GENOTYPE AND NUTRITION EFFECTS ON STAND-LEVEL LEAF AREA IN LOBLOLLY PINE

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INTRODUCITON

Interest in intensive plantation forestry has grown considerably within the Southern United States in recent years. This comes as no surprise considering the South's strong agricultural history, and like agriculture, forestry is shifting toward more intensive manipulation of genetic and site resources. Large gains in productivity have already been made in loblolly pine *(Pinus taeda* L.) with up to 35% improvement in volume production possible with second-generation improved stock (Li et al. 1999). Even with current knowledge of nutrient and water limitations tremendous gains can be made in productivity once the knowledge is applied (Allen et al. 1990). To continue to see increased gains in stand productivity it is important to understand how stand characteristics vary across genotypes and site conditions.

One of the more important stand characteristics for assessing productivity is total stand leaf area. Wang and Jarvis (1990) found that total leaf area was critical in applying the MAESTRO model when studying changes in photosynthetically active radiation (PAR) absorption, photosynthesis, and transpiration. Leaf area index (LAI) can be increased with the application of fertilizer on nutrient poor sites and with irrigation on droughty sites (Zhang et al. 1997; Albaugh et al. 1998), and strong family differences have been found in LAI for loblolly pine (Althoff 1994; McCrady and Jokela 1998).

Even though there is documentation on how LAI is strongly affected by genetics and resource availability, there is a lack of information on genotype by environment (GxE) interactions in this trait. Although no significant change in family ranking has been found in loblolly pine growth characteristics, certain families have been shown to be more genetically unstable across various site conditions than other families. This can be very important in operational deployment, since greater gains will be realized if the more responsive families are allocated to the best sites with the more expensive treatments (McKeand et al. 1997). The following research will identify some genetic and environmental effects in stand level leaf area.

METHODS

The study site is located in the Sandhills of North Carolina (Scotland Co.) in a split plot design with two fertilizer treatments (Control = no nutrients; Fertilized = elevated levels of N, P, K, Ca, Mg, S). Within each treatment are ten half-sib loblolly pine families from two provenances (ACP = Atlantic Coastal Plain; LPT = Lost Pines Texas). Each family plot consists of 100 trees planted at 5' x 7' spacing. The full blocks are replicated ten times.

LAI was estimated using the Li-Cor LAI2000 plant canopy analyzer. Each plot was measured after their fifth growing season in January and March of 1999 then averaged to estimate LAI from the 1998 cohort only. Plot volume estimates were made by measuring the height and diameter at breast height (DBH) of each tree. Analysis of variance was done on height, volume, LAI, and growth efficiency in order to identify significant differences and interactions among treatments, provenances and families within provenances.

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RESULTS AND DISCUSSION

The treatment effects are dramatic due to the natural infertility of the Sandhills site. Height growth has been consistently higher in the fertilized plots throughout the life of the study. Annual volume increment, and LAI have both shown a three-fold increase due to nutrient addition.

The ACP provenance has significantly greater production in per acre volume than the LPT provenance (25% greater on control sites and 12% greater on fertilized). Early research suggested that the LPT families were "drought-hardy" and may do well on these sandy, well drained sites. However, even on the control plots, LPT families do not do as well as the ACP families. This trend also holds true for height and LAI.

Family comparisons are not as clear cut as the treatment and provenance effects. There are significant differences between the best and worst families of each provenance in volume and LAI but not all families are significantly different from one another. It is also important to note that while there is strong volume-LAI correlation at the provenance level, no such correlation can be found at the family level. Since high leaf area for a family doesn't necessarily indicate high volume production, other factors must play a greater part.

Growth efficiency (as unit of volume per unit of LAI) was analyzed to see if it could explain some of the family differences. A 21% difference was found between the lowest and highest LPT families and a 30% difference in ACP. This shows that at the family level it is important not only to know how much leaf area the stands can produce but how efficiently it can use those leaves to produce timber volume.

Some significant GxE was found but no rank changes were detected at either the family or provenance level. This is further support for the practice of putting the best genetic stock on the best sites.

CONCLUSIONS

Growth response to fertilizer amendments has been large and consistent across the study. The ACP provenance performs better than the LPT across both treatments with some GxE. There are significant family differences but it is important to take into account growth efficiency as well as total LAI when identifying productive families. With the small amount of GxE identified it is still recommended that the best families be places on the best sites. This study has not been able to identify the physiological mechanisms behind the differences in growth efficiency. It is recommended that further research be done in this direction.

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LITERATURE CITED

Albaugh, T.J., H.L. Allen, P.M. Dougherty, L.W. Kress, and J.S. King. 1998. Leaf area and above- and below-ground growth responses of loblolly pine to nutrient and water additions. For. Sci. 44(2).

Allen, H.L., P.M. Dougherty, and R.M. Campbell. 1990. Manipulation of water and nutrients- practice and opportunity in southern U.S. pine forests. For. Ecol. Mngt. 30:437-453.

Althoff, P. 1994. Genetic variation in light interception and its relationship to productivity of twelve open-pollinated loblolly pine families. MS Thesis. Dept. of Forestry. North Carolina State University. Raleigh, NC.

Li, B., S. McKeand, and R. Weir. 1999. Impact of forest genetics on sustainable forestry – results from two cycles of loblolly pine breeding in the U.S. J. Sus. For. (in press)

McCrady, R.L.and E.J. Jokela. 1998. Canopy dynamics, light interception, and radiation use efficiency of selected loblolly pine families. For. Sci. 44(1):64-72.

McKeand, S., R.P. Crook, and H.L. Allen. 1997. Genotypic stability effects on predicted family responses to silvicultural treatments in loblolly pine. So. J. Appl. For. 21(2):84-89.

Wang, T. and P.G. Jarvis. 1990. Influence of crown structural properties on PAR absorption, photosynthesis, and transpiration in Sitka spruce: application of a model (MAESTRO). Tree Physiology. 7:297-316.

Zhang, S., H.L. Allen, and P.M. Dougherty. 1997. Shoot and foliage growth phenology of loblolly pine trees as affected by nitrogen fertilization. Can. J. For. Res. 27:1420-1426.