Response of Dipterocarp Seedling to Various Light Conditions under Forest Canopies

By

Takeyoshi SUZUKI[1] and Domingo V. JACALNE[2]

Summary : This paper deals with the response of six dipterocarp species to various lighting conditions under forest canopies. Under the heavily shaded condition at 1.8% of full sunlight, the survival rates of *Shorea almon*, *S. polysperma* and *Parashorea malaanonan* seedlings were about 10～35%, within a few months of planting. However, the seedlings of *Hopea foxworthyi* and *Vatica mangachapoi* had high survival rates of 85.0% and 97.5% respectively at the same light intensity. The rate of *Anisoptera thurifera* was 65.0%. At 11.7% and 18.9% of full sunlight, all species tested in the experiments showed significantly high rates of survival. In full sunlight condition, about 20～50% of *S. polysperma*, *H. foxworthyi* and *V. mangachapoi* seedlings were damaged, probably due to the strong desiccation and high temperature during the dry season. The maximum growth in height, diameter and dry matter weight for all species was attained in full sunlight. The growth rate slowed with the decrease in light intensity. The degree of reduction in weight increment for most species tested under moderately shaded conditions of 18.9% and 11.7% of full sunlight, however, was smaller than that of the light intensity itself. Under heavily shaded conditions of 4.8% and 1.8%, this relationship was reversed. Among the species tested, the seedlings of *S. almon*, *S. polysperma*, *P. malaanonan* and *A. thurifera* grew vigorously under bright conditions and those of *V. mangachapoi* and *H. foxworthyi* grew relatively slower than the former group even at the high light intensity. On the other hand, the degree of changes in the growth under various light conditions were generally larger in the group of *S. almon*, *S. polysperma*, *P. malaanonan* and *A. thurifera* than in the group of *V. mangachapoi* and *H. foxworthyi*.

Contents

1. Introduction

The forest in the Philippines is represented by tropical rain forest with a dominance by the family Dipterocarpaceae, which produces the bulk of the commercially valuable timbers.

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(1) Kansai Branch,
(2) College of Forestry, Univ. of the Philippines, Los Baños

There are 8 genera and 51 species known in the Philippines. They have been the source of the so called "Lauan" or "Philippine mahogany", famous in the world timber market. At one time, the wood production export that came mostly from these forests was the biggest dollar earner for the country. These dipterocarp forests, however, have been rapidly depleted. The modern logingg system and the increasing rate of forest destruction through kaingin contributed to the reduction of the dipterocarp forest areas. In order to reverse or at least stop this trend, these forests should be effectively regenerated[5)12)18)].

Since it takes many years for the dipterocarp species to regenerate naturally in the tropical rain forest zone, it is thought that some artificial intervensions, such as treatment of stand structure and forest floor, will be necessary to accelerate plant succession in forestry practice. In this study, some basic properties of several dipterocarp species and their relation with their light requirements were investigated.

2. Materials and method

1) Experimental site

Four experimental plots under different forest canopies and one plot in open land were established in the Makiling Experimental Forest, which belongs to the College of Forestry, University of the Philippines at Los Baños. An area of about 100 m² for each plot was cleaned by removing litters and undergrowth, such as climbing bamboos, rattans, vines, brushwoods and grasses, and about 50 m² in that area was slightly cultivated in order to plant the dipterocarp seedlings. These experimental plots are located at the foot of Makiling mountain and the elevation is about 300 m above sea level. The soil is clay loam with a small amount of humus on the surface. As for the climatic conditions in the Makiling forest area and its surrounding in Laguna province, there are two pronounced seasons, dry from November to April, wet during the rest of year, as shown at Table 1.

Table 1. Climatic condition data (UPLB-CF)

	1981		1982	
	Temp.	Rainfall	Temp.	Rainfall
January	23.60	27.4	24.9	17.3
February	25.50	9.2	25.4	7.9
March	27.00	1.6	26.4	17.2
April	25.15	5.0	28.1	23.8
May	25.33	87.5	28.6	151.1
June	23.89	136.5	28.1	146.3
July	24.00	173.7	27.6	128.7
August	24.40	173.5	27.4	161.4
September	23.43	114.5	27.5	175.9
October			27.1	171.9
November	22.49	184.5	26.4	170.3
December	20.84	74.3	25.4	43.7

Note. Temperature ; Degree C
Rainfall ; mm

Table 2. Relative light intensity in experimental plots

	Sept. 17 1981	June 10 1982	May 28 1983	Note
Plot	Relative light intensity %			
Control	100.0			Photometer LMT Pocket Lux
I	18.9	15.5	16.1	
II	11.7	10.3	12.6	
III	4.8	3.6	4.2	
IV	1.8	1.3	1.7	

The light conditions in every plot were measured by photometer. The relative light intensities at the floor of four experimental plots of which the crown closures are different respectively are shown in

Table 2. They were calculated from the light intensity estimated simultaneously inside and outside at a given time, usually between 10:00 a. m. and 2:00 p. m. The value of relative light intensity changes a little in proportion to sunlight intensity outside caused by the transition of sun and prevailing weather condition, and also with the changes in crown closure of forest trees, including undergrowth, through years. Accordingly, relative light intensity measurements, taken on September 17, 1981, when the weather state was overcast with thin cloud are representative. Hereafter, the five experimental plots are named control plot in open land, 18.9% plot, 11.7% plot, 4.8% plot and 1.8% plot respectively in the discussion.

2) **Seedlings of dipterocarp species used**

The seeds of *Shorea almon* FOXW. (local name : Almon), *Shorea polysperma* MERR. (Tanguile), *Parashorea malaanonan* MERR. (Bagtikan), *Anisoptera thurifera* BLUME (Palosapis) and *Vatica mangachapoi* (Narig) were collected from the Makiling Experimental Forest, Makiling Botanical Garden and Quezon National Park from July to August, 1981. These seeds were germinated under laboratory conditions and the seedlings were raised at the nursery located in the Makiling Experimental Forest Station. In addition, the wildlings of *Hopea foxworthyi*. (Dalingdingan) collected from the Quezon National Park were also planted in the nursery in August, 1981. Twenty to forty seedlings of these species were transplanted in each plot, using the earth ball method, with a distance of about 30 cm between them at the end of October, 1981. The size and dry weight of planted seedlings are shown in Table 3. Since they were transplanted very carefully and watered from time to time for two weeks after planting, most of them could root in each given site. After planting, periodic monitoring of survival and growth of the seedlings had been done up to May, 1983.

3. Results and discussion

1) **Survival rate**

The changes in the survival rates of planted seedlings under various light conditions for about one year are shown in Fig. 1. The quick reduction in number of some seedlings at the early stage of experimental period under heavily shaded conditions was primarily related to low light intensity. Among the dipterocarp species used, a significant number of seedlings of Almon, Bagtikan and Tanguile in the heavily shaded 1.8% plot died within a few months of planting. On the other hand, the seedlings of Narig and Dalingdingan were surviving with

Table 3. Size and weight of seedling

Species	H (cm)	D (mm)	H/D	W_{SB} (g)	W_L (g)	W_R (g)	W_T (g)
Almon	10.5	1.4	7.5	0.09	0.14	0.05	0.28
Tanguile	10.9	1.6	6.8	0.09	0.16	0.10	0.35
Bagtikan	9.7	1.4	6.9	0.08	0.13	0.10	0.31
Palosapis	9.5	1.7	5.6	0.06	0.14	0.07	0.27
Dalingdingan	6.4	0.8	8.0	0.03	0.04	0.03	0.10
Narig	4.7	1.1	4.3	0.02	0.03	0.02	0.07

Note. W_{SB} : weight of stem and branch. W_L : weight of leaf. W_R : weight of root. W_T : Total weight of seedling.
Almon (*Shorea almon*). Tanguile (*Shorea polysperma*). Bagtikan (*Parashorea malaanonan*). Palosapis (*Anisoptera thurifera*). Dalingdingan (*Hopea foxworthyi*). Narig (*Vatica mangachapoi*).

high percentages of 97.5 and 85.0% respectively under the same light intensity. That of Palosapis was 65.0%. These results indicate that Almon, Tanguile and Bagtikan were shade-intolerant species, whereas Naring and Dalingdingan were tolerant, and Palosapis was moderately tolerant. In the 4.8% plot, about 80% of Almon and Dalingdingan seedlings, and around 90% or so of other species seedlings were surviving during the same term. A high percentage of survival for all species was maintained at the 11.7% and 18.9% plots during the period. Under full sunlight in the control plot, about 50% of Dalingdingan seedlings and 20~30% of Tanguile and Narig seedlings died in the six months following planted, probably due to the soil desiccation and the high temperature from April to May in 1982.

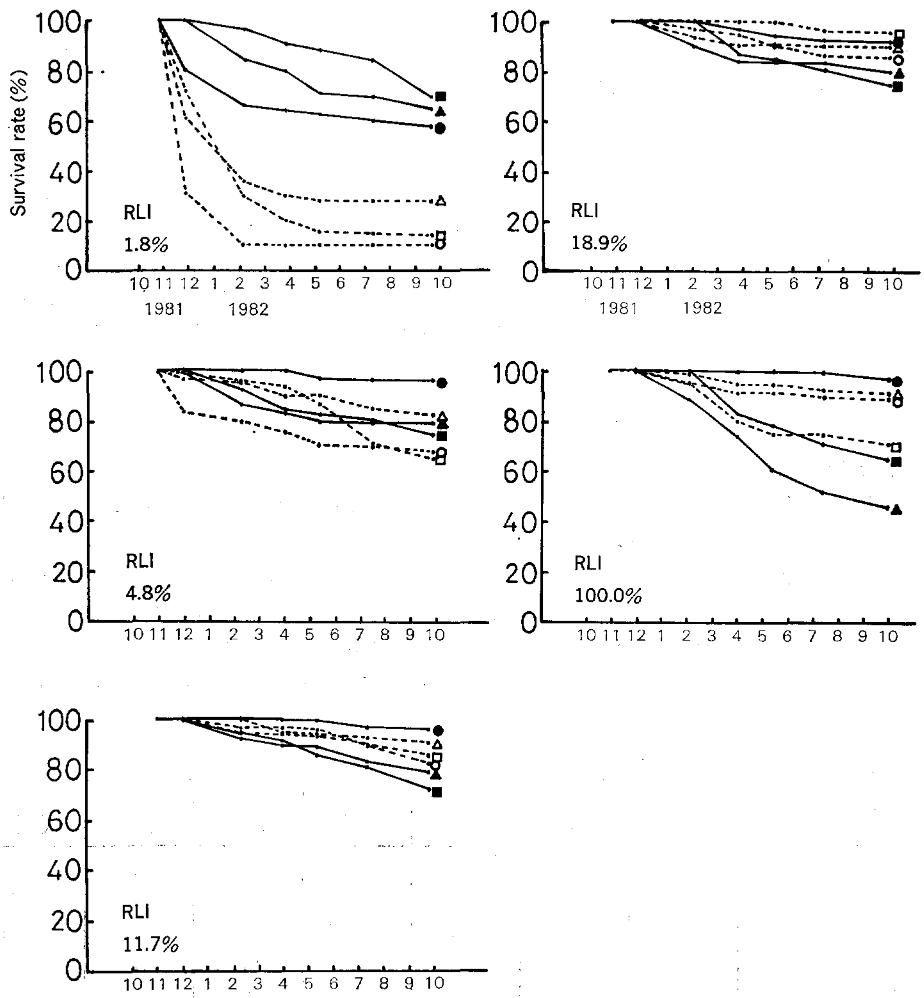

Fig. 1. Survival rate of seedlings under various light conditions.

Note : ---○ Almon. ---△ Bagtikan. ---□ Tanguile. ——● Palosapis. ——▲ Dalingdingan. ——■ Narig.
RLI=Relative Light Intensity.

2) **Growth in height and diameter at base**

The transition in height growth of seedlings of six dipterocarp species surviving during the investigation term is shown in Fig. 2. It was observed that the height growth of each species was in general very slow during the early period, but the growth gradually accelerated in the later period. The biggest height growth in all species was attained in the control plot. The average height of Almon, Bagtikan, Tanguil and Palosapis reached 110～145 cm in the control plot at the end of the experiment, while that of Dalingdingan was 82 cm and Narig 29 cm. These average heights decreased with increase in shading. In the 11.7 and 18.9% plots, however, the heights of Almon, Tanguile, Dalingdingan and Narig were reduced to 70～80% of the control, while that of Palosapis was down to around 50%. On the other hand, the height of each species in the 4.8% plot was about 10～20% to that in the control plot. In the 1.8% plot, the height growth was severely restricted for all species.

The seedling heights of Tanguile, Bagtikan, Palosapis and Dalingdingan in the control plot by the end of experiment had increased by at least ten times, but these of Narig increased only about five times. These growth rates decresed in all species with decreasing light intensity.

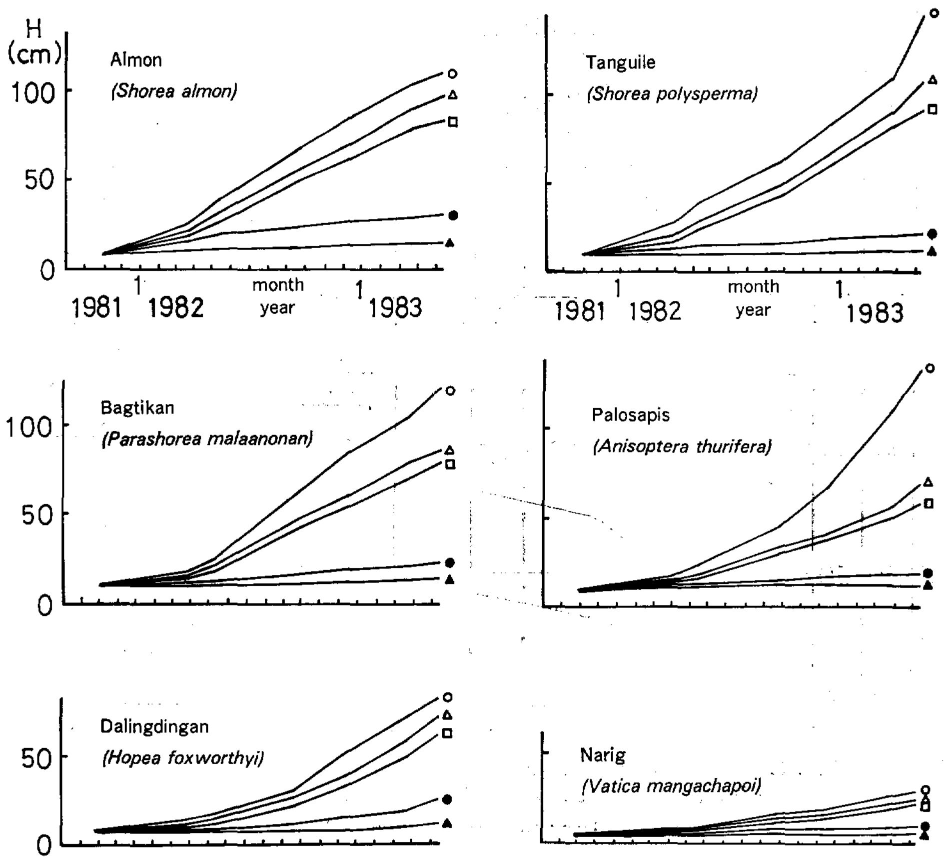

Fig. 2. Height growth of seedlings under various light conditions.
Note : —○ Control plot. —△ 18.9% plot. —□ 11.7% plot.
—● 4.8% plot. —▲ 1.8% plot.

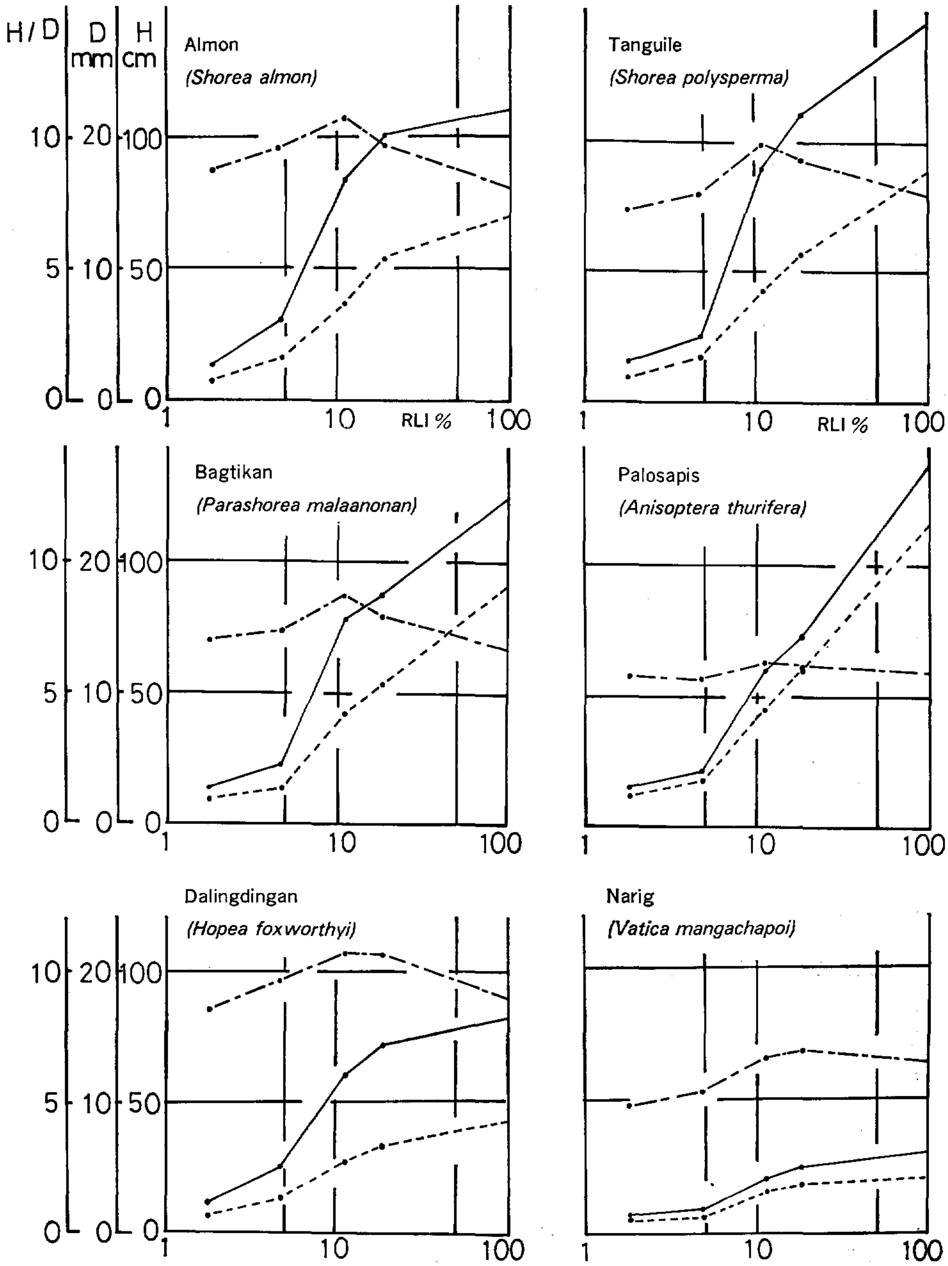

Fig. 3. Relationship between relative light intensity and average height, diameter at base and H/D ratio.
Note : —— H. - - - D. -•-•- H/D.

The average height (H), diameter at base (D) and H/D ratio at the end of experiment are shown in Fig. 3. Since the diameter growth was inhibited more than the height growth under a certain shading, the H/D ratio increased in general with the reduction of light intensity. This remarkable tendency was observed in the 11.7% and 18.9% plots. Among the species, the degree of change in the H/D ratio with shading was relatively greater in the seedlings of Almon, Tanguile and Bagtikan than in those of Palosapis and Narig. In the 1.8 % and 4.8% plots, however, these tendencies could not be confirmed very clearly because of the scanty growth in both height and diameter in all species. According to results reported by SASAKI and MORI[15], *Vatica odorata* reached the maximum H/D ratio at 30% of the open light and *Hopea helferi* at 10%, and they noted that *Hopea helferi* has an adaptation to a lower light intensity than *Vatica odorata*. From this view point, it seemed that the seedlings of Palosapis were adapted better to a certain shading than the other species.

3) **Dry matter production and its distribution into parts**

It is considered that one of the most useful measures for evaluating the influence of light

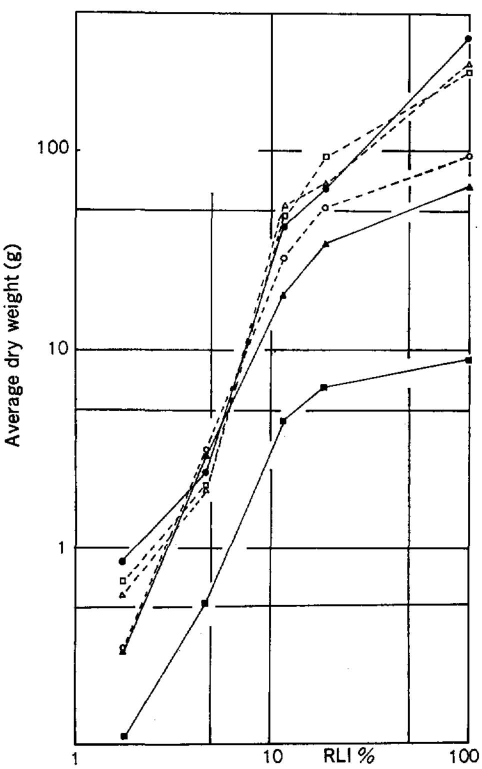

Fig. 4. Relationship between relative light intensity and average dry weight of seedlings.

Note : ---○ Almon. ---△ Bagtikan.
---□ Tanguile. ——● Palosapis.
——▲ Dalingdingan. ——■ Narig.

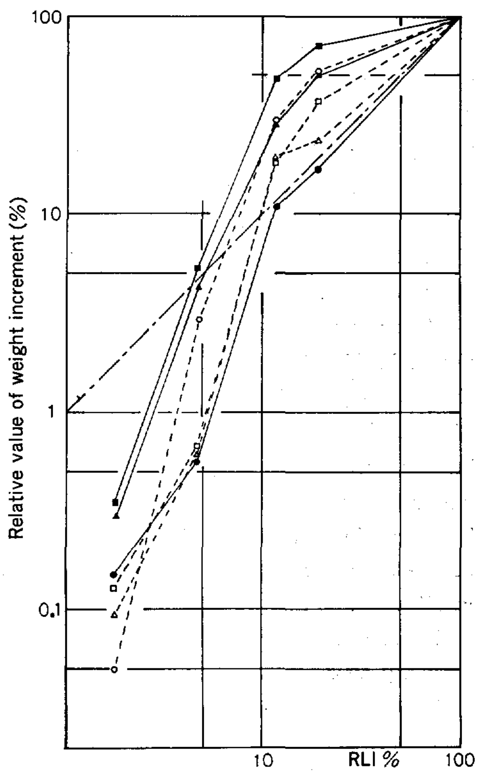

Fig. 5. Relationship between relative light intensity and relative value of weight increment. Daylight=100.

Note : ---○ Almon. ---△ Bagtikan.
---□ Tanguile. ——● Palosapis.
——▲ Dalingdingan. ——■ Naring.

intensity is dry matter production of seedlings and the distribution into different parts is also an additional interest. These aspects in relation with light intensity are shown in Fig. 4 and 6.

The strking feature of the data was the overwhelming superiority in the dry matter weight of seedlings in all species grown in the control plot under full sunlight, although there were large differences in this weight among the species. Average dry weight of Almon seedling was 97.2 g, Bagtikan 268.1 g, Tanguile 254.6 g, Palosapis 388.7 g, Dalingdingan 66.7 g and Narig only 8.9 g. Those dry matter weights decreased greatly with the reduction of light intensity. The dry matter weight in the 1.8% plot was extremely small for all species, and confined to nearly the same weight as that of original seedling planted in October, 1981. So the seedlings of each species in the control plots were several hundreds times in dry matter weight to those in the 1.8% plots.

Fig. 5 shows the relationship between the relative light intensity and the relative value of weight increment of seedling in which the relative value in the control plot is set at 100. In looking at the criterion line passing through the control (100 on the right axis) with an inclination of 45°, the relative values of each species, except Palosapis, in the 11.7% and 18.9 % plots were above the criterion line. This means that the rate of reduction in the weight increment under the range of these light conditions was smaller than the reduction ratio of the light intensity itself. Among the species, the relative values of Dalingdingan, Narig and Almon were at higher positions than the other species, which means that the reduction ratios in the weight increment of these three species were smaller than the others under the range of these light conditions. On the other hand, most of the relative values of each species grown in the 4.8% and 1.8% plots were under the criterion line, especially so in the 1.8% plot. These findings may suggest that the weight increment of these dipterocarp species seedlings decreases greatly under a relative light intensity of less than 10%.

There was a marked trend on the distribution of dry matter production into parts as shown in Fig. 6. That is, as the relative light intensity decreased, the percentage of leaf to the total dry matter weight of seedling increased in general, while that of the stem portion did not change so much, and those of branch and root decreased. Of parts of seedlings, the largest proportion in dry matter weight was in leaves. Besides, since the degree of reduction under low light intensity was generally greater in the root growth than in the top growth in all species, the T/R ratio of these seedlings increased as the relative light intensity decreased. Among the species, the degree of changes in the T/R ratio in relation with light conditions was a little larger in Almon and Palosapis than in Narig and Dalingdingan. Sasaki and Mori[15] reported that, compared with the dipterocarp seedlings grown at a high light intensity, those grown at 30~50% of open light had tall and slim shoots with dark green leaves and relatively poor root systems, and also that these seedlings under the shade were unhardened and succulent. And they mentioned that this type of seedling is generally sensitive to soil desiccation and so the T/R ratio is one of the important indicators for the outplanting of nursery stoks.

The ratio of seedling height to dry weight of top part is considered an index of morphological quality. Since a weak seedling or planting stock grown under insufficient light intensity generally indicates high value of this ratio, it is considered an index of weakness[20]. The relationship of this ratio to the relative light intensity is shown in Fig. 7. Among the species, the seedlings of Tanguile, Bagtikan and Palosapis showed relatively small values in the control

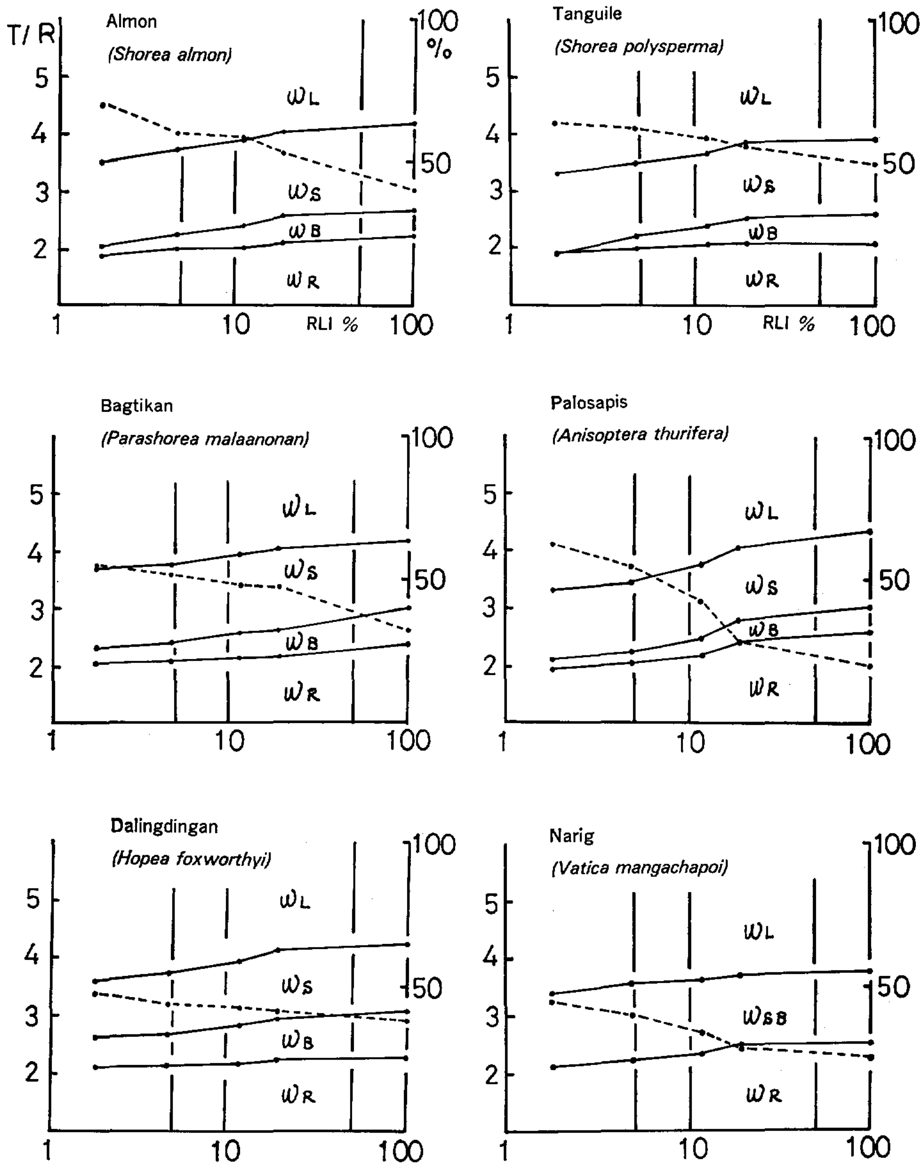

Fig. 6. Relationship between relative light intensity and ratio of average dry weight of stems, branches, leaves and roots to whole seedling weight.

Note : W_S, W_B, W_L and W_R denote dry weight of stems, branches, leaves and roots, respectively. ...... : T/R ratio.

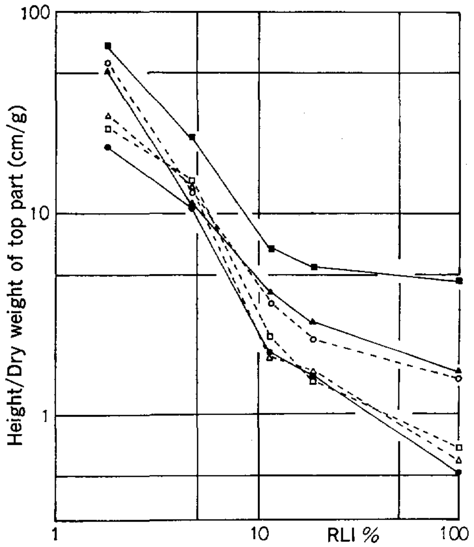

Fig. 7. Relationship between relative light intensity and degree of weakness.

Note : ---○ Almon. ——● Palosapis.
---△ Bagtikan. ——▲ Dalingdingan.
---□ Tanguile. ——■ Narig.

plot, but these values increased greatly as the light intensity decreased. On the contrary, the seedlings of Narig and Dalingdingan indicated somewhat higher values of this ratio than the others in the control plot. It was assumed that the high mortality of these two species in the control plot (Fig. 1) might be partly caused by the high values of this ratio in the control plot.

4) **Size of leaves**

The average size of leaves and the ratio of leaf area to leaf weight, which represents the thickness of leaf, in relation with the relative light intensity are shown in Fig. 8. The size of leaves in the control plots was the largest in all species. The average leaf area and leaf weight of Almon in the control plot were 78.4 cm^2 and 0.59 g respectively, those of Tanguile were 103.0 cm^2 and 0.87 g, Bagtikan 91.4 cm^2 and 0.75 g, Palosapis 102.7 cm^2 and 0.85 g, Dalingdingan 4.9 cm^2 and 0.026 g and Narig 9.6 cm^2 and 0.11 g respectively. These sizes decreased with decreasing light intensity. Since the reduction ratio of these sizes under low light intensity was in general greater in the leaf weight than in the leaf area of each species, the ratio of leaf area to leaf weight increased as the light intensity decrased. And it seemed that the changes in these ratios were a little larger in the leaves of Almon, Tanguile, Bagtikan and Palosapis than in those of Dalingdingan and Narig. Some similar tendencies on the leaves of *Shorea assamica, Hopea helferi, Dipterocarpus oblongifolius* and *Vatica odorata* in Malaysia were also observed[10)15)].

5) **Application to forestry practice**

Virgin and overmature tropical rain forests usually consist of a large number of tree species. Among these tree species, some of dipterocarp species grow up to be large trees with straight boles reaching a height from 40 to 50 m and a diameter up to 150 cm or more, and generally form the dominant story of the forests with a few other large tree species. The dense canopy of such a dominant story often allows very little light to pass through the canopy so that the forest floor is practically devoid of not only regenerated dipterocarp seedlings but also shrubby and herbaceous plants. In the poorly developed forests or logged over forests, on the other hand, many understory plants such as vines, palms, climbing bamboos and others are frequentlypresent. These shrubby plants also cover the forest floor and make the light conditions unfavourable for the regeneration and growth of useful dipterocarp seedlings. Some other natural factors such as soil, moisture, litter, heat and wind also more or less influence the regeneration of dipterocarp species, especially so in their early stages, through flowering, production of seeds, dissemination, germination and survival. Those factors are interrelated and any alteration in any one of them invariably affects others[1)17)18)].

Among the natural factors mentioned above, however, sunlight is one of the most impor-

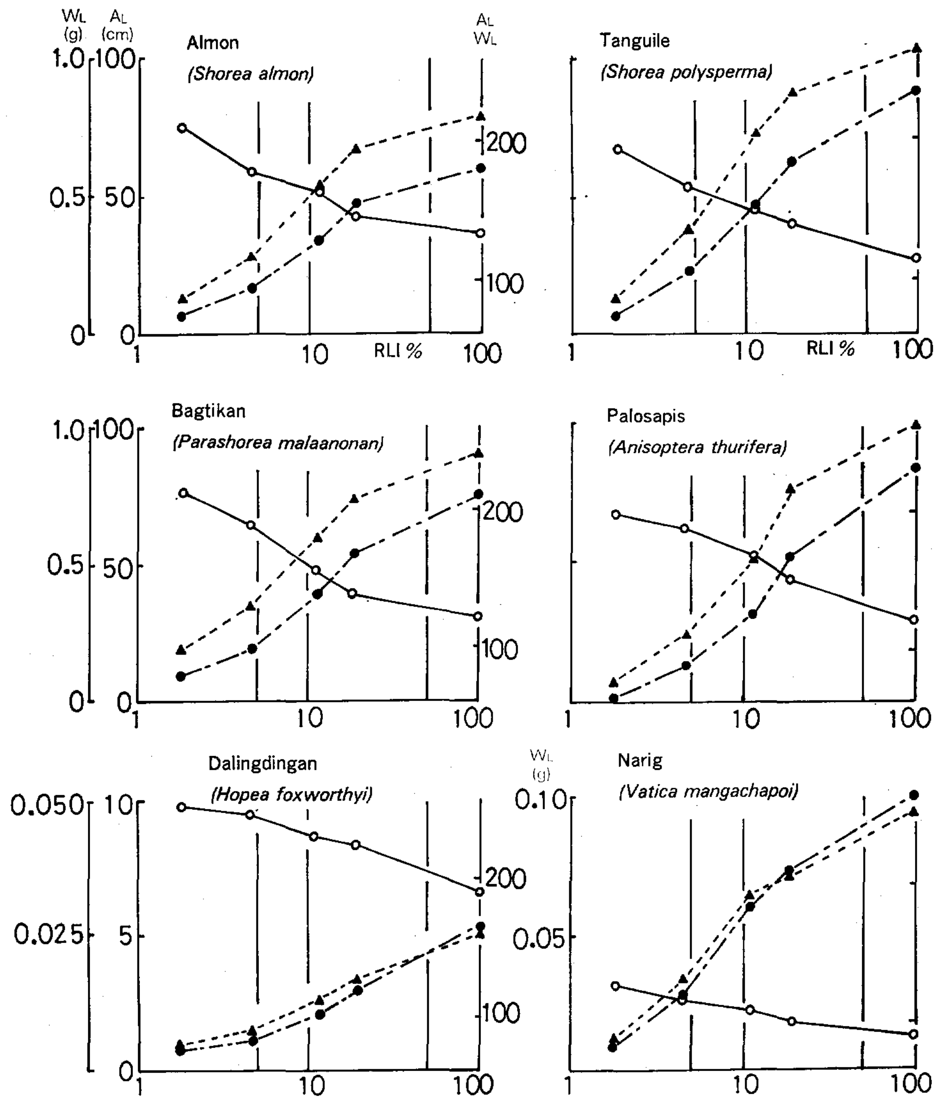

Fig. 8. Average leaf weight (WL), average leaf area (AL) per piece and AL/WL ratio under various light conditions.

Note : ---● Average leaf weight. ---▲ Average leaf area.
——○ AL/WL ratio.

tant for plant growth. It affects plant growth not only directly through photosynthesis but also indirectly through its effects on other environmental factors. In the practice of real forestry where it is desired to secure the regeneration under the forest canopy, considerable attention should be paid to the light conditions in order not only to carry out regeneration but also to reduce its cost as much as possible.

The features and quality of light in the forest has been studied by many researchers. The light reaching the forest floor is classified into two distinct elements with different light spectra, direct sunlight (sunflecks) through canopy holes and gaps and diffused light. The light spectral composition on the forest floor differs greatly from direct sunlight outside of the forest, and this composition affects seedling growth especially morphological development through some kinds of phytochrome actions[2)3)6)7)16)19)].

According to a fundamental study conducted by MORIKAWA *et al.*[9)], the light compensation point which means the physiological minimum light intensity of young *Shorea* was determined as 400～1600 lux depending on the growth conditions. And MORI[10)] reported that an accumulation of storage starch in the inner bark of *Hopea helferi* stem was restricted remarkably at below 1000 lux of light intensity. In general, the light intensity under the continuous canopies of tropical rain forest is usually about 2% or so of the full sunlight which is around 500～1000 lux in the diffused light. This light intensity is very close to the light compensation point for photosynthesis of dipterocarp species[9)15)].

On the other hand, it was recognized that the maximum rate of photosynthesis in lowland rain forest trees of Peninsular Malaysia was in a range between 5000～35000 lux with some variations among the species and growth conditions to which the seedlings were exposed previously[8)]. The seedling growth of many dipterocarp species is more or less inhibited under strong sunlight, and it is considered that the cause may be due to other environmental factors which are altered by the irradiation of strong sunlight[11)17)18)].

SASAKI and MORI[15)] studied the effects of light intensity on the seedling growth of several dipterocarp species planted under the forest canopy in Malaysia and reported as follows. The quantitative growth of seedlings was largely affected by the amount of light energy reaching forest floor. Within a range of light intensity between 500～5000 lux in diffused light level which was equivalent to about 2～15% of the light flux in the open area on an overcast dry, the brighter the site was, the greater the seedling growth was. They mentioned that a minimum 1500 lux by a steady state of diffused light or 8% by the relative light intensity was required for seedling growth, and that at least 2000 lux by diffused light or 10% by the relative light intensity should be secured for regeneration. The tendencies and suggestions mentioned above are in accordance with the results obtained by the authors' experiment on six dipterocarp species in the Philippines, although there are some variations in individual species.

BAUR[4)] grouped a number of tree species in the tropical rain forests into three classes, that is, secondary species, truly tolerant species and gap-opportunists. The secondary species requires almost complete light for survival and growth. They are usually fast growing species, and most of them are short-lived, only growing to small trees. The truly tolerant species are typical trees composing the understory, requiring considerable shade for their early development. They include, however, some trees which ultimately reach the overstory. Some of the slower growing dipterocarp species appear to belong to this class. Gap-opportunist species include many of the valuable trees that ultimately make up much of the rain forest overstory. Their growth is slow and inactive under shade, but if light conditions improve, they grow rapidly. Through the results and tendencies obtained in this study, it may be possible that, among the six dipterocarp species studied, Almon, Tanguile and Bagtikan belong to BAUR's gap-opportunists group. And Dalingdingan and Narig probably belong to the truly tolerant species.

The seedlings of Palosapis have a wide adaptability in various light conditions. As stated above, they can survive even at a heavily shaded site, and can grow up very vigorously in bright conditions. From the view point of silviculture, the wideness of adaptability of seedling to light conditions as Palosapis shows is important, because the wider the adaptability is, the easier the raising and planting of seedlings and tending plantations. From this aspect, Palosapis seems to be one of the most favourable species for the practical regeneration. SASAKI and MORI[16] suggested in their report that *Shorea talura*, *Vatica odorata* and *Hopea helferi* in Malaysia have similar adaptability in the response to various light conditions. It is considered that selecting the dipterocarp species with a wide adaptability for the environmental conditions might be one of the important research subjects for the successful regeneration.

In the forestry practice for regeneration, the light conditions on the forest floor should be controlled with proper timing to allow the continuous growth of dipterocarp seedlings which are the target of regeneration. The group shelterwood or group selection system is well suited for providing the suitable light conditions. The most difficult point in this silvicultural operation is to reconcile the need to open the forest canopy for the growth of dipterocarp species and at the same time to control the growth of shrubby vegetations.

In fundamental studies, it was recognized that the maximum growth of dipterocarps seedlings in some species was attained at about 30～50% or more in relative light intensity[11)15)]. Under a high light intensity on the forest floor, however, the competition between the dipterocarp seedling and other shrubby plants will be intense. Namely, the area will be taken over by jungle growth of light-demanding plants such as climbing bamboos, vines and so on. The dipterocarp seedlings will be suppressed under these sunny plants, and later, short-lived, small, non-dipterocarp trees dominate the area. In order to control these shrubby and weedy vegetations, some routine works such as regular patrols to check them and periodical weeding should be necessary, and these operations will require a great deal of manpower. Besides, there is a great variation in the growth rate at different stages of development[5)14)]. So it is expected that the silvicultural operations for controling the light intensity on the forest floor should be manipulated in accordance with the stage of seedling growth depending on the individual characteristics of each species. Since the experiments in this study had been carried out under a limited scale for two and half years only, the results obtained are still far from conclusive. It is necessary to accumulate a number of concerned research works for the final conclusion. However, some recommendations can be drawn from the present study.

The forest canopy should be opened moderately so that the relative light intensity on the forest floor is about 10～15% for the seedlings of Almon, Tanguile, Bagtikan and Palosapis, and around 5～10% for those of Dalingdingan and Narig in their early stage of regeneration. Under these light conditions, the seedlings of these dipterocarp species can grow continuously and at the same time the jungle growth of light demanding plants may be more or less inhibited. After the dipterocarp seedlings grow up into the pole stage where the height exceeds that of understory plants, additional thinning can be performed so that the relative light intensity in the forest might be 30～50% or more in order to promote the growth of dipterocarp saplings.

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異なる林内照度下におけるフタバガキ科稚樹の生長*

鈴　木　健　敬[(1)]・Domingo, V. JACALNE[(2)]

摘　　要

東南アジアの熱帯降雨林で有用なフタバガキ科樹種の更新には，林内更新技術がきわめて重要である。本研究では，このような更新技術の確立に資するため，6種の有用なフタバガキ科稚樹の生長や形態に及ぼす林内光環境の影響を検討した。すなわち，異なる林内相対照度1.8%，4.8%，11.7%，18.9%および開放した対照区に植栽した6種類のフタバガキ科稚樹〔苗高5～11 cm（樹種平均)〕の生長をおよそ1年半にわたって調べた。強い庇陰下にある1.8%区では，植栽後約3か月で，*Shorea almon*, *S. polysperma*, *Parashorea malaanonan* の生存率が10～35%に減少したのに対し，*Hopea soxworthyi*, *Vatica mangachapoi* では85%，97%の高い生存率を維持した。*Anisoptera thurifera* は65%であった。11.7%区，18.9%区では全体に高い生存率を示した。対照区では，乾季の乾燥や高温などにより，*S. polysperma*, *H. soxworthyi*, *V. mangachapoi* などの30～50%が被害をうけた。植栽稚樹の樹高生長，直径生長，重量生長などは，いずれも対照区において最高を示し，庇陰が強まるとともに減少した。しかし，18.9%区，11.7%区などにおいては，減光の割合には，生長量の減少割合が少なく，強い庇陰下にある4.8%区，とくに1.8%区では著しい生長低下が認められた。樹種別にみると，明るい環境で旺盛に生長する *S. almon*, *S. polysperma*, *P. malaanonan*, *A. thurifera* などは庇陰による生長減退が著しく，反対に耐陰性の大きい *H. soxworthyi*, *V. mangachapoi* などは対照区でも前者に比べて生長量は小さかった。庇陰による形態的な変化は，樹種により異なるが，H/D比，T/R比，個体重に対する葉重の割合，葉重に対する葉面積の割合などが，照度の低下とともに，ある範囲で増大する傾向を認めた。各樹種の光環境による反応は，その生育段階によって変化すると考えられるので，樹下植栽による更新法の確立には，なお長期的な観察が必要と思われる。

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(1) 関西支場
(2) フィリピン大学林学部造林環境学科
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