

SEASONAL CHARACTERISTICS OF WOOD FORMATION IN HOPEA ODORATA AND SHOREA HENRYANA

by

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SUMMARY

Seasonal characteristics of wood formation were investigated using the pinning method in *Hopea odorata* and *Shorea henryana* in a natural dry evergreen forest of eastern Thailand. The position of cells having initiated S₁-layer formation at the time of pinning was estimated in the zone where cells were directly injured by the pinning and consequently destroyed. The position of cambial initials at the time of pinning was estimated in the zone where cells were indirectly affected by the pinning and continued their physiological activity resulting in the formation of aberrant cells. Traumatic resin canals were occasionally formed in *Shorea*. These canals were formed after pinning and could, therefore, not record the exact time of the pinning. Diameter growth of both species was greatest in the rainy season and decreased in the dry season.

Key words: *Hopea odorata*, *Shorea henryana*, wood formation, pinning method, cambial initials, S₁-layer, tropical trees.

INTRODUCTION

Even though tropical trees often have growth rings, their ring boundaries are not always as clear as those in the trees of temperate zones, and their relationship to seasonal events is often not known. There are few reports on the periodicity or seasonal characteristics of wood formation in tropical trees (e.g., Rogers 1981; Boninsegna et al. 1989; Détienne 1989; Jacoby 1989). Information on seasonal characteristics of tree growth, especially wood formation, in tropical trees is useful for developing management plans for tropical trees and forests.

The pinning method (Wolter 1968) has been a useful tool for studying the timing of events in wood formation. This method mostly has been applied to the study of temperate zone trees (Shimaji & Nagatsuka 1971; Yoshimura et al. 1981a, b; Kuroda & Shimaji 1983, 1984) and rarely to tropical trees. Shiokura (1989) reported a pinning experiment using a nail for tropical trees, with pinning intervals of three months. The amount of growth per interval was clarified, but the exact position of marking of cambial initials and the differentiating zones has remained obscure.

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In this report the pinning method was applied to two tropical tree species to investigate the possibility of marking cambial initials and differentiating zones and to obtain information on seasonal characteristics of wood formation.

The pinning method by definition is the application of a minute mechanical injury that results in aberrant cells as the time marker. The term 'pinning' is used in this paper even though a nail was used instead of a tiny pin.

MATERIALS AND METHODS

Materials

One tree each of two tropical tree species of Dipterocarpaceae, *Hopea odorata* and *Shorea henryana*, grown in a natural dry evergreen forest in Sakaerat, eastern Thailand, was selected for the experiment. These two species are dominant in the forest. The tree height and the diameter at breast height were 30 m and 80 cm for *Hopea* and 35 m and 70 cm for *Shorea*. Tree age was unknown for both species.

Pinning was done every month from July 1991 to July 1992, using a nail of 2 mm in diameter. Figure 1 indicates the pinning positions in a tree. Blocks of 2 cm in radial depth containing the pinned wood were collected on August 1, 1992 by a saw and a chisel without felling the tree. The blocks were fixed with 3% glutaraldehyde.

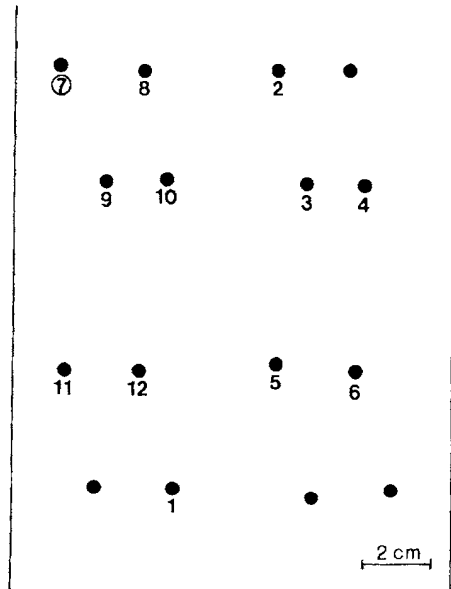


Fig. 1. Schematic illustration of the pinning points on a trunk.

Methods

Softening of wood blocks

Both species had very hard xylem, so the blocks were softened in 55% hydrofluoric acid. The softening time was one week for blocks to be cut with a sliding microtome, and three to four weeks for blocks to be resin-embedded and cut with a rotary microtome.

Sectioning and staining

Thick sections (mainly transverse sections), 20–30 μm , were cut using a sliding microtome. They were stained with safranin and fast green for light microscopy.

Small blocks with pinned wood were embedded in Epoxy resin and thin sections, 2–3 μm in thickness, were cut with a glass knife on a rotary microtome. These thin sections were observed under a polarizing microscope.

RESULTS AND DISCUSSION

Characteristics of growth rings

Transverse sections of *Hopea* and *Shorea* are shown in Figure 2 and 3, respectively. Both species are diffuse-porous. Axial parenchyma is mostly diffuse-in-aggregate in *Hopea* and aliform in *Shorea*. Detailed observation revealed that both had growth rings.

In *Hopea* a growth-ring boundary is marked by a band of parenchyma with small diameter vessel elements. The cell wall thickness of wood fibres were thinner on the outer side of the boundary than on the inner side (Fig. 2).

In *Shorea* (Fig. 3), at the growth-ring boundary, the aliform parenchyma has longer wings and narrower vessel elements. The wood fibres had – as observed in *Hopea* – thinner cell walls in the outer side of the boundary than in the inner side.

During the one-year experiment one growth ring was formed in the latter half of the dry season in *Hopea* but no growth ring was formed in *Shorea*.

The latest growth-ring boundary formed before the start of the pinning was used as a reference line for each species when the amount of wood formation was measured in every month on a transverse section.

Anatomical characteristics of wound tissue

A transverse section of wound tissue induced by pinning in *Hopea* is shown here in Figure 4. The wound tissue was divided into two zones although it showed a very complicated structure. In zone 1 cambial initials and cells in the differentiating zone had been directly affected by pinning injury. They had been crushed and cell wall formation had been interrupted in the cells living at the time of pinning. Cells in this zone, therefore, retained the cell wall organization at the time of pinning, even if they were deformed.

The structural characteristics of zone 1 were observed with polarized light as well as conventional illumination (Fig. 5). Arrowheads in Figure 5a indicate outermost bark-side cells which showed birefringence of S_1 -layer under a polarizing microscope. Observation of the same section under a conventional microscope revealed that the residue of deformed cells was attached on the cells indicated by arrowheads (Fig. 5b).

It was considered that the cells indicated by the arrowheads are the cells that were initiating S_1 -layer formation at the time of pinning in each section. The position of the initiation of S_3 -layer formation was not clarified in this experiment.

In zone 2, cambial initials and cells of the differentiating zone were affected by the pinning injury but plasma membranes were not destroyed. These cells, therefore, were considered to have continued their physiological activity and to form aberrant cells or wound tissues.

In transverse section, wound tissue showed the following characteristics from the pith side to the bark side:

- 1) A region including callus-like cells and cell debris.
- 2) A region having mostly axial parenchyma-like cells and no vessel elements.
- 3) A region having small vessel elements.

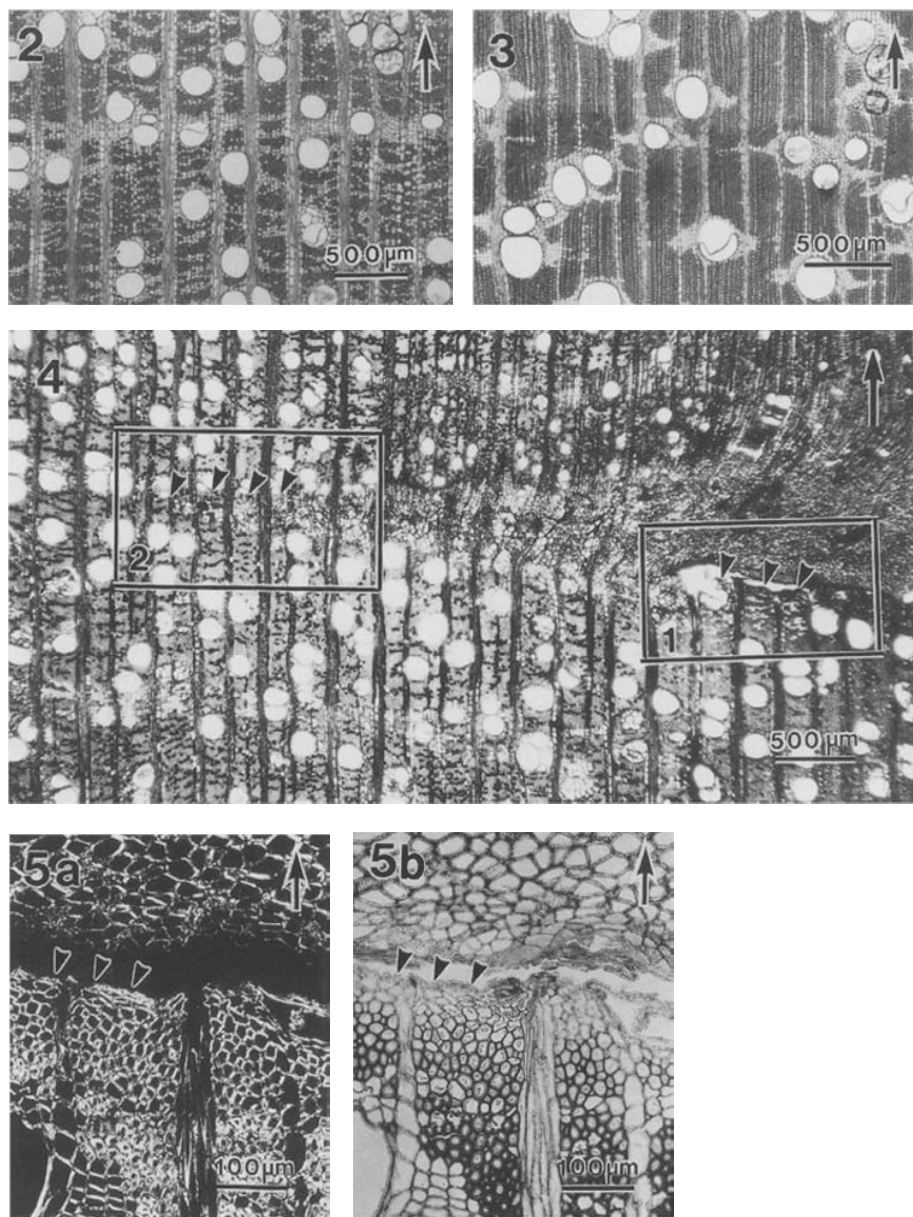


Fig. 2. Transverse section of *Hopea* showing a growth-ring boundary. — Fig. 3. Transverse section of *Shorea* showing a growth-ring boundary. — Fig. 4. Transverse section of *Hopea* showing wound tissue with two zones marked. Zone 1: tissue directly affected by pinning injury with plasma membranes destroyed; arrowheads indicate the deduced site of the initiation of S₁-layer formation. Zone 2: tissue not directly affected by pinning injury with plasma membranes intact; arrowheads indicate the deduced site of cambial initials. — Fig. 5. Transverse sections corresponding to zone 1 observed under a polarizing microscope (a) and a conventional microscope (b) in *Hopea*. Arrowheads indicate the deduced site of the initiation of S₁-layer formation. — Arrows in Fig. 2–5 indicate the direction of the bark side.

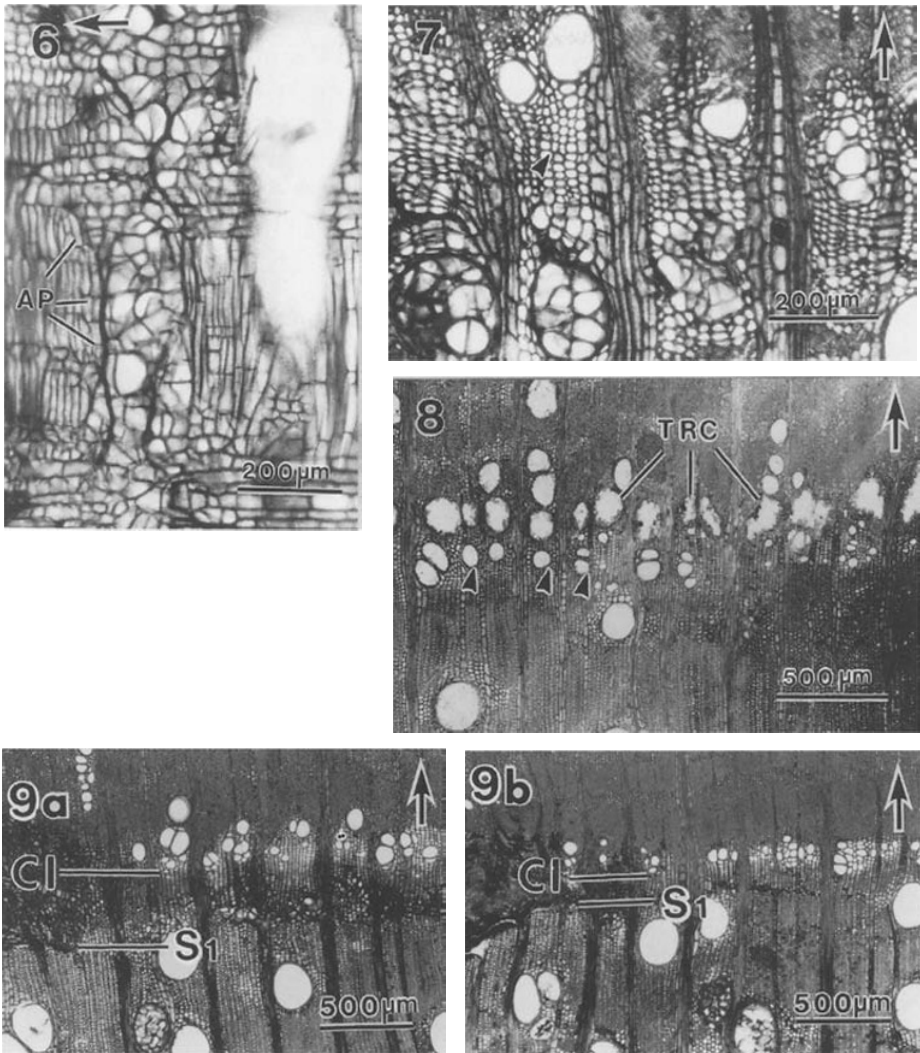


Fig. 6. Radial longitudinal section of zone 2 in Fig. 4 (*Hopea*). AP: axial parenchyma cell. — Fig. 7. Transverse section of *Hopea* showing the increase of cell rows (arrowhead). — Fig. 8. Transverse section of *Shorea* showing traumatic resin canals (TRC) located on the bark side of the deduced site of cambial initials (arrowheads). — Fig. 9. Transverse sections of wound tissues of *Hopea* caused by pinning, (a) in October (rainy season), (b) in February (dry season). CI: deduced site of cambial initials; S₁: cells that have initiated S₁-layer formation. — Arrows in Fig. 6–9 indicate the direction of the bark side.

Callus-like cells were considered to have been formed by ray parenchyma cells filling the gap formed after injury. The cell debris was supposed to have originated from cells differentiating and enlarging at the time of pinning, and to correspond with “the stripe of cell wall residue” reported by Yoshimura et al. (1981a).

A radial section of the region appearing to have mostly axial parenchyma-like cells revealed that they were indeed axial parenchyma cells (Fig. 6). These cells differentiated after pinning. It is suggested that this region of axial parenchyma cells includes derivatives of cells that were cambial initials and xylem mother cells at the time of pinning.

In the region with small diameter vessels a point where the number of cell rows increased tangentially (Fig. 7) was noted. This increase could have been caused by the anticlinal division of cambial initials. The line which connected the innermost point of anticlinal divisions was considered theoretically to be the location of cambial initials at the time of pinning. Practically this line coincided with the line of the innermost small-size vessels. This line was, therefore, adopted as the marker of cambial initials (CI) at the time of pinning and used for measurements.

The anatomical features of wound tissue of *Shorea*, including the marking of cambial initials and the position of the cells having initiated S₁-layer formation, were basically the same as in *Hopea*.

Traumatic resin canals

There have been some reports on the formation of traumatic resin canals after pinning injury. Kuroda and Shimaji (1983) observed traumatic resin canals in *Tsuga sieboldii* and Shiokura (1989) reported the formation of gum/resin canals in some species in Dipterocarpaceae.

In this experiment traumatic resin canals were occasionally observed in *Shorea* but not in *Hopea*. Figure 8 shows one example of traumatic resin canals in *Shorea*. The traumatic resin canals were located towards the bark side of the line of estimated cambial initials at the time of pinning.

Kuroda and Shimaji (1983) reported that the estimated position of cambial initials at the time of pinning was located towards the bark side of epithelial cells constituting resin canals. Shiokura (1989) also used gum/resin canals as the marker of the pinning.

In this experiment traumatic resin canals, even if they were formed, were judged not useful as a marker of the cambium position because they did not reveal the exact position of cambium at the time of pinning.

Comparison of wound tissues between rainy and dry seasons

Wound tissues which included information on the location of cambial initials and the differentiating zone at the time of pinning were compared between rainy and dry seasons (Fig. 9a, b). The distance between cambial initials and the cells having initiated S₁-layer formation was wider in the rainy season than in the dry season. This indicates that cell division was more frequent in the rainy season.

Seasonal characteristics of wood formation

Table 1 shows monthly radial growths of *Hopea* and *Shorea*, monthly rainfall and monthly average temperatures. In *Shorea* a part of the pinning parts did not include the

Table 1. Monthly radial growth, monthly rainfall and monthly average temperature.

Month	Monthly radial growth (mm)		Monthly rainfall (mm)	Monthly average temperature (°C)
	<i>Hopea</i>	<i>Shorea</i>		
1991 August	0.30	0.55	156.5	24.5
September	0.50	—	254.8	24.6
October	0.35	0.60	141.3	23.1
November	0.30	—	0.0	24.2
December	-0.05	0.60	14.2	22.7
1992 January	0.25	—	22.1	21.8
February	-0.10	0.75	0.5	26.5
March	0.10	—	19.1	29.5
April	0.45	-0.20	46.9	31.2
May	0.05	—	27.5	30.5
June	1.30	0.65	80.1	28.0
July	0.95	—	61.2	27.3

latest growth ring formed before the start of the pinning experiment because the radial length of the block was not long enough. The statistical analysis was, therefore, carried out only with *Hopea*.

Many factors are considered to be related with wood formation. Among them the correlations between monthly radial growth and monthly rainfall or monthly average temperature in *Hopea* were investigated in a scatter diagram (Fig. 10). The monthly radial growth has a higher coefficient of correlation with monthly rainfall ($r = 0.32$) than with monthly average temperature ($r = 0.17$).

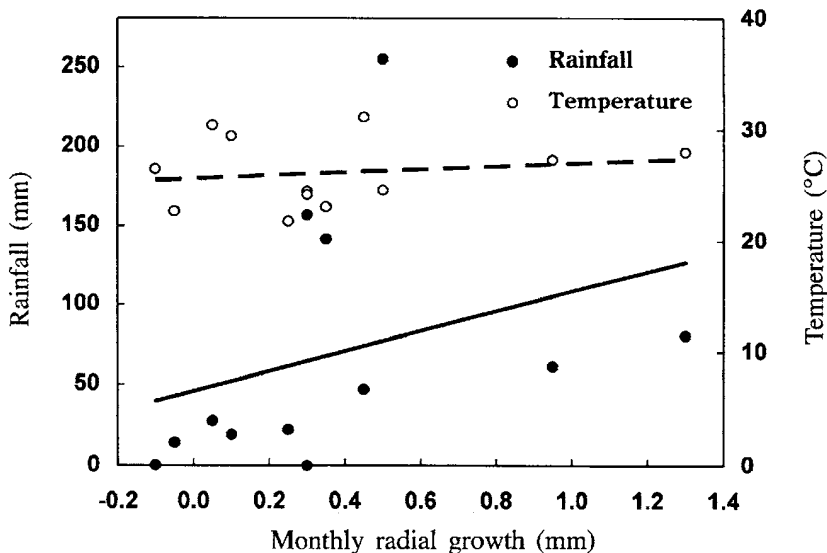


Fig. 10. Correlations between monthly radial growth of *Hopea* and monthly rainfall or monthly average temperature.

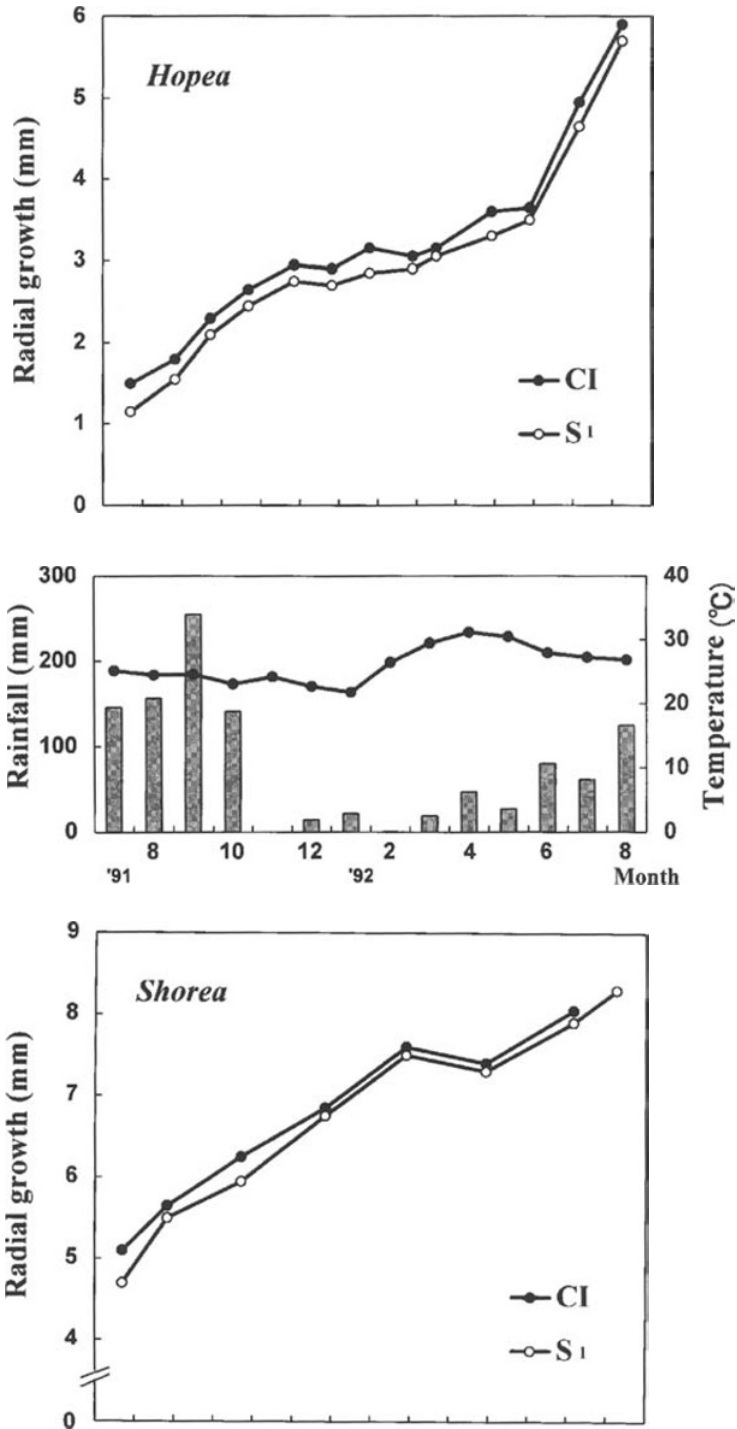


Fig. 11. Relationship between wood formation and meteorological data for *Hopea* and *Shorea*.

The relationships between radial growth in *Hopea* and *Shorea* and the meteorological data are shown in Figure 11. In *Hopea* more wood was formed in the rainy season than in the dry season. However, the amount of the radial growth is not always proportional to the rainfall. For example, the radial growth in August, September and October in 1991 was smaller than in June and July in 1992. One of the possible reasons is low light intensity on a rainy day. Another possible reason is the effect of the soil moisture content which shows, in general, a time lag of the rainfall.

A more detailed relationship between wood formation and meteorological factors should be clarified in future research.

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