Impact of Silvicultural Practices on Loblolly Pine Wood Quality

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Abstract

Two thirds of the timber harvested in the United States is harvested in the South, with the majority being produced from loblolly pine (*Pinus taeda* L.). Loblolly pine plantations are increasingly being managed using intensive silvicultural practices that aim to increase tree growth and yield per ha but minimal information is available on the impact of these silvicultural practices on wood properties. This paper summarizes findings from several studies that have investigated the effects of common silvicultural practices on wood properties, including fertilization and herbicide control of competing vegetation at planting, thinning and mid-rotation fertilization and planting density.

Key Words: competition control, fertilization, loblolly pine, *Pinus taeda*, silvicultural practices, wood quality

Introduction

The Southern United States of America (USA) is a critically important region in terms of timber production. It is estimated that approximately 60 percent of the wood used in the United States and 15 percent of the wood consumed globally is produced in this region (Wear and Greis 2002). This region is also responsible for approximately 80% of the nation's tree planting activities, with the majority of seedlings (84%) planted being loblolly pine (*Pinus taeda* L.) (McKeand et al. 2003) a southern pine species well adapted to growth on a wide range of sites. Currently there are more than 12.1 million hectares of pine plantations in the southeast United States, with the area projected to increase by 83 percent to over 22.2 million hectares in 2040 to meet future timber demands.

Intensively managed plantations utilizing genetically improved planting stock in conjunction with advanced silvicultural practices, are believed to be the best strategies to meet future timber demands, rather than managing more hectares of forest (Li et al. 1999). In terms of genetic improvement Li et al. (1999) reports that loblolly pine trees grown from seeds obtained from first-generation seed orchards have produced 7-12 percent more volume per hectare at harvest and from second-generation seed orchards it is estimated that gains in volume will be 13-21 percent more than trees grown from wild seed. It is also expected that clonal or varietal forestry will play a crucial role in meeting future timber demands. While relatively new to the southern USA, clonal forestry is being viewed as a way to improve the competitiveness of the USA in global wood supply markets (Sorensson 2006).

Silvicultural practices vary but most commonly include initial planting density, site preparation including competition control and fertilization at planting, and thinning and fertilization at mid-rotation. Research has also been conducted on silvicultural practices that are not considered operational, including the effects of annual fertilization on wood properties, fertilization at different intervals and intensities and fertilization with irrigation. Each of the silvicultural practices described can have an effect on the volume of wood produced and its quality but presently minimal information is available on the impact of these silvicultural practices on the wood properties of loblolly pine.

The following report will focus on research conducted by the Wood Quality Consortium (WQC) that has investigated the effects of silvicultural practices, in particular fertilization, on the wood properties of loblolly pine. The WQC is a research partnership between the University of Georgia, Warnell School of Forestry and Natural Resources, the USDA Forest Service, Southern Research Station and forest industry members.

Planting Density

Presently one of the most important silvicultural decisions in the southern USA relates to planting density. Forest managers are planting at wider spacings and using weed control and fertilization to grow chipping-saw and sawtimber size trees in shorter rotations in response to weak demand for small diameter loblolly pine. However, planting at wide spacing stimulates diameter and crown growth that can result in larger diameter branches

(Baldwin et al. 2000; Sharma et al. 2002). The diameter of knots is an important characteristic which can degrade southern pine dimension lumber and veneer (Clark et al. 1994, Clark and McAlister 1998).

The effect of initial spacing on wood quality and yield per ha for loblolly pine was examined by sampling a 21-year-old unthinned spacing study (Clark et al. 2008). The study was established the Coastal Plain of Georgia in1984 and contained 11 spacings. For this study seven spacing's ranging from 1.8×2.4 m (2244 trees/ha) to 3.6×3.6 m (746 trees/ha) were sampled. Twenty-one trees per spacing were felled, and all branches were measured. Total stem green weight per ha of wood and bark to a 75 mm dob top was estimated to be highest in the 1.8×3.6 m, 2.4×3.0 m and 2.4×3.6 m spacing's. Estimated volume of lumber per ha was slightly higher in the 2.4×3.6 m spacing compared to the 3.6×3.6 m spacing. Average number of knots, knot diameter and average maximum knot diameter increased with increased spacing.

Fertilization and Competition Control at Planting

An increasingly common silvicultural practice to increase the growth of young loblolly pine is the use of herbicide treatments to control competing vegetation. Herbicide applications during the first few years following plantation establishment reduces herbaceous and woody competition and subsequently increases the growth of loblolly pine owing to the additional availability of moisture and nutrients. The addition of fertilizer at this time is also a common practice and can produce appreciable improvements in growth. Until recently little has been known about the effects of these practices on loblolly pine wood properties.

Two studies conducted by the WQC have examined the effects of herbicide and herbicide and fertilizer treatments. The first of these examined the effects of complete control of woody, herbaceous and woody plus herbaceous competition for the first 3 to 5 years on the growth and wood properties of loblolly pine. The study was established in 1984 at 13 locations across the southern USA and was called the Complete Omission Monitoring Project or COMP (Miller et al. 1991; Miller et al. 2003). Miller et al. (2003) reported that with near complete herbaceous and woody control, increases in pine merchantable volume per ha averaged 23 to 121% at age 15. In terms of wood properties woody plus herbaceous competition control significantly increased growth at all locations, did not significantly reduce ring specific gravity (SG) or earlywood or latewood, and did not significantly affect the proportion of latewood in the annual ring. However, woody plus herbaceous competition control did significantly increase growth during juvenile wood formation in years 1 to 5 and thus increased the juvenile wood core by an average of 19%. Deceases in cross-sectional weighted latewood and SG of 10% and 3% respectively were observed owing to increased growth during the juvenile period in trees that received the woody plus herbaceous treatment. Growth gains substantially offset the reductions in weighted percent latewood and SG.

In a related study the long-term effects of site preparation, early fertilization and weed control on the wood properties of loblolly pine were examined (Mora 2003). The wood

samples examined in this study were obtained from four regeneration trials established by the North Carolina State Forest Nutrition Cooperative (FNC) between 1978 and 1981 in southeastern USA. Trees from five different treatments were selected for examination; 1. control (low site preparation), 2. intensive site preparation, 3. intensive site preparation plus fertilization, 4. intensive site preparation plus herbicide application and 5. intensive site preparation plus fertilization and herbicide application.

The intensive treatments were found to increase individual tree volumes with responses ranging from 29 to 33%. Despite the increased growth shown by the trees under the intensive cultural treatments wood properties (earlywood, latewood and ring SG and latewood percent) were generally not significantly different from those observed for control plots. The transition age from juvenile to mature wood (based on latewood SG, the earlywood to latewood threshold was equal to 0.48) was also examined. Where strong growth responses to fertilization and weed control were observed, the transition age between juvenile and mature wood was unaffected or decreased, while strong growth responses related to herbaceous weed control increased the transition age in intensive silvicultural plots compared to control plots (Mora 2003; Mora et al. 2007).

To summarize both studies, significant growth responses occurred however wood properties were largely unaffected. Owing to the growth response the juvenile core was increased but proportionally it was no different in size to that of the control trees (see Fig. 1). If in practice, on the other hand, trees would be grown to similar final diameters, the trees with weed control would attain that size sooner and with a higher proportion of juvenile wood.

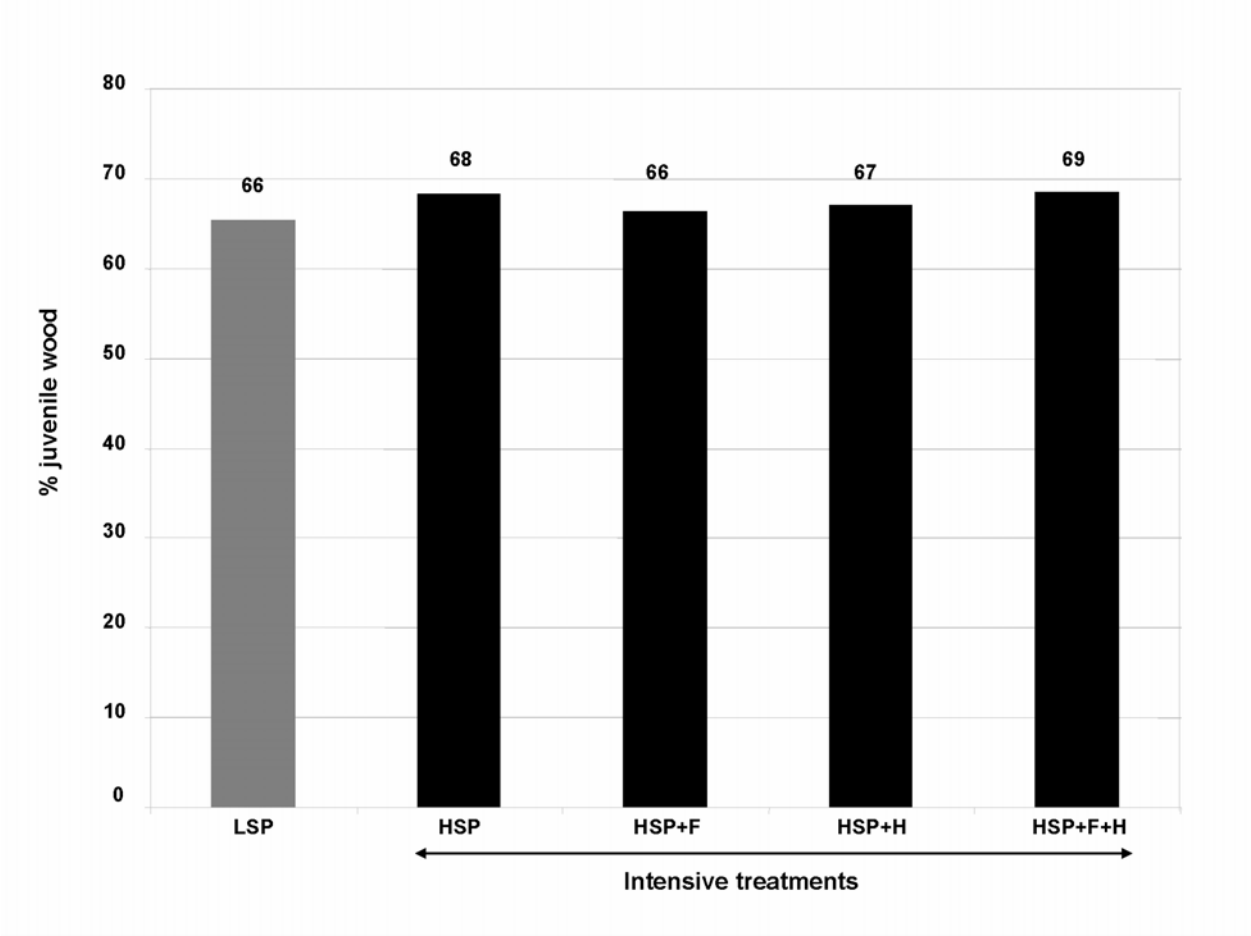

Figure 1 – Proportion of juvenile wood for each treatment (all sites). Source Mora (2003).

Mid-rotation Thinning and Fertilization

Mid-rotation fertilization following thinning is another common silvicultural practice in the southern USA. Thinning is important as it improves the growth of the remaining trees therefore maintaining the vigor of the stand. It also enhances the overall quality of the stand by concentrating growth on the best trees. Fertilization following thinning aids the growth response and can also be used to ameliorate some soil deficiencies.

Fertilization at mid-rotation has been rapidly adopted for the management of southern pine plantations with the area fertilized at mid-rotation increasing from 81,000 ha in 1997 to 0.6 million ha in 2002 (FNC 2006). Fox et al. (2006) report growth improvements in the range of 3.5-6.9 m^3/ha/year and attributed the increased production following mid-rotation fertilization and thinning to the removal of nutrient limitations from the site and a subsequent increase in light interception capacity (facilitated by an increase in the leaf area of fertilized trees). As with other silvicultural treatments wood properties are influenced by mid-rotation fertilization and thinning. The following is a brief description of studies conducted by the WQC.

The first of these studies (Antony et al. 2008a) was based on samples from a study planted in 1970 by the Forest Nutrition Cooperative in New Bern, North Carolina, USA. The stand was thinned in 1983 and different rates of fertilizer (Control- 000, 112, 224 and 336 kg/ha, along with 28 kg/ha of phosphorus with all treatments) applied in 1984. Wood properties including modulus of elasticity, air-dry density and tracheid anatomical properties were measured for each of the three post-fertilization annual growth rings using near infrared (NIR) spectra obtained from the radial face of strips cut from the disks. A decrease in stiffness, air-dry density, tracheid wall thickness, and an increase in tracheid radial diameter were observed for the heaviest fertilizer treatment (336 kg/ha) compared to the control and the 112 kg/ha treatment. Microfibril angle (MFA), cell tangential diameter, and tracheid perimeter showed little change. Wood properties of trees receiving fertilizer rates of 112 and 224 kg/ha were not significantly affected. Indicating that mid-rotation fertilization (at appropriate levels) following thinning can achieve considerable gains in growth while not impacting on the wood properties of loblolly pine.

A later study based on the same samples (Antony et al. 2008b) examined changes in earlywood, latewood and ring SG and latewood percent at various heights. Figure 2 shows the variation observed for latewood SG at breast height for the different fertilizer treatments. Fertilization at the highest rate (336 kg/ha N) significantly reduced both ring SG and latewood SG averaged over the four years immediately following mid-rotation fertilization, but that these values returned to control levels in just a few years. Wood properties of trees which received 112 and 224 kg/ha N were not affected following treatment. It was also observed that there was no height related trend in wood property changes due to fertilization. In terms of growth a significant response was observed for basal area growth for the whole-disk average and for the 4-year average post fertilization.

A similar study has recently been completed by the WQC (Love et al. 2008) examined SG responses of slash pine (*Pinus elliottii*) and loblolly pine following mid-rotation fertilization. Findings were similar to those reported by Antony et al. (2008b).

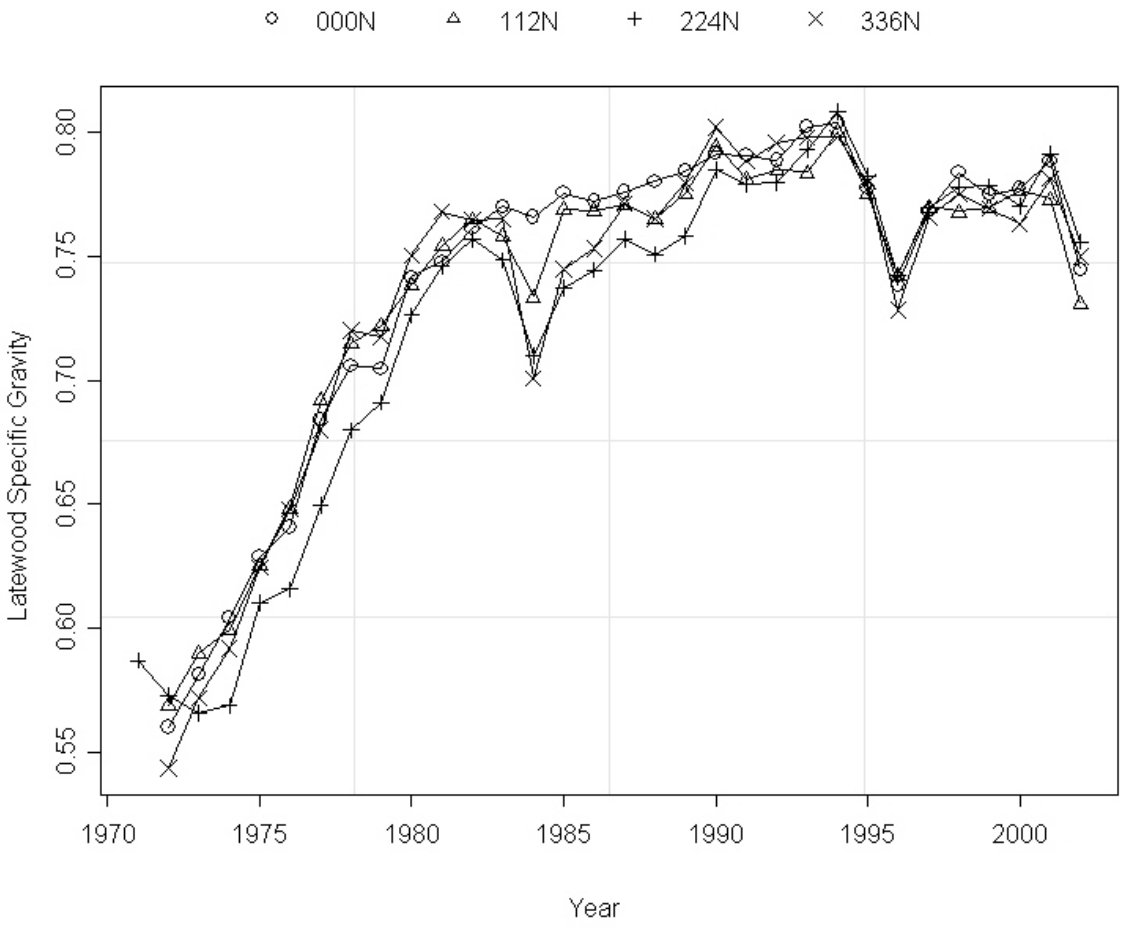

Figure 2 - Variation in latewood SG at breast height for 4 different fertilizer treatments. Source Antony (2006).

In summary mid-rotation fertilization post thinning produces a growth response. Wood properties are negatively affected but only for the heaviest rates of fertilizer applied and only for a short period of time, i.e. the effect is transient with wood properties returning to levels similar to that of untreated trees within a few years.

Annual Fertilization

While annual fertilization is not practiced operationally research that has sought to determine the growth potential of loblolly pine in the southeastern USA under intensive silvicultural practices (Borders and Bailey 2001), report dramatic increases in growth (up to 270%) and suggest that intensive cultural practices would be economically beneficial. Treatments included: intensive mechanical site preparation, complete vegetation control with multiple applications of herbicides, annual high rates of nitrogen fertilization, and complete vegetation control plus annual high rates of nitrogen fertilization. The impact of such practices on wood properties were examined by Clark et al. (2004) who found that complete vegetation control plus annual high rates of nitrogen fertilization increased the diameter of the juvenile core 62% and thus the proportion of stem basal area in

juvenile wood. Annual ring earlywood SG was not affected by treatments, while annual ring latewood SG was significantly reduced for the fertilized and herbicide plus fertilized trees. In addition, annual fertilization alone or in combination with vegetation control reduced weighted stem SG 6 to 10% compared to that of trees receiving only the site preparation treatment.

Present WQC fertilization / wood property research

Interest exists in optimizing plantation growth and fertilizer application throughout the life of a stand. In a regionwide study (Regionwide 18) established by the FNC, trials are underway that will quantify the rates and frequencies of nutrient application to optimize growth and fertilizer use efficiency throughout a rotation. In an ongoing study the effects of various nutrient doses (0, 67, 134, 201 and 268 kg/ha of N) and frequencies (2, 4 and 6 years) on wood quality are being investigated. The study aims to address the following questions:

- What frequency / dose combinations provide the optimal balance between growth response and wood quality?
- Do multiple applications of fertilizer lengthen the period of juvenile wood formation and how does it differ between regions?
- Do multiple applications of fertilize change the trajectory to mature wood formation?

Recommendations

Based on recent findings of the Plantation Management Research Cooperative (PMRC), the Consortium for Accelerated Pine Productivity Studies (CAPPS), and the WQC it is planned to develop a set of silvicultural recommendations for optimizing timber value from loblolly pine plantations.

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