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Natural Distribution and Suitable Method for Plantation of Two *Dryobalanops* Species in Negara Brunei Darussalam

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Summary : Natural distribution and suitable method for plantation of both *Dryobalanops aromatica* and *Dryobalanops lanceolata* are investigated in Negara Brunei Darussalam in order to develop the technique for enriching degraded forests. In natural forest, the former species is distributed on flat and wide ridge while the latter species on steep slope. That is, both species have their own slope sites to be distributed. The characteristics of their spatial distribution are closely related to the suitable sites for their quick growth.

Growth of the seedlings in line planting of *D. aromatica* and gap planting of both *D. aromatica* and *D. lanceolata* are carried out. The results of line planting show that seedlings in various line width grow quickly in wide line planting. In widest line planting, the seedlings grow more quickly on the upper and middle part of the slope. In the case of gap planting, seedlings are planted in artificially created gaps of various sizes and slope sites. Both species grow more quickly in broad gap. The seedlings of *D. aromatica* grow more quickly both on the upper and the middle part of slope while the seedlings of *D. lanceolata* grow more quickly only on the middle part of slope. The slope sites where each species grow quickly is closely related to its spatial distribution in natural forest. Therefore, it is necessary to make broad opening of canopy for the seedlings to grow quickly. It is also important to consider the site suitability of each species considering the characteristics of each species.

1 Introduction

Negara Brunei Darussalam is situated in North-western part of Borneo island with abundant tropical rain forests. Its total area is nearly same as Chiba-prefecture of Japan. In spite of the small land area, Brunei has relatively higher forest ratio; that is, 81% of total land area is covered with forests and 73% of total forest is primary undisturbed forests (ANON., 1987).

Although this country has higher forest ratio, degraded secondary forests are increasing in area as the harvesting timbers and the development of this country proceed. To recover these degraded forests, it is important to establish silvicultural methods for artificial planting using indigenous species such as Dipterocarp species. These silvicultural methods for Dipterocarp species are one of the most urgent matter to be established in this country. Therefore, it is important to understand the characteristics of species that are going to be planted.

This report will focus on the species from genus *Dryobalanops* which is one of the most abundant, popular and valuable genus of *Dipterocarpaceae* in Brunei Darussalam (ASHTON, 1964; SYMINGTON, 1943). Species from this genus is called Kapur. Sawn timber production of this genus is about 16% to total production (ANON., 1987). Four species from genus *Dryobalanops* are distributed in Brunei Darussalam such as *D. aromatica, D. lanceolata, D. beccarii* and *D. rappa* (ASHTON, 1964). Their local names are Kapur Peringgi, Kapur Paji, Kapur Bukit and Kapur Paya, respectively. The first

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three species are distributed in lowland mixed Dipterocarp forests and last species mainly in fresh water swamp. The special reference will be paid to the first two species in this report.

This report will discuss that these two species have their own suitable site for planting and this suitability is closely related to their natural distribution. This report will also discuss the suitable method for planting. The seedlings of two *Dryobalanops* species were planted by line planting and gap planting. The suitable line width of line planting and suitable size and site of gap planting will be discussed.

This study was carried out under the cooperation between Forestry Department of Brunei Darussalam and JICA (Japan International Cooperation Agency) Forest Research Project Team in Brunei Darussalam.

2 Experimental site and method

2.1 Spatial distribution of three *Dryobalanops* species in natural forests

Natural distributions of *Dryobalanops* species were studied in Bukit Patoi, Bukit Peradayan and Kuala Belalong in Temburong district (Fig. 1). These three sites are in natural forests except the lower part of Bukit Peradayan, which seemed to be logged before. Bukit Patoi and Bukit Peradayan are situated in Peradayan forest reserve.

There were mass flowering of *Dryobalanops* species from May to August, 1992 throughout Brunei Darussalam. We measured diameter at breast height (DBH) and altitude above sea level (asl) of all trees which had fruits near the trail in each site from June 1992 to July 1992. At the same time, the angle of the upper and lower slope of each tree were also measured in Bukit Patoi and Kuala Belalong. Because it is difficult to identify the species of genus *Dryobalanops* only by leaves, we identified all the measured trees of *Dryobalanops* species both by fruits and leaves according to WOOD and MEIJER (1964) and ASHTON (1964).

2.2 Trial plantation of *Dryobalanops* species

The experimental site of trial plantation is an area of 13ha located in the secondary forest near compartment 7 of Andulau forest reserve (Fig. 1). Selective cutting was carried out twenty years ago in this area. Although *D. aromatica* is abundant in compartment 7 of Andulau forest reserve, which is located next to the experimental site, there is small number of *D. aromatica* in the experimental site. The influence of harvesting on the quality of this secondary forest seems to be great.

2.2.1 Experimental design of trial plantation

(1) Line planting

Four plots for line planting were set on the same slope which is facing eastward. The size of these plots are 4m×50m, 6m×70m, 10m×100m and 15m×70m, respectively. The longer side of each plot is located from ridge to valley. The direction of each plot is from east to west. The west end of each line is located on the ridge, east end near the river in the valley.

These four plots are regarded as line plantings which have various line width such as 4, 6, 10 and 15m width line planting, respectively. Each plot has similar topography and soil condition (upper part: Red Dry, lower part: Yellow Moisture (TAKAHASHI, 1994)). Therefore, the difference in the growth rate of planted seedlings is mainly resulted from the various line width.

Seedlings of *D. aromatica* were planted in each plot of line planting. There is one row, which has 17 seedlings in 4m width line planting. In 6m width line planting, there is also one row, which has 23 seedlings. There are three rows in 10m and 15m width line planting. Each row has 33 seedlings in 10m width line planting and 24 seedlings in 15m. The total number of the planted seedlings were 17 (17×1), 23 (23×1), 99 (33×3) and 72 (24×3), respectively. The distance between each row is 3m in 10 and 15m width plot. In each row, the seedlings were planted with 3m interval in each plot.

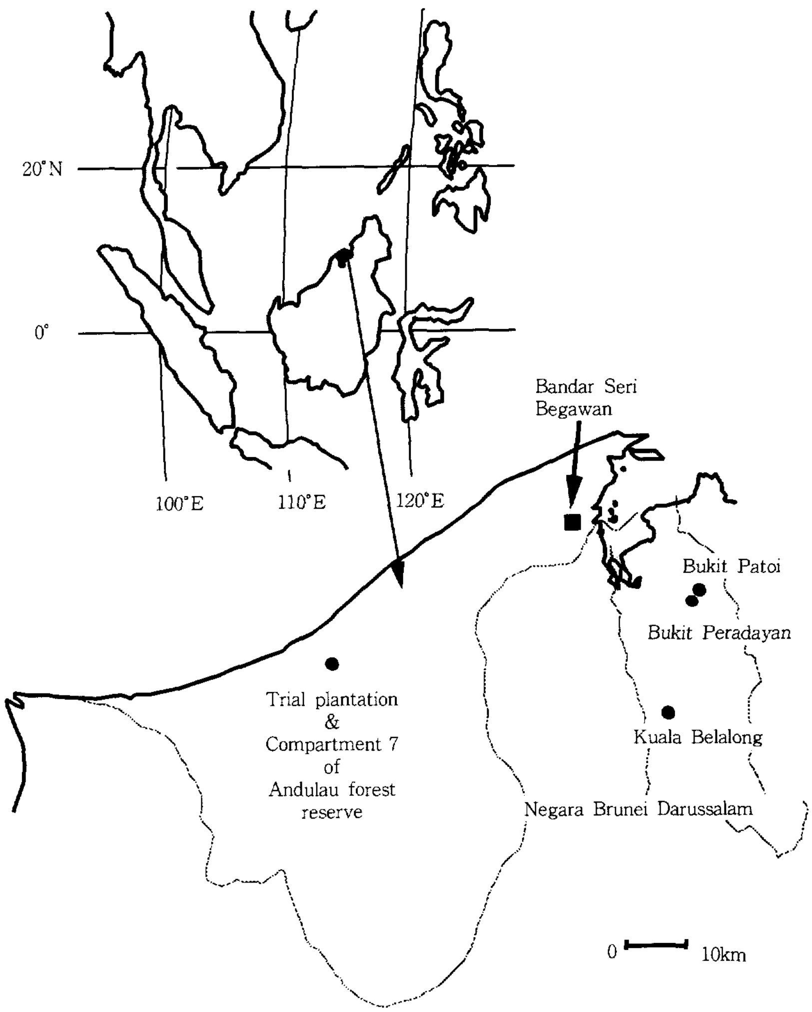


Fig. 1. Map of Negara Brunei Darussalam

(2) Gap planting

Seedlings of both *D. aromatica* and *D. lanceolata* were planted in artificially created canopy gaps for the experiment of gap planting. All plots of gap planting are categorized into four treatments as follows:

1) 20m×20m in size on the upper part of the slope

2) 10m×10m in size on the upper part of the slope

3) 20m×20m in size on the middle part of the slope

4) 10m×10m in size on the middle part of the slope

Each treatment has 2, 4, 2 and 4 plots, respectively.

The gap size was determined by the height of upper trees. The height of upper trees surrounding each 20m×20m size plot is approximately equal to the length of one side of this square shaped plot. That of upper trees surrounding each 10m×10m size plot is approximately equal to two times its length.

Soil type is yellow dry in the upper part and yellow moisture in the middle part (TAKAHASHI, 1994). The plots on the upper parts of the slope are located on flat and wide ridge, which is similar to the topography of *D. aromatica* in natural forests. The plots of the middle are located on relatively steep slope, where *D. lanceolata* is likely to be distributed in natural forests. The seedlings of *D. aromatica* and *D. lanceolata* were planted together in each plot. Spacing of planted seedlings is 3m ×3m. Eighteen seedlings of each species in each 20m×20m size plot and eight seedlings of each species in each 10m×10m size plot.

2.2.2 Method

(1) Felling and planting

All trees inside each plot of line planting and gap planting were felled from December, 1988 to February, 1989. These felled trees were removed outside for the convenience of both planting and measurement of seedlings. After felling, seedlings were planted. Planting of seedlings was finished in March, 1989.

(2) Measurement of seedling growth

The height, leaf number of every seedling planted in the plots of both line and gap planting were measured in April, June, August, October, December of 1989, February, April of 1990, June of 1991 and June of 1992. The diameter at ground were measured in April of 1989, April of 1990, June of 1991 and June of 1992.

(3) Collection of seedlings

Wildings of *D. aromatica* and *D. lanceolata* were used for planting materials. The seedlings of *D. aromatica* were collected in Bukit Labi forest reserve and those of *D. lanceolata* were in Bukit Patoi. The seedlings of each species were pulled carefully from forest floor, transferred to plastic bags and nursed under forest canopy for two or three month. The quality of seedlings were hence very low because of short nursing period and no hardening.

(4) Microclimate measurement

The microclimate in each plot was measured according to the schedule shown in Table 1 using MES801 (Koito) as a data logger. The light condition of seedlings in line planting were also measured using sun station from 11 June, 1992 to 6 July, 1992. Three sensors were set in each line (upper, middle and lower part of slope) and three sensors in the open area for control. Light condition of seedlings in gap plantings were measured using sun station which were left from 27 May, 1992

Table 1. Schedule of microclimate measurement in the experimental site

No	Starting date	Ending date	Interval	Sensors	Site
1	30May,1989	6June,1989	10min.	Air temp.	In 20m×20m gap of upper part and under adjacent forest canopy
			10min.	Humidity	Same as above
			10min.	Soil temp.	Same as above
			10min.	Light intensity	In 20m×20m gap
			10min.	Rainfall	In 20m×20m gap
2	27April,1989	27April,1989	3min.	Light intensity	Centre,south,west,east and north part of 20m×20m gap of upper slope
3	6May,1989	27May,1989	30min.	Soil moisture	In 20m×20m gap of upper part and adjacent forest canopy
			30min.	Rainfall	In 20m×20m gap of upper part
4	7June,1989	27June,1989	30min.	Soil moisture	Upper and lower part on the slope of 15m width line planting
			30min.	Rainfall	Middle of 15m width line planting
5	4Sep,1989	14Sep.,1989	10min.	Light intensity	In 10m×10m gap of upper part on slope
			10min.	Light intensity	In 10m×10m gap of upper part on slope

to 10 June,1992. Two sensors of sun station were left in each gap and two in open area for control.

The height of the upper trees which were surrounding the plots were measured. Eight, twelve, sixteen and twelve upper trees were measured in 4, 6, 10 and 15m width plots, respectively in May, 1990. Eight upper trees surrounding 20m×20m gap and four upper trees surrounding 10m×10m gap were measured at the same time. The result of this measurement is shown in table 2.

(5) Weed

Dry weight of weed was measured one year after planting. Two 1m×1m plots were set in the upper, middle and lower part of 6m and 15m width line planting. Two 1m×1m plots were set in each 20m×20m gap planting and one 1m×1m plot in each 10m×10m gap planting. All above-ground weeds inside each plot were harvested and brought back to the laboratory in Sungai Liang nursery. In the laboratory, the weeds were separated into woody plants and grass. The woody plants were also separated into photosynthetic part and non-photosynthetic part. After that, each part was dried in oven at 80℃. After drying, their weight were measured.

Table 2. Average height of upper trees which are surrounding the plots both of line planting and gap planting

Line planting

Line width	Average tree height(m)
4m	16.8
6m	18.1
10m	17.1
15m	17.4

Gap planting

Gap site	Average tree height(m)
Upper	23.3
Middle	26.3

3 Result and discussion

3.1 Spatial distribution of three *Dryobalanops* species in natural forests

Bukit Patoi is located in the northern part of Peradayan forest reserve. The altitude of the summit is about 300m above sea level (asl). There is steep slope in the lower part and is wide and flat ridge in the upper part. Most of *D. lanceolata* are distributed on the steep slope between 60m and 200m above sea level while most of *D. aromatica* is distributed on wide and flat ridge above 180m asl in Bukit Patoi (Fig. 2).

D. beccarii is distributed being mixed with *D. lanceolata* in Bukit Patoi. The fruiting timing of *D. beccarii* was observed to be delayed from two other species for one week. *D. lanceolata* and *D. beccarii* are thought to be seperated by timing of fruiting. In other sites such as Bukit Labi and Bukit Basong, *D. beccarii* is observed distributed being mixed with *D. aromatica.*

Bukit Peradayan is situated near Bukit Patoi. The topography and the pattern of distribution is similar to those in Bukit Patoi. The lower part is mostly consisted of steep slope and the upper part mostly of relatively flat and wide ridge. In the lower part, only one mother tree from *D. lanceolata* was found although there were several seedlings of this species. In the upper part, *D. aromatica* is distributed being mixed with *Agathis borneensis.*

Kuala Belalong has steep slopes in lower part and a narrow summit. There was no *D. aromatica* found in this area. *D. lanceolata* is distributed on the steep slope more than 80m asl. *D. beccarii* is distributed being mixed with *D. lanceolata.*

The spatial distribution of *D. aromatica* and *D. lanceolata* is related to the topography where each species is distributed (Fig. 3). Most of *D. aromatica* were on flat slope in Bukit Patoi. Most of upper angles are between 1° to 10° and lower angle 0° to 15°. On the other hand, most of *D. lanceolata* are distributed on steep slope in both of Bukit Patoi and Kuala Belalong. Most of upper angles are between 0° to 20° in Bukit Patoi and 15° to 35° in Kuala Belalong. Most of lower angles are between 5° to 30° in Bukit Patoi and 15° to 35° in Kuala Belalong. These results also indicate that these two species are distributed in the sites which have different topographical characteristics.

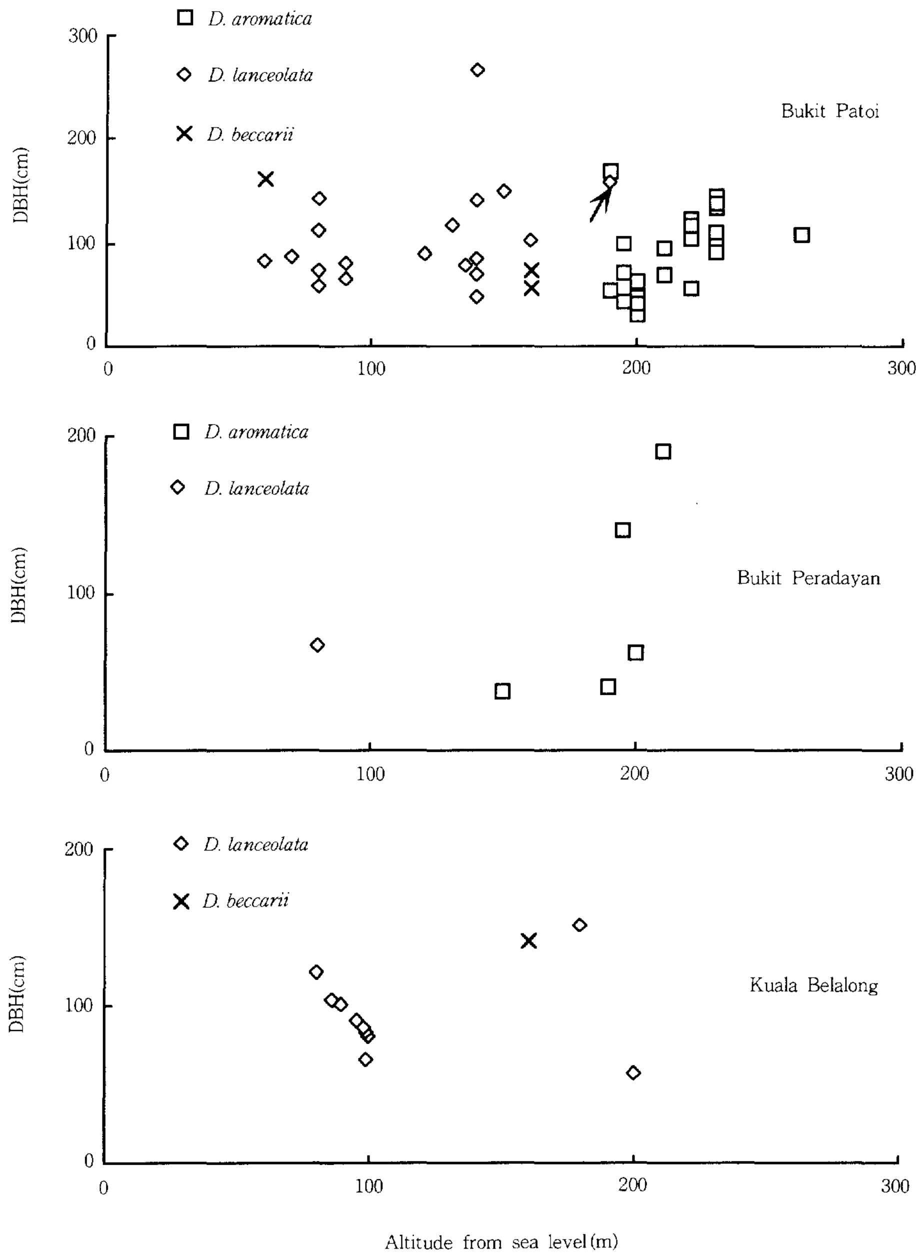
3.2 Trial plantation

3.2.1 Line planting

(1) Microclimate in line planting

The relative light intensity in each plot of line planting was 17.1, 28.6, 67.3 and 83.5% in 4, 6, 10 and 15m width line planting, respectively. The seedlings receive more sunlight in wider width line planting than in narrower width line planting. Since the difference in height of upper trees surrounding each plot is small (Table 2), the line width is a main factor to determine the light condition in each plot. There is a small difference in light intensity between each three part of the slope, because the relative light intensity was 90.9, 80.6 and 80.2% in the upper, middle and lower part of 15m width line planting, respectively.

In spite of the small difference in light intensity between the upper and lower part, there is great difference in the soil water condition between them (Fig. 4). The soil became drier faster in the upper part of the slope than in the lower part. The soil water condition also varies according to the depth. The soil in the upper part at 15cm depth became drier less than -49kPa at which the capillary bond



Note : Seeds of pointed *D. lanceolata* in Bukit Patoi seemed to be mixture of both *D. lanceolata* and *D. aromatica*

Fig. 2. Altitude of three *Dryobalanops* species distributed in the three experimental sites

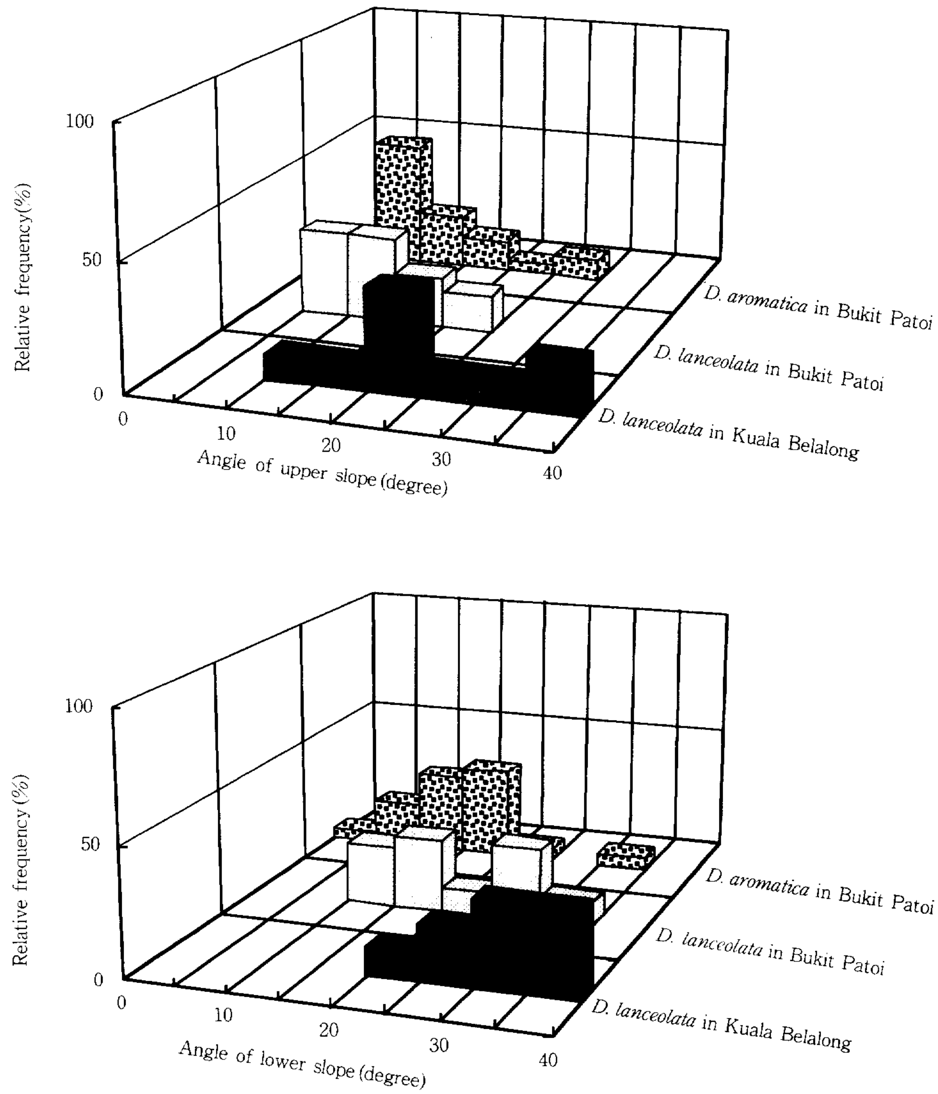


Fig. 3. Relative frequency of vertical angles to both the upper and lower slope from each *Dryobalanops* tree

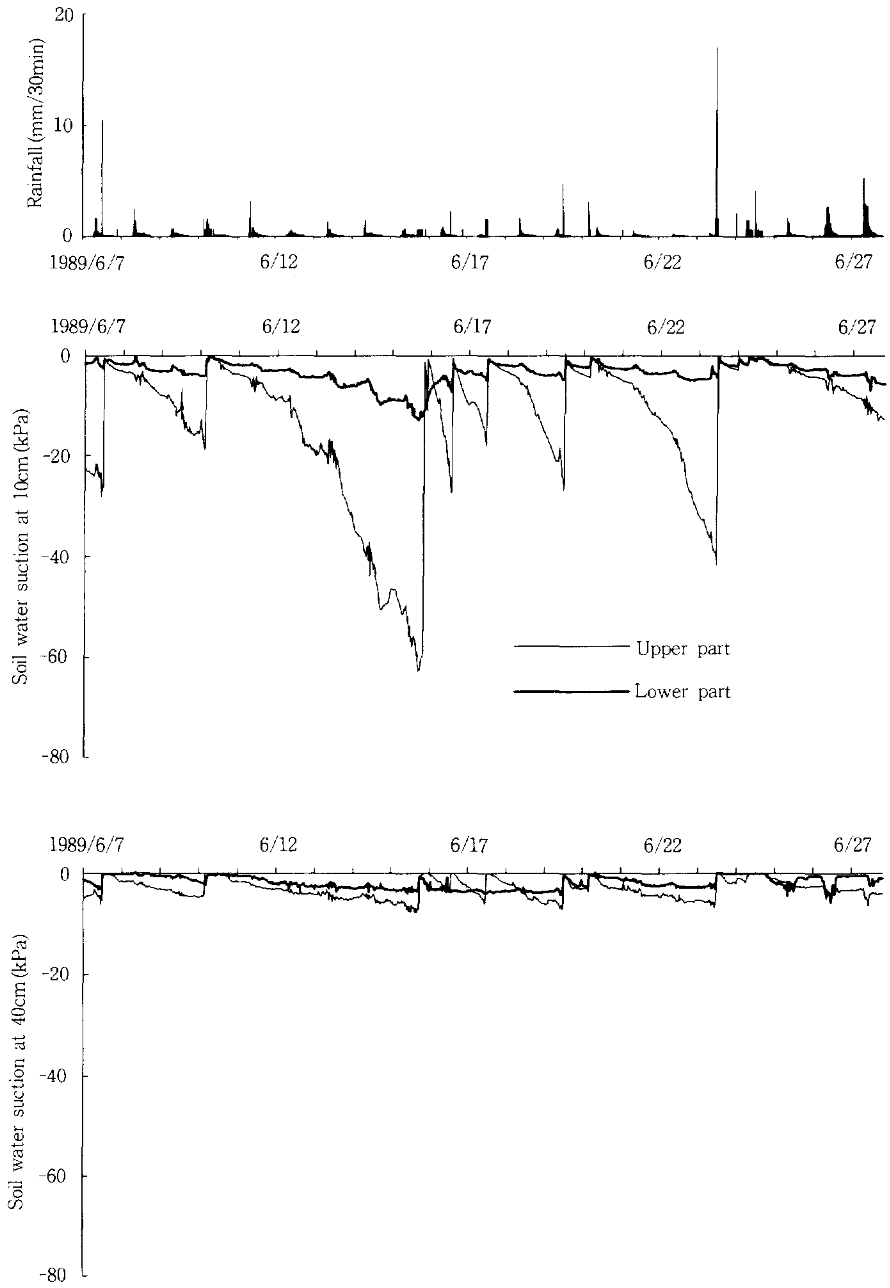


Fig. 4. Rainfall in the middle and soil water suction in the upper and the lower part of 15m width line planting plot

in the soil is ruptured while the soil water condition at 40cm depth on both parts of slope is constantly wet.

(2) Influence of line width on seedling growth

The seedlings of *D. aromatica* in narrower line width plot showed a higher survival rate with exception of those in 6m line width plot (Fig. 5). The reason of low survival rate in 6m line is not clear. Low quality of the seedlings is one of the reasons of low survival rate in wider line. The planted seedlings were from wildings which were regenerated on forest floor of the natural forest. These wildings usually have poorly developed roots and shade leaves, which are not suitable for surviving under strong sunlight. Since the seedlings receive almost full sunlight in 15m width plot, these planted seedlings were too weak to survive under such severe conditions.

The seedlings showed the largest increment in average height, diameter at ground and leaf number per individual in 15m width plot (Fig. 6) in spite of the low survival rate. TANG (1980) reported that in the case of *Shorea parvifolia* which were planted under forest canopy, the earlier removal of upper trees accelerated the growth rate of the seedlings. Both cases of *D. aromatica* and *Shorea parvifolia* show the fact that the seedlings need wide line width for their quick growth.

(3) Influence of slope sites to seedling growth

In order to analyze suitable sites on slope for the growth of the seedlings of *D. aromatica*, the seedlings in 15m width line are divided into three groups associated with the location on the slope such as the upper, the middle and the lower. The upper part is near the ridge, the lower part is near the river in the small valley and the middle part is between these two parts.

The survival rate was higher in upper part than in other two parts in spite of less preferable condition of drier soil in the upper part. After April of 1990, the survival rate became stable in the upper part although that of the lower part was decreased after that (Fig. 7).

The average height, diameter at ground and leaf number per individual showed the largest increment on the upper part and the smallest increment on the lower part of the slope (Fig. 8). Although the difference in the increment between the upper and the lower part of the slope is relatively small, there seems to be particular site on slope, where seedlings of *D. aromatica* grow more quickly.

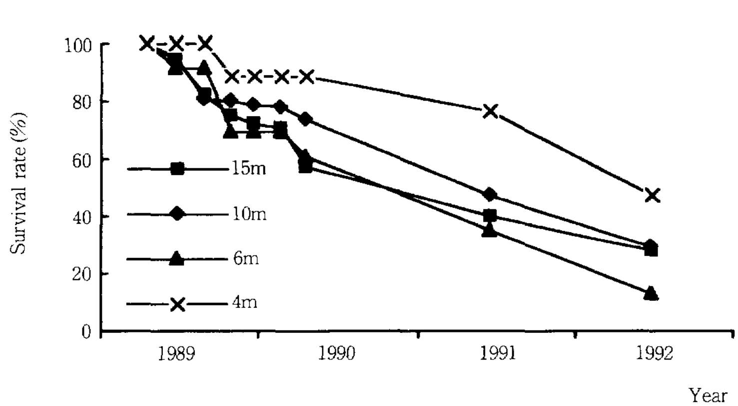


Fig. 5. Survival rate of the seedings of *Dryobalanops aromatica* planted in various line width of line plantings

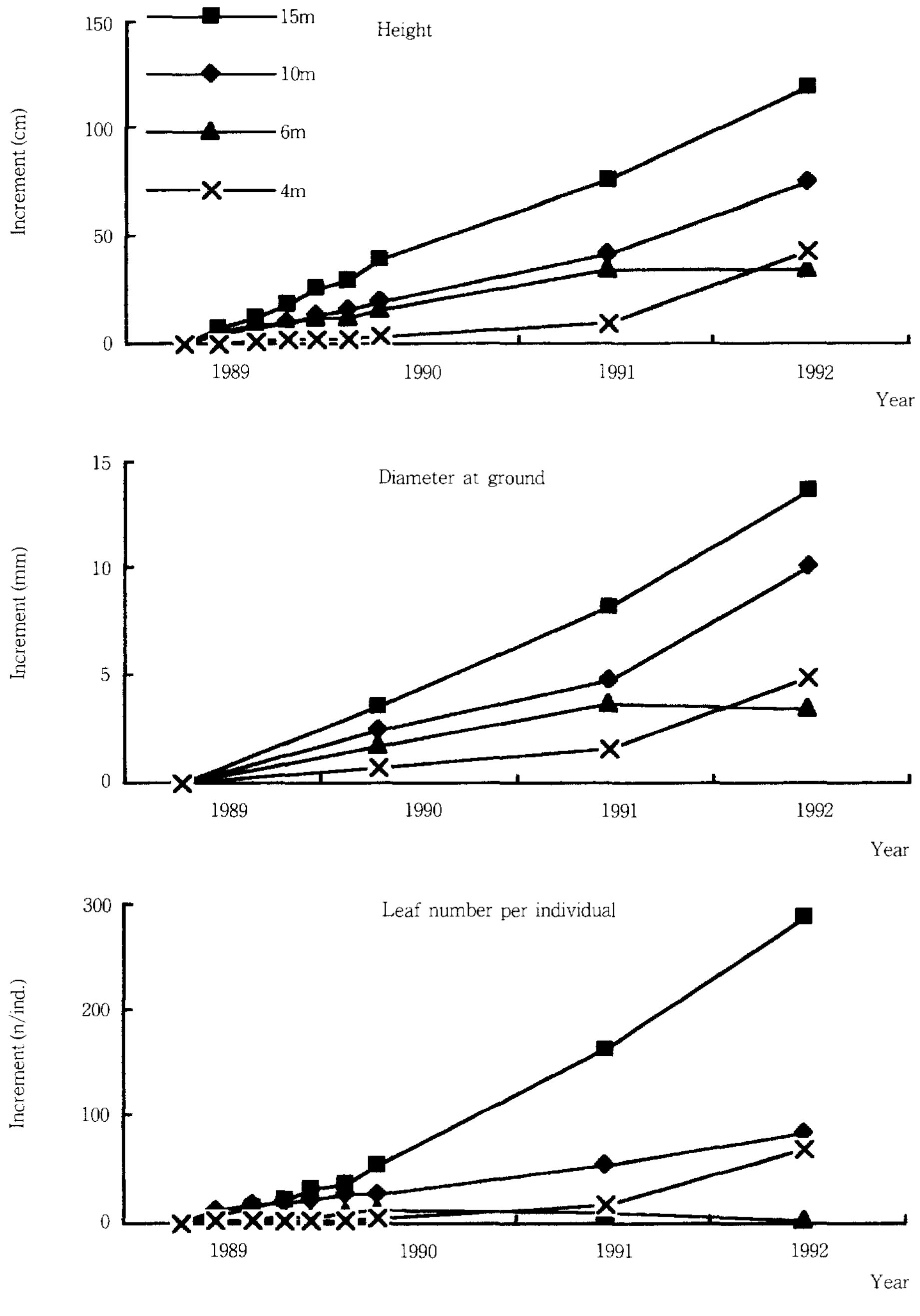


Fig. 6. Growth increment of the seedlings of *Dryobalanops aromatica* planted in various line width of line plantings

(4) Weeds

Weeding is an important treatment for the maintenance of plantation site. The investigation of weed dynamics is important to determine the timing of weeding. The dry weight of weeds varied according to the line width. In every site on the slope, the weed in 15m width plot was greater than that in 6m width plot (Fig. 9). The wider line width thus accelerates the weed growth as well as the seedling growth.

The dry weight of weeds also varied according to the site on the slope. The lower part has the greatest weed weight and the upper part has the smallest weight both in 6m and 15m width plot. The soil moisture is the one of the largest factors to affect the weeds. The content of weeds also varied according to the site of the slope. Grass species were dominant in the lower part of both 6 and 15m line width plot. Most of the weeds on the upper part is composed by the sprout from woody plants. Planting sites should be determined considering these characteristics of weed regeneration.

3.2.2 Gap planting

Gap planting involves planting seedlings in artificially created canopy gap. In forests, when a mother tree fall down, a canopy gap emerges and this canopy gap makes environment of seedlings more preferable for their quick growth. Instead of waiting mother tree to fall down, all trees inside a certain small area which is selected as plantation site are felled for artificial canopy gap to carry out gap planting. Therefore, gap planting resembles the regeneration process promoted in natural forest.

(1) Microclimate in a gap

The light condition in canopy gap varied according to the gap sizes and the height of surrounding upper trees. The relative light intensity was 68.3, 25.9, 47.1 and 15.7% in 20m×20m of upper part, 10m×10m of upper part, 20m×20m of middle part and 10m×10m of middle part, respectively. The relative light intensity in broad gap is higher than that in small gap in the case

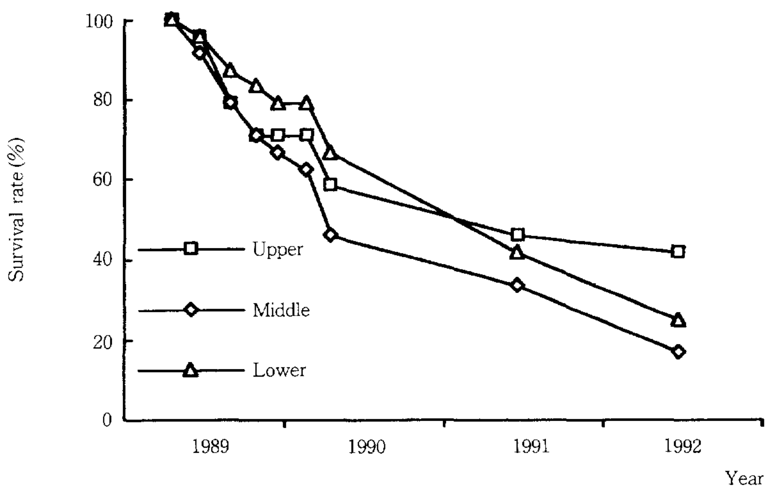


Fig. 7. Survival rate of the seedlings of *Dryobalanops aromatica* in upper, middle and lower part of 15m width line planting plot

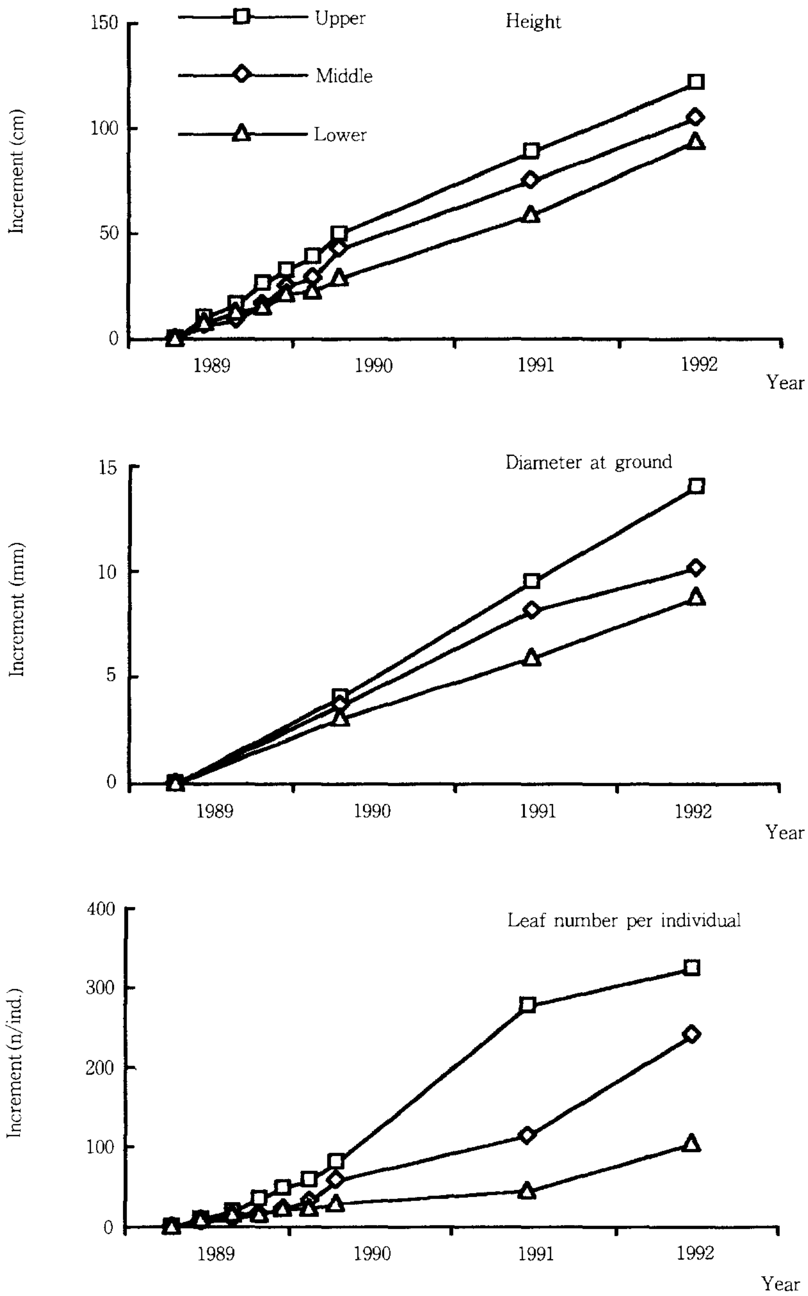


Fig. 8. Growth increment of the seedlings of *Dryobalanops aromatica* planted in upper, middle and lower part of 15m width line planting plot

of same site on the slope. The light intensity of gaps on the upper part of the slope is higher than that in the gaps on the middle part if the gap size is same largely due to the higher height of surrounding trees of the gaps on the middle parts (Table 2).

The duration of receiving direct sunlight was determined by gap size. The seedlings in the centre of 20m×20m receive direct sunlight for about four hours a day and those in 10m×10m for about two hours. Starting and finishing time of receiving direct sunlight varied according the location in the gap (Fig. 10). The north and south edge of the gap also receive the direct sunlight during same period. The west edge of the gap receives the direct sunlight earlier than this period such as 9 am to 1 pm. The east edge of gap receives later such as 11 am to 3 pm. In each site of the gap, duration of direct sunlight is similar (Fig. 11).

Air temperature, humidity and soil temperature at 10cm depth in the gap were different from those under canopy. The air temperature in the 20m×20m gap is higher than that under canopy from 8 am to 6 pm and nearly same from 6 pm to 8 am (Fig. 12). The humidity in the 20m×20m gap is always lower than that under canopy. The difference between these two parts is largest at noon and smallest at midnight (Fig. 12). The soil temperature at 10cm depth in the 20m×20m gap is always higher than that under canopy. The difference in the soil temperature between two parts is largest at 2 pm and smallest at 6 am (Fig. 12). The air temperature, humidity and soil temperature are influenced by light condition. On 3 and 5 June, the light intensity was low due to the rainy or cloudy weather. On these two days, air temperature and soil temperature were lower and humidity is higher than the other days. The air temperature, humidity and soil temperature were hence closely related to the light condition (Fig. 12).

The soil water condition in the canopy gap is clearly different from that under forest canopy. The soil in the gap is wetter than that under forest canopy (Fig. 13). The soil under forest canopy at 15cm, in particular, dried more than -49kPa, at which the capillary bond in the soil ruptured, after about three days with little rainfall. This result is thought to be largely due to the fact that the transpiration by leaves is much greater than the evaporation from soil surface in the gap.

Soil water condition is one of the advantages of canopy gap. Canopy gap also alters the soil water condition (MINCKLER *et al.* 1965) as well as the light condition (CANHAM, 1990). There are relatively large number of reports on relationship between the growth of Dipterocarp seedlings and the light condition (NICHOLSON, 1960 ; SASAKI, 1981 ; SUZUKI, 1986 ; TOMBOC, 1978). The length of planted seedling's root is usually less than 15cm. Because in this study, the soil water condition at a depth of less than 15cm was not measured, we can not discuss how the soil water condition influence the survival rate and the growth rate of seedlings.

(2) Survival rate

The survival rate of both species is higher in small gap than in broad gap (Fig. 14). One reason of low survival rate is severe microclimatic conditions in broad gap such as higher air temperature, soil temperature and lower humidity. The survival rate of the seedlings in the upper part gaps is lower than that of seedlings on the middle part gaps. The soil water condition according to the sites on slopes is the one of the largest reasons of this difference.

There was a difference in survival rate between these two species. The difference in survival rate of *D. aromatica* seedlings between four treatments is relatively small. However, the survival rate of *D. lanceolata* seedlings in broad gap on the upper part of slope is lower than other three treatments. This difference in characteristics of survival rate between these two species is mainly resulted from their own characteristics that *D. aromatica* is distributed on drier sites such as upper parts of slope in natural forests while *D. lanceolata* on wetter sites such as middle parts of slope.

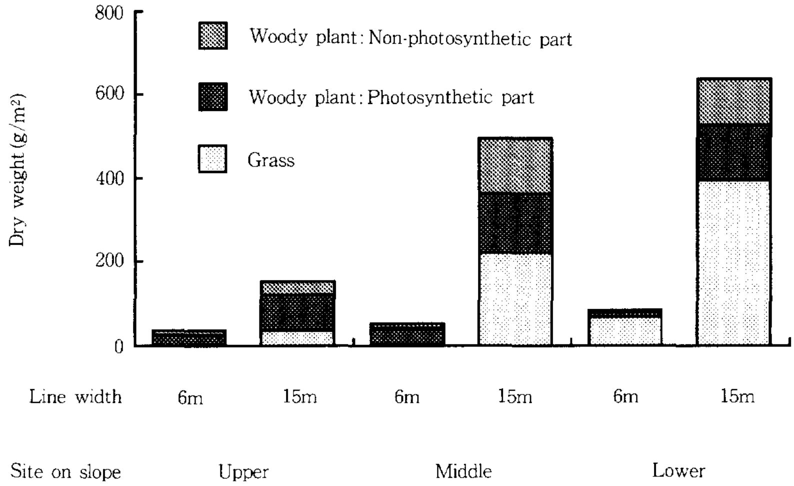


Fig. 9. Dry weight of weeds collected one year after condtructing the plots for line plantings

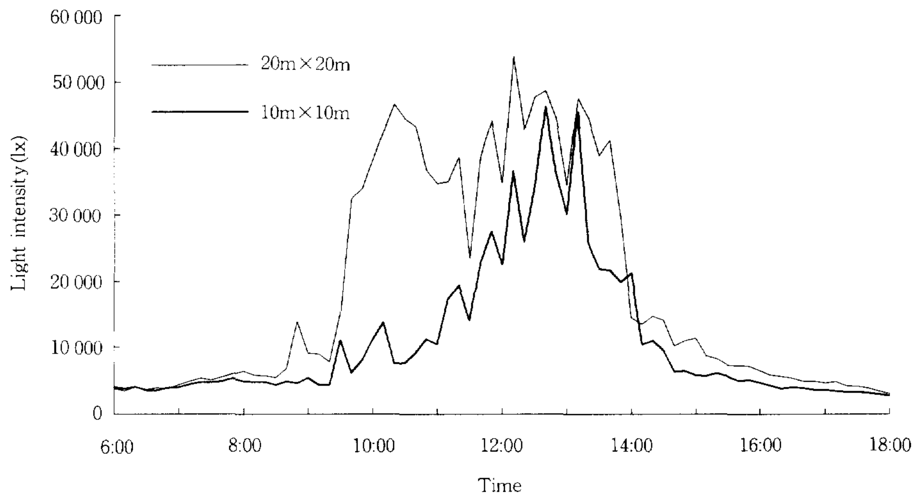


Fig. 10. Diurnal pattern of light intensity in artificial gap with different size measured from September 4 to September 14, 1989

(3) Growth increment

The seedlings of both species showed different characteristics in growth rate. The seedlings of *D. aromatica* showed the largest height increment in 20m×20m gap on the upper part until April of 1991 (about one year after the first measurement), while other three treatments showed similar height increment at this time. After April of 1991, the seedlings in 20m×20m on the middle part accelerated their height growth (Fig. 15). On the other hand, the seedlings of *D. lanceolata* showed the largest height growth in 20m×20m on the middle part, while other three treatments showed similar increment all the time (Fig. 15).

The increment of both diameter and leaf number showed this characteristic in height increment more clearly (Figs. 16, 17). These two factor's increments of *D. aromatica* seedlings in broad gap on both upper and middle part are significantly greater than those in small gap on both parts. The difference in the increments of diameter and leaf number between the upper and middle parts of 20m ×20m gap is much closer than that in the height increment. However, in the case of *D. lanceolata*, the seedlings in broad gap on middle part show the largest increment of both diameter and leaf number while other three treatments show similar increments.

The seedlings of both species grow quickly in broad gap than in small gap. Once the planted seedlings are established, more preferable condition of light and soil water in broad gap accelerate the seedling growth. Therefore, the seedlings need wide opening of canopy for their quick growth.

The seedlings of *D. aromatica*, which is distributed on the drier site in natural forest, grow quickly both on the upper and middle part of the slope. On the other hand, the seedlings of *D. lanceolata*, which is distributed on the wetter site in natural forest, grow quickly only on the middle part of the slope. This difference in growth rate between these two species is mainly resulted from their characteristics. Thus, these characteristics of each species should be considered when planting site is selected.

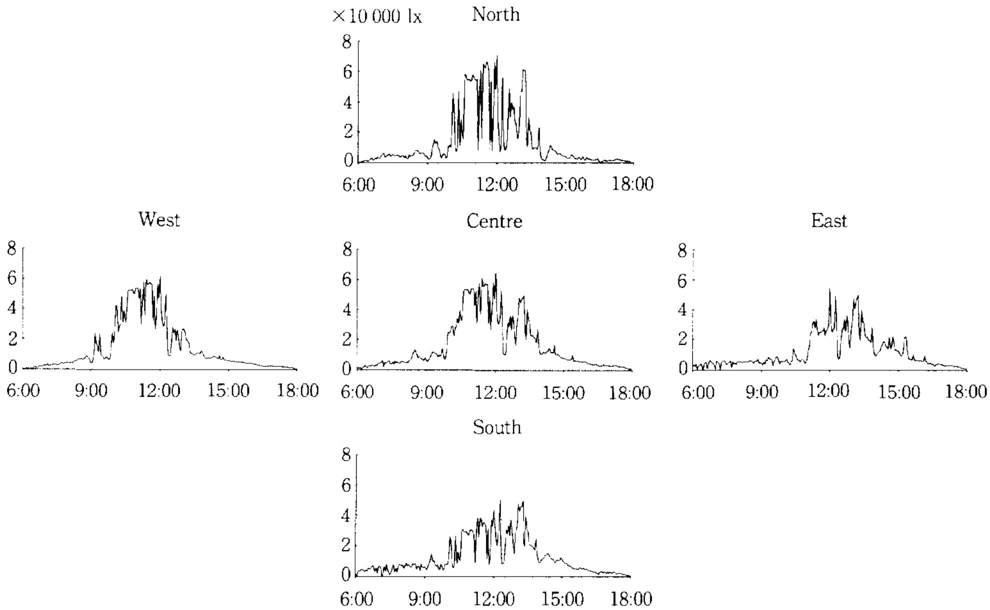


Fig. 11. Diurnal pattern of light intensity at various location in a gap of upper part on the slope

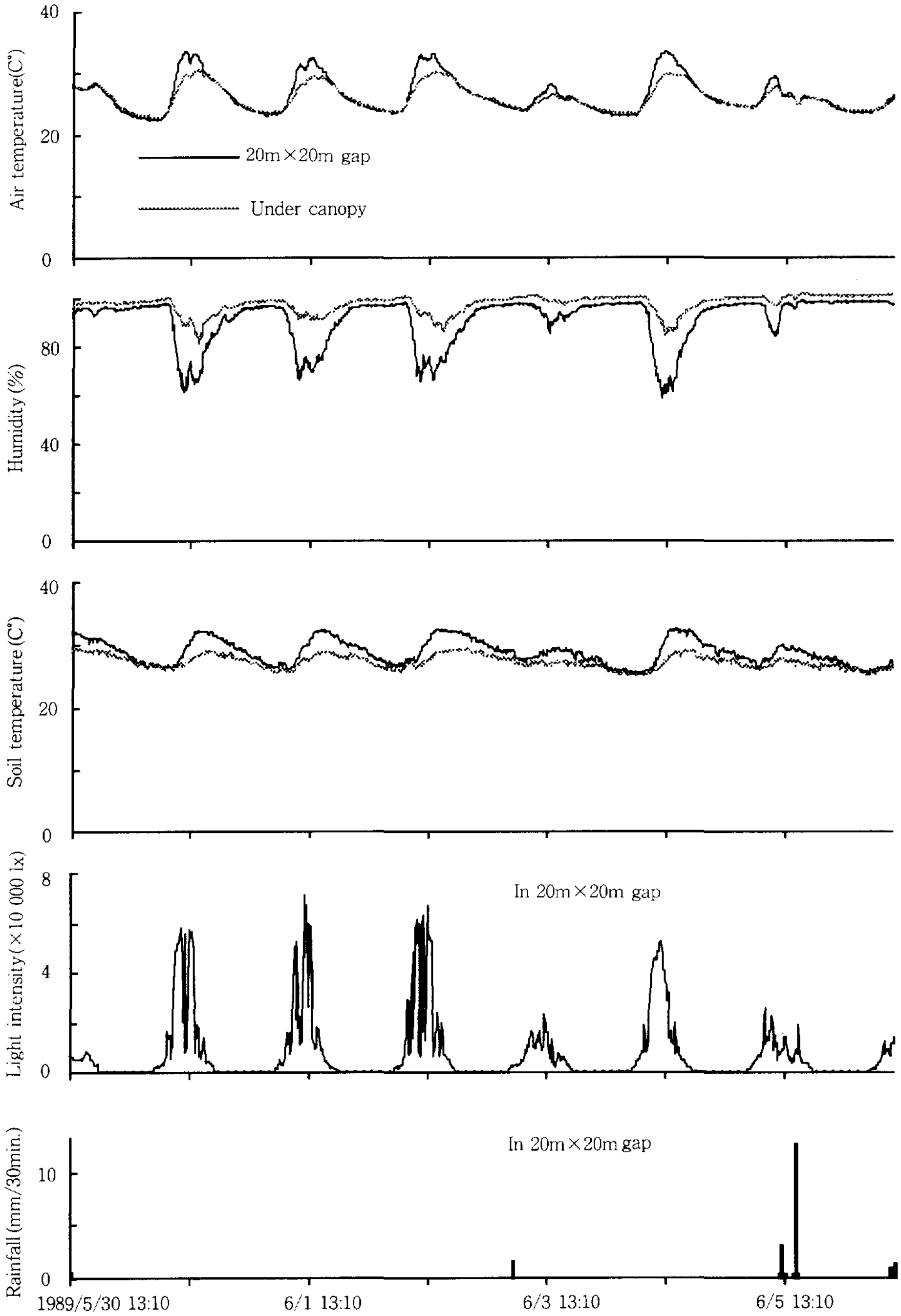


Fig. 12. Air temperature, humidity and soil temperature in the 20m×20m gap on the upper part of slope and under adjacent forest canopy and light intensity and rainfall in that 20m×20m gap

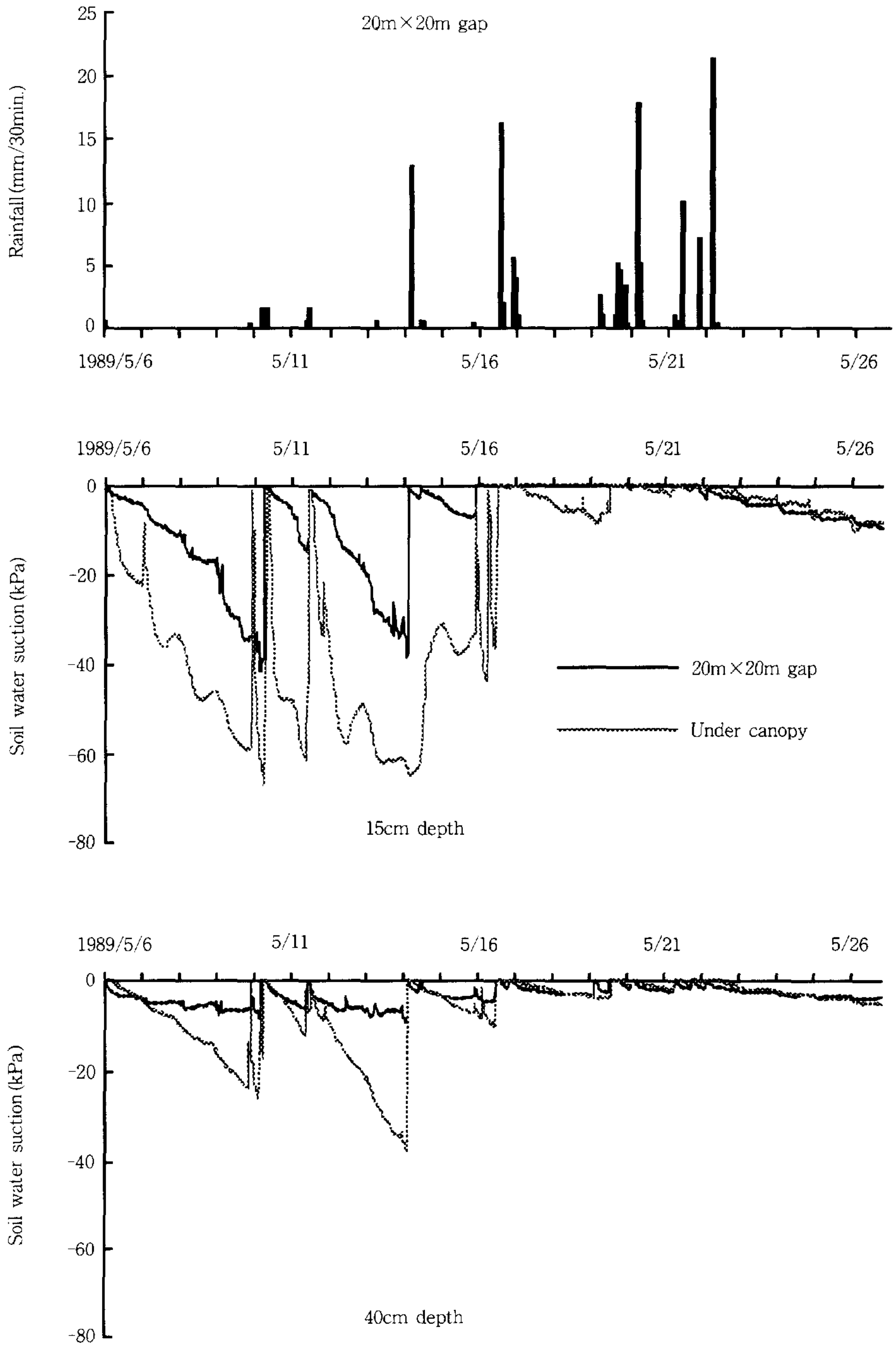
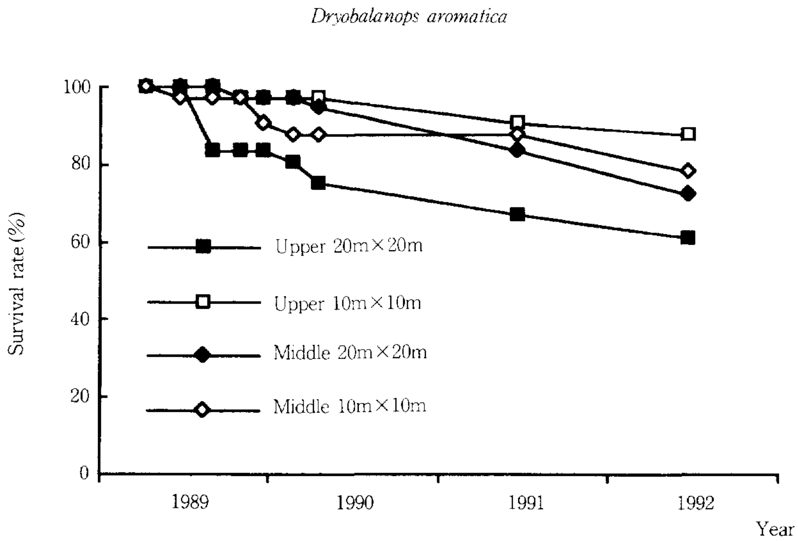


Fig. 13. Rainfall in the 20m×20m gap and soil water suction in that gap and under adjacent forest canopy



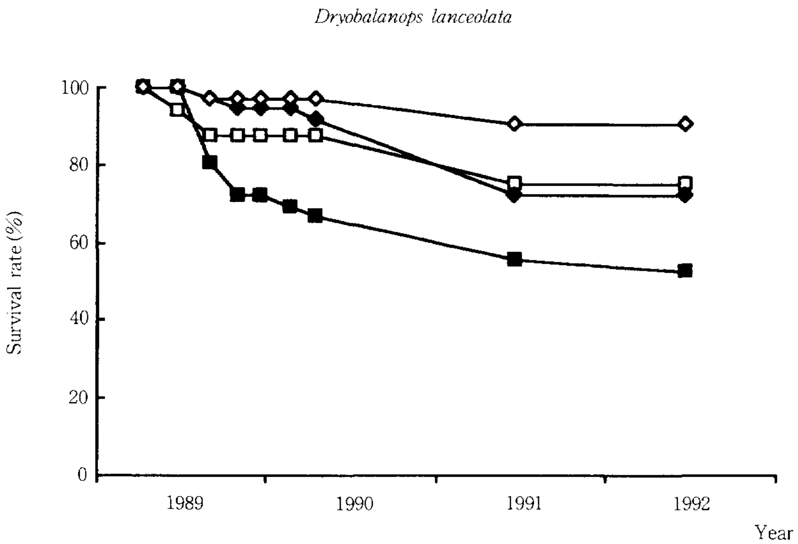


Fig. 14. Survival rate of the seedlings of two *Dryobalanops* species planted in various treatments of gap plantings

(4) Weeds

The growth of weeds was affected by the gap size and the gap site as is mentioned in the weeds in line planting. The dry weight of weeds in broad gap was bigger than that in small gap of same site. The dry weight in the lower site is also greater than that in the upper site if the size is same (Fig. 18). The content of weeds in the upper part differs from that in the middle part. The tendency of weed quality is similar to that in line planting; that is, most of upper part weeds consists from sprout from woody plants and lower part from grass.

As the result, the weeds in gap planting is less than those in line planting although the growth rate of seedlings in gap planting is much higher than that of seedlings in line planting. This fact also shows the advantage of gap planting.

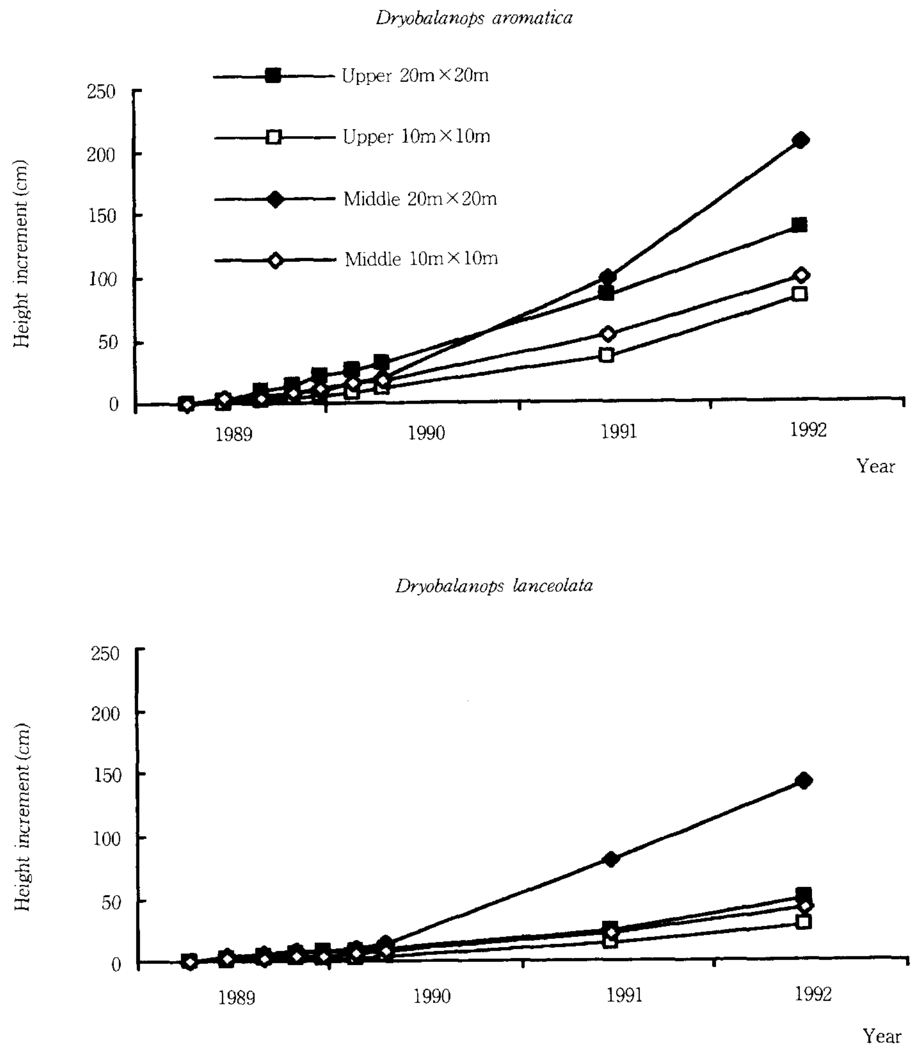
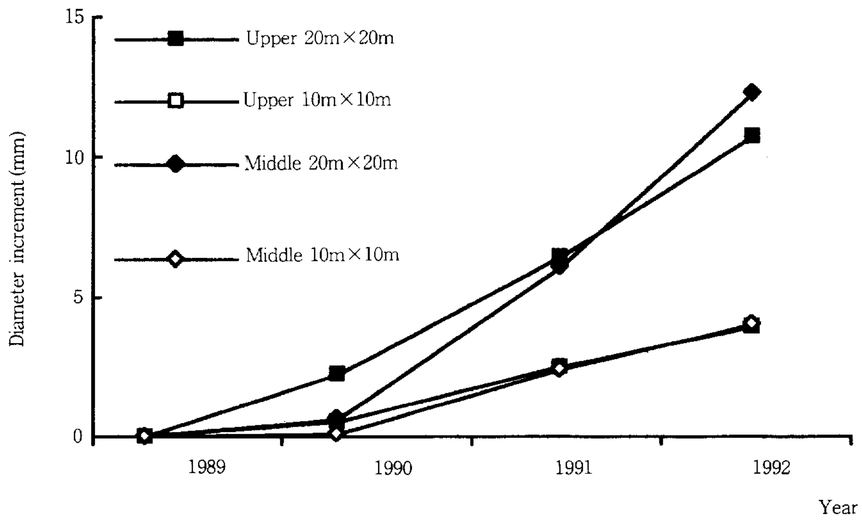


Fig. 15. Average height increment of the seedlings of two *Dryobalanops* species planted in four treatments of gap plantings

Dryobalanops aromatica



Dryobalanops lanceolata

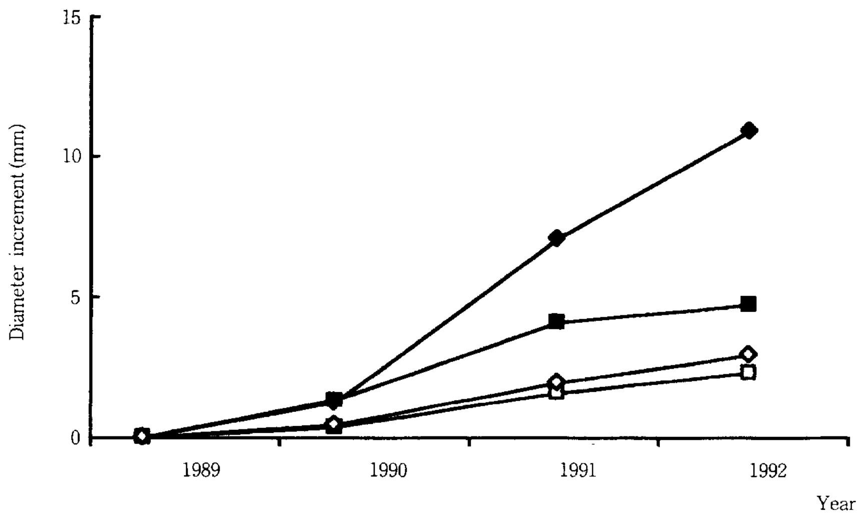
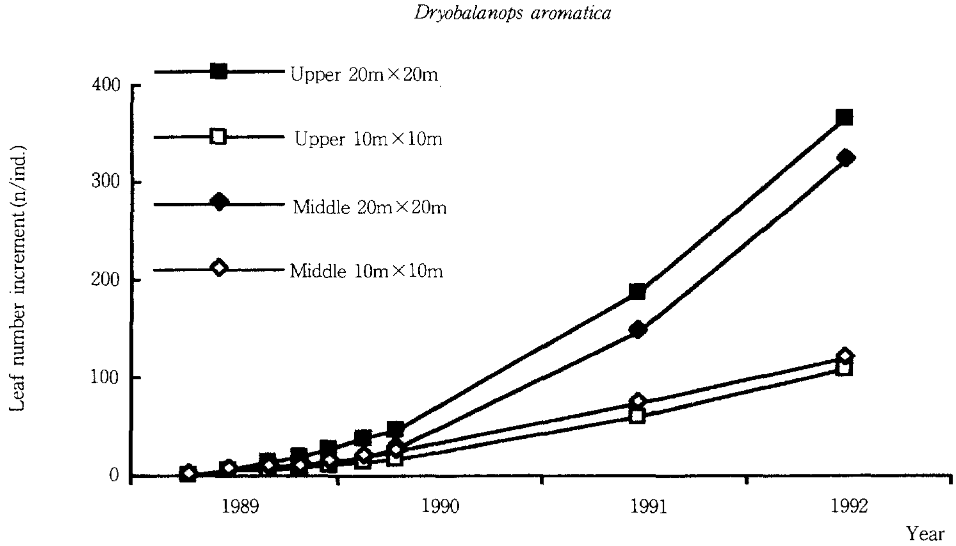


Fig. 16. Average increment of diameter at ground of the seedlings of two *Dryobalanops* species planted in various treatments of gap plantings



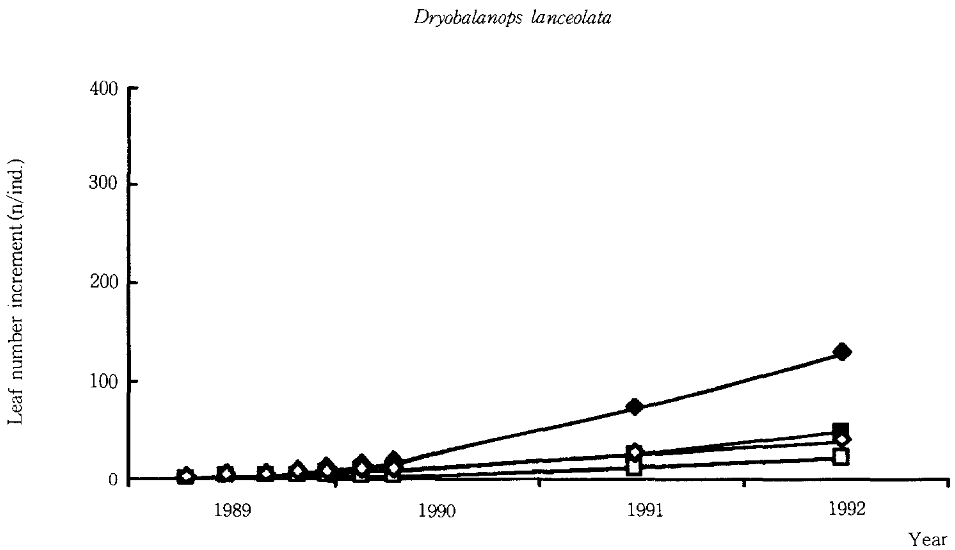


Fig. 17. Average increment of leaf number of two *Dryobalanops* species planted in four treatments of gap planting

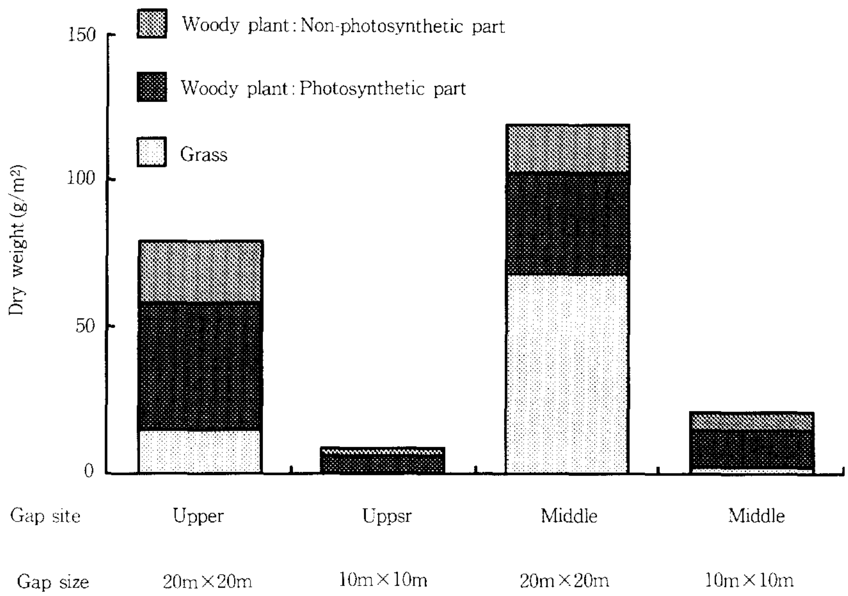


Fig. 18. Dry weight of weeds collected one year after constructing the plots for gap plantings

4 Conclusion

It is necessary for both species to prepare the broad opening of canopy where their seedlings were planted. Both species also have its own suitable site for planting. *D. aromatica*, which is distributed in upper site on slope, grows quickly both on the upper and the middle part of slope, while *D. lanceolata*, which distributed in middle site, grows quickly only on the middle part of slope. When planting is carried out, these site suitability should be considered to maximize the growth rate of planted seedlings.

Reference

ANON.: Annual report, 1986, Forestry Department, Brunei Darussalam, 1987

ASHTON, P.A.: Manual of the Dipterocarp trees of Brunei State, Oxford University Press, 242pp. (1964)

CANHAM, D. C. *et al.*: Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests, Can. J. For. Res., **20**, 620-631(1990)

MINCKLER, L. S. *et al.*: Reproduction of hardwood 10 years after cutting as affected by site and opening size, J. For., **63**, 103-107(1965)

NICHOLSON, D. I.: Light requirements of seedlings of five species of Dipterocarpaceae, Malayan Forester, **23** (4), 344-356(1960)

SASAKI, S. *et al.*: Growth response of Dipterocarp seedlings to light, Malaysian Forester, **44**, 319-345(1981)

SUZUKI, T. *et al.*: Response of Dipterocarp seedlings to various light condition under forest canopies, Bull. For. & For. Prod. Res. Inst., 336, 19-336(1986)

SYMINGTON, C. F.: Foresters' manual of Dipterocarps, Malayan forest record **16**, 244pp.(1943)

TAKAHASHI, M. *et al.*: Ultisols under Secondary Mixed Dipterocarp Forest in Brunei and Their Nutritional Characteristics, Bull. For. & For. Prod. Res. Inst., 366, 57-78(1994)

TOMBOC, C. C. *et al.*: White lauan (*Shorea contorta*) in the open and under second-growth forest canopy, Sylvatrop, **3**, 205-210(1978)

TANG H. T. *et al.*: Preliminary results of two six-year old under-planting trials at Tapah hills forest reserve, Perak, Malaysian Forester, **43**, 193-211(1980)

WOOD, G.H.S. and MEIJER, W.: Dipterocarps of Sabah (North Borneo), Sabah Forest Record, **5**, 344pp.(1964)

ブルネイダルサラム国におけるフタバガキ科リュウノウジュ属2樹種の天然分布と適切な植栽方法

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摘　要

伐採により有用樹が減少し、劣化した二次林の質的な向上を目指すため、フタバガキ科リュウノウジュ（*Dryobalanops*）属の2樹種の天然分布と様々な二次林内の伐開地に植栽された両樹種の植栽後3年間の成長を報告する。

両樹種のうち、*D. aromatica*は、斜面上部の比較的広くて平坦な尾根上に天然分布していた。一方、*D. lanceolata*は、斜面中部の急斜面上に天然分布していた。つまり、前者は後者に比べて、より土壌の乾きやすいところに天然分布している。

この両樹種のうち、*D. aromatica*を、熱帯地方で広く行われているラインプランティングをまねた線状の伐開地に植栽した。線状の伐採地の幅が広いほど*D. aromatica*の生存率は低かった。しかし、樹高や直径などの増加量は幅が広いほど大きかった。このように、この樹種が早く成長するためには樹冠を大きく開ける必要があった。また、斜面上部、中部に植栽された稚樹は下部に植栽された稚樹より成長がよかった。

次に、天然分布の異なる両樹種を、それぞれの樹種が天然分布している地形に似ている斜面上部と中部に伐開した大きさ20m×20mと10m×10mの人工的なギャップ内に植栽した。これをギャッププランティングとした。生存率は、両樹種ともギャップが大きいほど低くなっている。しかし、大きいギャップは多少生存率が低くなるものの成長は早かった。大きいギャップ内では、光が多くあたり、また、土壌も湿っていることが分かった。このような大きいギャップ内の微気象の優位性が、大きいギャップ内に植栽された稚樹の成長を促進するものと思われた。また、斜面上の位置の違いによって、大きく成長の傾向が違っていた。より乾いた尾根筋に天然分布する*D. aromatica*は、斜面上部と中部の樹高成長に大きな差は出なかったが、*D. lanceolata*は斜面中部の大きいギャップ内でのみ大きな樹高成長量を示した。このように両樹種には、それぞれの樹種の特性に応じた植栽適地があった。

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