# INFLUENCE OF FAMILY AND SPACING ON JUVENILE LOG QUALITY OF LOBLOLLY PINE

J.B. Campbell, S.B. Land Jr., H.W. Duzan Jr.[1]

Abstract.--Eight selected North Carolina families (based on growth rate and crown size from prior progeny tests) and one local unselected seed source were tested for juvenile log quality in a 10-year-old progeny test at three spacings in northeast Mississippi. The traits used to distinguish log quality were: sweep, number of limbs, average limb diameter, average size of largest branch, height to base of live crown, and form class. The North Carolina families exhibited significantly higher quality characteristics for all traits when compared to the local seed source. Differences were found among the eight selected families for all of the log quality traits except number of limbs. Spacing-by-family interactions were observed for average limb diameter. Interactions were associated with (a) smaller family differences at the closer spacing and (b) some large family rank changes between spacings. It was concluded that selection for fast-grown, small-crown families in North Carolina was effective in improving juvenile log quality in Mississippi, especially in plantations grown at wide spacings (8 x 8 ft. or greater).

Keywords: *Pinus taeda* L., sweep, stem form, limb traits, GxE interactions.

## INTRODUCTION

Log quality and the resulting lumber quality of loblolly pine (*Pinus taeda* L.) are determined by number, size and soundness of limb knots, by stem straightness, and by stem taper. These traits can be influenced by spacing and genotypes among trees. Since the juvenile stem represents the core of the future log, measurements of limb and stem traits at an early age provide an indirect measure of the effects of spacing and family on the quality of that log and the resulting lumber quality. Campbell (1962) has stated that log imperfections are a result of the defects of the underlying wood.

The most important grading defects found in southern yellow pine are number and size of limbs (Campbell, 1962). Campbell (1962) defines a limb as a branch that is one-half inch or larger in diameter. This includes knots, stubs, holes, and overgrowths. The length and shape of the crown also influence the size of the limbs (Sprinz and Burkhart 1989). Another important stem quality characteristic is straightness. Williams and Lambeth (1989) concluded that a direct measure of stem curvature or sweep from a straight eight-foot pole was an easily obtained quantitative measurement of stem straightness in the first log of young trees, and that it was more repeatable than straightness scores of the entire stem that were determined subjectively.

Conflicting results have been reported on the relationship between stem characteristics and subsequent quality and yield of the resulting lumber. Gaby (1972) showed a positive correlation between knots and direction of warp.

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[1]Graduate Student and Professor, Forest and Wildlife Research Center, Mississippi State University, Mississippi State, MS 39762, and Research Station Manager, Weyerhaeuser Company, Columbus, MS 39701.

However, Shelley *et al.* (1979) found no relationship, and Beard *et al.* (1993) reported that only nine percent of the variation in lumber warp was related to growth traits. The fact that the number of lumber grades used in the latter studies was restricted is the most likely explanation for the difference in the results. It was noted that log quality can affect the relative percentages of lumber in the different grades.

Genetic variations in stem traits that might affect log quality have been reported for many species. Douglass *et* al. (1993) found significant genetic variation in sweep among five loblolly pine seed sources. These seed sources ranged from coastal North Carolina to Arkansas and Oklahoma. The North Carolina Piedmont source had the least sweep. A significant genotype-by-site interaction for sweep was present at the seed source level, but the interaction was much smaller for families within sources. The coastal North Carolina source and a central Mississippi-Alabama source had the greatest variability in sweep. In studies with other tree species, heritability has been higher for stem straightness and volume growth than for crown characteristics (Ferguson *et al.* 1977; Otegbeye 1988).

It is generally reported that spacing among trees influences straightness, frequency and size of knots, and diameter/height growth patterns (Daniel *et* al. 1979). Loblolly pines at wider spacings tend to have larger diameters, greater sweep and sweep length, larger knot size, and increased taper.[2] Wiley and Zeide (1988) also observed that wider spacings produced trees with larger d.b.h. and crown ratio. Closer spacings induce smaller diameter, less sweep, smaller limbs, and a base of the live crown that is higher than less dense spacings (Smith 1986).

The purposes of this study were to determine how family and spacing affect juvenile log quality and to learn if family-by-spacing interactions exist for juvenile log quality in a ten-year-old loblolly pine plantation.

## METHODS

### Plant Material

Open-pollinated progenies from eight selected trees in eastern North Carolina, as well as a commercial seed source (used as a check) from east-central Mississippi and west-central Alabama, were provided by Weyerhaeuser Company. The eight families were chosen based on performance in 12-year-old progeny tests in North Carolina and represented combinations of fast and slow growth rates with large and small crowns (Table 1). "Fast", "slow", "large", and "small" are relative terms referring to extreme combinations in a set of families represented in the progeny tests at 6 - 15 sites. Crown size was actually a performance level based on crown score, which was determined from crown length, crown width, and limb diameter.

[2] Land, S. B., and J. D. Hodges. 1992. Influence of initial plantation spacing on defects and log grades in 33-year-old loblolly pine stands. Funded contract between International Paper Company and the Department of Forestry, Mississippi State University, Mississippi State, MS.

## Field Planting

Seeds were collected in November 1984 and grown in leach tube containers for five months by Weyerhaeuser Company. The container seedlings were planted in early May 1985 at two sites on the Mississippi State University school forest in Winston County, Mississippi (Secs. 5 and 6, T16N, R14E). One site was an old field, and the other was a clearcut-and-site-prepared area that had previously been an old pine stand.

Three spacings were represented at each site: 5 x 5 feet, 8 x 8 feet, and 10 x 10 feet. Each spacing contained the eight families in "mixed-family" and "pure-family" plots. The unselected commercial check was included as a "pure-family" plot in each spacing to provide a local comparison for the North Carolina families.

**Table 1**. Characteristics of families used in study.

| Parent Tree Identity | Characteristics | |
|---|---|---|
| | Growth Rate | Crown Size |
| 1-A | Fast | Small |
| 1-B | Fast | Small |
| 2-A | Fast | Large |
| 2-B | Fast | Large |
| 3-A | Slow | Small |
| 3-B | Slow | Small |
| 4-A | Slow | Large |
| 4-B | Slow | Large |
| 5 | Commercial Check | |

## Sample Size and Measurements

Sample size was determined by conducting a preliminary study and then basing calculations on the standard error of a key variable (number of limbs) being measured using the non-central f-distribution. The number of samples calculated yielded a power of 0.80 at an alpha level of 0.05 for a minimal detectable mean difference of 1.1 times the standard error (Kirk 1968). This indicated that a sample size of four trees per plot (replication by family by spacing) would be required. The following measurements were taken from November 1994 through February 1995 at the end of the tenth growing season:

1. diameter at breast height (dbh)
2. diameter outside bark at stump height (1 ft)
3. diameter outside bark at 17.0 feet
4. height to live crown (ft)
5. total height (ft)
6. crown class (dominant or codominant)
7. crown width in two directions (along rows) (ft)
8. diameter of largest limb (between 1-ft and 17-ft height on stem)

9. limb talley into four 1/2-in.diameter classes from 0.5 to 2.5 in.:
   (a) by first and second 8-foot logs (above 1-foot stump)
   (b) by status (live, recent dead, or old dead [where "old dead" represents punky, partly shed limbs]) (gives 24 variables for limb tallies)
10. height to lowest live and dead limbs (above 1-foot stump)
11. straightness score for the entire tree
    (1 = straightest ... 4 = most crooked)
12. sweep (to the nearest tenth inch), as measured in the first 16-foot log by the maximum deviation from a 12-foot straight pole)

DBH, crown width, and total height of tree are only reported as study means in this paper.

Statistical Analysis

Analysis of variance was for a split-plot design arranged in randomized complete blocks and repeated at two locations. The main unit treatment factor was spacing, and the subunit treatment factor was family. Four sample trees were randomly selected within each "pure-family" plot for each spacing and location, with the stipulation that these sample trees must be dominant or codominant in crown class, free of any disease, and not forked. In total, four trees within each of 216 plots (8 replications, by nine "families" by three spacings) were measured.

## RESULTS AND DISCUSSION

The average tree was 38 feet tall, six-inches in diameter at breast height, and 11-feet in crown diameter.

Spacing

Spacing significantly affected average limb diameter, number of limbs, form class, height to live crown, and average size of largest branch (Table 2). The 5 x 5 ft. spacing had the smallest limbs, the fewest limbs per first 16-ft. log, the highest form class, and the smallest diameter of largest branch. However, no significant differences were found among spacings for sweep. Closer spacings did not improve straightness of the stem.

Family

The North Carolina families ranked higher in log quality than the commercial check for nearly all traits (Table 3). The only exception was that they had more limbs per 16-ft. log than the local source (Table 3). This indicates that selection for improved juvenile log quality in eastern North Carolina is beneficial when trees are planted in northern Mississippi.

For the most part, the faster growing families had better juvenile log quality than the slow-growing families (Table 4). Families representing fast growth rate had smaller limbs, better form class, and taller height-to-live crown than the slow growth families. Height-to-live crown was an indicator of how much of the stem was free of live limbs at age 10. Thus, having a greater height-to-live crown reflected no further increase in knot size, quicker shedding of limbs, and faster overgrowth of knots. The slow-growing families did have less sweep than fast growing families, however (p-value=0.0002).

Table 2. Means and P-values for measured traits based on three different spacings.

| Trait | Spacing* | | | P-value |
|---|---|---|---|---|
| | 5x5 ft. | 8x8 ft. | 10x10 ft. | |
| Average limb diameter per tree (in) | 0.8 A | 0.9 B | 1.0 C | 0.0066 |
| Number of limbs per 1st 16-ft. log | 21 A | 27 B | 28 C | 0.0372 |
| Form class (17-ft. diameter/1-ft. diameter) (%) | 74 A | 73 B | 70 C | 0.0582 |
| Height to the base of live crown (ft) | 21.8 A | 17.7 B | 14.7 C | 0.0080 |
| Diameter of largest branch (in) | 0.95 A | 1.3 B | 1.6 C | 0.0055 |
| Sweep (in) | 1.2 A | 1.2 A | 1.2 A | 0.8386 |

* Spacing means for the same trait are not significantly different at alpha = 0.05 if they are followed by the same letter.

Among the fast growing families, considerable differences existed between the two crown types. Comparisons within the fast-growth families showed that the small crown families had fewer number of limbs, smaller limbs, and less sweep than the large-crown families. However, differences between the two families within a growth-by-crown-size group were usually not significant. An exception was form class in the fast-growth, small-crown group, where family 1-B had a higher form than 1-A. Among the large crown families 2-B had smaller average limb diameter, smaller largest branch, and a much more crooked stem than 2-A. Family 2-B had the highest degree of sweep of any of the selected North Carolina families.

The differences found among slow-growing families were less than those among the fast-growing families. No significant differences were found for the important Quality characteristics, of sweep, diameter of largest branch, or average limb diameter. The slow-growth families only showed significant differences for number of limbs per tree and height to live crown. Among the small-crown families, 3-B had the least number of limbs and least sweep (family 3-B was the only family with a sweep less than one inch [0.95 in.)). Family 3-A had the highest height to live crown. Family 4-A had a larger average limb diameter, fewer limbs per tree, and a higher form class than family 4-B (p-values = .0449, .011, .013 respectively).

Selections made in eastern North Carolina for growth rate and crown size held true when planted in northern Mississippi. The family classes showed differences in juvenile log quality at all spacings. However, the differences among families are greater at the wider spacings. This is important, since the wide spacings are more often used today.

Table 3. Means and P-values for North Carolina families and the commercial check.

| | Ave. limb diam. (in) | # limbs per tree (in) | Form class (%) | Ht. to live crown (ft) | Diam. largest branch (in) | Sweep (in) |
|---|---|---|---|---|---|---|
| North Carolina Selected Material | 0.85 | 25 | 73 | 18.3 | 1.2 | 1.1 |
| Commercial Check | 0.96 | 26 | 69 | 16.3 | 1.5 | 1.6 |
| P-value | 0.0001 | 0.37 | 0.0002 | 0.0021 | 0.0126 | 0.0043 |

A significant spacing-by-family interaction occurred only for average limb diameter (p-value = 0.008). This interaction could be attributed to large family rank changes between spacings and smaller differences among the families at the 5 x 5 ft. spacing than in the wider spacings (Table 5). The only significant difference for the 5 x 5 ft. spacing was for the commercial check. The 8 x 8 ft spacing and the 10 x 10 ft. spacing provided significant differences among selected families as well as the commercial check. The wider spacings gave a much greater range in average limb diameter than the 5 x 5 ft. spacing. For all spacings the commercial check had the largest average limb diameter. The smallest limbs found at the 5 x 5 ft. spacing were in families 3-A and 4-B. At the 8 x 8 ft. spacing families 1-B and 2-B had the smallest average limb diameter. And at the 10 x 10 ft. spacing 1-A and 1-B showed the smallest limbs (1-A was the only family at this spacing that had an average limb diameter under 0.9 inches).

## SUMMARY AND CONCLUSIONS

1. The selected North Carolina families proved to be superior to the local seed source for juvenile log quality when planted in northeast Mississippi.

Table 4. Means and P-values for comparisons among North Carolina families.

| Preselected Characteristic | Ave. limb diam. (in) | # limbs per tree | Form class (%) | Ht. live crown (ft) | Diam. largest branch (in) | Sweep (in) |
|---|---|---|---|---|---|---|
| Fast Growth | 0.85 | 25 | 73 | 18.8 | 1.2 | 1.2 |
| Slow Growth | 0.86 | 25 | 72 | 17.8 | 1.2 | 1.0 |
| P-value | .0222 | .7124 | .0132 | .0001 | .1697 | .0002 |
| Fast Growth, Small Crown | 0.84 | 24 | 74 | 18.4 | 1.2 | 1.1 |
| Fast Growth, Large Crown | 0.85 | 26 | 73 | 19.2 | 1.2 | 1.3 |
| P-value | .0494 | .0009 | .0584 | .0003 | .1479 | .0004 |
| Slow Growth, Small Crown | 0.86 | 26 | 73 | 18.1 | 1.2 | 1.1 |
| Slow Growth, Small Crown | 0.87 | 25 | 72 | 17.5 | 1.2 | 1.1 |
| P-value | .2719 | .0129 | .0739 | .0059 | .8192 | .9461 |

Table 5. Average limb diameter rankings of all families and their means for each spacing.

| 5 x 5 ft. | | 8 x 8 ft. | | 10 x 10 ft. | |
|---|---|---|---|---|---|
| Family | Mean* | Family | Mean* | Family | Mean* |
| 3-A | 0.76 A | 1-B | 0.82 A | 1-A | 0.89 A |
| 4-B | 0.76 A | 2-B | 0.82 A | 1-B | 0.91 AB |
| 4-A | 0.77 A | 3-A | 0.84 AB | 2-B | 0.91 AB |
| 1-A | 0.77 AB | 1-A | 0.84 AB | 3-A | 0.94 ABC |
| 2-B | 0.77 AB | 4-B | 0.85 AB | 4-B | 0.94 ABC |
| 2-A | 0.77 AB | 3-B | 0.85 AB | 3-B | 0.96 ABC |
| 3-B | 0.78 AB | 4-A | 0.87 AB | 2-A | 0.97 BC |
| 1-B | 0.79 AB | 2-A | 0.88 B | 4-A | 1.00 C |
| 5 | 0.80 B | 5 | 0.97 C | 5 | 1.10 D |

* Means followed by the same letters are not significantly different at alpha 0.01.

2. Wider spacings gave greater average limb diameter, more limbs, lower form class, less height to base of live crown, and greater diameter of largest branch than narrow spacings. However, sweep was not significantly different between spacings.

3. Generally, family characterization based on prior tests in North Carolina held true in this progeny test in Mississippi.

4. Family 1-A was the best overall family in the study for juvenile log quality, because it usually ranked high in each category.

5. In conclusion, selection for fast growth and small crowns will be effective in improving juvenile log quality, particularly at the wide spacings.

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