短　報

# Some characteristics of growth ring structure and heartwood of teak (*Tectona grandis*)

— Comparison of two plantation sites, central and west Java, Indonesia —

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# チーク（*Tectona grandis*）の成長輪構造と心材の二三の特徴

—インドネシア中部・西部ジャワの人工林の比較から—

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Key words: *Tectona grandis*, growth ring, heartwood, starch, lipids

キーワード：*Tectona grandis*，成長輪，心材，デンプン，脂質

## 1. Introduction

Teak (*Tectona grandis*) is a tree species which is indigenous to tropical monsoon Asia including southern and central India, Myanmar, Laos People's Democratic Republic and northern Thailand (White 1991). Demand for quality timber has made teak the most widely planted hardwood species even in the areas outside the natural distribution such as Southeast Asia, Africa and Latin America (Katwal 2003).

Many researches of teak from various aspects, therefore, have been carried out. Studies from the viewpoints of wood quality (Bhat et al. 1987, Bhat et al. 1989), the relationship between tree growth and wood formation (Rao et al. 1966), heartwood characteristics (Ferguson 1934, Nobuchi et al. 1996) were reported.

In the areas of natural distribution of teak it is obvious to have rainy season and dry season. Tropical areas cover wide range from wet to dry habitat. How does wet or dry habitat affect tree growth and wood formation in teak?

Nishimukai (1999) observed the growth ring structure of the plantation grown teak in Peninsular Malaysia that belonged to tropical rain forest area. It was revealed that growth ring numbers more than plantation age were counted because of the formation of many false annual rings.

In Java Island, Indonesia, it is said that teak wood in west Java, that belongs to tropical rain forest area, has darker color of heartwood than that of central or east Java, where it has clear dry season.

In this report, therefore, growth ring structure and heartwood characteristics were preliminary investigated with special reference to water conditions. Two plantation sites in Java Island, Cepu in central Java and Sukabumi in west Java were selected. The former belongs to the area with clear dry season and the latter to the tropical rain forest area.

## 2. Materials and methods

### 2. 1. Research sites and materials

Two sites, Cepu in central and Sukabumi in west Java were selected. The monthly rainfall data of the average of 5 years from 1994 to 1998 are indicated in Fig. 1. It is clear that Cepu has the drier season than Sukabumi.

The sample trees are listed on Table 1. The exact tree height was not measured. One wood disk at the breast height from each sample tree was collected for the investigation.

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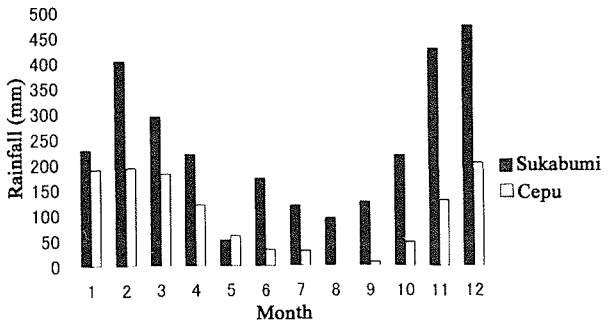


Fig. 1 Monthly rainfall of the average of 5 years from 1994 to 1998.

Table. 1 Descriptions of sample trees.

| Site | Tree No. | Age (year) | DBH (cm) |
|---|---|---|---|
| **Cepu** | **1** | **80** | **53** |
| | **2** | **80** | **50** |
| | **3*** | **5** | **7** |
| | **4*** | **5** | **9** |
| | **5*** | **5** | **8** |
| | **6** | **25** | **27** |
| | **7** | **25** | **22** |
| **Sukabumi** | **8** | **36** | **34** |
| | **9** | **36** | **38** |
| | **10** | **21** | **18** |
| | **11** | **21** | **17** |
| | **12** | **26** | **27** |

*: Heartwood was not formed yet.

### 2. 2. Methods

#### 2. 2. 1. Growth ring structure

Macroscopic and microscopic observations of growth rings were carried out. For the light microscopy transverse sections of about 20 $\mu$m in thickness were stained with safranine.

For the quantitative analysis of vessel pore size, transverse sections were analyzed with an image analyzing system (Scion image). The area of the measurement was a rectangle of about 5 mm x 10 mm (radial x tangential) including a growth ring boundary. The radial length corresponded to one growth ring width.

#### 2. 2. 2. Heartwood characteristics

(1) Cytological observation

Reserve substances of starch grains and lipid droplets were exclusively observed. Fresh wood blocks were fixed with 3% glutaraldehyde. Radial longitudinal sections of 20 $\mu$m were stained with iodine potassium for starch grains and with Sudan IV for lipid droplets.

(2) Chemical analysis of total lipids

Total lipids of sapwood and outer heartwood were chemically analyzed based on Folch's method (Folch et al. 1957). The results were shown as the weight percentage of lipids based on dry wood.

(3) Heartwood coloration

The color of tangential surface of outer heartwood was measured with a color and color-difference meter (Nippon Denshok, Z-1001DP). Only the lightness index (L*) based on Japan Industrial Standard JIS Z-8729 (1980) was adopted in this report. The area of surface measured was within a 6 mm diameter circle.

## 3. Results and discussion

### 3. 1. Growth ring structure

Transverse surfaces of radial strips of Cepu and Sukabumi samples are shown in Photo. 1. The growth ring structure was observed more clearly in Cepu samples than those of Sukabumi. Teak is reported to be ring-porous wood and deciduous tree (Rendle 1979, Pearson and Brown 1981, Rao and Dave 1981). The vessels of pore zone were considered to be larger in Cepu samples than Sukabumi.

Light micrographs of transverse sections of two sites are indicated in Photo. 2. For the comparison a transverse section of plantation grown teak in northern Thailand is also shown. These three light micrographs are comparable because they were taken in the outer part of the breast height disk of similar sized trees extracted from the same plantation age class.

In the pattern of Cepu, pore zone vessels showed larger diameter than those of Sukabumi resulting in more distinct ring-porous. It also resembled to the pattern of northern Thailand that belonged to the area of the natural distribution of teak.

To evaluate the difference of growth ring structure quantitatively, an analysis with the image analyzing system was carried out. Figure 2 shows the distribution of vessel area of two sites. In Cepu vessel area distributed in wide range from large to small. In Sukabumi even the largest group of vessels that

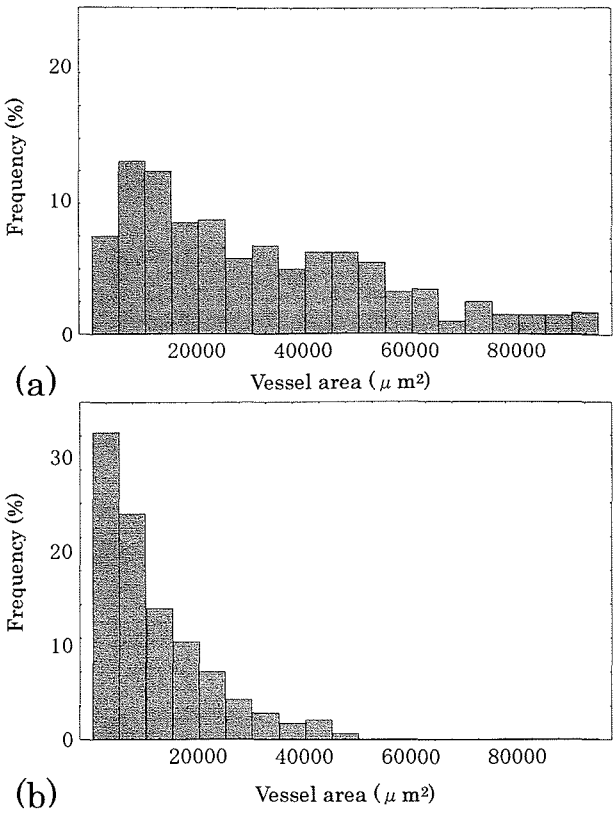


Fig. 2 vessel area distribusion. (a) Cepu, (b) Sukabumi.

constituted pore zone showed small values.

From the viewpoint of tree physiology, vessel has the function of water transportation in xylem from the roots to the leaves. It is considered that the difference of water condition might affect the pore size especially of pore zone.

The real mechanism of the affection of the water deficit to vessel size is still unresolved. In the area with dry season such as Cepu, it is supposed that trees might have the dormant period especially when they shed leaves. In the data of seasonal characteristics of wood formation of teak in northern Thailand, wood formation started in the end of dry season or beginning of rainy season after long term cessation of cambial activity (Nobuchi et al. 1996). When the wood formation starts, the formation of large sized vessels is postulated to have an advantage for the rapid water transportation (Zimmermann 1983).

In the wet habitat such as Sukabumi, the term of shedding leaves would be very short. Teak planted in wet habitat or tropical rain forest area, therefore, shows evergreen nature in which growth ring structure has the tendency of diffuse-porous wood nature although it would keep hereditary ring-porous wood. It is summarized that the growth ring structure of wet habitat showed semi ring-porous wood (IAWA 1989) and that of dry habitat ring-porous wood.

In the future activity the phenological observation of leaves together with the study of seasonal characteristics of wood formation in two zones are necessary.

### 3. 2. Heartwood characteristics

#### 3. 2 1. Cytological features

Cytological observation of tissues was carried out especially to clarify the relationship of reserve substances to heartwood formation. Photograph 3 (a, b, c) and Photo. 4 (a, b, c) show radial longitudinal sections of outer sapwood, inner sapwood and outer heartwood stained with iodine potassium and Sudan IV, respectively.

Ray and axial parenchyma cells contained much amount of starch grains in the outer sapwood. They decreased abruptly in the middle and inner sapwood and completely disappeared in heartwood. The complete disappearance of starch grains in heartwood region coincides with the past reports (Frey-Wyssling and Bosshard 1959, Higuchi et al. 1964).

Lipid droplets in ray and axial parenchyma cells were small in size and lesser amount in outer sapwood. They increased in middle and inner sapwood parallel with the decrease of starch grains. In the inner sapwood the droplets changed to the larger size. In heartwood large sized lipid droplets were also observed.

In addition to ray and axial parenchyma cells, wood fibers also had starch grains and lipid droplets (Photo. 5). Their patterns of increase and decrease were similar as those in ray and axial parenchyma cells. These wood fibers were considered to be "living wood fiber" because they had reserve substances and had the living function.

Fahn and Leshem (1963) reported the existence of the libriform fibers retained living protoplasts in many woody plants. Fahn and Arnon (1963) also studied the changes of the living wood fibers of *Tamarix aphylla* in transition from sapwood to heartwood. Recently, Zhang et al. (2004) observed them in *Albizia julibrissin*.

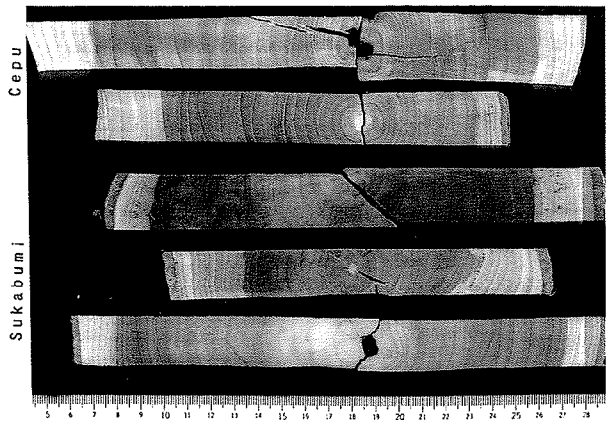


Photo 1 Radial strips of sample trees of Cepu and Sukabumi.

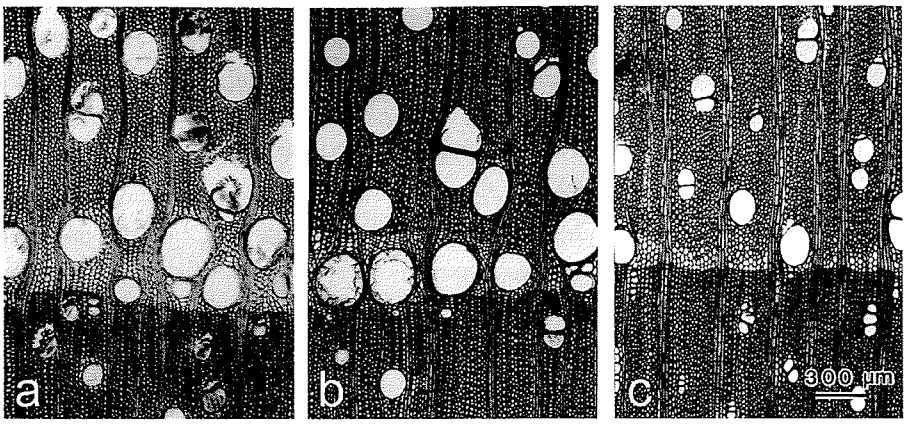


Photo 2 Light micrographs of transverse sections stained with safranine. (a) Thailand, (b) Cepu, (c) Sukabumi.

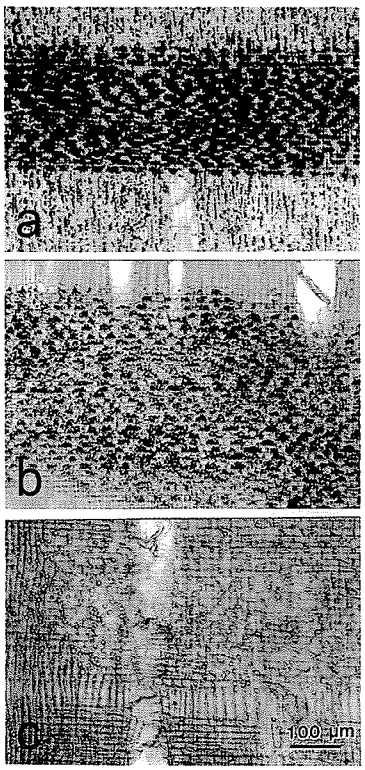


Photo 3 Light micrographs of radial longitudinal sections stained with iodine potassium. (a) Outer sapwood, (b) inner sapwood, (c) outer heartwood.

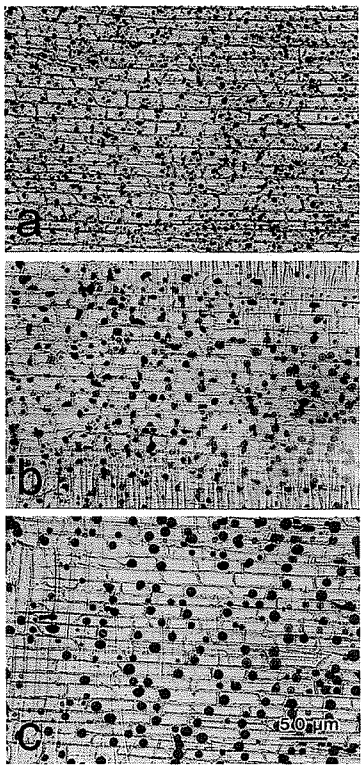


Photo 4 Light micrographs of radial longitudinal sections stained with Sudan IV. (a) Outer sapwood, (b) inner sapwood, (c) outer heartwood.

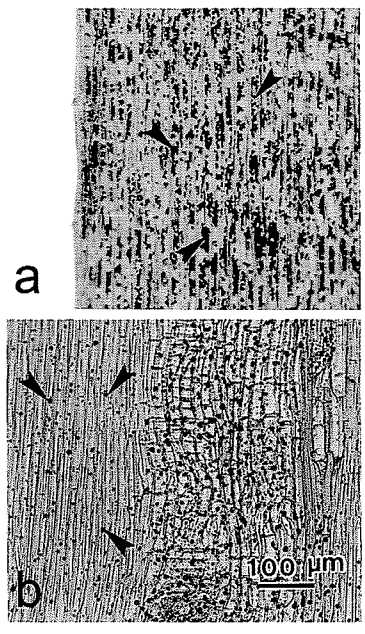


Photo 5 Light micrographs of radial longitudinal sections. (a) Starch grains in living wood fiber (arrow heads), (b) lipid droplets in living wood fiber (arrow heads).

From the cytological observation of reserve substances, it was clarified that teak had much amount of lipid droplets both in sapwood and heartwood except outer sapwood. Having lipid droplets in wood fibers was another particular feature of teak wood. Changes of reserve substances in the transition from sapwood to heartwood were basically the same in two sites.

### 3. 2. 2. Chemical analysis of total lipids

In the wood quality viewpoint it is reported that teak wood had waxy nature in touch (Saiki 1982). It is postulated that lipid droplets would closely relate to the waxy nature of wood. Chemical analysis of total lipids was, therefore, performed.

The results of chemical analysis of total lipids of sapwood and heartwood in two sited are listed on Table 2. In two sites both sapwood and heartwood showed the larger value of total lipids. Kramer and Kozlowski (1979) reported that the concentration of lipids in vegetative structures of plants was quite low, often being less than 1% of the dry weight. Assarson and Akerlund (1966) also reported that the content of fats was about 0.3-0.4%, that of waxes about 0.08-0.09% (based on dry wood) as determined for *Picea abies* and *Pinus sylvestris*.

Table. 2 Chemical analysis of total lipids.

| Site | Part | Lipids (%) |
|---|---|---|
| Cepu | Sapwood | 5.1 |
| | Heartwood | 7.7 |
| Sukabumi | Sapwood | 5.8 |
| | Heartwood | 7.4 |

The present data indicated far large amount of total lipid than the reports. It is also reported that the percentage of free fatty acids is considerably higher in heartwood than in sapwood (Fengel and Wagener 1984). It was clarified that teak wood had much amount of total lipids both in sapwood and heartwood, which had close relation to the waxy nature of wood surface.

The difference of lipids in two sites was not clarified quantitatively and qualitatively.

### 3. 2. 3. Heartwood color

In Java Island, it is said among local people that teak wood in central or east Java has better quality than those of west Java because the former has brighter color of heartwood.

To evaluate the heartwood coloration, wood surfaces, 4 of Cepu and 5 of Sukabumi, were measured with a color and color-difference meter. The data of lightness index (L*) that indicates brightness were as follows.

Cepu: 59.7 (Standard deviation 3.4)

Sukabumi; 54.3 (Standard deviation 2.2)

L*values of perfect white and perfect black theoretically show 100 and 0, respectively. The heartwood color of Cepu was, therefore, judged to be lighter than that of Sukabumi.

Two main factors, genetic factor and edaphic factor, are postulated to affect heartwood color in one species. In sugi (*Cryptomeia japonica*) the researches of heartwood color especially focused on black and red heartwood color have been conducted.

Kawazumi et al. (1991a) investigated heartwood color in relation to cultivars. Kawazumi et al. (1991b) also studied the relationship between growth rate and heartwood moisture content. Bunazawa (2002) compared heartwood color of plantation sugi in a single stand of a cultivar and reported that trees having better growth rate (radial growth) showed darker heartwood.

Cultivars were not investigated in the present study. It is the future research point. The radial growth rate of sample trees in two sites, Cepu and Sukabumi, were 3.6 and 4.2 mm/year, respectively. This result is not inconsistent with the report of sugi.

Heartwood color is one of the most important factors characterizing wood quality in teak. It is an important research viewpoint to study the relationship between heartwood color and the edaphic conditions such as soil fertility, soil moisture content etc. in a single cultivar of teak.

It was concluded that differences in growth ring structure and heartwood color in the wood of two research sites, were clarified. Based on the present preliminary results, more detailed study will be continued.

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