TECHNICAL NOTE: IMPACT OF FERTILIZATION ON WITHIN-TREE VARIABILITY IN YOUNG LOBLOLLY PINE (*PINUS TAEDA*)

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Abstract. Density, ring width, and cell structure were analyzed at different sampling heights and growth ring numbers in a young loblolly pine tree (*Pinus taeda*) that had received multiple applications of fertilizer. Results indicated that earlywood and latewood tracheid length increased with increment of growth ring number and height, but fertilization did not appear to measurably influence cell length. As tree height increased, density decreased but latewood cell wall thickness increased. During the fertilization period, ring width and earlywood cell diameter increased, whereas density, latewood cell wall thickness, and latewood percentage decreased. Earlywood cell wall thickness did not appear to be influenced by fertilization and did not vary greatly with increment of growth ring number.

Keywords: Anatomical properties, fertilization, wood quality, loblolly pine.

INTRODUCTION

Pine plantation management in the southern US has shifted from operational silviculture to large-scale replanting and intensive management during the last 60 yr (Fox et al 2007b). Loblolly pine (*Pinus taeda*) is the predominant species in these plantations because of its favorable response to intensive management (Fox et al 2007a).

Improving productivity of plantations through fertilization is now considered a viable, if not vital, silvicultural option (Fox et al 2007b). However, the question of how the expected growth gains from fertilization impact wood quality has yet to be fully explored. Although information about the effects of fertilization on loblolly pine anatomical properties is found in previous research (Posey 1964; Megraw 1985, 1986; Blanche et al 1992; Jokela and Sterns-Smith 1993; Shupe et al 1996; Larson et al 2001; Nyakuengama et al 2002; Rojas 2005; King et al 2008; Love-Myers et al 2009), extensive analyses at various growth ring positions and heights within individual trees are lacking and results are conflicting. To effectively use wood resources, more end-use-oriented, rigorous data on wood properties may be required. Therefore, the goal of this study was to evaluate anatomical properties within individual loblolly pine trees at different growth ring numbers and heights during and following fertilization in a young tree.

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MATERIALS AND METHODS

A 9-yr-old loblolly pine with a history of three fertilizations was sampled from Reynolds Homestead Forest Resources Research Center in Critz, VA (lat. 36°40′ N, long. 80°10′ W). Seedlings were hand-planted between February and June 2000 in parallel strips of 10 rows spaced 3.0 m apart. Fertilizer was applied three times during the first 4 yr (June 2001, March 2002, and May 2004). In March 2002, 490 kg/ha of ammonium nitrate fertilizer (34N–0P–0K) was applied. Diammonium phosphate (18N–46P–0K) was applied at 490 kg/ha in May 2004. The combined fertilizer applications added a total of 304 kg/ha nitrogen, 121 kg/ha phosphate, 41 kg/ha potassium, and 39.2 kg/ha sulfur.

Stem segments were cut to 0.3 m long from the tree at three different heights (0.5-1.5 m, 1.5-4.0 m, and 4.0-7.0 m). Wood strips 5 (thick) × 20 mm (long) were cut from pith to bark for ring width measurements. Ring width of each growth ring was measured at 12% MC using a microcaliper. Oven-dry density (oven-dry mass to oven-dry volume, kg/m^3) was determined using a QTRS-01X tree ring analyzer (Quintek Measurement Systems [QMS], Knoxville, TN). Density was measured in the radial direction at a sample step size of 0.12 mm. Material mass attenuation coefficients for the QMS software were calibrated from specific gravity measurements based on ASTM (2004) methods.

To measure cell length from each growth ring and height, small blocks were cut from a 1.6 (thick) × 10 mm (long) wood strip and macerated using Franklin's method (Franklin 1945) with gentle heat applied for 7 da. Fifty length measurements were achieved for individual earlywood and latewood groups throughout different growth ring positions and heights. Cell wall thickness and cell diameter measurements were made from thin sections taken from individual blocks of earlywood and latewood for each growth ring and height. The blocks were soaked in water for 24 h, and several 30-μm-thick sections of earlywood and latewood were cut using a sliding microtome (GSL 1 sledge microtome; Swiss Federal Research Institute, Birmensdorf, Switzerland). The thin sections were stained with a 0.5% Safranin O solution. Twenty-four h after staining, cell wall thickness and cell diameter measurement were conducted using a light microscope (Nikon, Tokyo, Japan; SMZ-LT). Tracheid length, cell wall thickness, and cell diameter were determined using a light microscope (Nikon YS2-T) equipped with a digital camera (Nikon DXM122F) and Image-Pro Plus software (Version 5.0; Media Cybernetics, Inc., Bethesda, MD).

RESULTS AND DISCUSSION

Table 1 shows the anatomical properties of loblolly pine associated with growth ring position, height, and fertilization period. When fertilizer was applied (rings 1-4), ring width increased but latewood percentage decreased. Megraw (1985) reported that fertilization might delay latewood development. We determined that in the years after fertilizer was applied, ring width decreased and latewood percentage increased. However, ring width and latewood percentage did not exhibit consistent trends with increment of height.

Density decreased rapidly following fertilization and slowly increased after the last fertilization. With increment of height, average density value decreased, which agreed with results from previous studies (Megraw 1985; Zobel and Sprague 1998; Mörling 2002).

Earlywood and latewood tracheid length increased with increment of growth ring number, however fertilization did not have a measurable influence on tracheid length. With increment of height, average earlywood and latewood tracheid length increased. It has been speculated that more anticlinal division occurs at the base of the tree where growth is relatively faster than at higher levels, and this could decrease the time and nutrition for cell elongation (Bannan 1967).

With increment of growth ring number, latewood cell wall thickness increased but earlywood

Table 1. Anatomical properties of loblolly pine associated with growth ring number, height, fertilization period.[a]

	D (kg/m^3)	RW (mm)	LP (%)	CL, E (mm)	CL, L (mm)	CWT, E R (µm)	CWT, E T (µm)	CWT, L R (µm)	CWT, L T (µm)	CD, E R (µm)	CD, E T (µm)	CD, L R (µm)	CD, L T (µm)
Growth ring	↑	↓	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
1-4	382.9	9.41	0.22	1.86	1.87	2.49	2.33	3.41	3.64	30.6	28.6	22.4	25.0
	(38.5)	(3.48)	(0.08)	(0.35)	(0.36)	(0.38)	(0.36)	(0.82)	(0.93)	(7.06)	(7.20)	(5.04)	(4.91)
5-9	437.1	9.23	0.32	2.31	2.38	2.82	2.76	4.94	5.81	39.3	34.4	25.0	29.4
	(60.4)	(1.52)	(0.10)	(0.45)	(0.43)	(0.38)	(0.41)	(1.15)	(1.21)	(6.96)	(5.92)	(5.11)	(5.35)
Height	↓, ↓	↓, ↑	↓, ↑	↑, ↑	↑, ↑	↑, ↓	↑, ↓	↑, ↑	↑, ↓	↑, ↓	–, ↓	–, ↑	↓, ↑
0.5-1.5 m	438.0	10.0	0.29	1.85	1.96	2.52	2.43	3.87	4.46	33.7	32.8	23.0	28.7
	(35.0)	(2.67)	(0.12)	(0.36)	(0.41)	(0.43)	(0.48)	(1.04)	(1.30)	(7.19)	(6.61)	(5.11)	(5.43)
1.5-4.0 m	401.1	8.67	0.23	2.05	2.14	2.80	2.65	4.19	4.66	37.0	32.3	23.3	25.4
	(57.6)	(2.98)	(0.10)	(0.46)	(0.50)	(0.39)	(0.37)	(1.40)	(1.61)	(8.40)	(6.76)	(5.47)	(5.72)
4.0-7.0 m	355.8	9.20	0.26	2.28	2.22	2.60	2.46	4.20	4.55	32.0	27.7	24.4	26.2
	(37.8)	(2.60)	(0.07)	(0.44)	(0.44)	(0.36)	(0.41)	(1.23)	(1.59)	(8.48)	(7.47)	(5.01)	(4.87)
Fertilization	↓	↑	↓	–	–	–	–	↓	↓	↑	↑	↑	↑

[a] D, density; RW, ring width; LP, latewood percent; CL, cell length; CWT, cell wall thickness; CD, cell diameter; E, earlywood; L, latewood; R, radial wall or direction; T, tangential wall or direction; ↑, increase; ↓, decrease; –, not showing a consistent trend.

cell wall thickness did not vary much. Latewood cell wall thickness decreased during the three fertilization periods. With increment of height, earlywood and latewood cell wall thickness did not show a consistent trend, except for radial latewood cell wall thickness increasing. In contrast to cell wall thickness, earlywood cell diameter rapidly increased but latewood cell diameter decreased during the three fertilization periods.

Although results from this study are limited to loblolly pine under specific and intensive forest management practices, our measurements indicate that fertilization treatment influenced anatomical properties. Decreased latewood cell wall thickness and latewood percentage together with increased earlywood cell diameter and ring width combined to decrease ring density. The trends of anatomical properties with increment of growth ring and height were found to be different, indicating that complicated but interrelated anatomical changes occurred during and following fertilization.

CONCLUSIONS

With increment of growth ring number, density, latewood percentage, cell length, cell wall thickness, and cell diameter increased but ring width decreased. With increment of height, density decreased but cell length increased.

Increased ring width and earlywood cell diameter and decreased density and latewood percentage were found during fertilization periods. However, cell length did not measurably vary during the fertilization period compared with postfertilization measurements, and latewood cell wall thickness decreased with fertilization.

The complicated relationship between anatomical characteristics and fertilization provides further evidence that wood quality is not determined by an individual property but rather a combination of blended attributes. In the final analysis, success will depend on eventual end uses for the wood materials.

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