GEOGRAPHIC VARIATION IN WOOD PROPERTIES OF *PINUS TECUNUMANII*

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ABSTRACT

Wood properties of *Pinus tecunumanii* were studied on 108 trees collected from four different departments of Guatemala (Baja Verapaz, Zacapa, Totonicapán, and El Quiché). Unextracted and extracted specific gravities were calculated from 108 cores (one per tree) of 4.5 mm diameter. The specific gravity varied from 0.51 to 0.56 with a weak decreasing trend from east to west. Most of the extractives were found in the core segment closest to the pith. Tracheid measurements were recorded on 11-mm cores from Baja Verapaz and Zacapa with tracheid length, cell-wall thickness, lumen width, and tracheid diameter being recorded. With the exception of tracheid length, all the measured cell characteristics showed highly statistical differences between locations and among trees. Most of the variation was within and between trees. Tracheid diameter and lumen width were highly correlated. The wood of the Tecun Umán pine showed extreme variability, especially in tracheid dimensions. Overall, however, the wood of this species is quite usable for both solid wood and pulp products.

Keywords: *Pinus tecunumanii,* wood properties, specific gravity, geographic variation.

INTRODUCTION

Among the approximately twenty pine species present in Central America, *P. tecunumanii* Schw. ex Eguiluz et Perry probably has the trees of the best form. It is a large tree reaching 55 m in height and 1.2 m in diameter, is straight, bearing small and compact crowns with usually over three-quarters of its bole being clear of branches. It grows in pure or mixed stands, mainly in the central highlands of Guatemala. Its range, however, extends to El Salvador, Honduras, and probably Mexico (Eguiluz and Perry 1983). This species was strongly recommended for plantations in Guatemala and in the tropics by Schwerdtfeger (1953) and later by Mittak (1977), but it was just recently that seed collections have begun (1981) and no operational plantings have been made.

Unfortunately, the Tecun Umán pine is threatened by several destructive factors. The most serious of these are bark beetle attacks (*Dendroctonus* sp.), wild fires, firewood cutters, and peasant farmers (Daugherty 1973; Veblen 1976, 1978). The insect attack in Totonicapán has recently depleted the population sampled in 1979 for this study (Dvorak 1981a). The pressure of such destructive factors, along with the need for new seed sources to test as exotics in many countries around the world, have aroused the concern of the industries, conservationists,

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and governments that have already started seed collections for plantations and establishment of preservation banks on several locations in Guatemala and Honduras (Dvorak 1981b). This study is in part a result of the joint effort to explore the variation in wood properties of *P. tecunumanii,* along with the collection of germplasm material used to establish provenance trials inside and outside its natural habitat.

The purpose of this study was to determine the geographic variation pattern of specific gravity and tracheid dimensions in wood of *Pinus tecunumanii*; wood of this species has never before been analyzed.

MATERIALS AND METHODS

Specific gravity

Increment cores were collected in 1979 and 1980 from four different locations of Guatemala as follows: twenty-four cores of 4.5 mm diameter were collected from Finca INAFOR, San Jerónimo, Department (=State) of Baja Verapaz; twenty-one from Sierra de las Minas, Zacapa; fifteen from Sierra Santa Maria Tecun; and fifteen from Patsajón, El Quiché. One core through the pith was extracted from each tree, at breast height (1.3 m above ground). Each core was wrapped in plastic, labeled, and inserted into plastic tubes to avoid dehydration and breakage. The cores were held in cold storage until the specific gravity determinations were made. Only knot-free cores and those free of resin pockets and severe compression wood were used.

Because the variation and growth pattern of this species are not well known, and the annual rings did not indicate a clear differentiation between juvenile and mature wood, every core was divided into four segments of ten or more rings as follows: 1–10, 11–20, 21–30, and 31+ based on normal annual rings. This was difficult because false rings were common in trees from all the locations sampled. Cores were soaked in water until they sank, then were weighed in air and under water on a Mettler electronic balance. Cores were oven-dried at 85 C for 50 hours. After they were cooled, their dry weight was obtained. The specific gravity was determined on an oven-dry to green volume ratio, as follows:

$$\text{S.G.} = \frac{\text{Oven-dry weight of core (grams)}}{\text{Core green volume (cm}^3\text{)}}$$

The green volumes were determined by the traditional water displacement method (soaked weight of core in air minus submerged weight of core).

Wood extractives were removed using a Soxhlet extraction apparatus. Cores were placed in the Soxhlet steam distillator and enough extraction solution (2 parts of commercial benzene: 1 part of 95% ethyl alcohol) was put on the wood, so that the boiling flasks remained constantly one-fourth full during the 25 hours of extraction. Cores were then rinsed in running water for 24 hours and oven-dried before they were reweighed. The extracted specific gravity was calculated with the formula previously used.

The percentage of extractives removed was calculated using the formula:

$$\text{\% of extractives} = \frac{\begin{array}{c}\text{Unextracted oven-dry weight minus}\\ \text{Extracted oven-dry weight}\end{array}}{\text{Extracted oven-dry weight}}(100)$$

A normality test on the weighted average specific gravity was performed using the Univariate Procedure of SAS (1979). An analysis of variance was performed using the General Linear Models procedure of SAS, on the weighted average specific gravity of core diameter 4.5 mm.

Tracheid measurements

Increment cores 11 mm in diameter were collected at breast height, eleven at Finca INAFOR, and twenty-two in Sierra de las Minas. Each core was split at the 15th ring and 30th ring from the pith for tracheid determination. If any tree was under 23 years of age, only the 15th ring was measured. Slices of summer wood were placed in vials containing a mixture of half 30% H_2O_2 and half glacial acetic acid and incubated for 24 hours. The solution was removed and the tracheids were rinsed in distilled water several times. Fuschin stain was added, as well as three drops of formaldehyde for preservation.

There were four variables measured: tracheid length, cell-wall thickness, lumen width, and tracheid diameter. A preliminary sample size determination was calculated for each variable, using the standard formula:

$$n = \frac{t^2 S^2}{E^2}$$

where: n = sample size required
t^2 = squared t-table value
S^2 = sample variance
E^2 = desired error (in units)

Based on the preliminary sampling, the number of observations recorded for tracheids at ring 15 was 35 and at ring 30 was 65 ($E = 0.1$ mm). For cell-wall thickness, twenty observations were recorded (across the middle), while for lumen width and tracheid diameter, ten measurements were taken with an error of 2 μ, 5 μ, and 4 μ, respectively. Straight and complete tracheids were measured when recording length, under a stereomicroscope equipped with a 10× eyepiece. A 10× light microscope, equipped with a special 12.5× eyepiece was used to measure wall thickness, lumen width, and tracheid diameter.

The same statistical analyses as were used for specific gravity were utilized for tracheids. In addition, a variance component estimate and a correlation analysis were performed on each tracheid characteristic. A percentage of each component was obtained by adding all the variance component estimates and dividing the component of each source by the total.

RESULTS AND DISCUSSION

Specific gravity

Small differences (0.01 to 0.02) were found between unextracted and extracted weighted average specific gravity (Table 1). Generally, specific gravity values for *P. tecunumanii* can be rated as high compared to other species. They were higher than those of most Mexican pines reported by Zobel (1965). The gravities of *P. tecunumanii* ranged from 0.51 to 0.56 across locations, with a weak decreasing trend from east to west (Fig. 1).

An analysis of variance showed no significant differences between locations (Table 2). The tree to tree variation could not be tested because only one specific gravity determination was obtained per tree, but the data strongly indicate that such variation is considerable.

TABLE 1. *Weighted average specific gravity by location of* Pinus tecunumanii *from Guatemala; calculated from 108 cores 4.5 mm in diameter.*

Location	Specific gravity	n	Mean	Standard error	Range	Coefficient of variation
Baja Verapaz	U	24	0.54	0.0079	0.60–0.45	7.2
	E	24	0.53	0.0084	0.59–0.44	7.8
El Quiché	U	15	0.54	0.0099	0.57–0.46	7.2
	E	15	0.53	0.0107	0.57–0.46	7.9
Totonicapán	U	15	0.52	0.0079	0.56–0.44	5.9
	E	15	0.51	0.0081	0.56–0.44	6.1
Zacapa	U	21	0.56	0.0133	0.64–0.43	10.9
	E	21	0.54	0.0162	0.64–0.35	13.8
Average	U	75	0.54	0.0057	0.66–0.43	11.3
	E	75	0.53	0.0059	0.66–0.35	11.8

n = number of samples; U = unextracted; E = extracted.

The population from Zacapa showed a steady increase in specific gravity from the pith to the outside of the tree; the other three populations showed a similar pattern but a slight decline on the 31+ core segment (Fig. 1). The data indicate that the breakpoint between juvenile and mature wood is around the 10th ring, as is true for most of the southern pines of the U.S.A. (Zobel et al. 1972). Therefore, the low variability among the other core segments 11–20, 21–30, and 31+ will not justify multiple fragmentation of this portion of the core in future studies.

For the extractives, it was found that the first core segment (1–10) contained most of the extractives, with a smooth decline (except trees from Totonicapán) toward the mature wood segments (Fig. 2). The extractive percentage in this segment ranged from 2 to 9% on trees from Totonicapán and Zacapa, respectively. Because the correlation between unextracted and extracted weighted average specific gravity was strong (r = 0.93), it is possible to avoid extractive removal on *Pinus tecunumanii* in future studies, especially on the mature wood segments of the core.

Tracheid dimensions

Table 3 summarizes the means and other statistics regarding the tracheid characteristics analyzed. The tracheid length of wood at the 15th ring was 0.07 mm shorter (4.1 mm) than those (4.8 mm) of mature wood (30th ring). The difference in cell-wall thickness in young wood of trees from Baja Verapaz was 1.7 μ lower

TABLE 2. *Analysis of variance results performed on 4.5 mm core diameters of* P. tecunumanii.

Weighted average specific gravity	Source of variation	Degrees of freedom	Mean squares
Unextracted	Locations	3	0.0049 ns
	Trees (Loc.)	71	0.0026
Extracted	Locations	3	0.0021 ns
	Trees (Loc.)	71	0.0026

ns = non-significant.

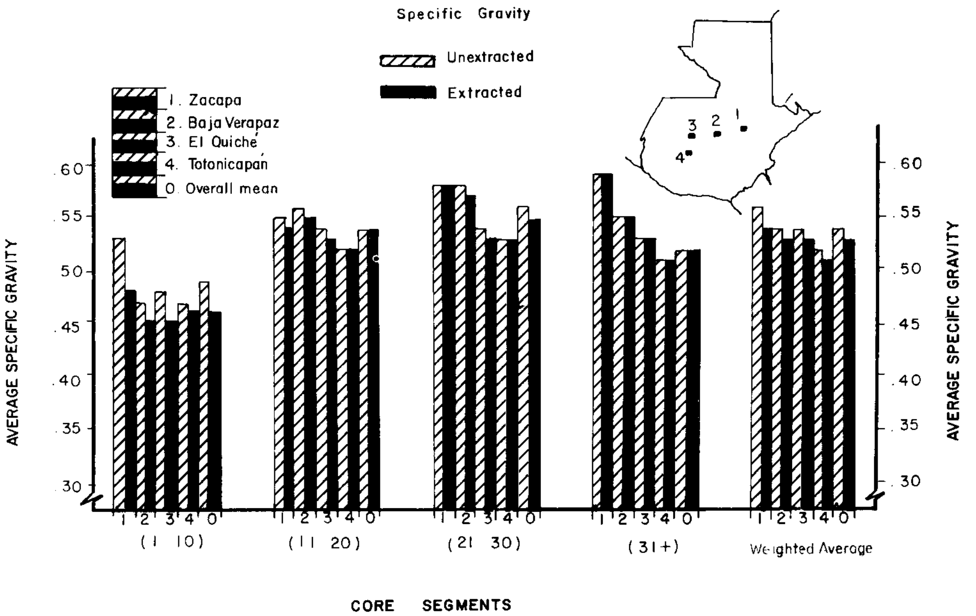

FIG. 1. Core segment means and weighted average specific gravity of *P. tecunumanii* from four locations of Guatemala (calculated from 108 cores of 4.5 mm diameter).

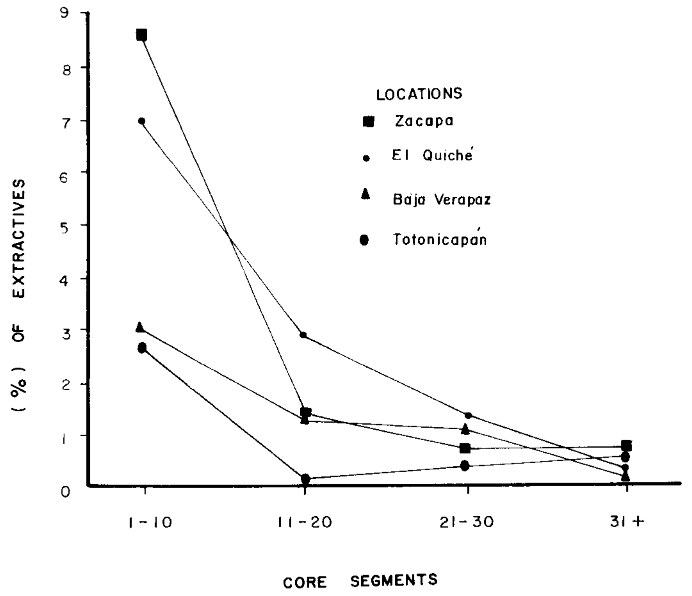

FIG. 2. Percentage of extractives per core segment of *P. tecunumanii* from four locations of Guatemala (calculated from 108 cores of 4.5 mm diameter).

TABLE 3. *Means and other statistics of tracheid dimensions of summerwood of* P. tecunumanii *from two locations of Guatemala.*

Trait	Ring	Location*	n	Mean	SE	Range	CV	Ave. location	Overall mean
Tracheid length (mm)	15th	BV	385	4.1	0.047	5.0–3.8	10.1	4.1	4.5
		Z	735	4.2	0.050	6.0–3.1	13.2		
	30th	BV	585	4.8	0.080	5.1–3.2	13.0	4.8	
		Z	1,235	4.9	0.200	6.1–3.0	16.0		
Cell wall thickness (μ)	15th	BV	112	10.5	0.226	17.5–5.8	22.8	10.8	11.9
		Z	218	11.1	0.169	18.6–4.8	22.4		
	30th	BV	90	12.2	0.317	20.2–6.1	24.7	13.0	
		Z	200	13.9	0.183	22.7–6.9	18.7		
Lumen width (μ)	15th	BV	112	32.6	0.982	63.6–13.5	31.9	31.0	28.8
		Z	218	29.4	0.635	59.1–7.7	31.8		
	30th	BV	90	30.3	1.149	57.9–5.5	36.0	26.6	
		Z	200	22.8	0.698	56.9–6.4	43.1		
Tracheid diameter (μ)	15th	BV	112	53.4	0.838	78.1–31.5	16.6	52.5	52.5
		Z	218	51.6	0.555	77.1–28.0	15.9		
	30th	BV	90	54.6	0.960	85.8–34.1	16.7	52.6	
		Z	200	50.6	0.613	73.0–32.1	17.1		

* BV = Baja Verapaz, Z = Zacapa. n = number of observations. SE = standard error. CV = coefficient of variation.

(10.5 μ) than for mature wood (12.2 μ), but this difference increased to 2.8 μ in trees from Zacapa (from 11.1 to 13.9 μ). Lumen width values (as expected) decreased as wall thickness increased, showing a negative correlation of r = −0.74 in young wood and r = −0.53 on mature wood (Table 4). Other high correlations were between tracheid diameter and lumen width (r = 0.85 and r = 0.81) on young and mature wood, respectively.

The unextracted and extracted weighted average specific gravity was highly and negatively correlated with lumen width on mature wood (r = −0.70 and r = −0.71, respectively) more than any other trait, including cell-wall thickness (r = 0.55 for unextracted and r = 0.54 for extracted weighted average specific gravity).

Since the weighted average extracted specific gravity to tracheid length correlation on young wood was low (r = 0.28) and even lower (r = 0.05) on mature wood (Table 4), the selection to increase specific gravity and tracheid length must be independent.

The analysis of variance results showed significant differences from tree to tree and between locations on the four characteristics measured (except for tracheid length). The variance component estimates indicated that most of the variation of tracheid length was present among trees. Interestingly, the remaining tracheid characteristics showed more variation between locations on mature wood than in young wood. However, the variation among trees was practically unchanged in both young and mature wood (between 20–40%). The high percentages (over 50%) of variation allocated to the error term indicate that additional variation not studied here explains portions of the variability.

In conclusion, this study showed that *P. tecunumanii* has highly variable wood properties. This variability was attributed to variation among trees and other

TABLE 4. *Correlation coefficients of tracheid dimensions and specific gravities of* P. tecunumanii *from Guatemala.*

	TL = 15th	TL = 30th	CWT = 15th	CWT = 30th	LW = 15th	LW = 30th	TD = 15th	TD = 30th	WAUSG
TL = 30th	0.42*								
CWT = 15th	0.23	0.14							
CWT = 30th	0.38*	0.16	0.58**						
LW = 15th	0.09	−0.09	0.74**	−0.53**					
LW = 30th	−0.02	0.12	−0.56**	−0.68**	0.69**				
TD = 15th	0.31	−0.06	−0.33	−0.36*	0.86**	0.57**			
TD = 30th	0.27	0.28	−0.30	−0.14	0.51**	0.82**	0.49**		
WAUSG	0.29	0.03	0.28	0.55**	−0.32	−0.70**	−0.25	−0.52**	
WAESG	0.28	0.05	0.25	0.54**	−0.33*	−0.71**	−0.28	−0.53**	0.93**

TL = tracheid length, CWT = cell wall thickness, TD = tracheid diameter, LW = lumen width. Rings from the pith = 15th and 30th. WAUSG = weighted average unextracted specific gravity. WAESG = weighted average extracted specific gravity. * = significant at the 5% level, ** = significant at the 1% level.

sources included in the error term, rather than between locations where differences were smaller. Additional locations in future studies might throw more light on the extent of among region variability. The specific gravity and tracheid dimensions of this species produce wood among the best of those known for Central American pines for use in solid wood and paper manufacture. Its specific gravity values were higher than those of many Mexican pines (with the exception of *P. oocarpa, P. lawsonii,* and *P. michoacana*), but its tracheid length values were rather similar to the Mexican species (Zobel 1965).

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