Above-ground Biomass and the Growth of Giant Ipil-ipil [*Leucaena leucocephala* (Lam.) de Wit] Plantations in Northern Mindanao Island, Philippines

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Introduction

In the Philippines, fast-growing species are often used for reforestation after logging in some areas. However, there are only a few ecological investigations on the biomass and the productivity of these species. Such investigations are necessary not only for selecting a suitable species for a given site, but also for a better prediction of the future yield. Besides, they would contribute to the analysis of the rate of energy flow through ecosystem. But many surveys are required for accomplishing these purposes.

In 1981, we conducted a field survey on the above-ground biomass of *Leucaena leucocephala* (Lam.) de Wit plantations in Mindanao. This species is a leguminous tree and now attracting considerable attentions because of its fast growth and possibility of multiple use such as lumber, charcoal and forage[9]. Thus far, however, the emphasis has rather been put on the studies in connection with forage and charcoal, and there have been few studies concerning its wood production. Recently, with the progress of identification of its strains, some yield trials of planted *Leucaena* have been carried out using several strains[3].

The present investigation was carried out under the collaborative "Silviculture Research Program" between UPLB College of Forestry, the Philippines, and the Tropical Agriculture Research Center, Japan.

Location of study area

The field survey was carried out in the three plantations of Initao, Naawan, and Upper Iligan of Mabuhay Agro-Forestry Corporation (MAFCO). Initao and Naawan belong to Misamis Oriental Province, and Upper Iligan to Lanao Del Norte Province. This survey area is located in the middle of and along the northern coast of Mindanao Island (Fig. 1).

According to meteorological observation, seasons of this area are not very pronounced, but relatively dry from November to April and wet during the rest of the year[10]. Table 1 shows mean values of monthly air temperature and rainfall from 1950 to 1975 at Cagayan

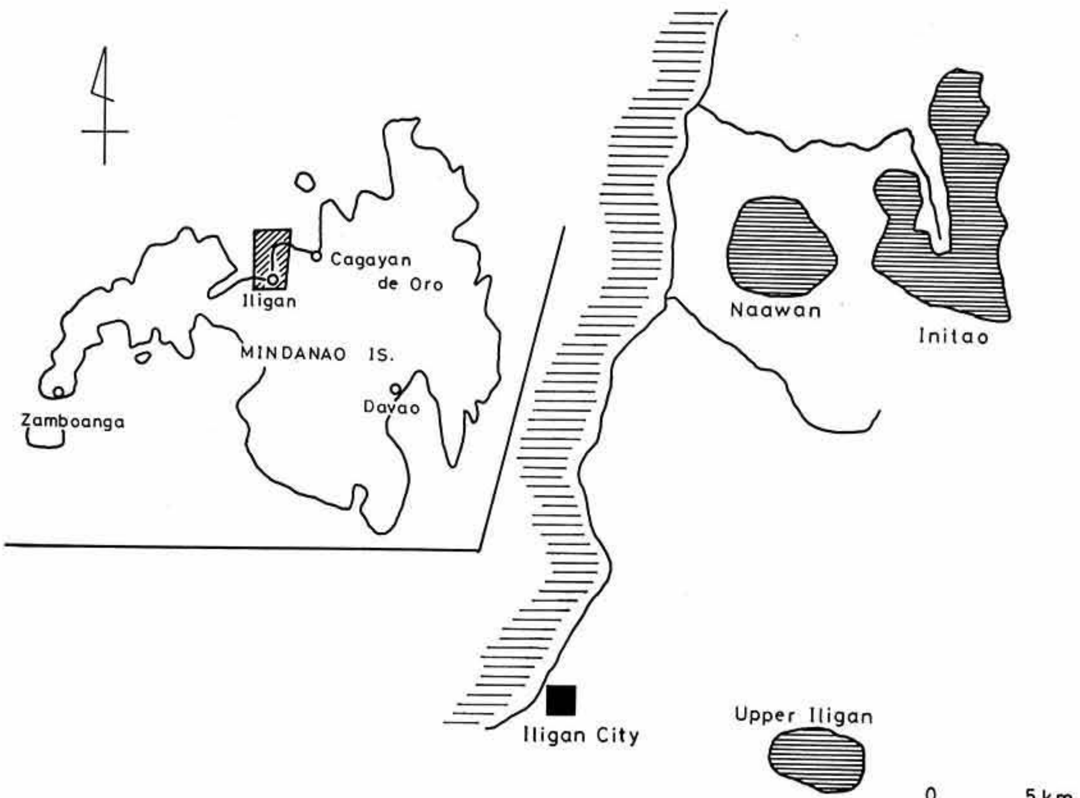

Fig. 1. Location of study stands

Table 1. Monthly mean air temperature(°C) and rainfall(mm) at Cagayan de Oro from 1950 to 1975[10]

	Jan.	Feb.	Mar.	Apr.	May	Jun.
Air temperature	25.76	25.11	26.48	27.49	27.97	27.53
Rain fall	100.33	62.75	45.18	38.33	111.56	214.26
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Air temperature	27.06	27.10	27.05	26.98	26.77	26.17
Rainfall	213.02	211.49	218.18	179.84	140.28	122.28

de Oro, about 50 km eastward from the study area[10]. Typhoons seldom hit Mindanao Island.

Materials and methods

The strain surveyed was K-8 of a Salvador type. Salvador type strains are generally called giant ipil-ipil in the Philippines. The ages of the study stands were all less than 5 years old.

To estimate the biomass of giant ipil-ipil plantations, two sample plots in Initao, six in Naawan, and one in Upper Iligan were established. Besides, two additional plots for thinning experiment were also established in Upper Iligan plantation. The crown closure of some study stands was still insufficient.

The previous condition of most study stands was abandoned corn land. Some coconut trees were observed around plots 1, 2 and 4 in Naawan.

Plot size was ordinarily 10 × 10 m, but it was often changed according to tree height and topography. After setting up the plot, light intensity inside and outside the plot was measured by electric photometer. After the measurement, diameter at 1.3 m high above the ground (DBH) of all trees in the plot was calipered, and then about seven sample trees of various sizes were selected and felled. After height of each sample tree was measured, the tree was divided into 1.0 m depth strata except the base and the top. Fresh weight of each part of each stratum, such as stem, branches, leaves and other living organs, was separately measured. For conversion of fresh weight to dry weight, small samples of each part were brought back to the laboratory and dried at 85°C to constant weight. To calculate leaf area of study stands, leaf area of leaf samples was measured by automatic area meter before drying. Stem volume of each sample tree was determined by Smalian method.

The biomass of undergrowth was determined by six sample subplots of 1 × 1 m in the plot. All plants in the subplots were clipped off, and their leaf area and dry weight were determined by the same procedure as in tree layer.

The period of field works was from late February to late March. General description of study stands is shown in Table 2.

Results and discussion

1) Estimation of average height and biomass

Average height of study stands in Table 2 was estimated using the relationship between height and DBH of sample trees. The relationship was represented by the following hyperbolic equation;

$$1/H = A/DBH + B$$

were H is height, and A and B are constants. By applying this equation to all trees in the plot, the average height of each stand was calculated. Constants A and B were obtained by the least squares method. They are presented in Table 3.

In this study, the allometric relation was used for the estimation of the biomasses of stems, branches and leaves of tree layer. This method is based on the relationship between DBH and the amount of various parts of sample tree. The relationship is represented as follows;

$$\log W = A \log DBH + B$$

where W is dry weight or volume, and A and B are constants. A and B were calculated by the least squares method and presented also in Table 3.

To estimate the amount of various parts per stand, it was required to calculate the amount of each part of a tree from the above equation and then to sum up the amount. But in case of organs such as flowers, seeds and seedpods, the allometric relation was not applied because the sample trees often had no these organs. These organs were put together as "others", and the biomass was estimated by the following equation;

$$Y = Y' \cdot G/G'$$

where Y and Y′ are the amount of others of total trees and that of sample trees, and G and G′ the basal area of total trees and that of sample ones, respectively. Results are shown in Table 4.

2) Biomass

(1) Stem volume

As shown in Table 4, the stem volume was largely different among stands. The volume of plots 2 in Naawan was about four times as much as plot 1 in Naawan in spite of the same stand age. The large difference observed among stands seems to be due not only to stand age but also to site conditions. As far as the study stands are concerned, the average annual increment of stem volume is likely to be more than 50 m^3/ha/year for good site and less than 9 m^3/ha/year for poor site respectively, disregarding differences in stand density. The result obtained in Taiwan showed that the annual volume growth of 1 to 3-year-old plantation of 2,500 trees/ha ranged from

Table 2. General description of study stands

Location		Initao		Naawan						Upper Iligan		
Plot No.		1	2	1	2	3	4	5	6	1	2	3
Elevation	(m)	90	90	20	20	20	20	20	20	200	200	200
Year of planting		Jul. 1977	Jul. 1977	Jun. 1978	Jun. 1978	Dec. 1979	Feb. 1980	Sep. 1979	Jun. 1977	Nov.* 1979	Nov. 1979	Nov.* 1979
Stand density	(No./ha)	9420	9210	11630	3965	3500	3100	7310	2650	12900	6400	9100
Average DBH	(cm)	4.0	4.6	2.6	6.6	3.4	4.7	3.4	8.7	2.9	4.4	2.9
Average height	(m)	9.2	10.1	5.7	11.6	4.7	8.1	6.0	14.8	7.4	—	—
Basal area	(m^2/ha)	15.77	18.88	6.65	15.56	3.60	5.78	7.35	17.83	10.04	11.23	7.20
Relative Light Intensity on the ground	(%)	3.9	6.4	43.0	7.3	59.0	21.2	29.4	14.2	9.4	—	—

* Broadcast-sowing

Table 3. Estimates of constants A and B of hyperbolic or allometric equation

Location		Initao		Naawan						Upper Iligan
Plot No.		1	2	1	2	3	4	5	6	1
Height*	A	0.2398	0.3055	0.4209	0.5463	0.4344	0.2247	0.1755	0.2058	
	B	0.0400	0.0618	0.0204	0.0446	0.0282	0.0957	0.0455	0.0582	
Stem volume** (cm^3)	A	2.4984	2.6031	2.7826	3.0992	2.7443	2.1502	2.2609	2.5544	
	B	2.3317	2.1859	2.0346	1.6707	1.9946	2.2140	2.5688	2.2714	
Dry weight of stem** (g)	A	2.4592	2.5459	2.8874	3.2077	2.6525	2.1468	2.5688	2.4545	
	B	2.0511	1.9381	1.6623	1.3278	1.7409	1.9802	1.9550	2.0738	
Dry weight of branches** (g)	A	2.5481	2.8524	3.2981	4.3339	2.1555	2.7613	2.9996	2.7006	
	B	1.0176	1.0152	0.4449	−0.0118	1.1493	0.9407	0.7260	1.0901	
Dry weight of leaves** (g)	A	2.2138	2.2896	2.5440	3.3544	2.1644	1.9523	2.7111	2.6512	
	B	0.8880	0.9963	0.6790	0.3000	1.1712	1.0992	0.4719	0.8053	
Leaf area** (cm^2)	A	2.2078	2.2882	2.5437	3.3551	2.1646	1.9518	2.7113	2.6535	
	B	3.1589	3.2655	2.9477	2.5680	3.4396	3.3680	2.7402	3.0722	

* $1/H = A/DBH + B$
** $\log W = A \log DBH + B$

Table 4. Estimation of biomass of each stand

Location		Initao		Naawan						Upper Iligan
Plot No.		1	2	1	2	3	4	5	6	1
Stem volume	(m^3/ha)	108.93	130.10	24.79	109.56	10.79	25.24	18.85	155.28	50.21
Stems	(ton/ha)	52.98	63.34	14.05	57.96	5.77	12.05	10.95	78.49	27.79
Branches	(ton/ha)	5.81	6.93	2.20	8.37	1.50	1.35	2.38	13.04	4.05
Stems and branches	(ton/ha)	58.79	70.27	16.25	66.33	7.27	13.40	13.33	91.53	31.84
Leaves	(ton/ha)	2.29	2.75	1.14	2.93	0.68	1.43	1.10	3.63	1.96
Others*	(ton/ha)	0.01	0.01	0	0.38	0.34	0.05	0.07	1.09	0.01
Total	(ton/ha)	61.09	73.03	17.39	69.64	8.29	14.88	14.50	96.25	33.81
Leaf area	(ha/ha)	4.23	5.08	2.12	5.44	1.26	2.66	2.04	6.73	3.64

* Others include flowers, seeds and seedpods.

Table 5. Biomass of undergrowth

Location	Plot No.	Leaves ton/ha	Others* ton/ha	Total ton/ha	Leaf area ha/ha	Main species
Initao	1	0.03	0.07	0.10	0.06	*Centrosema plumieri, Leucaena leucocephala, Beaumontia grandiflora*
	2	0.02	0.03	0.05	0.04	
Naawan	1	0.21	0.34	0.65	0.42	*Axonopas compressus, Centrosema plamieri' Leucaena leucocephala*
	2	0.27	0.66	0.93	0.56	*Kleinhovia Hsspita, Colocasia escalenta, Dysoxylum decandrum*
	3	0.26	0.70	0.96	0.50	*Centrosema plumieri, Triumfetta Bartramia, Paspalum conjugatum*
	4	0.16	0.26	0.42	0.34	*Leucaena leucocephala, Mimosa pudica, Eleusine indica*
	5	0.16	0.23	0.39	0.32	*Imperata cylindrica, Mimosa pudica, Leucaena leucocephala*
	6	0.06	0.10	0.16	0.12	*Ficus septica, Paspalam conjugatam, Leucaena leucocephala*
Upper Iligan	1	0.04	0.08	0.12	0.09	*Leucaena leucocephala, Paspalum conjugatum, Triumfetta Bartramia*
	2	0.07	0.09	0.16	0.14	*Imperata cylindrica, Centrosema plumieri, Leucaena leucocephala*
	3	0.02	0.01	0.03	0.04	*Triumfetta Bartramia, Leucaena leucocephala, Imperata cylindrica*

* Others exclude underground parts.

0.39 m^3/ha for the worst growth to 37.24 m^3/ha for the best[3]. In Hawaii, an annual growth of more than 80m^3/ha was recorded in a 2-year-old plantation with the stand density of 20,000 trees/ha[8]. This high value is considered to be due to favorable environment as well as high stand density. In the light of results obtained already, the average annual increments at early growing stage are generally expected to be 30–40 m^3/ha on good sites[9]. This value is approximately the same as that of other fast-growing species stands, *Albizzia falcataria* and *Gmelina arborea*[4]. But it is still uncertain whether this high growth rate continues until later stage.

(2) Dry weight

The large difference in dry weight of each part can be also recognized the same as in stem volume. Giant ipil-ipil appears to be one of the tree species which show the sensitive growth to site quality[3].

Prior to discussing about leaf biomass, we are going to refer to the crown closure of this strain. Fig. 2 shows a relationship between relative light intensity (RLI) and leaf area index (LAI) meaning all leaf area per unit ground area. The RLI decreases with the increase of LAI, and reaches less than 10% at LAI of over 3.0. This value seems to continue in the plots with LAI of over 3.0

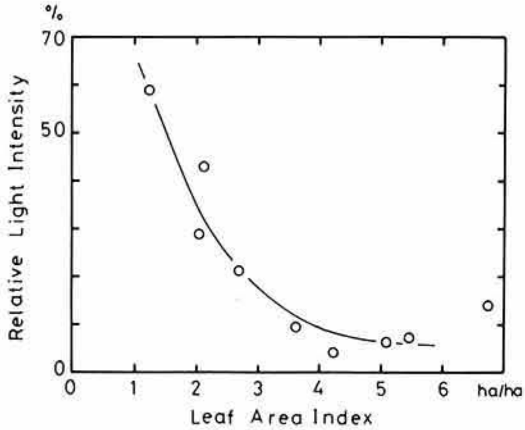

Fig. 2. Relationship between relative light intensity (RLI) and leaf area index (LAI).

although a high RLI was observed at 6.93 of LAI. Based on this result, the study stands with more than 3.0 of LAI were considered here as closed stands. In fact, these stands were visually closed. Plots of un-closed stands were plots 1, 3, 4 and 5 in Naawan.

Leaf biomass of the closed stands ranged from 1.96 to 3.63 ton/ha. These amounts are nearly equivalent to those of deciduous broad-leaved forests in Japan[6]. The LAI of the closed stands was almost the same as that of these forests[6]. But this value was larger than that of *Albizzia falcataria* and *Gmelina arborea*; 1.6–1.7 ton/ha for leaf dry weight and 1.6–2.2 ha/ha for leaf area[4]. The foliage amount of the closed stands, however, increased with the increase of basal area and average height, although lower branches had naturally been pruned already. It is widely assumed that the closed stand has a limited leaf amount specific to the species or ecologically similar groups. Therefore, this interesting phenomenon should be studied in connection with the limited leaf amount specific to this strain.

The quotient of the above ground biomass divided by the average height is called the apparent biomass density[7]. The apparent biomass density of the closed stands ranged from 0.46 to 0.72 kg/m^3, showing about half as small as that of forest in Japan[7]. In case of *Albizzia falcataria* and *Gmelina arborea*, it was 0.5–0.8 kg/m^3 in accordance with that of giant ipil-ipil[4]. The low apparent biomass density of giant ipil-ipil is thought not to be due to its specific gravity, because the specific gravity of about 0.54[9] is heavier than about 0.40 of *Chamaecyparis obtusa* in Japan[5]. The low density may be attributable to the height of this strain, which is considerably high as compared with its DBH. The value of the average height divided by its average DBH was over 170 cm/cm in most stands, especially it exceeded 200 cm/cm in Initao and Upper Iligan. In fact, we often observed the tall and slender stems bending violently before the wind just as bamboo.

The undergrowth consisted of abundant species. Total biomass of the undergrowth was

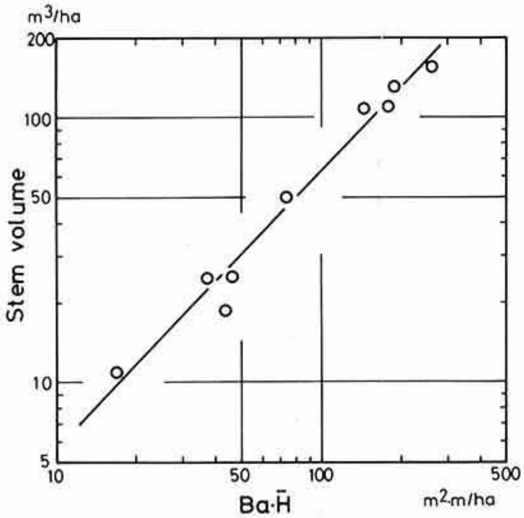

Fig. 3. Relationship between basal area × average height (Ba · $\overline{\mathrm{H}}$) and stem volume

estimated as 0.03–0.96 ton/ha (Table 5). This amount was much smaller than that of tree layer despite the abundance of species. But there was no significant difference in the amount between closed and un-closed stands.

3) Relationship between basal area×average height and stem volume and dry weight of various parts

Basal area × average height (Ba·H) was closely related with stem volume and dry weight of various parts, irrespective of the differences in ages, in stand densities and in site qualities. An example is represented in Fig. 3. These relationships can be expressed as follows;

$$\log V = 1.0449 \log \mathrm{Ba}\cdot\overline{\mathrm{H}} - 0.2982$$
$$\log W_S + W_B = 0.9789 \log \mathrm{Ba}\cdot\overline{\mathrm{H}} - 0.3907$$
$$\log W_L = 0.5868 \log \mathrm{Ba}\cdot\overline{\mathrm{H}} - 0.8702$$
$$\log W_T = 0.9486 \log \mathrm{Ba}\cdot\overline{\mathrm{H}} - 0.3030$$
$$\log \text{Leaf area} = 0.5857 \log \mathrm{Ba}\cdot\overline{\mathrm{H}} - 0.5999$$

where V is stem volume in m^3 per ha, and W_S, W_B, W_L and W_T dry weight in ton per ha of stems, branches, leaves and total parts of tree layer, respectively. In case of stem volume, the relationship between both could be closely approximated by the following equation;

$$V = 0.6322\ \mathrm{Ba}\cdot\overline{\mathrm{H}} + 0.2402$$

and this equation could be transformed into a more convenient form;

$$V \doteqdot 0.5\cdot(\sum \mathrm{DBH}^2)\cdot\overline{\mathrm{H}}$$

However, the attention should be needed in the application of these equations, particularly constants, to the stands in other areas or countries, because these figures might be valid only for the surveyed area in Mindanao.

In Naawan, MAFCO has an experimental plantation of giant ipil-ipil, and continues to measure DBH and height of all trees every 3 months since planting in June, 1979. Therefore, using these records and the above-mentioned equations, an estimation of growth process of the plantation was attempted by calculating Ba·$\overline{\mathrm{H}}$ of every 3 months and applying the calculated Ba·$\overline{\mathrm{H}}$ to the equations.

For the calculation, six sites of good, middle and poor of 1×1 m and of 2×2 m spacing were selected temporarily. And only stem volume and $W_S + W_B$ were calculated, because it is probable that the amount of leaves changes with months. Results are shown in Figs. 4 and 5.

As far as these figures are concerned, both stem volume and $W_S + W_B$ on the middle and the good site of 2×2 m spacing became nearly equal to those on the poor site of 1×1 m spacing 6 months after planting. However, those on the good site of 1×1 m spacing kept the largest amount all the time.

Figs. 4 and 5 imply that the growth rate decreases gradually with the advance of the growth as observed already in *Albizzia falcataria*[4)], and that the stem volume will reach 200 m^3/ha 3–4 years after planting on the good site, but only 40 m^3/ha on the poor site, suggesting that the difference in site qualities results in the great difference in the yield. These values, however, are the results by only one calculation. To estimate more accurately, it is still necessary to collect more data and to analyze such data in detail.

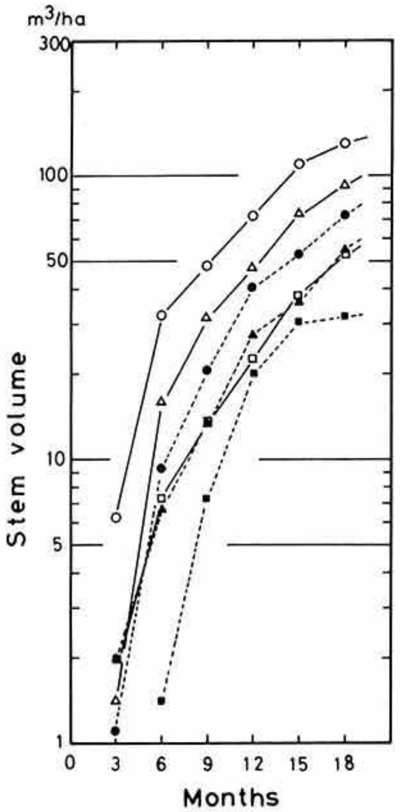

Fig. 4. Estimated growth curves of stem volume of 1 × 1 m spacing on the good(○), the middle(△) and the poor site(□), and of 2 × 2 m spacing on the good(●), the middle(▲) and the poor site(■).

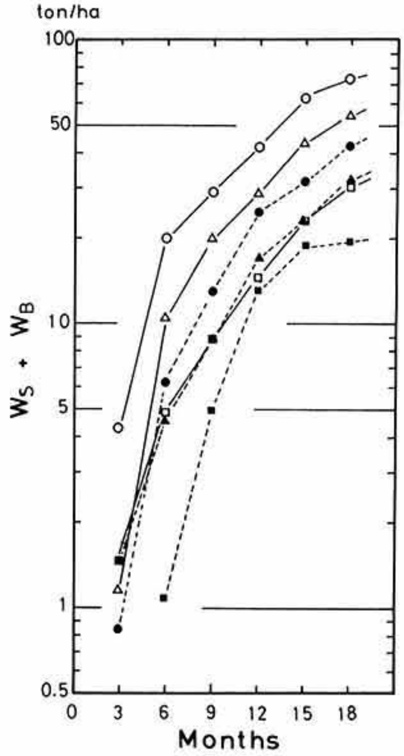

Fig. 5. Estimated growth curves of stems + branches of 1 × 1 m spacing on the good(○), the middle(△) and the poor site(□), and of 2 × 2 m spacing on the good(●), the middle(▲) and the poor site(■).

Abstract

Above-ground biomasses of nine giant ipil-ipil plantations were surveyed in northern Mindanao Island, Philippines. The strain surveyed was K-8 of a Salvador type. The biomass of each part varied widely with the stand with 11–155 m^3/ha for stem volume, 6–78 ton/ha for stem dry weight, and 8–96 ton/ha for total above-ground dry weight of tree layer. The leaf amount ranged from 0.7 to 3.6 ton/ha in dry weight or from 1.26 to 6.73 ha/ha in area, but the amount of closed stands was about 2.0–3.6 ton/ha or over 3.0 ha/ha. This amount agreed well with that of deciduous broadleaved forests in Japan. The apparent biomass density, the quotient of the above-ground biomass of tree layer divided by its average height, fell within a range between 0.46 and 0.72 kg/m^3 in closed stands. These values were approximately half as small as those of forests in Japan. Since the mean stem increment of each stand fluctuated from 10 to 50 m^3/ha/year, the wide variations of the biomass seemed to be due to stand age as well as to site quality. An estimation of the growth process showed that on a good site the stem volume reached 200 m^3/ha 3–4 years after planting, but on a poor site only 40 m^3/ha.

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