VARIATION IN SHRINKAGE PROPERTIES OF SECOND-GROWTH BALDCYPRESS AND TUPELO-GUM[1]

Elvin T. Choong, Peter J. Fogg, and *Carolyn B. Pollock*

Professor, Professor, and Research Associate
School of Forestry, Wildlife, and Fisheries
Louisiana Agricultural Experiment Station
Louisiana State University Agricultural Center
Baton Rouge, LA 70803

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ABSTRACT

Trees of baldcypress and tupelo-gum aged from 55 to 75 years, growing in a naturally regenerated stand in the Atchafalaya Basin in south Louisiana, were felled to provide samples for determination of shrinkage, specific gravity, and extractive content. Samples were taken from six heights and from three radial positions (=wood-types) along three radii. Differences among trees and among plots (which had different basal areas) were found for all measured variables. There were also variations in unextracted specific gravity with height in the tree and wood-type in baldcypress, and, except for specific gravity, with wood-type in tupelo-gum. After extraction, shrinkage effects of height and wood-type were reduced or disappeared. Specific gravity was generally lowest in the lower portion of the stem and in the outerwood. Correlation of shrinkage with specific gravity was highest in the outerwood, and extractive content was correlated with shrinkage in tupelo-gum but not in baldcypress.

Keywords: Baldcypress, tupelo-gum, shrinkage, specific gravity, tree height, wood-type, radial position.

INTRODUCTION

During the first decades of the 20th century, baldcypress [*Taxodium distichum* (L.) Rich.], commonly known as cypress, was a commercially important species. After the virgin stands were depleted, mostly by the 1930s, production of this species dropped drastically. Williston et al. (1980) estimated that nationwide annual production had dropped to less than 200 million bd ft in contrast to the peak production of 1 billion bd ft in 1913 (Steer 1948). Total volume of standing baldcypress, according to the most recent forest surveys, is 5.5 billion cu ft, approximately 30% of which is available as sawtimber. As the second-growth trees grow, interest in management of the stands is expected to increase, and more wood will become available on the market. Enquiries are continually being made by potential users of baldcypress as to its properties; however, there is no body of literature available on the properties of second-growth wood of this species. Information on the properties of old-growth baldcypress wood has been published (Forest Products Laboratory 1974; Mattoon 1915).

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Another relatively little-studied species that grows in conjunction with baldcypress is tupelo-gum or water tupelo (*Nyssa aquatica* L.). Together with swamp tupelo [*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.], tupelo-gum has the highest rate of occurrence of any hardwood species in bottomland hardwood-cypress forests of the southeastern United States (McKnight et al. 1981). The wood of tupelo-gum is regarded as having many favorable properties, and the wood is actually used in small quantities for a wide variety of uses (Panshin and de Zeeuw 1980).

In this paper, we report on the shrinkage properties of these two species, with emphasis on within-tree variation as exemplified by height in the tree and radial position or wood-type: innerwood, outerwood, or middlewood.

MATERIALS AND METHODS

Trees of the two studied species were felled from a stand in the Bayou Pigeon area of Iberville Parish, Louisiana, within the Atchafalaya Basin, that had regenerated after the clearing of the old-growth baldcypress in the first quarter of this century. The stand, typical of many in the area dating from that period, was relatively uniform in age (trees ranged from 55 to 75 years old) and was unmanaged. Overstory trees consisted almost exclusively of baldcypress and tupelo-gum. Although the stand was uniform in species composition, there was considerable variation in terms of basal area, stems per acre, and growth rate of individual trees. In conjunction with a thinning study conducted on this area (Prenger 1985), eight ¼-acre plots were sampled. The basal area of the sampled plots ranged from 196 to 260 sq ft per acre. It was planned to remove samples from nine baldcypress and two tupelo-gum trees in each of seven plots. However, this plan could not be followed in all plots. One plot yielded only six baldcypress trees, and another yielded only one tupelo-gum. The sampled trees were representative of the entire range of size found in the stand. Thus, the average diameter was 20.4 in. (ranging from 12.2 to 35.1 in.) for baldcypress and 24.5 in. (ranging from 14.7 to 31.5 in.) for tupelo-gum.

Each felled tree was sampled by the removal of cross-sectional disks at heights of 2, 4, 13, 21, 29, and 45 ft, except in trees that were too small to yield upper sample disks. When branches or overgrown knots coincided with the previously designated heights, the disks were displaced either immediately above or below the irregularities. The disks were approximately 8 in. in thickness, except for the lowest one in each tree, which was 2 in. thick.

The diameter of each section was measured; where fluting was present, the diameter of the largest circle that would fit inside the flutes was recorded as the diameter. Three 1-in.-wide radial strips, spaced at 120° intervals, were marked on the surface of each disk. These strips were positioned so as to exclude ring abnormalities, which indicated the presence of knots below the surface. Major drying defects that occurred in the disk from the time of felling until sample preparation were also excluded. Where satisfactory samples could not be obtained at the 120° spacing, the angle of separation was increased or decreased as much as 25°. The radial strips were then marked into three equal-sized subsections: inner, middle, and outer subsections. From each subsection, a sample was cut that measured 1 in. × 1 in. square in cross-section and ⅛ in. along the grain. For each measured property, the experimental design included the following classes:

	Baldcypress	Tupelo-gum
Plot	7	8
Sample trees per plot	9	2
Heights per tree	4–6	4–6
Radial position (wood-type)	3	3
Replications (radial strips)	3	3

Each sample was subjected to a sequence of treatments and measurements to obtain radial and tangential shrinkage and specific gravity in the unextracted condition.

All samples were first air-dried and then soaked in water for three days. In this water-swollen condition, the radial and tangential dimensions were measured before air-drying for one week and oven-drying at 105 C for 48 hours. The samples were weighed and the dimensions were again measured. Saturation was achieved by placing the samples in desiccators, which were evacuated with a vacuum pump for several hours, followed by flooding with water and alternating periods of vacuum and atmospheric pressure until no more bubbles appeared. After saturation, the samples were weighed. Chemical extraction of approximately one-fourth of the samples was carried out with hot water for 24 hours, and with toluene-alcohol mixture (2:1) for another 24 hours, followed by saturation; once more the weights and dimensions were determined. Air-drying for one week and oven-drying for 48 hours preceded the final determination of weights and dimensions.

Shrinkage in either radial or tangential direction was expressed as a percentage of the swollen dimension in the particular direction. The volumetric shrinkage was estimated by adding the radial and tangential shrinkages. This was based on the assumption of negligible shrinkage in the longitudinal direction and gives a close estimation of the true volumetric shrinkage (Choong 1969). The specific gravity, based on green volume, was determined by use of the maximum moisture content method (Smith 1954).

RESULTS AND DISCUSSION

The analysis of variance was used to test differences in specific gravity, radial, tangential, and volumetric shrinkage in unextracted and extracted condition, and extractive content for baldcypress and tupelo-gum (Table 1). Among-plot and among-tree differences were significant for all variables in baldcypress and in unextracted tupelo-gum. These differences accounted for as much as 17% of the variation in volumetric shrinkage of unextracted wood. Among-plot and among-tree variations were greater in baldcypress (12.9%) than in tupelo-gum (6.7%). In the case of unextracted specific gravity and shrinkages, height and radial position effects were significant in baldcypress. However, for tupelo-gum, only height was significant for all variables: no significant differences occurred in unextracted specific gravity among wood-types. After extraction, some of the properties no longer differed significantly. For instance, radial position no longer affected radial, tangential, or volumetric shrinkage in baldcypress, and extractive content did not vary significantly with height. After the samples were extracted, only height in the tree consistently had a significant effect on all variables, including extractive content in tupelo-gum.

TABLE 1. *Summary of analysis of variance for baldcypress and tupelo-gum.*

Variable	Unextracted					Extracted					
	DF	RS	TS	VS	SG	DF	RS	TS	VS	SG	EXTR[1]
					Baldcypress						
Plot	6	**	**	**	**	1	**	**	**	**	**
Tree	59	**	**	**	**	17	**	**	**	**	*
Height	5	**	**	**	**	5	**	**	**	**	NS
Wood-type	2	**	**	**	**	2	NS	NS	NS	**	**
					Tupelo-gum						
Plot	7	**	**	**	**	1	NS	**	NS	NS	NS
Tree	14	**	**	**	**	2	NS	NS	*	NS	*
Height	5	**	**	**	**	5	**	**	**	**	**
Wood-type	2	**	**	**	NS	2	NS	**	NS	NS	NS

* Significant at 5% level of probability.
** Significant at 1% level of probability.
NS Not significant.
[1] The symbols refer to: RS—radial shrinkage, TS—tangential shrinkage, VS—volumetric shrinkage, SG—specific gravity, and EXTR—extractive content.

The average shrinkage values of unextracted baldcypress were 2.6 and 6.7% for radial and tangential direction, respectively. For tupelo-gum the averages were 3.4 and 6.8%. The tangential shrinkage for baldcypress was somewhat higher than the published value (6.2%) in the Wood Handbook (Forest Products Laboratory 1974), whereas the radial shrinkage in baldcypress and the shrinkage in both directions in tupelo-gum were all somewhat lower than published (3.8, 4.2, and 7.6%).

Effect of radial position

The average values for measured properties are shown in Table 2 for the three wood-types in unextracted and extracted form for both species. In unextracted baldcypress, radial and tangential shrinkage were highest in the innerwood and lowest in the outerwood (Table 3). However, in the extracted condition, neither the radial or tangential shrinkage differed between innerwood and outerwood. Specific gravity also was higher in the innerwood than the outerwood in both unextracted and extracted condition. This indicates a pattern of decrease in specific gravity from pith to bark for both species. This trend in specific gravity could explain the trend in shrinkage of unextracted wood. The radial and tangential shrinkage of unextracted innerwood differed from that of outerwood, while the ratio of innerwood to outerwood for radial shrinkage was 1.28. When the extractives were removed, a greater amount was removed from the innerwood (3.2%) than from the outerwood (2.3%). The expected increase in shrinkage associated with a slight reduction in specific gravity caused by chemical extraction confirms the bulking action of extractives in the cell wall. The increase in shrinkage was from 18 to 29%, accompanied by a reduction in specific gravity of 3 to 8% on average.

Unextracted tupelo-gum wood had the least shrinkage and lowest specific gravity in the outerwood, as did baldcypress. Paul and Marts (1934) reported the same trend in a study of five tupelo-gum trees from Concordia Parish, Louisiana. After extraction, in contrast to the baldcypress, tupelo-gum's radial shrinkage no longer

TABLE 2. *Average values of selected wood properties for baldcypress and tupelo-gum.*

Measured property	Baldcypress Unextracted	Baldcypress Extracted	Tupelo-gum Unextracted	Tupelo-gum Extracted
		Outerwood		
Number of samples	411	102	131	24
Radial shrinkage, %	2.1 (1.0)[1]	2.7 (1.2)	2.8 (0.9)	3.5 (1.1)
Tangential shrinkage, %	6.2 (1.2)	7.9 (1.7)	6.0 (1.3)	7.3 (1.6)
Sp. gravity, green volume	0.29 (0.09)	0.28 (0.09)	0.32 (0.10)	0.29 (0.09)
Extractive content, %	—	2.3 (1.9)	—	3.7 (0.6)
		Middlewood		
Number of samples	717	197	209	47
Radial shrinkage, %	2.6 (1.3)	3.1 (1.5)	3.3 (1.2)	4.1 (1.2)
Tangential shrinkage, %	6.8 (1.1)	8.0 (1.5)	6.8 (1.4)	8.1 (1.2)
Sp. gravity, green volume	0.35 (0.10)	0.32 (0.10)	0.37 (0.11)	0.36 (0.10)
Extractive content, %	—	2.2 (3.0)	—	3.4 (0.7)
		Innerwood		
Number of samples	1,025	281	264	54
Radial shrinkage, %	2.7 (0.9)	3.4 (1.1)	3.7 (1.0)	4.1 (1.8)
Tangential shrinkage, %	6.8 (1.1)	8.0 (1.1)	7.2 (1.4)	8.4 (1.1)
Sp. gravity, green volume	0.37 (0.06)	0.35 (0.07)	0.38 (0.08)	0.36 (0.07)
Extractive content, %	—	3.2 (4.8)	—	3.3 (0.6)

[1] Numbers in parentheses refer to standard deviation.

differed between innerwood and outerwood (Table 1), yet the tangential shrinkage showed a similar trend to that in the unextracted wood. Outerwood had a significantly higher extractive content (3.7%) than both innerwood (3.3%) and middlewood (3.4%). The removal of the extractives (averaging 3.4%) resulted in increases in shrinkage of 11 to 35% and in reduction of specific gravity of 3 to 10 percent on average.

Effect of specific gravity

Good correlations were found between volumetric shrinkage and specific gravity for both species and wood-types in the unextracted and extracted forms (Table 4). The correlations consistently show higher values in the outerwood and lower values in the innerwood, which is a similar pattern to that found in longleaf and slash pines (Choong et al. 1988).

The relationships between volumetric shrinkage and specific gravity in the wholewood of baldcypress and tupelo-gum are shown in Fig. 1. Specific gravity accounted for more than 56% (and as high as 66%) of the variation in volumetric shrinkage in both species. In the unextracted baldcypress and tupelo-gum, the slopes of the regression equations were too low for an indication of the fiber saturation point, which Stamm (1964) identified on a percentage volume per unit weight basis. In both species, however, the extracted regression equations show steeper slopes, and thus the apparent fiber saturation estimated by this method becomes higher. When wood-type is considered (Fig. 2), the relationship between volumetric shrinkage and specific gravity shows a different trend. In tupelo-gum, volumetric shrinkage is highest in the innerwood and lowest in the outerwood at any given specific gravity; but, in baldcypress, this trend applies only at the lower specific gravity range.

TABLE 3. *Duncan's multiple range test for wood characteristics of baldcypress and tupelo-gum by height and radial position.*

	Characteristic[1]								
				Baldcypress					
Height	RS	TS	VS	SG	ERS	ETS	EVS	ESG	
1	D[2]	E	E	D	D	D	E	D	
2	C	D	D	C	C	D	D	C	
3	A	A	A	A	A	A	A	A	
4	A	B	A	A	A	B	AB	A	
5	A	C	B	A	AB	B	B	A	
6	B	E	C	B	B	C	C	B	
Radial position	RS	TS	VS	SG	ESG	EXT			
Innerwood	A	A	A	A	A	A			
Middlewood	B	A	B	B	B	B			
Outerwood	C	B	C	C	C	B			
				Tupelo-gum					
Height	RS	TS	VS	SG	ERS	ETS	EVS	ESG	EXT
1	D	C	D	D	C	D	C	C	A
2	C	B	C	C	B	C	B	B	A
3	A	A	A	B	A	A	A	A	B
4	A	A	A	AB	A	AB	A	A	B
5	A	A	A	A	B	ABC	AB	A	B
6	B	B	B	AB	AB	BC	AB	A	A
Radial position	RS	TS	VS	ETS					
Innerwood	A	A	A	A					
Middlewood	B	B	B	A					
Outerwood	C	C	C	B					

[1] Abbreviations: RS: radial shrinkage, TS: tangential shrinkage, VS: volumetric shrinkage, SG: specific gravity, ERS: extracted radial shrinkage, ETS: extracted tangential shrinkage, EVS: extracted volumetric shrinkage, ESG: extracted specific gravity, EXT: extractive content.

[2] Identical letters in a column indicate means which do not differ significantly at the 1% level of probability. ("A" always indicates a higher numeric value than later letters of the alphabet.)

TABLE 4. *Correlations of wood characteristics for various radial positions (wood-types) in baldcypress and tupelo-gum.*

Relationship	Wholewood	Outerwood	Middlewood	Innerwood
	Baldcypress, unextracted			
Vol. shrinkage vs.				
tree height	0.38[1]	0.65	0.47	0.12
Sp. gravity	0.75	0.87	0.82	0.62
Sp. gravity vs.				
tree height	0.68	0.81	0.73	0.60
Rad. shrinkage	0.82	0.85	0.84	0.72
Tang. shrinkage	0.51	0.79	0.53	0.20
	Baldcypress, extracted			
Vol. shrinkage vs.				
tree height	0.49	0.60	0.55	0.42
Sp. gravity	0.81	0.92	0.83	0.75
Sp. gravity vs.				
tree height	0.66	0.73	0.72	0.57
Rad. shrinkage	0.85	0.92	0.90	0.77
Tang. shrinkage	0.63	0.85	0.63	0.56
Extractive content vs.				
tree height	NS[2]	NS	NS	NS
Vol. shrinkage	NS	NS	NS	NS
Sp. gravity	NS	−0.19	NS	NS
Rad. shrinkage	NS	NS	NS	−0.15
Tang. shrinkage	NS	NS	NS	NS
	Tupelo-gum, unextracted			
Vol. shrinkage vs.				
tree height	0.47	0.74	0.50	0.23
Sp. gravity	0.81	0.90	0.82	0.71
Sp. gravity vs.				
tree height	0.80	0.88	0.81	0.74
Rad. shrinkage	0.86	0.89	0.88	0.82
Tang. shrinkage	0.69	0.85	0.71	0.51
	Tupelo-gum, extracted			
Vol. shrinkage vs.				
tree height	0.40	0.85	0.63	NS
Sp. gravity	0.77	0.96	0.87	0.54
Sp. gravity vs.				
tree height	0.77	0.96	0.86	0.68
Rad. shrinkage	0.65	0.93	0.91	0.41
Tang. shrinkage	0.75	0.92	0.77	0.54
Extractive content vs.				
tree height	−0.32	−0.65	−0.55	NS
Vol. shrinkage	−0.58	−0.75	−0.75	NS
Sp. gravity	−0.63	−0.72	−0.77	NS
Rad. shrinkage	−0.42	−0.78	−0.78	NS
Tang. shrinkage	−0.64	−0.67	−0.66	−0.59

[1] Numbers are correlation coefficients significant at 1% probability level.
[2] NS = Not significant.
Note: Number of samples used for analyses are shown in Table 2.

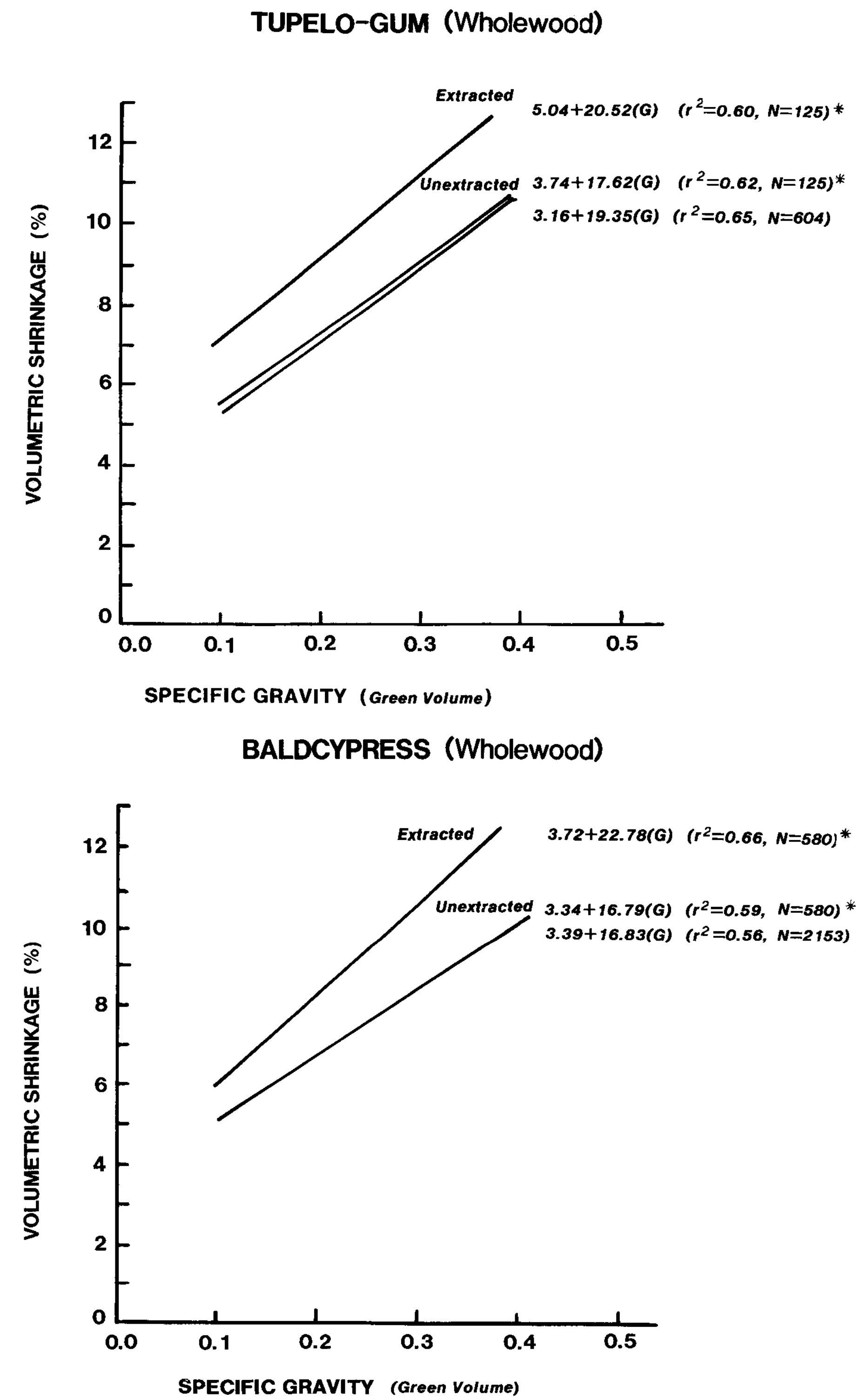
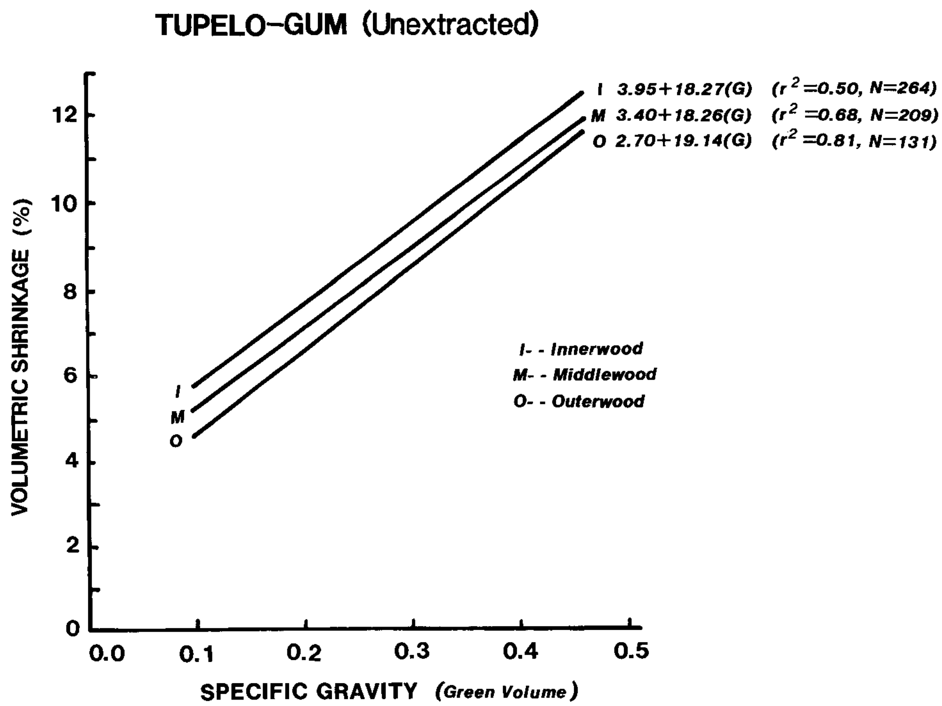


FIG. 1. Relationship of volumetric shrinkage and specific gravity in the wholewood of baldcypress and tupelo-gum. (* Smaller sample number is for the samples which were extracted.)



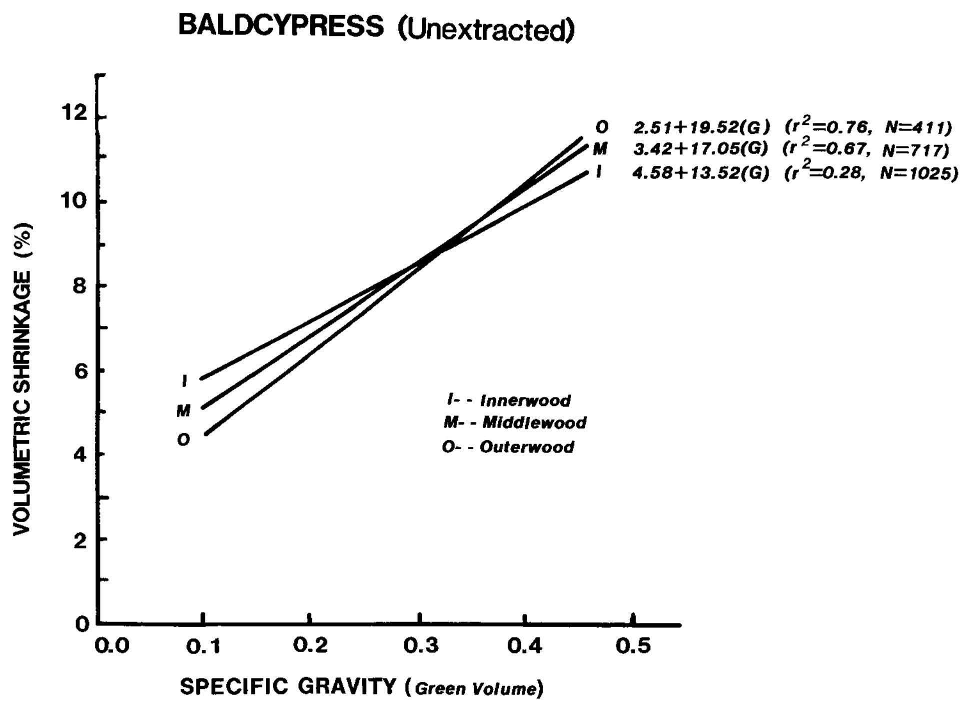


FIG. 2. Relationship of volumetric shrinkage and specific gravity for various wood-types in baldcypress and tupelo-gum.

Effect of extractive content

The correlations between extractive content and height in the tree and between extractive content and volumetric shrinkage differ between the two species (Table 4). In baldcypress, no significant correlations were found. The difference in the effect of the extractives may have some relationship with the differing quantity of extractives present in each species. For instance, the outerwood and middlewood of tupelo-gum had approximately 1.5 times the extractives of baldcypress. The greater the amount of extractives removed, the greater the impact to be expected from their removal. The effect of extractives on shrinkage in baldcypress was negligible. However, an apparent relationship between extractive content and volumetric shrinkage does exist in tupelo-gum. The removal of extractives would be expected to cause a closer relationship between shrinkage and specific gravity, since the extractives, to the extent that they may be concentrated in the fine structure of the cell wall normally occupied by water, generally reduce shrinkage (Nearn 1955; Choong 1969). Since extractives may have this bulking effect on the cell wall and thus may tend to reduce shrinkage, a relationship between extractive content and unextracted volumetric shrinkage would support this view that shrinkage was modified by the presence of extractives (Fig. 1). The difference between the two species with respect to the shrinkage-extractive relationship may relate to the nature of the extractive and also to the location of the extractives. Tupelo-gum extractives may be concentrated in the cell wall, whereas the baldcypress extractives either do not have significant bulking capability or are found elsewhere more than in the cell wall (for instance, in the abundant parenchyma cells).

Effect of height in the tree

The relationship between volumetric shrinkage and height is shown in Fig. 3 for various wood-types in both species and for that between specific gravity and height in Fig. 4.

Height had a pronounced effect on volumetric shrinkage and specific gravity in both unextracted and extracted forms for the two species. In both species, the lowest values were found in the butt sections with an increase to a maximum at ⅓ height (13 ft) and a tendency to decrease slightly above that point. These specific gravity trends are consistent with those reported by Laundrie and McKnight (1969). The trees from which the samples were taken were subjected to frequent and prolonged flooding, generally from December through July. The mean high water mark on the trees was measured at 9.3 ft above the ground. Volumetric shrinkage and specific gravity were significantly lower in samples taken below the mean water mark than in samples taken above it. Only limited information is available in the literature about the relationship between volumetric shrinkage and height in the tree. Yao (1969) and Choong et al. (1988) have shown that volumetric shrinkage decreases with increasing height. Since there is a good correlation between volumetric shrinkage and specific gravity, therefore, specific gravity also decreases with increasing height. Panshin and de Zeeuw (1980) reported that in most softwoods, specific gravity seems to follow this general pattern, but in hardwoods, specific gravity variation with height shows very little consistency and no overall pattern. They further stated that the specific gravity of species that grow

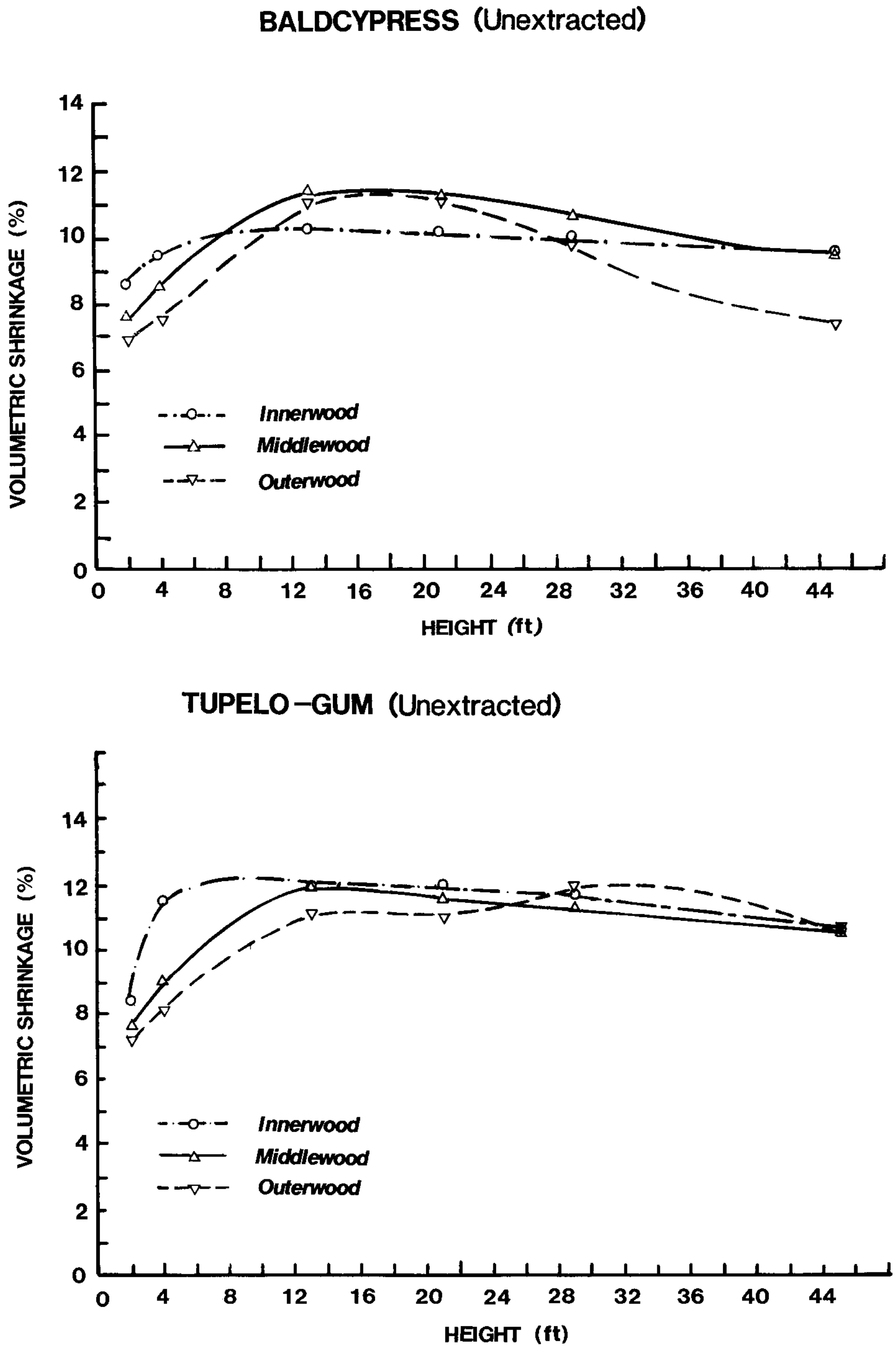
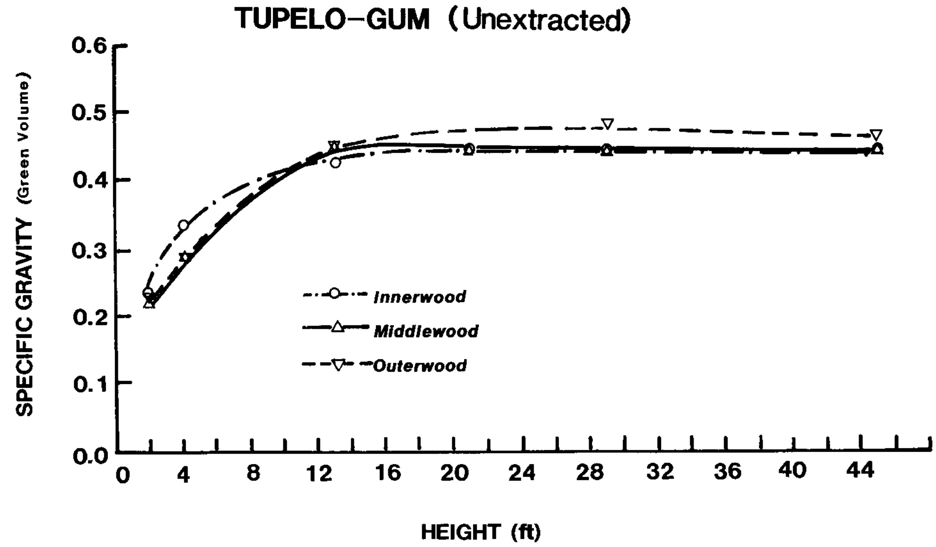


FIG. 3. Relationship of volumetric shrinkage and height for various wood-types in baldcypress and tupelo-gum.



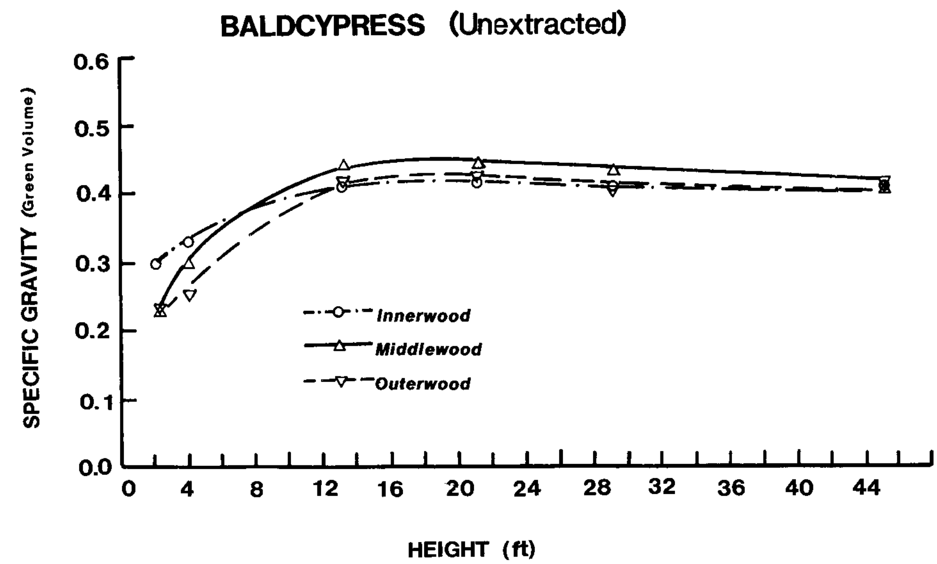


FIG. 4. Relationship of specific gravity and height for various wood-types in baldcypress and tupelo-gum.

on flooded sites is low in the butt log but increases in upper sections of the trunk. The pattern we found in baldcypress and tupelo-gum appears to be typical of trees growing on periodically flooded sites.

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