

論 文

インドネシア，東ジャワ，マディウンにおける チーク林の現存量と一次生産量

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Estimation of the biomass and net primary production in a planted teak forest in Madiun, East Java, Indonesia

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ジャワ島東部のマディウンにおいて，若いチーク人工林の生産量と比較するために，より年齢が大きく，一般的なチーク人工林，植栽後10年から40年までのチーク人工林に，0.1 ヘクタールの調査区22個を設定し，それらの現存量と生産速度を推定した。

推定に先立って2000年，2001年の4月に樹木個体間の相対成長関係を調べるために，調査地周辺の個体から，胸高直径，枝下幹直径等の測定を行った。2000年と2001年の9月に調査区の毎木調査を行い，その間の現存量の差と月2回の落葉量調査から森林の純生産量を推定した。

年齢の大きなチーク林での純生産速度は，若いチーク林の値に比べると低く，それらの半分ほどの値であった。年齢の高いチーク林が示した低い生産力の値でも，日本の落葉広葉樹林，インド，タイでのチーク林の純生産速度に比べるとより高い値であった。若いチーク林では，林内で生産される農作物等のための耕耘，施肥等の効果，熱帯の長い生育期間とジャワ東部の多い降水量によって，高い生産力が維持されていたと推測された。

キーワード：チーク人工林，純生産力，相対成長法，東ジャワ

Permanent plots of 0.1 ha were established at 22 forests in the Forest District in Madiun, East Java. The biomass and productivity of planted teak forests (*Tectona grandis* Linn.) in old stands of 10 to 40-year-old were estimated and compared with those of young stands, already investigated in our previous study. In April 2000, sample trees selected around the plot were felled for collecting of stem weight and other related data needed for estimating the allometric relationships of various dimensions of individual trees e.g. stem diameter at breast height *DBH* and stem diameter at the lowest branch *D_B*. Tree censuses were conducted in the plots twice in September of 2000 and 2001. The productivity was estimated using the biomass increment during the period between the censuses and leaf production, which was estimated by measuring litter fall two times every month. The old stands showed lower net primary production (NPP), about half of the values for the young stands fertilized as one of the agroforestry practices. However, the NPP were higher than deciduous forests in Japan and teak stands in India and Thailand. The higher NPP in early stage seemed to be maintained by the intensive agricultural practices such as fertilization and tillage for agroforestry and by a long tree growth period in East Java under tropical climate.

Key words: Planted teak forest, net productivity, allometry method, East Javaty

Introduction

As the main timber species, teak (*Tectona grandis* Linn.) has been planted for the past two hundred years in monsoon climate regions of Indonesian lowlands^{2,28)}. Recently, teak plantations were established in a large area in Madiun, East Java, as a component of an agroforestry system to settle the social problems of the forest farmers. In agroforestry, trees and agricultural crops are planted in alternating lows, so that

the land can be used continuously by the forest farmers.

Although the area of teak forest is very large, precise investigation of dry matter production of teak forests has not been carried out. The productivity of young stages of the forest has been recorded, and results showed a high net production in 7-year-old forests under light conditions of 8.5 % in relative light intensity¹⁶⁾. The high productivity in the forest at a young stage was assumed to be caused by the tillage and fertilization for cultivation of agricultural crops in

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the agroforestry.

After five years, the tree density of the forests was controlled by thinning management. The growth rate of teak forests in Java depends on the site quality and thus varies from locality to locality. The resulting growth and yield is a complex one and involves silvicultural treatment, soil, drainage, rainfall, temperature, slope and human impact e.g., livestock grazing, forest fire and illegal cutting. Therefore, there are a lot of constraints to evaluate and quantify the exact level of impact. Various combinations of the above factors can influence the productive capacity of a site to different degrees.

In this report, productivity for 10 to 40-year-old stands was estimated by measuring the biomass increment and leaf litter production with measuring methods proposed by Kira⁶⁾ and Ogawa¹²⁾, who investigated forest productivity in Thailand and Cambodia.

Material and methods

About 30,000 ha of planted teak forests at the western foot of Mt. Lawu (7° 30' S and 112° 30' E) in East Java of Indonesia are being managed by Forest District of Madiun, State-Owned Enterprise of Java (Badan Usaha Milik Negara). Various aged forests grow on volcanic soil from 50m to 600m in altitude. The monthly mean temperatures and precipitation in 2000 - 2001 at the research site were consistent with a typical monsoon climate with a short dry season (July to September), as shown in the Fig. 1.

The study area was situated on a hillside about 145~

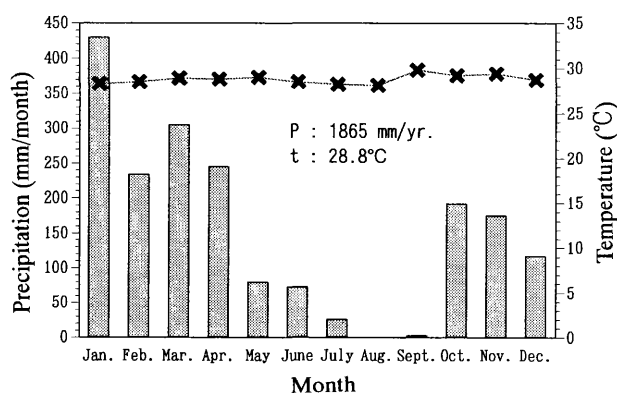


Fig. 1. Monthly means of precipitation and temperature in 2000-2001 in Madiun Forest District. Cross, temperature; histogram, precipitation.

370 m above sea level; the geological structure was volcanic and the soil type belonged to the red-brownish latosol in most of the area, and the topography is gently undulating⁹⁾.

Teak seeds are directly sown on the site and are grown together with other crops such as peanuts, cassava, maize and rice in the Madiun agroforestry system. *Leucaena glauca*, the *Leguminosae* tree species was also added by line planting for the purposes of supplying fodder, fuel wood, and green manure. This intercropping practice in the early years of the teak plantations had several beneficial effects e.g., increased areal utility, supply benefits to the local community and maintenance of the area free of the weeds³⁾. Leaves of *Leucaena glauca* are usually harvested at a half-year-old after sowing. Thinning of teak plantations is carried out five years after sowing in immature stands in order to stimulate the trees growth²⁶⁾.

To estimate the forest biomass and net production of the teak stands, 22 sample plots of 0.10 ha (25m × 40m) were set up in September 2000 in artificial teak forests of 10 to 40-year-old. The stands are located at 145m to 370m in altitude.

Stem diameter at breast height, *DBH* or at 1.3m above the ground (*D*) was measured for the all trees in the quadrates twice in September of 2000 and of 2001. At the same time tree height (*H*) was measured for selected sample trees.

For producing the allometric equations in individual trees, seven sample trees from 3 to 52-years old were cut down around the plots, and tree size as *D*, *H*, and weights of stem, branch and leaf of the sample trees were measured in April, 2000. To confirm the allometric relations among the aboveground parts, additional censuses for the teak trees were done in the dry season of September, 2000. 137 sample trees were measured for allometric relations between stem diameter at 1.3m above the ground (*D*) and stem diameter at the lowest branch (*D_B*), 24 trees for stem weight and 10 trees for branch weight. The amount of leaves was estimated from the relation between the values of square of diameter at the lowest branch (*D_B²*), using the relation between *D* and *D_B*. Root biomass was estimated from the assumption that it is 20 percent of the above ground woody organs after

Whittaker and Marks²⁹⁾, Karizumi⁴⁾ and Tadaki²⁰⁾.

The fresh samples were dried in a ventilated oven at 80°C for at least one week and weighed. Ratios of dry/fresh mass were calculated and used for converting fresh weight into dry weight.

Field observation suggested the consumption of leaves by herbivorous animals and insects (G) was not negligible so that the G-term was considered in the measurement. The amount of leaf losses by grazing of herbivores (G) was measured from holes and the discolored areas from the sample leaves⁸⁾.

To confirm leaf production per year, ten litter traps, 1m×1m in size, were set up in each stand in September, 2000, and the fallen litter was collected twice a month from October, 2000 to September, 2001. To estimate the decomposition rate of leaf three plots of 2m×2m in size were set up, and the amounts of decomposed leaf litter on the ground in 10-year-old and 15-year-old forests were measured in April the end of the rainy season 2001.

The relative light intensity in these forests was measured by a pair of electric photometers at 50 points in each stand and in the open land, respectively, in April, 2001.

The rainfall records for the past twenty two years were taken from six stations of the Weather Bureau distributed in the forest areas, including the Madiun Forest District (unpublished data). The monthly mean temperatures during the study period in 2000-2001 is shown in Fig. 1.

Yield and growth tables for teak forests in Indonesia were used to determine the site index of the stands³¹⁾.

Results

The number of plots, six levels of stand age, site

Table 1. Stand ages and number of plots set up in the present study (2000-2001)

Stand age years	Number of plots with census record	Site index	Altitude m, above sea level	Relative light intensity (%)
10	4	2.5	160	15
15	4	2.5	145	12
20	4	3.0	340	7
25	4	3.5	370	6
30	2	3.5	350	13
40	4	2.5	148	10
Total	22	-	-	-

indexes, altitude of stands and mean values of relative light condition under the stand are shown in Table 1. Relative light intensity shows slightly larger values than Japanese deciduous forests, 2.52 %¹⁴⁾, nevertheless a large amount of leaf biomass was measured in the young stands of our previous study¹⁶⁾. Some weeds and *Dalbergia sissoo*, an evergreen indigenous species, usually grows under the forest floor of planted teak forests. As shown by the climate data in Fig. 1, the precipitation in the measured period was higher than the previous year in 1999, and showed more moist conditions.

Net primary production (NPP) was described by the following equation^{6,10)}.

$$NPP = \Delta B + L + G, \quad (1)$$

where ΔB is the biomass increment of the forest between time 1 and time 2. L and G are the amounts of litter fall and grazing during the period.

Various amounts and partial biomass of trees were estimated from DBH by the allometric correlation method¹²⁾, as with our previous investigation for the teak plantations at a young stage¹⁶⁾. The relation of H (m) to DBH (D cm) was tentatively determined by the hyperbolic relation^{12,13)} as follows:

$$\frac{1}{H} = 0.8983 \frac{1}{D^{1.1}} + 0.0260 \quad (m, cm, n = 320, r^2 = 0.85) \quad (2)$$

Stem diameter of a tree was an excellent predictor of

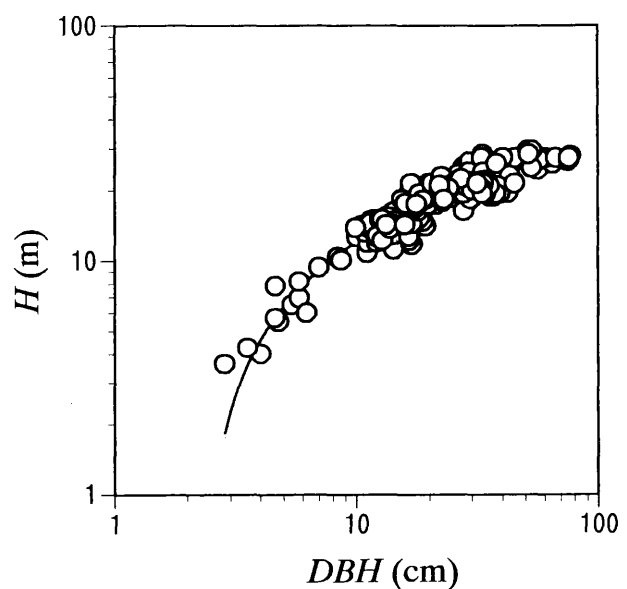


Fig. 2. Hyperbolic relationships between diameter at breast height (DBH) and tree height (H) for planted teak forests in the study area.

Table 2. Teak biomass of various stand ages

Stand age years	LAI ha/ha	Leaf biomass ton/ha	Stem biomass ton/ha	Branch biomass ton/ha	Root biomass ton/ha	Total biomass ton/ha
10	3.5 ± 0.3	4.0 ± 0.4	41.0 ± 2.0	15.1 ± 0.5	11.2 ± 0.5	71.4 ± 3.4
15	4.0 ± 0.2	4.6 ± 0.2	59.7 ± 0.7	23.3 ± 0.1	16.6 ± 0.1	104.2 ± 1.1
20	4.6 ± 0.6	5.1 ± 0.7	85.8 ± 14.6	35.7 ± 6.4	24.3 ± 4.2	150.8 ± 25.8
25	4.5 ± 0.4	4.9 ± 0.5	105.0 ± 8.3	46.4 ± 3.4	30.3 ± 2.3	186.5 ± 14.5
30	3.9 ± 0.0	4.2 ± 0.0	95.4 ± 0.0	42.8 ± 0.0	27.6 ± 0.0	170.1 ± 0.0
40	3.9 ± 0.2	4.3 ± 0.2	89.6 ± 8.0	39.2 ± 3.9	25.8 ± 2.4	158.9 ± 14.4

tree height, as shown in Fig. 2. Stem diameter at breast height explained more than 80 % of the variability in tree height. The remaining variability may be attribute to inherent tree, stand (densities and age class distribution), and/or site characteristics (soil and hydrological parameters). The equation showed that the relative rate of stem elongation was slightly higher than that of stem diameter increase ($h = 1.1$) in the initial stage of teak forest growth. Tree form changes from a stick-like form in early stages to an umbrella form after ten years old. Using the equation, the maximum height was estimated as 38.5 meters.

Since tree density was controlled well by farmers after 5-years, the relationships among measured tree dimensions drew a simple linear; suggesting the growth pattern of tree dimensions in each individual

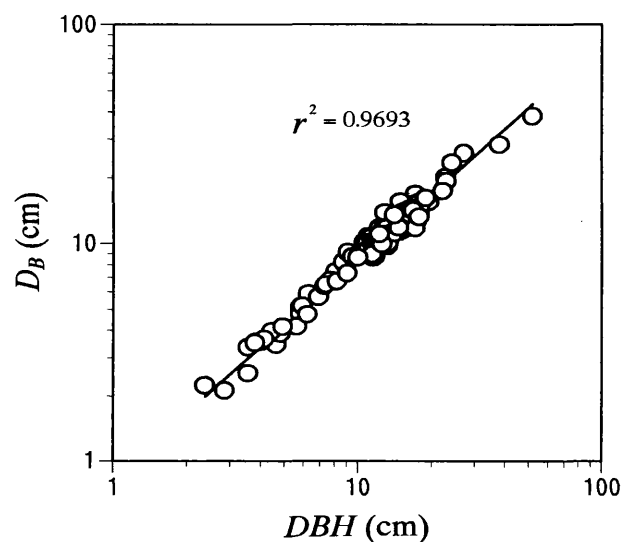


Fig. 3. Relation between diameter at breast height DBH (cm) and diameter at the lowest branch D_B (cm).

plant are closely inter-dependent. These features among tree form seemed to be caused by similar management methods applied in the sample stands, as

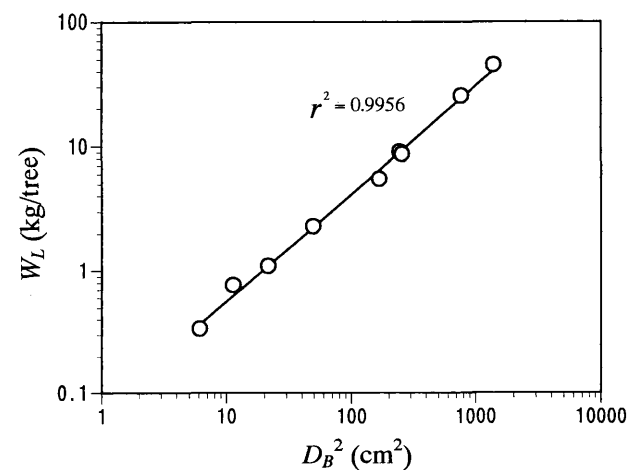


Fig. 4. Allometry between the oven-dry weight of leaves per tree W_L (kg) and square of diameter at the lowest branch D_B^2 (cm²).

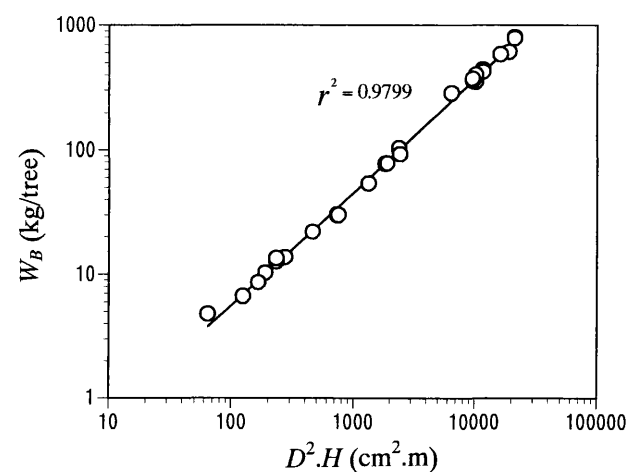


Fig. 5. Allometry between the oven-dry weight of branch per tree W_B (kg) and D^2H (cm².m), expressed by the linearity between the logarithms of the two amounts.

Table 3. Teak production of various stand ages

Stand age years	Total Biomass (stem,branch,root,leaf)			L	G	NPP
	Sep. 2000	Sep. 2001	ΔB	t/ha	t/ha	t/ha/yr.
	t/ha	t/ha	t/ha/yr			
10	69.5 $\pm$ 3.6	73.3 $\pm$ 2.8	3.8 $\pm$ 0.3	4.5 $\pm$ 0.1	0.5 $\pm$ 0.1	8.8 $\pm$ 0.2
15	101.4 $\pm$ 1.8	107.1 $\pm$ 0.3	5.7 $\pm$ 1.5	4.8 $\pm$ 0.1	0.6 $\pm$ 0.0	11.0 $\pm$ 1.6
20	145.4 $\pm$ 25.3	156.3 $\pm$ 26.4	10.8 $\pm$ 1.0	4.7 $\pm$ 0.0	0.6 $\pm$ 0.1	16.2 $\pm$ 1.0
25	180.7 $\pm$ 15.1	192.3 $\pm$ 13.8	11.7 $\pm$ 1.3	5.1 $\pm$ 0.0	0.6 $\pm$ 0.1	17.3 $\pm$ 1.3
30	162.0 $\pm$ 14.7	178.2 $\pm$ 0.0	16.2 $\pm$ 0.0	5.8 $\pm$ 0.4	0.5 $\pm$ 0.0	22.5 $\pm$ 0.0
40	155.7 $\pm$ 13.1	162.0 $\pm$ 15.7	6.3 $\pm$ 2.6	5.6 $\pm$ 0.2	0.5 $\pm$ 0.0	12.4 $\pm$ 2.4

ΔB : biomass (stem, branch, root and leaf) increment of the forest.

L, G : leaf litter and grazing during the period.

NPP : Net Primary Production = $\Delta B + L + G$.

shown in Fig. 3, Fig. 4 and Fig. 5.

The biomass values are shown in Table 2. Total biomass changed with stand age, reaching a peak in twenty five-year-old forests and declining thereafter. Leaf biomass increased steeply with age and had a maximum value of 5.1 ton/ha in twenty-year-old forests. The leaf biomass in the teak forests was slightly higher than values of those in deciduous broad-leaved forests in Japan, 2.7 ton/ha^{21,23)}. The mean value of leaf area index (LAI) was calculated as 4.6 ha/ha in the twenty-year-old forests under light conditions of 7 % in relative light intensity.

From the biomass, the NPP of each stand was estimated using Equation 1, as shown in Table 3. The values of NPP varied from 8.8 ton/ha/yr. to 22.5 ton/ha/yr. NPP increased with stand age and site index, reaching a peak in the thirty-year-old forest, 22.5 ton/ha·yr., and declining thereafter. The consumption of leaves by herbivores (G) was nearly the same value, 0.6 ton/ha, more or less 12 % of leaf weight among these stands. In most of teak forests in Java, teak bee-hole borer and insects pests such as leaf eating caterpillars, leaf-rolling and leaf-mining caterpillars, leaf-eating beetles and grasshoppers can be found. They vary in abundance by season, from locality to locality and also year to year, possibly due to varied climatic and topographical conditions²⁴⁾. In East Java, these defoliating insects, leaf eating caterpillars and grasshoppers are commonly found in

the early rainy season, November~December. There are also many species of leaf eating caterpillars in teak forests in India, and the most important are the teak skeletonizer *Eutectona machaeralis* (Lepidoptera : Pyralidae) and *Hyblaea puera* (Lepidoptera : Hyblaeidae). In both cases, total or partial damage of leaf loss of increment is reported to the tune of 8.2 % of total annual increment^{3,24)}.

The annual litter fall in the planted teak forests did not vary greatly among these stands, ranging from 4.5 ton/ha·yr to 5.8 ton/ha·yr, comprised of 100 percent leaf litter. Leaf litter production in 25, 30 and 40-year-old forests was slightly over 5 ton/ha·yr. These leaf-litter falls were nearly the same average measured in over twenty tropical forests, at 5.5 ton/ha·yr²⁵⁾.

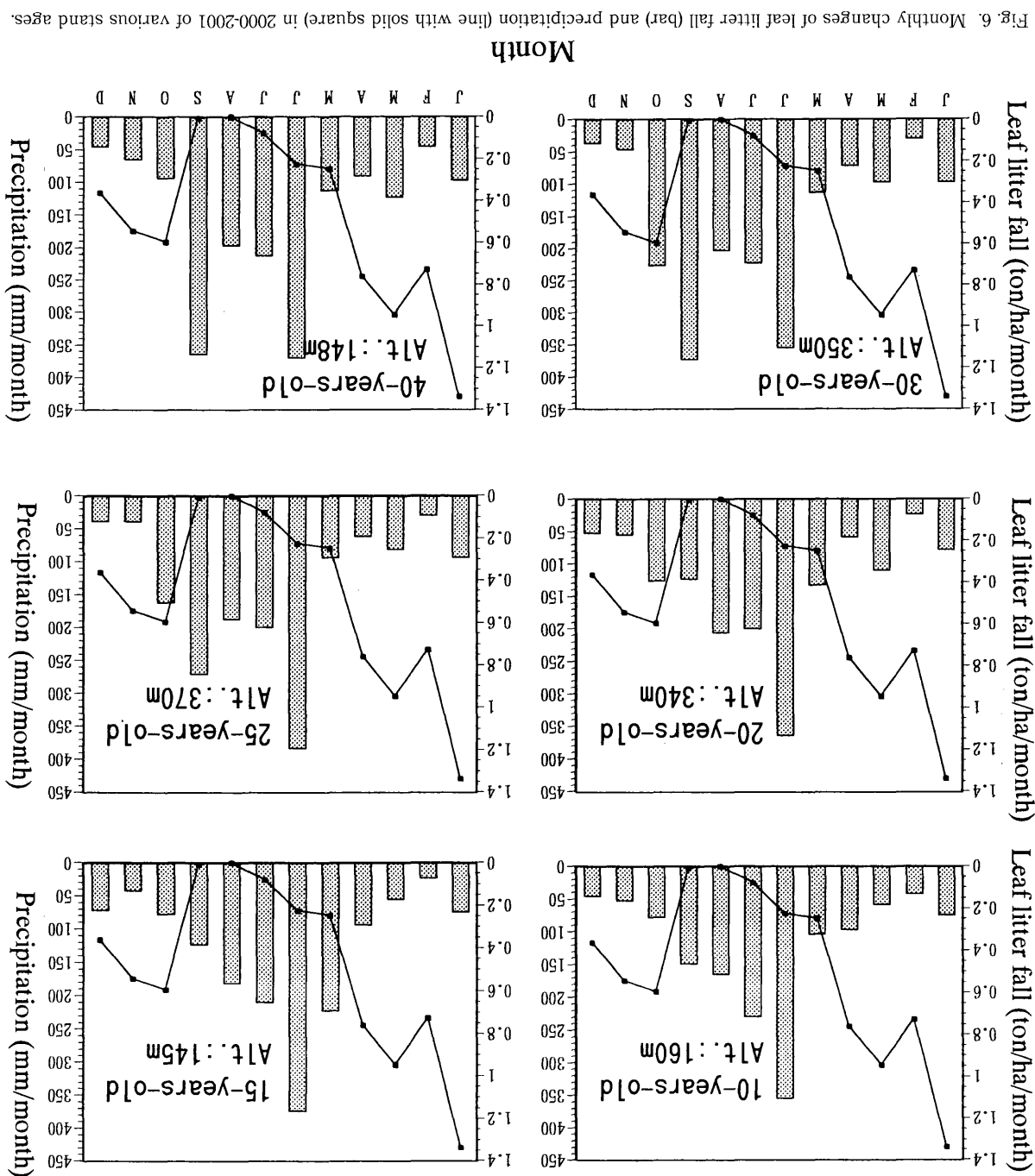
Discussion

Although the teak tree is usually considered as a deciduous species in tropical monsoon climates, it is often evergreen in moist regions¹⁷⁾. In this study site, young teak trees often have only a slight amount of leaves at the stem top in the dry season. In order to confirm the amount of leaves production in this area, leaf litter fall was measured in various stand ages. The patterns of leaf litter fall are different by stand age. In the younger stages of 10, 15 and 20-year-old stands, maximum leaf litter fall occurred in June. In the older stage, leaf litter fall had two peaks in June and

Stand	Leaf	Leaf	Annual	Mean	Leaf litter
age	biomass	litter	turnover	longevity	on the forest floor
years	ton/ha	ton/ha	per year	years	ton/ha
10	4.0±0.4	4.5±0.1	1.1	0.9	1.8±0.2
15	4.6±0.2	4.8±0.1	1.0	1.0	1.8±0.2
20	5.1±0.7	4.7±0.0	0.9	1.1	-
25	4.9±0.5	5.1±0.0	1.0	1.0	-
30	4.2±0.0	5.8±0.4	1.4	0.7	-
40	4.3±0.2	5.6±0.2	1.3	0.8	-

Table 4. The mean longevity of leaves of various stand ages

September, as shown in Fig. 6. Leaf biomass at the end of the rainy season and the amount of leaf obtained by the leaf litter collection method were compared and shown in Table 4. Both of the values are the same level. The mean longevity of leaves was calculated to be about 1.0 year. A sweeping generalization is thus reached that the teak forests produced around 4.0 ton/ha of leaves and shedded the same amount every year. Leaf litter on the forest floor in 10-year-old and 15-year-old forests was measured to



estimate the decomposition rate of leaf at the end of the rainy season, April 2001. The remaining amount of leaf litter on the ground was 40 percent of that annual leaf litter fall.

The NPP of the old forests in this study was nearly half of about 35 ton/ha/yr for 7-year-old forests obtained in our previous study¹⁶⁾, as shown in Fig. 7. It is well known that teak is a moderately fast growing species and will grow faster in initial years, but slow down afterwards³⁾. However, high production in the young stage might have been caused partly by application of intensive agricultural practices such as the fertilization and tillage in agroforestry¹⁾. Many artificial teak forests in Java are being grown in combination with many agriculture crops at least in the initial years of establishment. Wide inter-space having no shade is utilized as strips of agriculture field. In our previous study, field research in the early stages of forests was a pilot plantation proposed by Simon¹⁹⁾, characterized by more opportunity for forest farmers and/or unemployed people to participate under the state-owned forest company in the Madiun Forest District. The pilot plantation applied intensive agricultural practices such as tillage, weeding and fertilization. A lot of fertilizers, either chemical or manure were subsidized by the state-owned forest company, Madiun Forest District, two times for two years in middle of rainy season (February) in the

current years. The amount of chemical fertilizer, urea was 5 gr./seedling and 10 gr./seedling when the teak stands were at a half and one and a half years old, respectively, and manure fertilizers (cow dung, poultry manure, and decomposed rice straw) were 250 kg/ha for agricultural crops. First thinning within teak plantations is carried out four and half years old stands¹⁶⁾. On the contrary, the old teak forests were established with the *taungnya* system adopted from Burma (1856), which is characterized by low capital, without subsidy of fertilizers and fee for tillage, and cultivation of agricultural crops by forest farmers is limited until the third year, so that can have a negative influence on sustaining the teak forest plantations¹⁹⁾.

The leaf biomass in the early stage of forests was closely correlated to teak production¹⁶⁾. In other words, the high productivity is attributed to large leaf biomass²²⁾. On the contrary, the old teak forests did not show any clear change of leaf biomass to teak production. It related the change of relative stand density with stand age in managed forests. Managed teak forests in Java have a tendency to have lower relative stand density with increasing age because of thinning and/or pruning. In teak forests with high relative stand densities competition among individual trees is severe and low branches die earlier than in less dense stands. Total branch biomass will build up to an equilibrium value where production is balanced

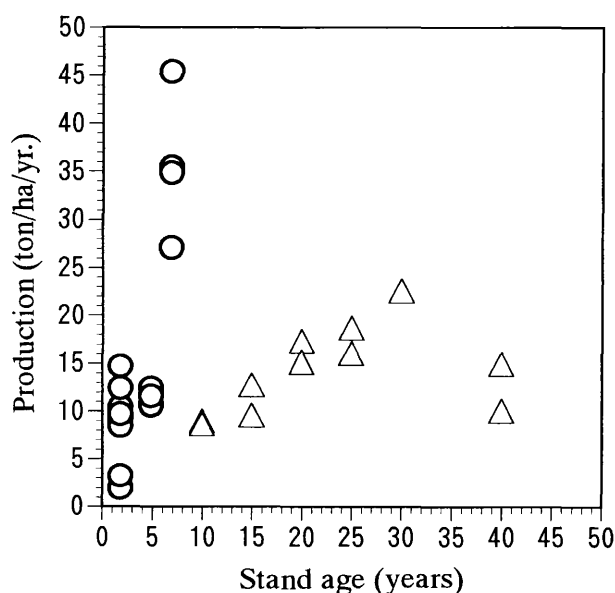


Fig. 7. Teak production of various stand ages. Circle, young teak forests in our previous study¹⁶⁾; triangle, old teak forests in the present study.

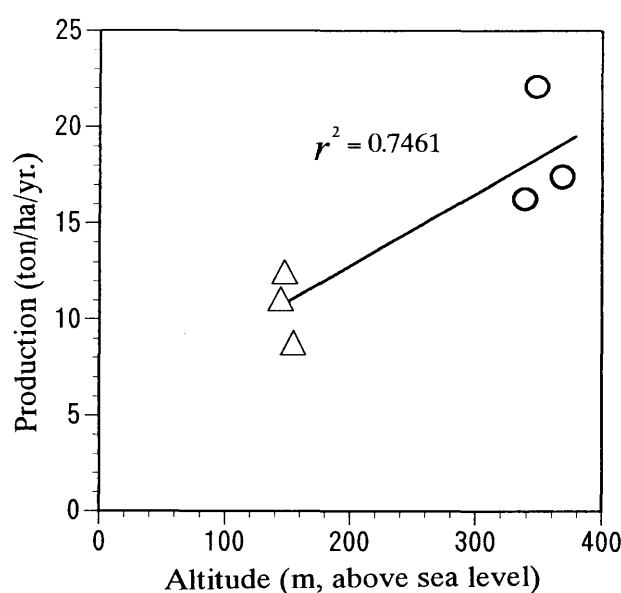


Fig. 8. Relationships between teak production and altitude. Triangle, low site index; circle, high site index.

by loss through death and shedding. This equilibrium value will be dependent on stocking, however, if the old teak stands are heavily thinned and/or pruned the equilibrium will be upset. Also, in stands where tending is frequent total biomass will never attain the value to be found in untended stands of the same stocking.

The site index and altitude affected production, as shown in Fig. 8. Teak production increased with site

index and altitude, and the relationships between production with site index and with altitude were close. The altitudinal range of teak forests varies from locality to locality, for instance in Java, the growth of teak forests becomes stunted above an elevation of 750 m above sea level¹⁵⁾. The altitudinal range of teak forests worldwide is from almost sea level to about 1300 m above sea level. However, the growth of this tree becomes stunted above an elevation of 750 m sea

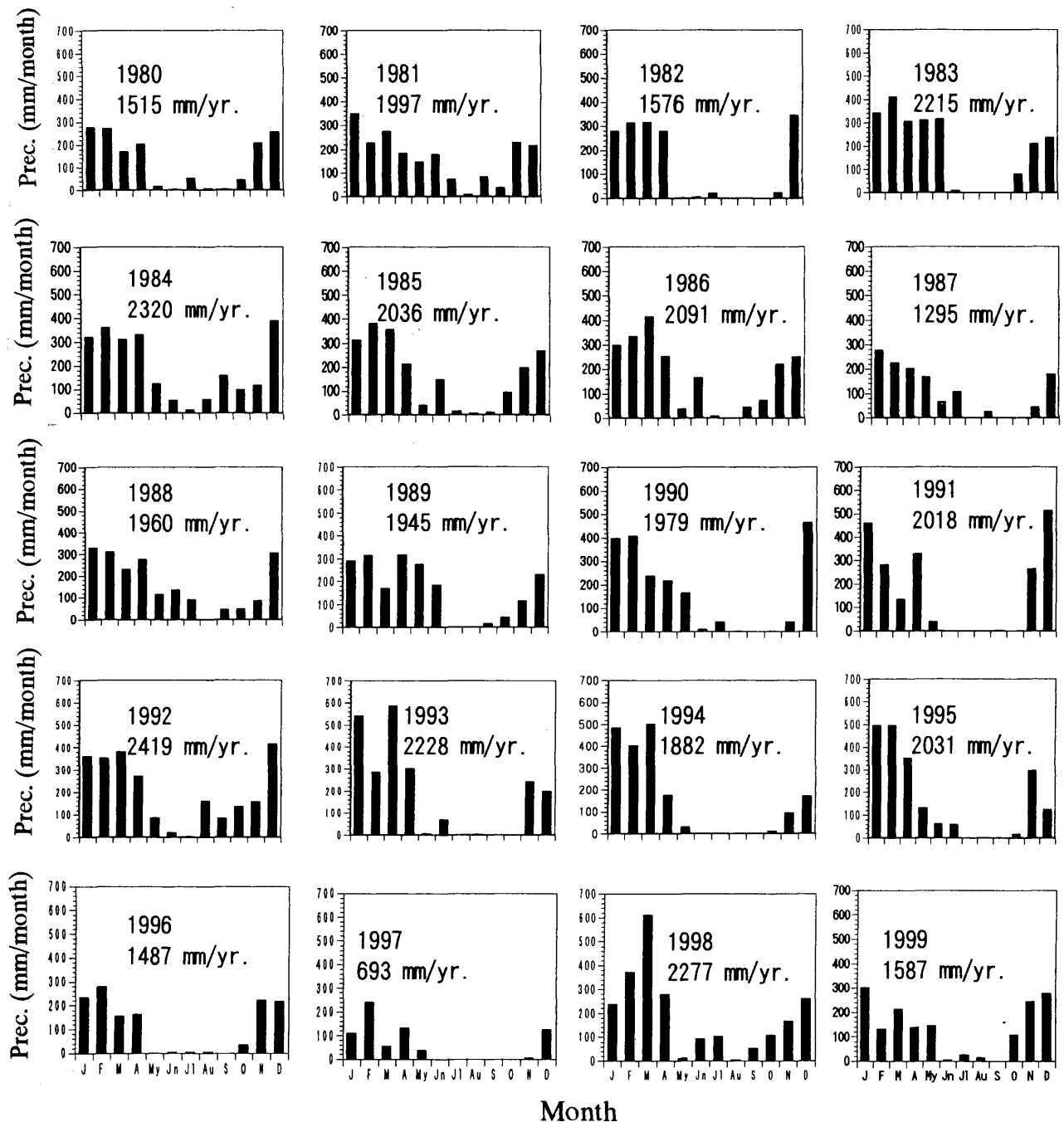


Fig. 9. Yearly changes of precipitation in the last twenty years (1980-1999) in Madiun Forest District.

level11). Teak trees require much rain, heat, humidity and deep soil for good growth, and need a tropical climate to develop fully²⁷⁾. Altitude is one factor that governed the site index through the amount of precipitation, and the site index affect the production. The amount of precipitation seemed to increase with altitude, therefore, higher altitudes means wetter conditions in Madiun, East Java.

The production of teak forests in Java may change with the length of the rainy season or amount of precipitation. The monthly mean precipitation for the past twenty years at the site varied considerably from 693 mm/yr to 2419 mm per year, as shown in Fig. 9. According to the Q-system proposed by Schmidt and Ferguson¹⁸⁾, the climate of the area belongs to rainfall types F to B. On Whitmore's²⁸⁾ map of rainfall types for the tropical Far East, the area is classified into types C and D (seasonal type). Fig. 9 provides a fairly good approximation of the climatic conditions in the area. August is the driest month, although it still sometimes receives rainfall. Droughts occur during El Niño, resulting in extended and drier-than-normal dry seasons. Such events occurred in 1982-1983, 1987, 1991 and 1997, and have resulted in water shortages and forest fires³⁰⁾. A dry year may cause low result in teak production.

In the tropic, rapid growth or productivity is quite well known⁵⁾. The net production of a tropical forest is higher than that of temperate forest⁷⁾. Although the production of the old teak forests in Madiun was smaller than those of young forests, the level was still higher than deciduous broad-leaved forests in Japan, 8.7 ton/ha/yr.²²⁾, and also still higher than those of similar age plantations in India, for instance at Gorakhpur, 12 ton/ha·yr., Chakia, 12.9 ton/ha·yr., Haldwani, 10.35 ton/ha·yr. and in Thailand, 8-10 ton/ha·yr.³⁾. Management strategy and results in Madiun, East Java may be the next problems to consider with dry matter production of teak forests.

References

- 1) BEBARTA, K.C. (1999) Teak : ecology, silviculture, management and profitability. 380pp, International Book Distributor, 9/3 Rajpur Road, Dehra Dun-248001, India.
- 2) CORDES, J.W.H. (1881) De djati-bosshen op Java. *Translated: Teak forest in Java*, 1992. 403pp, Yayasan manggala sylvalestari, Biro jasa konsultan perencanaan hutan, Malang. (In Indonesian).
- 3) JHA, K.K. (1999) Teak (*Tectona grandis*) farming. 125pp, IFS Forest Department Uttar Pradesh. International Book Distributing Co., India.
- 4) KARIZUMI, N. (1974) The mechanism and function of tree root in the process of forest production I : Method of investigation and estimation of the root biomass. Bull. Gov. for. Exp. Sta No. 259 : 1-99.
- 5) KAWAHARA, T., KANAZAWA, Y., and SAKURAI, S. (1981) Biomass and net production of man-made forests in Philippines. J. Jap. For. Soc. 63: 320-327.
- 6) KIRA, T., OGAWA, H., YODA, K., and OGINO, K. (1967) Comparative ecological studies on three main types of forest vegetation in Thailand. IV. Dry matter production, with special reference to the Khao Chong rain forest. 174pp, *Reprinted from* : Nature and Life in Southeast Asia Vol. V (ed.). Published by Fauna & Flora Research Society, Kyoto.
- 7) _____ and SHIDEI, T. (1967) Primary production and turnover of organic matter in different forest ecosystem of the Western Pasific. Japan J. Ecol. 17: 70-87.
- 8) LARSHEN, D.R. and KERSHAW, J.A. (1991) Leaf area measurements *In* Techniques and approaches in forest tree ecophysiology. Lassoie, J.P. and Thomas, M.H. (ed.), CRC Press, Inc., Boca Raton Ann Arbor Boston, 465-475 .
- 9) MARGONO, HAKNJOESOEBROTO, H. and HADITENOJO, P.S. (1989) Forest planning in Madiun Forest District. 123pp, Seksi Perencanaan Hutan Madiun, Jawa Timur. (In Indonesian).
- 10) MÖLLER, C.M., MULLER, D. and NIELSEN, J. (1954) The dry matter production of European beech. *Ibid.* 21: 253-335.
- 11) NEGI, S.S. (1996) Teak (*Tectona grandis*). 114pp, Bishen Singh Mahendra Pal Singh, India.
- 12) OGAWA, H. and KIRA, T. (1977) Methods of estimating forest biomass *In* Primary productivity of japanese forests: productivity of terrestrial communities. SHIDEI, T and KIRA, T. (eds.), Japanese Committee for the International Biological Program, University of Tokyo Press, 15-25.
- 13) _____, YODA K., OGINO, K. and KIRA, T. (1965) Comparative ecological studies on three main types of forest vegetation in Thailand. II. Plant biomass, *Reprinted from* : Nature and Life in Southeast Asia. 4 : 49-80.
- 14) OGINO, K. (1977) A beech forest at Ashiu : biomass, its increment and net production *In* Primary productivity of japanese forests: productivity of terrestrial communities. SHIDEI, T and KIRA, T. (eds.), Japanese Committee for the International Biological Program, University of Tokyo Press, 172-186.
- 15) POERWOKOESOEMO, R.S. (1956) Teak in Java. 241pp, Jawatan Kehutanan Republik Indonesia. (In Indonesian).
- 16) PURWANTO, R.H., SIMON, H. and OOHATA, S. (2002) Estimation of net primary production of young teak plantation under agroforestry management at Madiun, East Java. *In press* : TROPICS. The Japan Society of Tropical Ecology, Japan, 2002.

- 17) RIFFLE, R.L. (1997) An encyclopedia of dramatic landscape plants. Timber press, Inc. Portland, Oregon 97204, U.S.A, 336-337.
- 18) SCHMIDT, F.H. and FERGUSON, J.H.A. (1951) Rainfall types based on wet and dry period ratios for Indonesia with western New Guinea. Kementarian Perhubungan, Jawatan Meteorologi dan Geofisika, Verh. 42.
- 19) SIMON, H. (1991) Teak forest and prosperity : problems and its solving strategy. 224pp, Penerbit Aditya Media, Yogyakarta. (In Indonesian).
- 20) TADAKI, Y. (1965) Studies on production structure of forests (VII). The primary production of a young stand of *Castanopsis cuspidata* in Japan J. Ecol. 4:142-147.
- 21) _____. (1977) Leaf biomass *In* Primary productivity of japanese forests: productivity of terrestrial communities. SHIDEI, T and KIRA, T. (eds.), Japanese Committee for the International Biological Program, University of Tokyo Press, 39-44.
- 22) _____. (1985) Productivity of forests in Japan *In* Proceedings of an International Workshop in Japan. FUJIMORI, T. and WHITEHEAD, D. (eds.), 448pp, Forestry and Forest Products Research Institute Po Box. 16, Tsukuba Norin Kenkyu Danchi-Nai Ibaraki 303, Japan, 7-25
- 23) _____ and HATIYA, K. (1968) Forest ecosystem and their productivity. Ringyo kagaku gijyutu shinkousho, Kouhou press, K.K. 29:1-64. (In Japanese).
- 24) TEWARI, D.N. (1999) A monograph on teak (*Tectona grandis* Linn.f.). 479pp, International Book Distributors 9/3 Rajpur Road, Dehra Dun-248006, India.
- 25) UNESCO (1978) Tropical forest ecosystem. 683 pp, UNESCO-UNEP, France.
- 26) WARDONO, S., FATTAH, H.A. and POEDJORAHARDJO, D.S. (1977) Culture of teak plant by Perum Perhutani *In* Proceedings of the International Teak Symposium. Basha S., Mohanan, C. and Sankar, S. (eds.), 274pp, Thiruvananthapuram, Kerala, India, 12-14.
- 27) WARREN, W. (1997) Botanica : the illustrated A-Z of over 10,000 garden plants for Asia gardens and how to cultivate them. 878pp, Periplus Editions, Singapore.
- 28) WHITMORE, T.C. (1984) Tropical rain forests of the Far East, 2nd. 352pp, Clarendon press, Oxford.
- 29) WHITTAKER, R.H. and MARKS, P.L. (1975) Methods of assessing terrestrial productivity *In* Primary productivity of the biosphere. LIETH, H. and WHITTAKER, R.H. (eds.), 339pp, Springer-Verlag, New York, 55-118.
- 30) WHITTEN, T., SOERIAATMADJA, R.E. and AFIF, S.A. (1997) The ecology of Java and Bali. 969pp, Periplus Editions, Singapore.
- 31) WULFFING, H.E.W. (1932) Opstandtafels voor Djati-plantsoenen. 15pp, Balai Penelitian Kehutanan, Bogor.