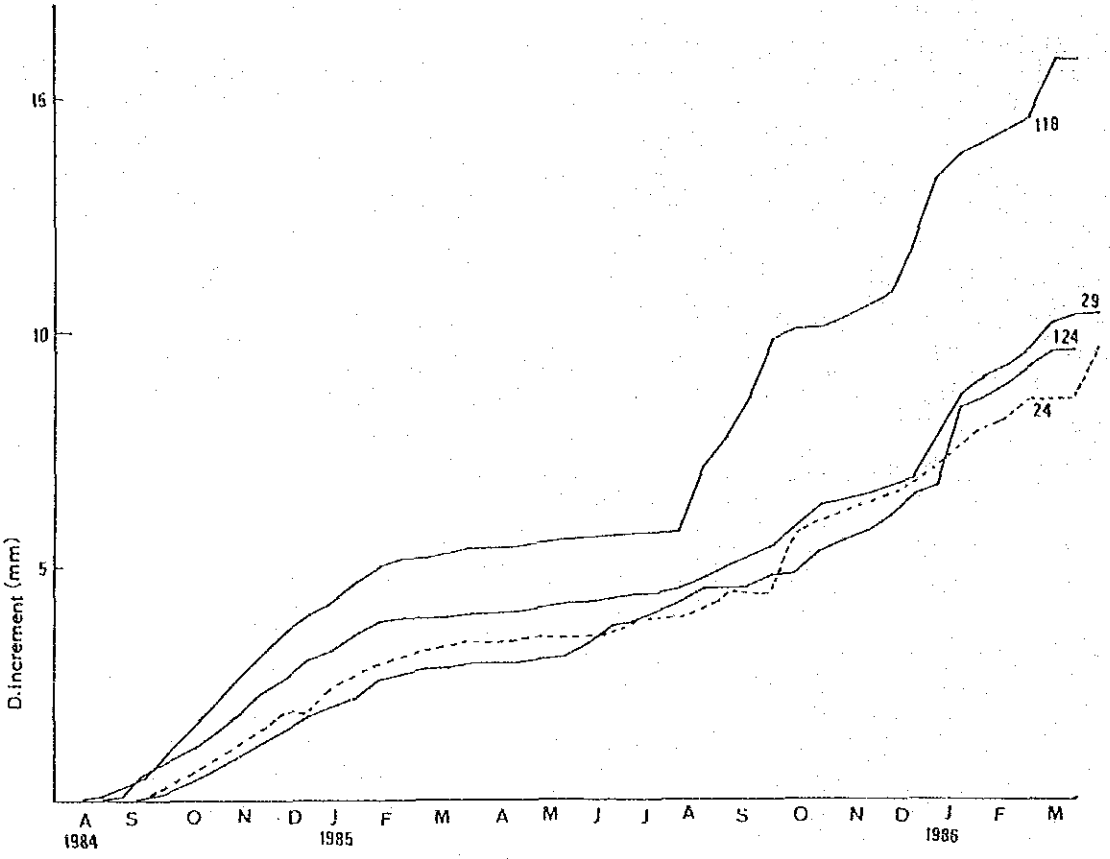


Fig.16 Micro diameter growth of Agathis trees in Agathis plot, Badas.

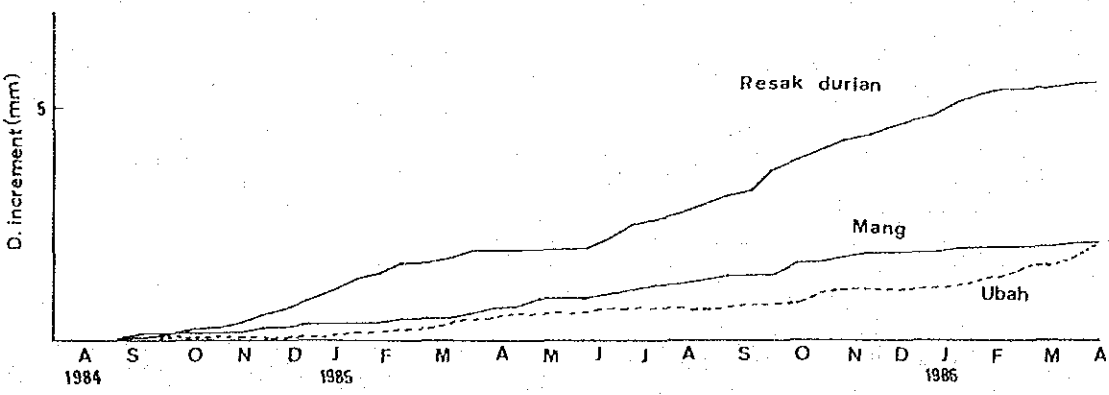


Fig.17 Micro diameter growth of non-Agathis trees in Agathis plot, Badas.

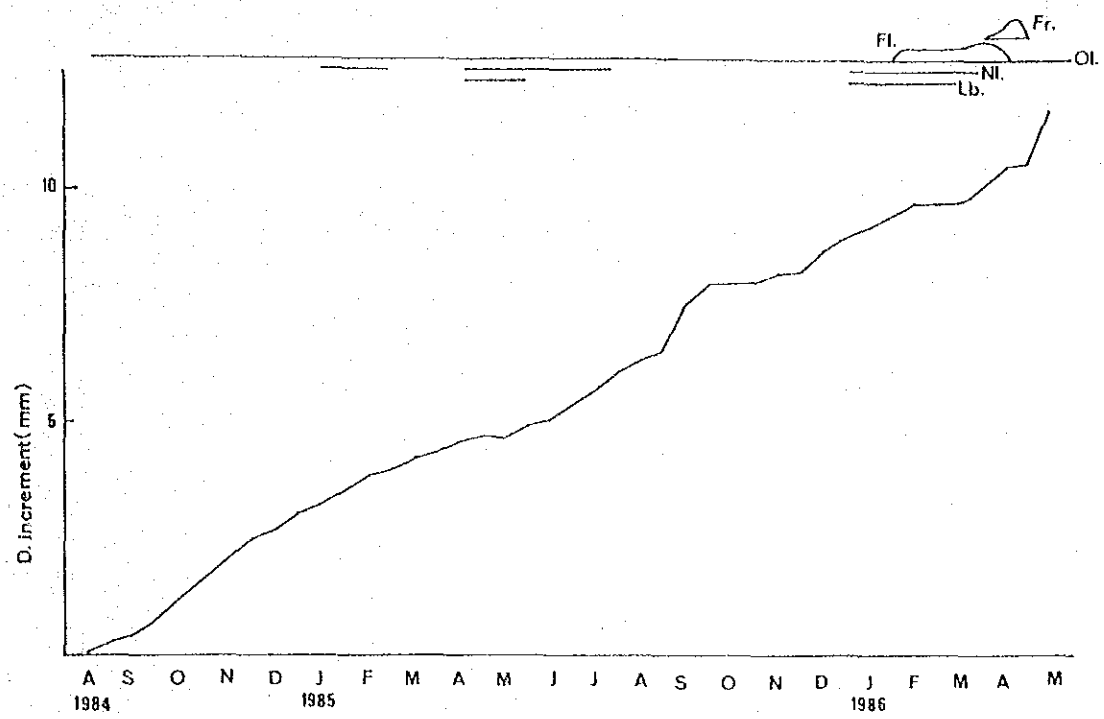


Fig.18 Relationship of micro diameter grwoth and phenological activities of Alan in Alan bunga forest.

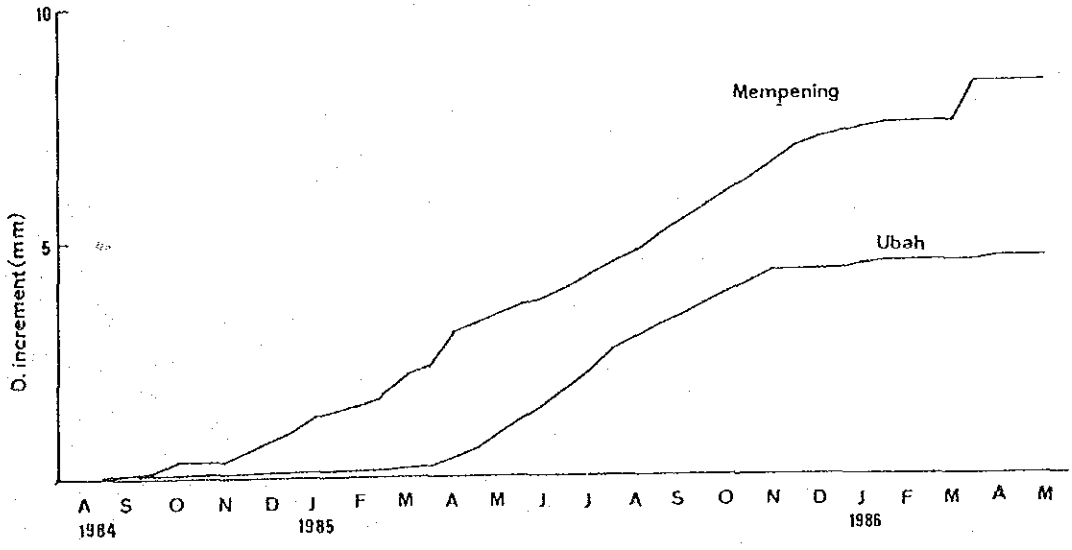


Fig.19 Micro diameter growth of non-Alan trees in Alan Bunga forest.

Table 1. Total number and basal area of trees in Agathis plot.
Only trees of 10cm DBH and over are shown.

| Vernacular Name | Botanical Name | Family | SP-1 (50x50) | | SP-2 (50x50) | | Total / ha | | % | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | B.A. | No. | B.A | No. | B.A $cm^2$ | No. | B.A. |
| Agathis | Agathis dammara (Lamb.) L.C. Rich. | Araucariaca | 83 | 84431.5 | 30 | 34611.8 | 226 | 238086.6 | 37.05 | 62.00 |
| Resak durian | Cotylelobium burckii (Heim) Heim | *Dipterocarpaceae* | 20 | 11262.1 | 28 | 12649.7 | 96 | 47823.6 | 15.74 | 12.45 |
| Nyatoh (1) | | Sapotaceae | 6 | 827.1 | 29 | 8885.5 | 70 | 19425.2 | 11.48 | 5.06 |
| Mengilas | Parastemon urophyllum A. DC. | Rosaceae | | | 12 | 6600.9 | 24 | 13201.8 | 3.93 | 3.44 |
| Ubah ribu | Eugenia bankense Hassk. | Myrtaceae | 7 | 820.1 | 4 | 483.0 | 22 | 2606.2 | 3.61 | 0.68 |
| Nyatoh (2) | | Sapotaceae | 4 | 1259.6 | 4 | 1075.1 | 16 | 4669.4 | 2.62 | 1.22 |
| Merpisang (1) | | | | | 7 | 1012.9 | 14 | 2025.8 | 2.30 | 0.53 |
| Mang | Hopea pentanervia Sym. | Dipterocarpaceae | 4 | 878.9 | 1 | 143.1 | 10 | 2044.0 | 1.64 | 0.53 |
| Bintangor (2) | Calophyllum sp. | Gutiferae | 2 | 216.2 | 3 | 418.6 | 10 | 1269.6 | 1.64 | 0.33 |
| Mengkulat | Ilex hypoglauca (Miq.) Loes | Anacardiaceae | 4 | 509.8 | 2 | 113.0 | 10 | 1245.6 | 1.64 | 0.32 |
| Alan | Shorea albida Sym. | Dipterocarpaceae | | | 4 | 3771.5 | 8 | 7543.0 | 1.31 | 1.96 |
| Dual | Lophopetalum sp. | Celastracea | 2 | 217.3 | 2 | 1262.9 | 8 | 2960.4 | 1.31 | 0.77 |
| Rengas | Melanorrhoea sp. | Anacardiaceae | | | 3 | 3876.5 | 6 | 7753.0 | 0.98 | 2.02 |
| Bintangor (3) | Calophyllum sp. | Guttiferae | | | 3 | 3206.0 | 6 | 6412.0 | 0.98 | 1.67 |
| Lusi | Garcinia sp. | Guttiferae | | | 3 | 1275.0 | 6 | 2550.0 | 0.98 | 0.66 |
| Kayu malam | Diosypros sp. | Ebenaceae | | | 3 | 852.8 | 6 | 1705.6 | 0.98 | 0.44 |
| Ubah (1) | Engenia sp. | Myrtaceae | 3 | 648.8 | | | 6 | 1297.6 | 0.98 | 0.34 |
| Medang (3) | | | | | 3 | 492.5 | 6 | 985.0 | 0.98 | 0.26 |
| Kedondong (1) | | | 3 | 345.9 | | | 6 | 691.8 | 0.98 | 0.18 |
| Bitis | | | | | 2 | 2072.4 | 4 | 4144.8 | 0.66 | 1.08 |
| Sempilau | Casuarina nobilis Johnson msc. | *Casuarinaceae* | 2 | 1668.5 | | | 4 | 3337.0 | 0.66 | 0.87 |
| Bintangor (1) | Calophyllum sp. | Guttiferae | 1 | 1187.9 | 1 | 171.9 | 4 | 2719.6 | 0.66 | 0.71 |
| Unknown (1) | | | | | 2 | 324.1 | 4 | 648.2 | 0.66 | 0.17 |
| Medang (1) | | | | | 2 | 314.4 | 4 | 628.8 | 0.66 | 0.16 |
| Ubah (2) | Engenia sp. | Myrtaceae | 1 | 145.2 | 1 | 134.7 | 4 | 559.8 | 0.66 | 0.15 |
| Medang (2) | | | | | 2 | 253.3 | 4 | 506.6 | 0.66 | 0.13 |
| Keranji | Dialium indum L. | Leguminosae | 1 | 80.1 | 1 | 124.6 | 4 | 409.4 | 0.66 | 0.11 |
| Ru | Casuarina sp. | Casuarinaceae | | | 1 | 1771.2 | 2 | 3542.4 | 0.32 | 0.92 |
| Mata ulat | Lophopetalum sp. | Celastraceae | 1 | 356.1 | | | 2 | 712.2 | 0.32 | 0.19 |