The Validity of A New Technique Differentiating between Juvenile and Mature Wood in Conifers*

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[Summary]

Our studied materials were tested on wood specific gravity of fifteen, 38-yr-old red pine trees from central Wisconsin and on tracheid length of fifteen, 39-yr-old Taiwan red-cedar trees from central Taiwan. An increment core sample was removed from each red pine sample tree in September 1995 and each Taiwan red-cedar sample tree in November 1994. All increment core samples were then separated into individual growth rings and their wood properties determined.

An analysis of variance was conducted on each set of wood data generated by varying the number of growth rings from 28 to 2 in the working sample for red pine and from 20 to 3 in the working sample for Taiwan red-cedar. The age of the juvenile-mature wood transition was set at a point where the variance component due to the effect of ring position reached 0%. The transition age between the 2 wood zones was at the 25th growth ring for red pine specific gravity and at the 33rd growth ring for Taiwan red-cedar tracheid length. This new method was proposed elsewhere, but not only worked for different coniferous species but also for different wood properties.

Key words: red pine, Taiwan red-cedar, juvenile wood, specific gravity, tracheid length.

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針葉樹未成熟與成熟材境界區分之新技術

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摘要

本實驗材料使用產自美國威斯康辛州中部之15株、38年生紅松之比重及產自台灣中部15株，39年生台灣紅檜之管胞長。紅松於1995年9月，台灣紅檜於1994年11月，就每一樣木，使用生長錐鑽取包含各生長輪之樣本，然後將所有生長輪再細分各生長輪，以便進行木材性質之測定。

以變分析方法探討每一組樣本，美國紅松由28～2個年輪組成，台灣紅檜由20～3個年輪組成，分析其不同變異成分，當不同年輪位置材質之變異成分達到0%時，以此做為未成熟與成熟材轉移帶之境界林齡。其林齡，紅松以比重方法求得者為25年，台灣紅檜以管胞長決定者為33年。這項新技術不僅可應用於其他不同樹種，也可應用於不同之木材性質。

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INTRODUCTION

Juvenile wood is formed under the strong influence of a live crown. When trees are young, there is a large proportion of juvenile wood in the center of the tree trunk. The negative effect of the presence of a large amount of juvenile wood on solid wood products has been documented (Zobel *et al.*, 1972; Senft and Bendtsen, 1984; Senft *et al.*, 1985; Curtis and Saucier, 1992). It was further reported that the negative impact of juvenile wood on mechanical properties was more pronounced in conifers than in hardwood species (Bendtsen, 1978; Bendtsen and Senft, 1986).

A new technique for the determination of the boundary between juvenile and mature wood was proposed by Lee and Wang (1996). The validity of the new technique on other wood properties of different tree species remains to be tested.

MATERIALS AND METHODS

Two conifers, one indigenous to North America and another native to Taiwan were selected to test the validity of the new technique.

Red pine (*Pinus resinosa* Ait.) was selected for specific gravity study because of its importance in the Lake States area of the U.S.. The test samples were taken from each of 15 trees in a study plantation established with a 1.8-m by 1.8-m spacing in 1957. The plantation is located in central Wisconsin, about 14 miles north of Stevens Point. It was thinned in 1977 to a basal area of about 16 m^2/ha (70 ft^2/acre) by removing every other row of trees. From the eastern aspect of each sample tree, we extracted a pith-to-bark increment core specimen (0.45-cm calibre) at stump height in September 1995. This was done for convenience because when all study specimens are sampled from the same cardinal direction at the same tree height (consistence rule), they will yield comparable information for our study purpose. Mean dbh and height based on 15 sample trees were 28 cm and 19 m, respectively.

Each increment core sample was further separated into individual growth increments under the dissecting microscope in the Stevens Point Laboratory. We decided to discard several growth rings near the bark due to an undesirable compression problem during the extraction process. Only 28 growth rings from each sample tree were studied (numbered 1, 2, 3···28 outward from the pith to the bark). Alcohol-benzene extractive-free specific gravity was determined and expressed on an ovendry weight and green volume basis (Smith, 1954).

Twelve sets of specific gravity data were created by varying the number of growth rings from 28 (ring numbers 1 through 28 analyzed) to 2 (ring numbers 27 through 28 analyzed) for inclusion in the working sample (Table 1). An analysis of variance was conducted, and estimated variance components were calculated for each of 12 sets of data according to the randomized complete block design. Results were compared with those of Shiokura (1982).

Taiwan red-cedar (*Chamaecyparis formosensis* Matsum.), an important economic species in Taiwan, was selected for trachied length study. Another 15 sample trees were selected from a study plantation established in 1955 with a 2.0-m by 1.5-m spacing. The plantation is located in central Taiwan at an elevation of about 2200 m and is characterized by 86% relative humidity, 4409 mm annual precipitation and 10.4℃ mean annual temperature. The rainy season runs from May to September and the area represents ideal growth conditions for Taiwan red-cedar. This plantation was thinned in 1979 to a basal area of about 30 m^2/ha.

A pith-to-bark increment core specimen (0.45-cm calibre) was extracted from the east cardinal direction of each sample tree at breast height in November 1994. Mean dbh and height of 15 sample trees were 36 cm and 22 m, respectively. Each increment core sample was separated into individual growth rings in the Taipei Research Laboratory. Each of 26 growth rings (numbered 1, 2, 3 to 12; 14 to 15; 17, 19, 21, 23 to 37, 39 outward from the pith to the bark) was macerated with a hydrogen peroxide-acetic acid-water mix-

Table 1. Sampling efficiency affected by the number of growth increments in the working sample from a red pine man-made forest

			Variance components (%)		
No. of rings sampled	Ring position	F Values	Ring position	Blocks	Error
28	1 to 28	24.429**[1)]	64	3	33
23	6 to 28	19.554**	59	3	38
19	10 to 28	10.737**	42	6	52
16	13 to 28	6.146**	27	9	64
12	17 to 28	4.980**	22	13	65
8	21 to 28	2.531*[2)]	10	12	78
7	22 to 28	2.019	7	10	83
6	23 to 28	1.982	7	4	89
5	24 to 28	1.194	2	0	98
4	25 to 28	0.630	0	0	100
3	26 to 28	0.762	0	0	100
2	27 to 28	0.899	0	0	100

1)** statistically very significant ($P \leq 0.01$).
2)* statistically significant ($P \leq 0.05$).

Table 2. Sampling efficiency affected by the number of growth increments in the working sample from a Taiwan red-cedar man-made forest

			Variance components (%)		
No. of rings sampled	Ring position	F Values	Ring position	Blocks	Error
20	7 to 39	76.471**[1)]	66	21	13
16	11 to 39	43.039**	50	32	18
13	15 to 39	20.527**	31	45	24
10	21 to 39	10.299**	15	62	23
8	25 to 39	6.578**	8	72	20
6	29 to 39	2.057	1	79	20
5	31 to 39	2.169	1	82	17
4	33 to 39	0.236	0	83	17
3	35 to 39	0.046	0	82	18

1)** statistically very significant ($P \leq 0.01$).

ture (1:4:5 by volume) at 40℃ for 54 h. Macerated material was stained with Safranin-o, and 60 tracheids were measured under a microscope equipped with a photographic device. Mean tracheid lengths were used as items in the statistical analysis.

An analysis of variance was conducted, and estimated variance components were computed for each of 9 sets of tracheid data created by varying the number of growth rings from 20 (ring numbers 7 through 39) to 3 (ring numbers 35 through 39) for inclusion in the working sample (Table 2). All analyses were carried out according to the randomized complete block design, and results were compared with those of Shiokura (1982).

RESULTS AND DISCUSSION

Pith-to-bark radial variation patterns in specific gravity and tracheid length are presented in Figs. 1 and 2, respectively. Red pine specific gravity data do not follow a distinctive 3-stage variation pattern (Fig. 1) reported elsewhere (Thomas, 1984; Thomas and Kellison, 1987; Clark and Saucier, 1991), however, the 3-stage variation pattern is obvious for Taiwan red-cedar tracheid data (Fig. 2). For that wood property, an initial period of rapid increase in tracheid length was noticeable for the first 20 growth rings (from the pith outward), followed by a transitional stage characterized by a rather slower increase in tracheid length. The transitional period covers approximately 8 to 10 growth rings. The 2nd stage

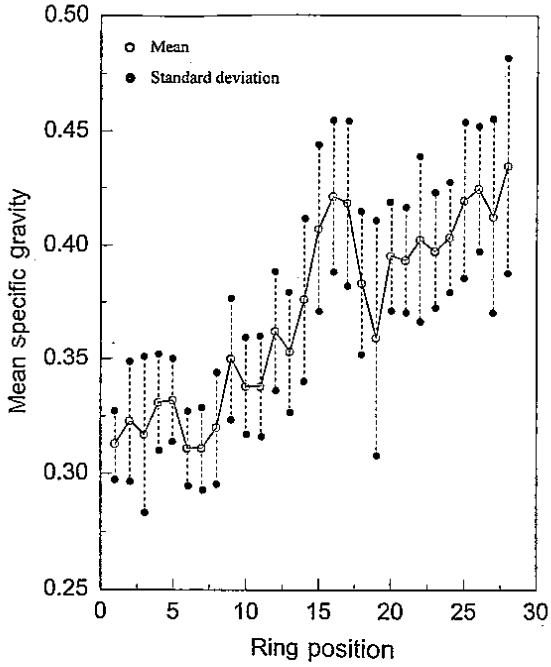

Fig. 1. Red pine mean specific gravity and its 1 standard deviation by individual growth increment positions.

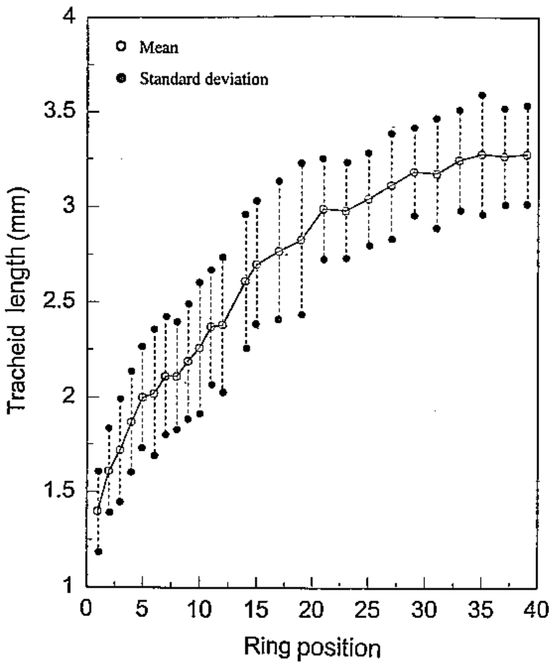

Fig. 2. Taiwan red-cedar mean tracheid length and its 1 standard deviation by individual growth increment positions.

in the tracheid curve is then followed by another (3rd) stage where tracheid length shows little increase or change.

To relate wood properties (specific gravity and tracheid length) with growth ring position, we applied a natural logarithmic (Ln) formula suggested by Shiokura (1982):

$$T = a + b\,(\mathrm{Ln}\,N)$$

where T represents wood properties, N is the ring position (1 to 28 for red pine specific gravity and 1 through 39 for Taiwan red-cedar tracheid length), and a and b are wood properties of the 1st growth ring and the slope of the regression, respectively. The wood property-ring position correlations (with 26 degrees of freedom for specific gravity and 24 degrees of freedom for tracheid length) were all statistically significant ($r = 0.837$, $a = 0.271$, $b = 0.0411$ for specific gravity; $r = 0.978$, $a = 1.078$, $b = 0.592$ for tracheid length) at the 1% level. Of the total variation in wood properties, 30% and 4% (= $1 - r^2$), respecitively, for specific gravity and tracheid length could not be accounted for.

The increasing rate of wood properties was calculated according to the following formula:

$$T(\%) = (T_{n+1} - T_n)/T_n \times 100$$

where T (%) is the increasing rate of wood properties, and Tn+1 and Tn are the wood properties at the (n+1)th and nth ring position from the pith outward. At the 19th ring from the pith, the rate of increase in specific gravity (red pine) dropped to 1% where Shiokura (1982) established the boundary between juvenile and mature wood. The rate of increase in tracheid length dropped to 1% at the 27th growth ring from the pith for Taiwan red-cedar.

According to the new technique, the age of transition from juvenile to mature wood is set at a point where the variance component attributable to the effect of growth ring position becomes 0% (Tables 1 and 2). In the present study, this point occurred at the 25th growth ring for specific gravity (red pine) and at the 33rd growth ring for tracheid length (Taiwan red-cedar). In predicting the boundary between the 2 wood zones, the proposed new method appears to work on different wood properties of different tree species. When trying it on the two test tree species, the new method results in a small difference of 5 to 6 yr from Shiokua's method (1982).

Several methods have been useful for estimating the period of juvenile wood formation.

Unfortunately, none of the existing methods yield consistent demarcation points separating the 2 wood zones. The existence of large variations in wood properties between tree species (Thomas, 1984; Loo *et al*., 1985; van Buijtenen, 1987) and within the same species, i.e., within- tree, tree-to-tree, and year-to-year variations (Bendtsen and Senft, 1986; Wolcott *et al.*, 1987) has been documented. Given this evidence, research workers certainly have the liberty of deciding on what method most suits their study purpose and then follow the consistency rule throughout their course of study.

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