LOBLOLLY PINE FOLIAR PATTERNS AND GROWTH DYNAMICS AT AGE 12 IN RESPONSE TO PLANTING DENSITY AND CULTURAL INTENSITY

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Examining the role of foliage in stand development across a range of stand structures provides a more detailed understanding of the processes driving productivity and allows further development of process-based models for prediction. Productivity changes observed at the stand scale will be the integration of changes at the individual tree scale, but few studies have analyzed crown attributes at the individual tree level. Studies analyzing loblolly pine (*Pinus taeda* L.) stand response to common silvicultural practices such as fertilization, control of competing vegetation, and density management are numerous. However, the physiological mechanisms that drive this response are not thoroughly understood (Jokela and others. 2004, King and others 2008, Tyree and others 2009, Will and others 2005).

Four Plantation Management Research Cooperative (PMRC) study installations were utilized to analyze the effects of planting density and cultural intensity on individual tree stem and crown attributes in non-thinned loblolly pine plantations in the Upper Coastal Plain and Piedmont of Georgia and Alabama. Treatments included six planting densities (740; 1,480; 2,220; 2,960; 3,700; and 4,440 trees ha^{-1}), in split-plot design with two cultural treatments (maximum and operational) that included different levels of fertilization and competition control (table 1). Treatment effects on stem and crown attributes were analyzed at age 12 using destructive sampling techniques.

Trees planted at lower densities were able to maintain larger crowns (increased live crown length, live crown width, leaf area, crown density). Less intra-specific competition in the lower planting density stands allowed for more light to reach the lower branches. Because leaf area is representative of photosynthetic surface area, it is assumed that individual trees planted at the lower densities were intercepting more light, allowing for increases in individual stem growth at the lower planting densities. Carlson and others (2009) and MacFarlane and others (2002) found similar patterns for loblolly pine planted at different densities. Specific leaf area (SLA), however, was generally lower in the lower planting density stands. SLA is typically greater under more light-limited conditions, resulting in more photosynthetic surface area per unit of needle biomass (longer, thinner needles), which may help mitigate the effects of increased shading present in densely stocked stands (Samuelson and others 2008, 2010; Will and others 2001).

Although the maximum cultural regime provided more frequent fertilization and competition control relative to the operational cultural regime, the operational treatment still provided considerable inputs (e.g. chemical competition control at planting and three fertilizer treatments). Although average nitrogen (N) concentration was lower for the trees grown under operational culture, it was still above the critical level of 1.10 percent for loblolly pine (Allen 1987), suggesting that loblolly pine nutrition was not markedly deficient for either treatment at age 12. Increases in foliar N concentration do not lead to a consistent observable increase in photosynthetic capacity for loblolly pine (Munger and others 2003). Additional N acquired by the foliage, however, may serve as a source for subsequent foliage development, which may consequentially drive additional stem growth (Borders and others 2004, Munger and others 2003, Tyree and others 2009, Will and others 2002). Although foliar N concentration significantly differed

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Table 1--Description of operational and maximum cultural treatments on the PMRC culture x planting density study

Site preparation treatment	Growing season	---------------Operational--------------- Chemical and mechanical	-------------------Maximum------------------ Chemical and mechanical
Fertilization	at planting	560 kg ha^{-1} 10-10-10	560 kg ha^{-1} 10-10-10
	2nd		673 kg ha^{-1} 10-10-10 + 131 kg ha^{-1} NH_4NO_3 + micronutrients
	4th		131 kg ha^{-1} NH_4NO_3
	6th		336 kg ha^{-1} NH_4NO_3
	8th	224 kg ha^{-1} N + 28 kg ha^{-1} P	224 kg ha^{-1} N + 28 kg ha^{-1} P
	10th		224 kg ha^{-1} N + 28 kg ha^{-1} P
	12th	224 kg ha^{-1} N + 28 kg ha^{-1} P	224 kg ha^{-1} N + 28 kg ha^{-1} P
Competition control (chemical)	1st	280 g ha^{-1} sulfometuron-methyl banded application + glyphosate and tryclopyr direct spraying	280 g ha^{-1} sulfometuron-methyl broadcast application + glyphosate and tryclopyr direct spraying
	2nd		841 g ha^{-1} imazapyr broadcast application
	3rd through 12th		Glyphosate and tryclopyr repeated direct spraying

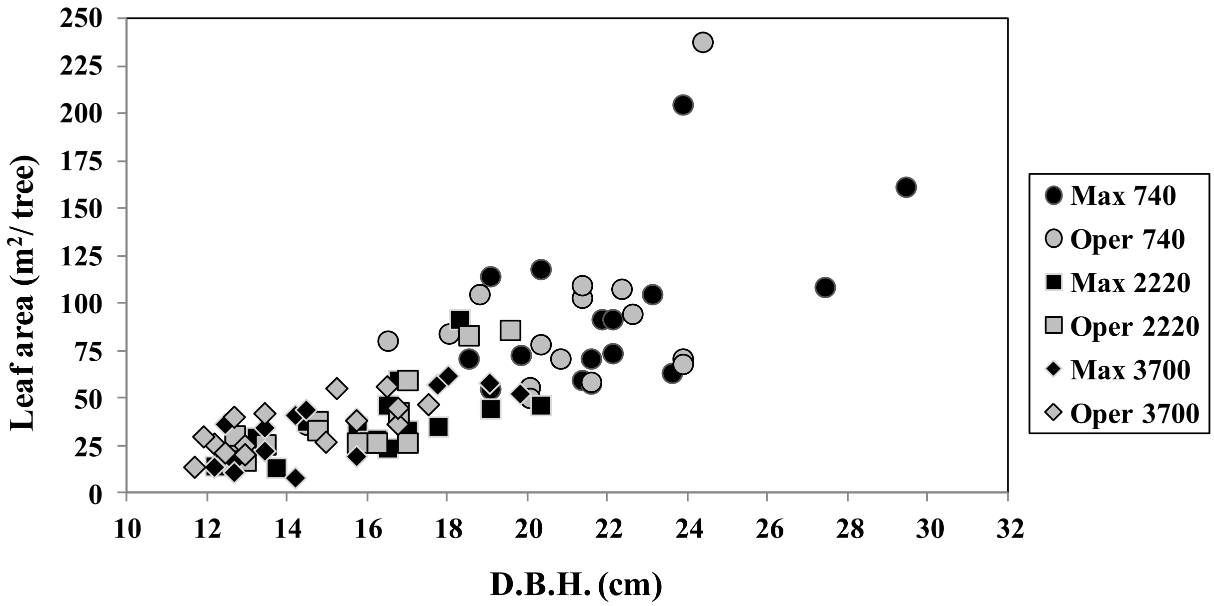

Figure 1--Relationship between individual tree d.b.h. and leaf area for destructively sampled trees on four PMRC loblolly pine installations at age 12. A sub-set of the planting density and culture treatment combinations is displayed for simplicity. The circle, square, and diamond symbols represent the 740; 2,220; and 3,700 trees ha^{-1} planting densities, respectively. The black symbols represent the maximum cultural intensity and the gray symbols represent the operational cultural intensity.

among planting densities, there was no consistent trend. Foliar N content per tree decreased with increasing planting density, primarily because N content is strongly related to foliar biomass.

The results suggest that trees of a given diameter at breast height (d.b.h.) had similar crown characteristics regardless of the silvicultural treatments they received (fig. 1). This does not suggest that culture or planting density do not affect crown characteristics, but rather that from a modeling point of view, the difference in crown characteristics (e.g. leaf area) can be adequately accounted for by variation in d.b.h., without explicitly considering further culture or planting density. It should be noted that this interpretation is limited to the age, genetics, locations, and treatments used in this study. Albaugh and others (2006) found similar results for loblolly pine grown on a nutrient poor, well-drained sandy soil in the Sandhills of North Carolina. Although fertilization had a significant effect on average d.b.h., stem height, and foliar mass, the fertilization effect was not significant in a model predicting individual tree foliar biomass where tree size (stem volume) was an independent variable (Albaugh and others 2006).

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