Integration of Crown Morphology and Leaf-level Physiology as a Tool for Predicting Differences in Aboveground Productivity Among Elite Families of Loblolly and Slash Pine

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Current silvicultural systems increasingly involve the deployment of genetically improved planting material, together with high-input silvicultural treatments to enhance forest productivity. As forest plantations become increasingly uniform, factors that limit tree growth should be identified in order to effectively alleviate those limitations. To this end, an important task is the identification of the biological bases of within and between-species differences in growth and productivity to enable effective choices of selection criteria.

Forest production depends on CO2 assimilation, but is rarely solely a function of leaf-level photosynthesis. Crown characteristics may affect tree growth by altering light interception and photosynthesis at canopy level. Strong light gradients are present in forest canopies, which often result in parallel changes in leaf morphology and leaf nitrogen for efficient use of light in photosynthetic CO2 uptake. However, the genetic basis of crown and canopy trait differences among southern pine taxa are not well understood, but critical in predicting productivity differences for managing sustainable forest ecosystems.

MATERIALS AND METHODS

Three sites of the PPINES study (Pine Productivity Interactions on Experimental Sites) of the Forest Biology Research Cooperative are located in east Texas and Louisiana in the West Gulf area. At each site, two contrasting silvicultural treatments (control and high intensity) are assigned to main plots, and six selected families of loblolly pine and one of slash pine are assigned to sub-plots. Each treatment has five replications at each site.

In our study we investigated the effects of intensive silvicultural treatment on crown morphology and within-crown leaf-level physiology, and relationships to aboveground productivity in two families of loblolly and one slash pine family. At the end of the second growing season we calculated crown volume from measurements of branch lengths and angles along the tree stem (Chmura et al. 2007). During the fourth and fifth growing seasons we measured tree and crown growth, and within-crown variation in specific leaf area (SLA cm2 g-1, amount of leaf area per leaf dry mass) and leaf nitrogen (N) on a sample of trees representing the range in tree size within each family and treatment. In the mid-season of fifth growing period, we measured light-saturated rates of photosynthesis at the leaf-level in three canopy strata.

RESULTS AND DISCUSSION

In young stands, before canopy closure (age 2 years), we found significant among-family differences in aboveground biomass production and crown structure, and between-species

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differences in leaf area density per unit of crown volume. Loblolly pine produced more flushes and longer branches than slash pine, but branch angles varied little among taxa. Across the sampled range of tree sizes, loblolly pine had larger crowns than slash pine trees, but maintained lower leaf area per given crown volume. Thus, slash pine maintained similar leaf area per tree as loblolly pine of the same age and size, compensating for a smaller crown size. Cultural treatment had no effect on crown traits.

The two loblolly pine families had a higher tree volume index than slash pine at two of three experimental sites, and tree growth was enhanced by the high intensity treatment. The two pine species also differed in patterns of aboveground biomass partitioning, with slash pine having a smaller fraction of biomass in branches than loblolly pine. Bole biomass was positively correlated with leaf area per tree, and the slope of this relationship was similar among the examined families.

The most productive loblolly pine family had a different crown shape than the two other families, with longer branches in the middle of the crown. We suggest that these differences in crown shape and associated leaf area distribution influenced light interception and CO2 assimilation at the canopy level, leading to differences in aboveground biomass accumulation among the examined families at age 2 years.

Crown development during the fourth and fifth growing seasons reflected the pattern expected for stands at canopy closure. Crowns receded from the lower tree trunk, and crown length followed these changes. Crown diameter converged in both species at the end of fifth growing season. The two loblolly pine families intercepted significantly more light (PAR – photosynthetically active radiation) than the slash pine family at the plot level in both years (Fig. 1).

The two pine species differed in SLA and leaf N – loblolly pine families had higher values of both traits. SLA increased and leaf N decreased with canopy depth, reflecting leaf-level acclimation to light gradients within the canopy when stands approach canopy closure. Within-crown gradients of leaf-level photosynthesis rates were similar at both sites when expressed on a leaf-area basis, but not on a leaf-mass basis. Area-based photosynthesis was weakly, but significantly correlated with leaf N, though the correlation varied among sites and cultural treatments. Light-saturated leaf-level photosynthetic rates followed N distribution within crowns, decreasing from the upper to lower canopy. These changes reflected the acclimation of leaf physiological properties to increased shading. However, the two pine species did not differ in leaf-level photosynthesis rates at any crown position.

Tree growth, defined as a yearly tree volume increase, based on a stratified sample of trees was not directly related to leaf-level photosynthesis rates, but was correlated with plot-level spatially averaged PAR interception (Fig. 1). The slope of the relationship did not differ between the two pine species, but the intercept was significantly higher for loblolly than for slash pine in fifth growing season. Intercepts differed in both years between the two cultural treatments when fitted across families and sites.

High intensity treatment, although effective in increasing biomass accumulation in all examined families, did not affect leaf morphology or physiology. Aboveground biomass production differed among the tested families and was related more to accumulated leaf area and its display within crowns than to differences in rates of leaf-level photosynthesis. Therefore, examination of stand-level light interception and its implications for canopy photosynthesis is needed to relate stand growth with physiological properties. However, any modeling effort should take into account observed patterns of within-crown variability in leaf morphological and physiological adjustments to microenvironment within forest canopy.

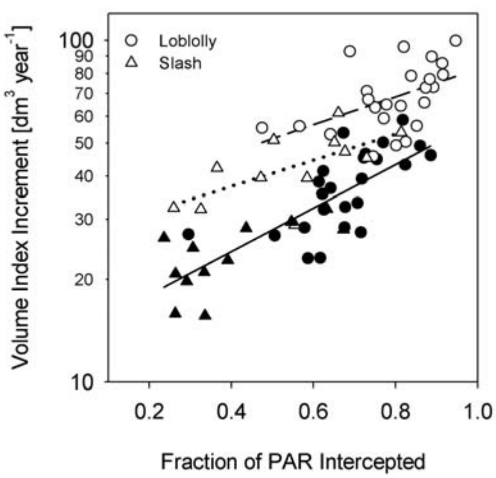

Fig. 1. Relationship of yearly tree volume index increment with plot-level interception of photosynthetically active radiation (PAR) in examined families of loblolly and slash pine. Shown are means for individual plots at two experimental sites in the West Gulf Coastal Plain area. Volume index was calculated for a stratified sample of trees; n = ranges from 4 to 6 for each point. Solid symbols with solid line represent the fourth growing season (2005) with a linear fit across two species and sites. Open symbols represent the fifth growing season (2006) with separate fits for loblolly pine (dashed line) and slash pine (dotted line).

RERERENCES

Chmura, D.J., M.S. Rahman and M.G. Tjoelker 2007. Crown structure and biomass allocation patterns modulate aboveground productivity in young loblolly pine and slash pine. Forest Ecology and Management. 243:219-230.