VESSEL AREA STUDIES IN WHITE OAK (*QUERCUS ALBA* L.)[1]

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ABSTRACT

White oak wood has a light blond color and a ring-porous character that make it appealing to consumers. Color and texture are two very important wood quality parameters in such woods. This study was done to examine factors that influence variation in the percentage of earlywood, latewood, and total growth ring vessel lumen areas. Attributes studied were age (radial distance from the pith), longitudinal position (stump and 8½ ft height) in the tree, and thinning effects. The percentage of earlywood vessel area was influenced by radial position in the trees, but was not influenced by growth ring width. The percentage of latewood vessel area was significantly and negatively influenced by growth ring width. Thinning had no effect on percentage of earlywood vessel area, but it reduced the percentage of latewood vessel area and total growth ring vessel area. By reducing total growth ring vessel area, thinning had a negative impact on texture in these trees.

Keywords: Growth-quality relationships, wood texture.

INTRODUCTION

White oak wood is used to produce a wide variety of appearance products, such as flooring, cabinets, and furniture. In recent years, consumer preferences for blond-colored and highly textured woods have led to continued rising demands for oak species. This trend is likely to continue given the potential for markets and the availability of the wood resource in the eastern United States.

Purchasers of hardwoods believe that texture and heartwood color are the two most important quality properties of wood used for veneers (Kesner 1986). Texture is influenced by the proportion of different types of cells within growth rings and the way the wood is cut or sliced to produce the desired appearance. In oak, the proportions of tissue types and fiber and vessel lengths are two measures of wood quality important to product quality in the solid wood and fiber sectors of the wood industry (Maeglin 1976; Maeglin and Quirk 1984). Tissue-type proportions, specifically the distribution of vessels on cross section, play an important role in determining the texture of wood.

Variability in wood properties is a subject to which much literature has been devoted. In

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general, variability can be influenced by: 1) age of tree (pith to bark variation), 2) the environment, and/or 3) genetics (Panshin and deZeeuw 1980). Studies on the genetic influence on hardwood properties have been somewhat limited. More studies have been done on age and environmental influences on wood properties of hardwoods, but more work still needs to be done, particularly in the area of environmental effects.

In a study on the effects of release on growth of white oak, Schlesinger (1978) reported that large, rapidly-growing released trees had the greatest absolute growth and grew 60% more than non-released trees. However, small, slowly-growing released trees had a 160% greater percentage response rate than similar trees that were not released. Thinning influenced the percentage growth rate of smaller trees more than that of larger trees.

Growth rate also has important effects on wood properties. In ring-porous species, the amount of earlywood remains relatively constant regardless of the rate of growth, whereas the amount of latewood is directly affected by growth rate (Haygreen and Bowyer 1982). The amount of latewood increases as growth rate increases and these thicker walled cells have a higher density than the cells of the earlywood portions of the increment. Hildebrandt (1960) demonstrated that oaks grown on poor, dry soils have little percent latewood, while those grown on moist, level soils have much latewood.

Faster grown, ring-porous wood is harder, more dense, and more difficult to machine but is stronger and more durable (Hale 1932; Jane 1970; Haygreen and Bowyer 1982; Behm 1986). Brazier (1985) indicated that slow grown ring-porous wood is preferred for processing where strength is not of special importance. Earlywood vessels contribute to the grain patterns of ring-porous hardwoods, particularly when they are sliced for veneer products.

Although many of the above studies focus on growth rate as a major factor in influencing variation in wood properties, Bendtsen (1978) stressed the importance of examining the interdependence of growth rate with other factors, such as age from the pith, on such variation in wood properties.

The purpose of this study was to examine the effects of age, location in the tree, and thinning on percentage of earlywood, latewood, and total vessel areas in white oak (*Quercus alba* L.). Age effects are considered to be pith to bark (or distance from the pith) variation. Because of similarities between the sites chosen for the study, we chose to examine the influences of an environmental factor, thinning, on percentage of vessel area.

MATERIALS AND METHODS

Forty trees from two plantings on the Crab Orchard National Wildlife Refuge in Southern Illinois were selected for this study. The trees were planted by the Civilian Conservation Corps about 1939 (estimated by ring counts on the stump). In 1973, one planting was thinned to a residual spacing of 20 by 20 ft (to a basal area of 80). Trees for the present study were harvested after 48 growing seasons. A previous article described the trees in detail and also described the results of specific gravity and board shrinkage determinations on these same trees (Phelps and Chen 1991).

Preliminary field observations revealed that each planting was composed of two diameter classes of trees, a 9- to 10-in. diameter class (hereafter called intermediate crown class trees) and a 13- to 14-in. diameter class (hereafter called codominant crown class trees). Ten trees from each crown class and from each planting were chosen for this study for a total of 40 trees. Two-in.-thick disks were removed from each tree at two heights, the base of the tree and at 8½ ft.

To determine the percentage of vessel areas within the growth rings, a radial segment, approximately ⅜ in. wide, was removed from each disk. Microtomed sections, 20 μm thick, were stained with safranin-fast green (using a procedure adopted from Sass 1958) and mounted in Euparal, a mounting resin miscible with ethyl alcohol. This was done to reduce the health concerns associated with the use of

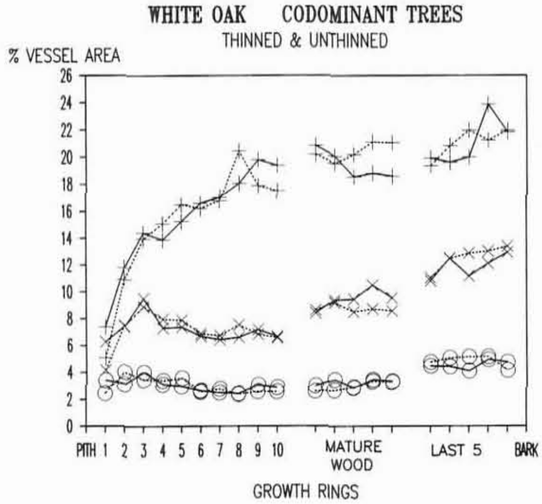

FIG. 1. Pith to bark variation in percentage of earlywood vessel area (+), percentage of latewood vessel area (O), and percentage of average total vessel area (×) within growth rings from the base disk in codominant trees from the thinned stand (solid lines) and unthinned stand (dotted lines).

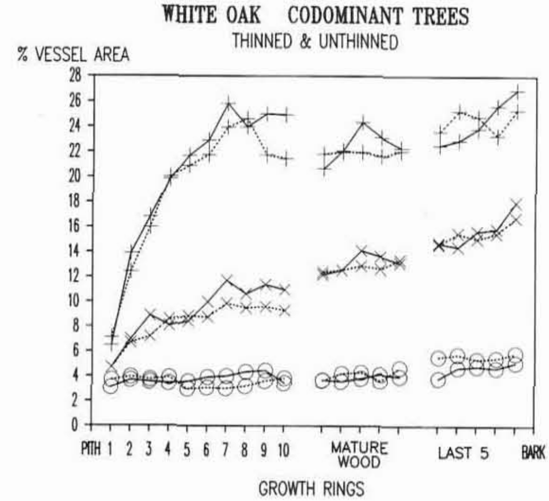

FIG. 2. Pith to bark variation in percentage of earlywood vessel area (+), percentage of latewood vessel area (O), and percentage of average total vessel area (×) within growth rings from the top (8½ ft) disk in codominant trees from the thinned stand (solid lines) and unthinned stand (dotted lines).

xylene. Samples were taken from the radial segment, which contained the first ten years of growth from the pith, growth rings that had the 24th growth ring as their center, and the last 5 growth rings in the disk. These growth rings were chosen so that the influence of location within the tree (both radially and longitudinally) and thinning on percentage of vessel areas in growth rings could be determined. It was assumed that the last five growth rings would represent those formed following thinning of the one "treatment" stand. The 5 growth rings with the 24th growth ring as their center represented mature wood formed prior to thinning of the treatment stand. In each growth ring, percentage of earlywood vessel area, percentage of latewood vessel area, and percentage of total growth ring vessel area were measured. In addition, growth ring width was measured. An image analysis system attached to a light microscope was used for the measurements. This system has been described in detail in Phelps and Workman (1992).

Data were plotted, a correlation analysis (Pearson's) was done, and within treatment or nested effects were examined using the GLM procedure in SAS (SAS Institute, Inc. 1985). A type III or partial sums of squares analysis was chosen for the nested effects because this tests for effects independently of other effects in the analysis.

RESULTS AND DISCUSSION

Figures 1 to 4 illustrate the radial and longitudinal trends observed in percentage of vessel areas in codominant and intermediate trees from the thinned and unthinned sites. The percentage of earlywood vessel areas (+) from trees from the thinned site (solid lines) and the unthinned site (dotted lines) both showed continual increases during the first ten years in percentage area occupied by vessels in the earlywood (Fig. 1). In the growth rings in the mature heartwood region (growth rings 22 to 26 in the base disk) and in the growth rings near the bark (growth rings 44 to 48 in the base disk), some variation but little increase was observed. The percentage of the growth ring occupied by latewood vessels (O) in the thinned

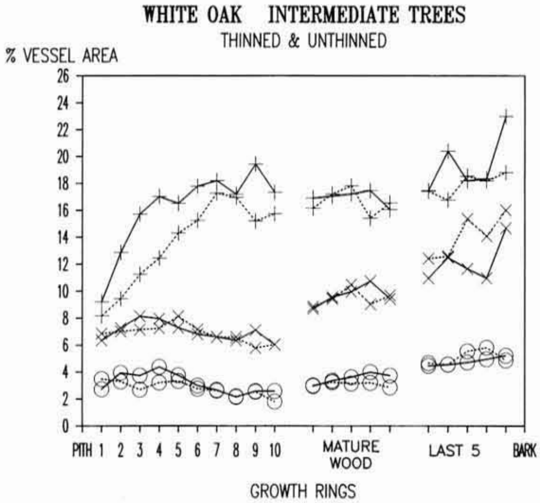

FIG. 3. Pith to bark variation in percentage of earlywood vessel area (+), percentage of latewood vessel area (O), and percentage of average total vessel area (×) within growth rings from the base disk in intermediate trees from the thinned stand (solid lines) and unthinned stand (dotted lines).

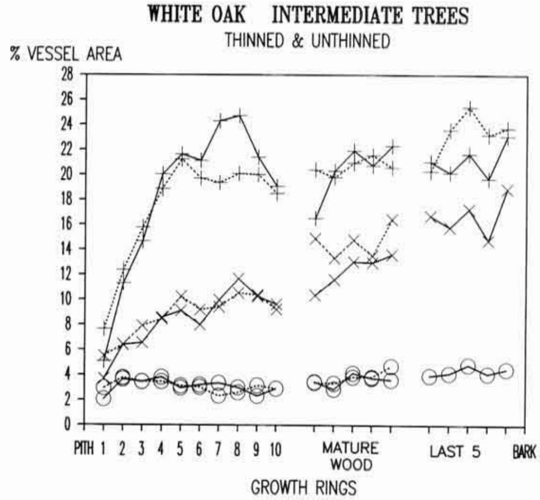

FIG. 4. Pith to bark variation in percentage of earlywood vessel area (+), percentage of latewood vessel area (O), and percentage of average total vessel area (×) within growth rings from the top (8½ ft) disk in intermediate trees from the thinned stand (solid lines) and unthinned stand (dotted lines).

trees (solid lines) and unthinned trees (dotted lines) showed some increase over the radial extent of the sampled areas, but the percentages of vessel areas in the growth rings nearest the bark were slightly greater than those in the other increments. Plots of the data in Figs. 2 to 4 show similar trends. Further discussion of site, dominance and longitudinal location effects will follow when the statistical analyses are described.

Correlation analysis

Correlation analyses were conducted on the data and the results are given in Table 1. The correlations support the observations described above for Figs. 1 to 4. The percentage of earlywood vessel areas showed a significant increase with radial position (0.21). This was probably influenced more by the variations seen in the first 10 years of growth. The correlation could possibly have been higher if only the first 10 years were examined. The percentage of vessels in the total growth ring also showed a positive, significant increase with distance from the pith. As expected, significant correlations were observed between the percentage of vessels in the total growth ring and the percentage of earlywood (0.67) and latewood vessels (0.54).

In a previous study on black walnut, Phelps and Workman (1992) found no significant correlation between width of growth ring and percentage of earlywood vessel area. The same was found in this study on white oak. Percentage of latewood vessel area was, however, negatively correlated with width of growth ring (−0.22). These results support previous observations that the percentage of earlywood vessel areas remains the same in oak, regard-

TABLE 1. *Pearson's Correlation Matrix for 40 white oak trees.*

	Early-wood vessel area (%)	Late-wood vessel area (%)	Growth ring vessel area (%)	Growth ring width
Distance from pith	0.21	0.03^{ns}	0.12	0.08
Earlywood vessel (%)		0.30	0.67	−0.02^{ns}
Latewood vessel (%)			0.54	−0.22
Growth ring vessel (%)				−0.57

^{ns} Indicates that the correlation is not significantly different from 0, alpha = 0.05.

TABLE 2. *Within treatment effects for percentage of earlywood vessel areas.*

Source	df	Type III SS	Mean square	*F* value	Pr > *F*
		Growth rings 1 to 5; mean = 13.97 percent			
SOURCE	1	83.82	83.82	7.91	0.0052
DOMINANCE(SOURCE)	1	34.61	34.61	3.27	0.0716
TREE(DOMINANCE)	9	170.90	18.99	1.79	0.0686
HEIGHT(TREE)	9	111.10	12.34	1.16	0.3168
GRING(HEIGHT)	8	6,764.17	845.52	79.77	0.0001
		Growth rings 6 to 10; mean = 19.83 percent			
SOURCE	1	278.62	278.62	20.29	0.0001
DOMINANCE(SOURCE)	1	31.66	31.66	2.31	0.1298
TREE(DOMINANCE)	9	248.32	27.59	2.01	0.0374
HEIGHT(TREE)	9	229.64	25.52	1.86	0.0571
GRING(HEIGHT)	8	254.08	31.76	2.31	0.0198
		Mature wood; mean = 19.95 percent			
SOURCE	1	0.66	0.66	0.04	0.8406
DOMINANCE(SOURCE)	1	3.23	3.23	0.20	0.6571
TREE(DOMINANCE)	9	210.09	23.34	1.43	0.1754
HEIGHT(TREE)	9	219.14	24.35	1.49	0.1510
GRING(HEIGHT)	8	141.47	17.68	1.08	0.3765
		Last five growth rings; mean = 21.60 percent			
SOURCE	1	0.44	0.44	0.02	0.8891
DOMINANCE(SOURCE)	1	0.01	0.01	0.00	0.9812
TREE(DOMINANCE)	9	1,215.82	135.09	5.91	0.0001
HEIGHT(TREE)	9	469.83	52.20	2.29	0.0168
GRING(HEIGHT)	8	379.20	47.40	2.08	0.0375

less of ring width, but the percentage of latewood vessel areas is influenced by width of the growth ring. In addition, the percentage of vessel area in the total growth ring was significantly (and negatively) correlated with growth ring width (−0.57). As growth rates increase, the percentage of vessel area proportionally decreases. This result might also be expected based on the results of previous research.

Nested design analysis

This analytical tool was used to examine longitudinal and thinning effects on the variables tested. Since the percentage of earlywood vessel area continually increased until the 6th growth increment and then leveled off, the data were divided into 4 groups of 5 growth increments for this level of analysis. Growth rings 1 to 5 and 6 to 10 represented the core wood portion of the trees. Mature wood came from growth rings 22 to 26, and the "after treatment" represents the 5 increments formed after thinning in the treatment stand.

Percentage of earlywood vessel area.—Source (thinned vs. unthinned sites) effects were significantly different in growth rings 1 to 5 and 6 to 10 (Table 2). Source effects were not significantly different in the mature wood portions of the tree. Previous research on these sites showed some differences in site index between the two areas. Possibly differences in site quality were expressed in the percentage of earlywood vessel areas when the trees were younger and were not expressed when the trees reached more mature conditions. Thinning effects (differences between source in the last formed growth rings) were not observed. Between tree effects were mixed with the only significant difference (less than 0.01) being found in the growth rings formed nearest the bark. Longitudinal position or height effects were nonsignificant, and growth ring or radial

TABLE 3. *Within treatment effects for percentage of latewood vessel areas.*

Source	df	Type III SS	Mean square	F value	Pr > F
Growth rings 1 to 5; mean = 3.57 percent					
SOURCE	1	1.11	1.11	0.71	0.3994
DOMINANCE(SOURCE)	1	2.71	2.71	1.73	0.1893
TREE(DOMINANCE)	9	21.26	2.36	1.51	0.1428
HEIGHT(TREE)	9	32.54	3.62	2.31	0.0158
GRING(HEIGHT)	8	19.64	2.45	1.57	0.1329
Growth rings 6 to 10; mean = 3.10 percent					
SOURCE	1	10.02	10.02	9.76	0.0019
DOMINANCE(SOURCE)	1	0.89	0.89	0.87	0.3522
TREE(DOMINANCE)	9	11.10	1.23	1.20	0.2928
HEIGHT(TREE)	9	22.20	2.47	2.40	0.0118
GRING(HEIGHT)	8	9.04	1.13	1.10	0.3622
Mature wood; mean = 3.48 percent					
SOURCE	1	0.59	0.59	0.52	0.4726
DOMINANCE(SOURCE)	1	0.10	0.10	0.09	0.7654
TREE(DOMINANCE)	9	26.76	2.97	2.61	0.0064
HEIGHT(TREE)	9	20.10	2.23	1.96	0.0434
GRING(HEIGHT)	8	12.49	1.56	1.37	0.2088
Last five growth rings; mean = 4.98 percent					
SOURCE	1	15.55	15.55	6.27	0.0129
DOMINANCE(SOURCE)	1	5.91	5.91	2.38	0.1238
TREE(DOMINANCE)	9	59.45	6.61	2.66	0.0058
HEIGHT(TREE)	9	50.39	5.59	2.26	0.0193
GRING(HEIGHT)	8	24.26	3.03	1.22	0.2862

effects were highly significant only in the first 5 growth rings.

These data show that the effect of age from the pith on percentage of earlywood vessel area was significant (at the 0.05% level) in the first 10 growth rings and in the last 5 growth rings. Longitudinal position or height effects were seen only in the last 5 growth rings. Dominance (whether the tree was codominant or intermediate) had no effect on percentage of earlywood vessel area. Thinning apparently had no effect on percentage of earlywood vessel area.

Percentage of latewood vessel area.—The effect of source on percentage of latewood vessel area was evident only in growth rings 6 to 10 and in the last 5 growth rings (Table 3). There is no clear explanation for this since no trend is evident. Dominance of the tree had, again, no effect on the percentage of latewood vessel areas. Tree effects were noticed in the mature wood portion of the trees and not in the core wood portions of the trees. Height or longitudinal position effects were observed in every case. And growth ring, or radial position, effects were not significantly different for percentage of latewood vessel area.

Percentage of total vessel area.—Source (thinned vs. unthinned) did not have significant effects on percentage of total vessel area except in the outermost five growth rings (Table 4). This was apparently strongly influenced by percentage of latewood vessel area (see Table 3), not the percentage of earlywood vessel area in the growth ring. Dominance had no significant effects in the first 10 growth rings but did in the more mature regions of the trees. Height effects were observed in growth rings 6 to 10. Radial effects were observed in each grouping of growth rings.

TABLE 4. *Within treatments effects for percentage of total growth ring vessel areas.*

Source	df	Type III SS	Mean square	F value	Pr > F
	Growth rings 1 to 5; mean = 7.40 percent				
SOURCE	1	0.54	0.54	0.13	0.7161
DOMINANCE(SOURCE)	1	6.25	6.25	1.53	0.2176
TREE(DOMINANCE)	9	162.43	18.05	4.41	0.0001
HEIGHT(TREE)	9	61.66	6.85	1.67	0.0939
GRING(HEIGHT)	8	532.99	66.62	16.28	0.0001
	Growth rings 6 to 10; mean = 8.31 percent				
SOURCE	1	15.12	15.12	5.11	0.0244
DOMINANCE(SOURCE)	1	6.95	6.95	2.35	0.1263
TREE(DOMINANCE)	9	33.66	3.74	1.26	0.2552
HEIGHT(TREE)	9	85.19	9.47	3.20	0.0010
GRING(HEIGHT)	8	68.66	8.58	2.90	0.0038
	Mature wood; mean = 11.23 percent				
SOURCE	1	2.55	2.55	0.47	0.4930
DOMINANCE(SOURCE)	1	47.14	47.14	8.69	0.0034
TREE(DOMINANCE)	9	71.05	7.89	1.46	0.1633
HEIGHT(TREE)	9	57.93	6.44	1.19	0.3024
GRING(HEIGHT)	8	120.40	15.05	2.77	0.0055
	Last five growth rings; mean = 15.04 percent				
SOURCE	1	400.50	400.50	21.88	0.0001
DOMINANCE(SOURCE)	1	289.98	289.98	15.84	0.0001
TREE(DOMINANCE)	9	495.46	55.05	3.01	0.0018
HEIGHT(TREE)	9	308.56	34.28	1.87	0.0548
GRING(HEIGHT)	8	423.15	52.89	2.89	0.0039

Growth ring widths.—Significant differences were observed within many of the effects tested (Table 5). Source effects were observed in all growth ring groupings. Dominance (intermediate vs. codominant) effects were most significant in the mature wood regions of the trees. Significant differences between trees within dominance groups were also observed. Height effects were observed only in growth rings 6 to 10, and growth ring effects within height were evident in each grouping. In the mature wood regions, significant differences were observed in all effects except height within tree. The width of growth rings was influenced by each effect except for height effects (exception of growth rings 6 to 10).

SUMMARY

The percentage of earlywood vessel area in growth increments was influenced by radial position in the trees, primarily within the core wood portion of the tree. Percentage of earlywood vessel area was not influenced by growth ring width. Percentage of latewood vessel area was significantly and negatively influenced by width of growth rings. The effects of thinning were not observed in percentage of earlywood vessel area, but were observed in percentage of latewood and total vessel area. Growth ring width was apparently influenced by all effects except longitudinal position (height).

It appears that thinning had the effect of reducing the total percentage of vessel area in the growth rings, particularly in the intermediate trees. This trend was seen, to a lesser extent, in growth rings formed after thinning in the codominant trees. By reducing the percentage of vessel area, thinning reduced texture in the trees in this study. Thinning, therefore, would have a negative influence on the white oak trees if they were destined for veneer use.

TABLE 5. *Within treatment effects for growth ring widths.*

Source	df	Type III SS	Mean square	F value	Pr > F
		Growth rings 1 to 5; mean = 3.86 micrometers			
SOURCE	1	7.59	7.59	5.66	0.0179
DOMINANCE(SOURCE)	1	5.40	5.40	4.03	0.0454
TREE(DOMINANCE)	9	74.23	8.25	6.16	0.0001
HEIGHT(TREE)	9	14.63	1.63	1.21	0.2855
GRING(HEIGHT)	8	403.85	50.48	37.67	0.0001
		Growth rings 6 to 10; mean = 5.27 micrometers			
SOURCE	1	6.70	6.70	5.19	0.0234
DOMINANCE(SOURCE)	1	1.88	1.88	1.45	0.2286
TREE(DOMINANCE)	9	32.71	3.63	2.81	0.0033
HEIGHT(TREE)	9	45.98	5.11	3.96	0.0001
GRING(HEIGHT)	8	24.45	3.06	2.37	0.0172
		Mature wood; mean = 2.87 micrometers			
SOURCE	1	13.00	13.00	27.80	0.0001
DOMINANCE(SOURCE)	1	10.33	10.33	22.09	0.0001
TREE(DOMINANCE)	9	17.85	1.98	4.24	0.0001
HEIGHT(TREE)	9	2.96	0.33	0.70	0.7054
GRING(HEIGHT)	8	11.32	1.41	3.03	0.0026
		Last five growth rings; mean = 2.02 micrometers			
SOURCE	1	4.97	4.97	13.48	0.0003
DOMINANCE(SOURCE)	1	5.43	5.43	14.70	0.0001
TREE(DOMINANCE)	9	21.83	2.43	6.57	0.0001
HEIGHT(TREE)	9	4.88	0.54	1.47	0.1579
GRING(HEIGHT)	8	10.09	1.26	3.42	0.0008

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