# GEOGRAPHIC VARIATION IN GROWTH AND WOOD QUALITY OF LOBLOLLY PINE IN NORTH CAROLINA

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## ABSTRACT

Two studies of geographic variation in growth and wood quality of young loblolly pines in North Carolina have indicated that the overall performance of coastal seed sources has been superior to that of Piedmont, sandhills and fall line seed sources. Coastal sources produced up to 12 per cent greater heights and up to 30 per cent greater volumes and dry weights than other sources. Variation in wood specific gravity and moisture content was primarily associated with plantation location, with all sources exhibiting their highest specific gravities and lowest moisture contents in coastal plantations. In a comparison of loblolly with slash pine in coastal and fall line plantations, loblolly sources were from 21 to 35 per cent taller, produced from 12 to 47 per cent greater volumes, and had from 7 to 38 per cent more dry weight than slash.

## INTRODUCTION

Recent information on geographic variation in the southern pines has indicated the possibility of important amendments to the hypothesis of the superiority of local seed sources. In a summary of the first ten years of the Southwide Pine Seed Source Study, Wells and Wakeley (1966) have stated the general conclusions that seedlings from western sources have demonstrated higher survival and lower fusiform rust (Cranartium fusiforme) infection than seedlings from more easterly sources. However, seedlings from coastal sources have usually grown faster than seedlings from inland sources. In a study of geographic variation of loblolly pine in Georgia, Kraus (1968) confirmed these results with only minor exceptions which were apparently due to local site conditions in the Georgia flatwoods. Coastal sources of loblolly pine planted in a 13-year-old plantation of the Southwide Pine Seed Source Study in Alabama have also exhibited greater volumes and dry weights than inland sources (Saucier and Taras, 1968). The two studies reported here present additional data illustrating geographic variation of loblolly pine in North Carolina for both wood and growth characteristics.

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## DESCRIPTION AND PROCEDURES

The two separate studies in this report have been summarized together because of similarities in objectives, designs, and results. The primary objective of both studies was to evaluate the effect of the seed source of loblolly pine on growth and wood quality in North Carolina. The first study (NCSU) was initiated from a series of six seed source areas, established as part of the variation studies summarized by Thorbjornsen (1960). These seed source areas were located on an east-west transect extending from the lower coastal plain to approximately the western limit of the natural range of the species. Each seed source area was composed of three natural stands, located at least one mile apart. Each of these stands was sampled with a collection of open-pollinated seed from five "accessible" trees within the stand. On the basis of topography and soils these seed source areas were grouped into the following provinces: coastal, areas 1(Jacksonville), and 6 (Magnolia); sandhills,3/ areas 7 (Cedar Creek), and 8 (Raeford); Piedmont, areas 9 (Rockingham), and 10 (Wadesboro)(Figure 1).

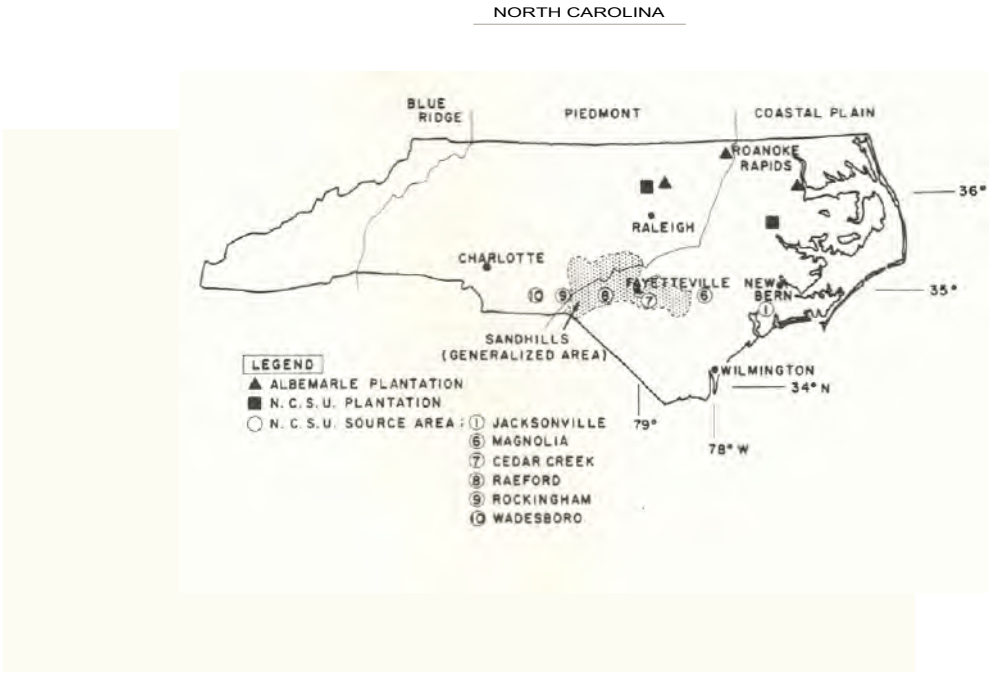


Figure 1. Plantation and source area locations

sandhills: a distinctive area of well-drained and excessively-drained soils located in the coastal plain-Piedmont transition zone in the southern part of the state. The characteristic soil association is Lakeland-Norfolk.

Seedlings from each of the source stands (a total of 18 individual stands) were planted in a randomized, complete-block design, at a 7 x 7-foot spacing, in square, 25-tree plots, replicated four times in each plantation. The coastal plantation located near Washington (Beaufort County) had a site index of 85 and moderately well drained soils, while the Piedmont plantation near Creedmoor (Granville County) had a site index of 80 and well drained soils. Both plantations were in the seventh growing season when the study data were obtained.

The second study (Albemarle) originated from industrial seed collections representing natural stands within coastal, fall line, 4 / and Piedmont provinces of the state. Seedlings from each source were planted with the use of the same plantation design as in the NCSU study, with plantations located in each of the three provinces (Figure 1). A commercial lot of slash pine (seed source unknown) was included in the coastal and fall line plantations. The coastal plantation located near Edenton (Bertie County) had a site index of 90 and was situated on imperfectly drained soils, while both fall line and Piedmont plantations had site indices of 85, with well drained soils. These were located near Roanoke Rapids (Halifax County) and Louisburg (Franklin County), respectively. These plantations were in the fifth growing season when the study data were obtained.

Due to the effects of planting mortality, widespread mouse damage, logging damage, fusiform rust infection, and differential competition, there was a great variation in the number of surviving trees on each plot in the NCSU study. Therefore, the ten largest trees in each plot were selected as the potential crop trees of the plantations. Each of these trees was felled, a wood disk from one to two inches in thickness was obtained at breast height, and the total height and diameter at one-half height was measured and recorded. The total number of trees measured and sampled in this study was 1,109. In the Albemarle study, heights and diameters at breast height were measured for all living trees in each plot (945 trees). Wood disks were obtained from four randomly selected trees per plot (192 trees). In order to make the two studies as comparable as possible, growth data from the Albemarle study were converted to a 10-crop-tree basis. (The bias resulting from this conversion appeared to be uniform for all sources.)

The methods of handling wood disks and subsequent laboratory analysis followed the procedures given by Zobel, et al. (1968). Because of the young age of the trees, only juvenile wood was obtained. Since previous studies had indicated only minor variation in the resin content of wood of young trees (e. g., Stonecypher and Zobel, 1966), only unextracted specific gravities were obtained. All moisture content percentages were calculated on a dry weight basis. Analyses of variance were calculated on the original area and seed source means, using a nested analysis procedure. Total tree wood volumes were

4/ Fall line: a poorly defined transition zone between the coastal plain and the Piedmont, characterized by topography and soils which are common to both provinces.

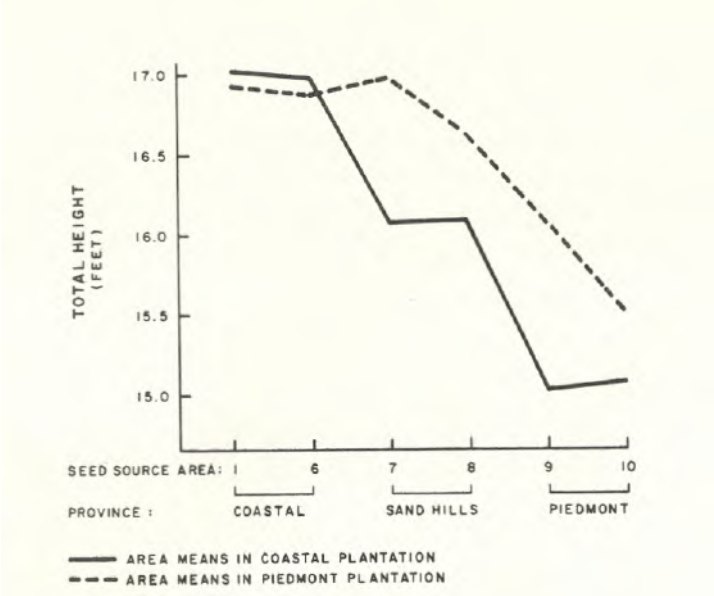


Figure 4. NCSU study: seed source area mean heights related to geographic origin

Wood Quality

There was a great amount of individual tree variation in both specific gravity and moisture content. On a plot-mean basis, however, the differences between sources within the same plantation were relatively slight. Significant differences in specific gravity and moisture content were observed between plantations in both studies. In each study, the highest specific gravity values and the lowest moisture contents were recorded in the coastal plantations. The highest moisture contents recorded in either study were those from the Albemarle fall line plantation, where all source means were greater than 200 per cent.

The frequently reported negative relationship between specific gravity and moisture content (Zobel, et al., 1968) was evident in these studies, with only a few minor exceptions. There appeared to be no meaningful relationships between either specific gravity or moisture content and the growth characteristics which were evaluated.

The economic importance of the volume and specific gravity differences between plantations became more evident when individual tree volumes were converted to dry wood weights per acre. (A hypothetical acre was assumed to contain 600 trees of the same dimensions and wood properties as those of the study trees.) In the NCSU study, a hypothetical coastal acre would have produced 6,016 pounds of dry wood while trees from the same sources planted

in the Piedmont would have produced 4,968 pounds, a difference of more than one-half ton of dry wood per acre in 7-year-old plantations (Table 1). The average yield of the coastal province for both plantations was 169 pounds more than the average yields of the sandhills province, and it was 1,067 pounds more than that of the Piedmont province. In the Albemarle study, coastal and Piedmont plantations would have produced about the same dry weight per acre, which amounted to 365 pounds more than the yield of the fall line plantation. The average yield of the coastal source for all plantations was about 101 pounds more than that of the Piedmont source and about 198 pounds more than that of the fall line source (Table 2).

Loblolly vs. Slash

The inclusion of a commercial lot of slash pine in the coastal and fall line plantations of the Albemarle study provided some interesting data on the comparative performance of the two species grown under the same environmental conditions. In the coastal plantation the mean height of all loblolly sources was 35 per cent greater than the slash mean height; and the coastal and Piedmont loblolly sources each averaged 42 per cent taller than the slash (Table 3, Figure 5).

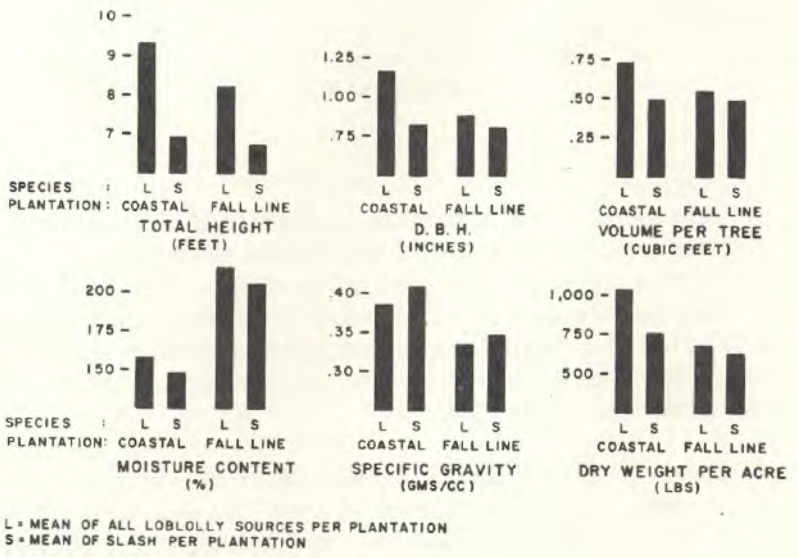


Figure 5. Albemarle study: growth and wood quality of loblolly and slash pine by plantation

The mean volume of all loblolly sources in the coastal plantation was 47 per cent greater than that of the slash, a rather large difference at six years of age. In the fall line plantation, loblolly sources exceeded the slash mean height by 22 per cent while the coastal and Piedmont sources combined were about 25 per cent taller. The mean volume of loblolly was 12 per cent greater than the slash in this plantation. Combining the data from both plantations resulted in a 29 per cent superiority in both height and volume of loblolly over slash. Slash exhibited a higher specific gravity and lower moisture content than any of the loblolly sources in both plantations.

When total tree dry weights for the two species were compared it was evident that the slightly higher specific gravity of the slash was relatively unimportant in comparison with the large volume superiority of the loblolly. For example, the loblolly with 47 per cent greater volume in the coastal plantation had 38 per cent more dry weight than slash, even though the latter had a higher specific gravity. On a per acre basis, the difference in dry weight between the species would be considerable, even at this age. As a hypothetical example, assuming 600 trees per acre of the same dimensions and wood properties as those in the coastal plantation, total yield of dry wood per acre of loblolly would amount to 1,031 pounds compared to 752 pounds from one acre of slash, or a difference of 279 pounds per acre. The often-mentioned early growth superiority of slash certainly does not apply to the conditions of this study. Although these plantations are far from the natural range of slash pine, the soils of the two plantations are typical of many areas in the South where slash has been extensively planted.

## DISCUSSION

### Growth

The small differences in growth characteristics between plantations in both studies do not seem unusual in view of the young age of the plantations (5 and 7 years) and the narrow range of site index (80 to 90). It does seem of interest that in the Albemarle study all sources, including the fall line source, grew slower in the fall line plantation than in other locations. This may have been the result of an unusual plantation site for which none of the three sources were well adapted.

The overall superiority of the coastal sources in both studies is in good agreement with the previously cited reports by Kraus, Saucier and Taras, and Wells and Wakeley. The fall line source, which might have been expected to demonstrate a wide adaptability to plantation location, recorded the poorest overall performance of any source in the Albemarle study. It is possible that heavy cutting **in** fall line areas has resulted in a depletion of the genetic quality of these stands. Since the soils in fall line areas are frequently better drained than those in adjacent areas, many fall line tracts are heavily

logged during wet weather. Under these circumstances, continued overcutting over a period of many years could be expected to reduce the genetic quality of the stands in this area.

Although detailed comparisons between individual seed source stands in the NCSU study were not made, seedlings from one of the coastal stands were outstanding in all characteristics. This source (one stand in the Jacksonville area) had the greatest mean height for both plantations combined and a relatively high specific gravity in both plantations. It is interesting to note that seedlings from this same county (Onslow) performed very well in several plantations of the Southwide seed source study (Wells and Wakeley, 1966). The Onslow County source ranked first in both height and volume in plantations in Alabama and Louisiana, first in volume and second in height in a Mississippi plantation, and first in height and third in volume in an Arkansas plantation.

The evaluation of wood quality often raises a question of the relative importance of the environment compared with the genetic characteristics of the stand. These studies present evidence that the environmental control of juvenile wood specific gravity is stronger than the genetic control. In both studies, differences in specific gravity between plantations were much greater than the differences between seed sources within plantations. The large within-plot variation should not be overlooked, however, as this provides the raw material for gains via individual tree selection. Furthermore, these studies should not be interpreted as evidence that meaningful differences in specific gravity do not exist between geographic areas within the state. The stands, areas, and commercial collections from which these studies originated were not intended to be representative samples of the natural populations of loblolly pine within the state.

The evidence relevant to the degree of genetic divergence of loblolly pine within the state appears to be inconclusive. Significant differences between sources within plantations were found in only one plantation (NCSU coastal). In this plantation each province appeared as a well-defined "step" in the relationship between seed source location and total height (Figure 4), indicating greater differences in height growth between provinces than within. On the other hand, the same relationship in the Piedmont plantation appeared to be clinal, with height growth primarily related to an environmental gradient. In the NCSU study, both coastal and Piedmont sources were taller in their "native" plantations than in other locations, indicating the possibility of adaptive differences in height growth. These growth patterns appear to indicate that there are geographically related genetic differences in growth within the species. It is not clear, however, whether these differences reflect racial, ecotypic, or clinal divergence within the species.

Although coastal sources have performed well in several locations in these studies, extreme caution should be exercised regarding the planting of coastal sources outside of their natural range. Even though coastal sources have

produced greater volumes of wood than Piedmont, fall line, or sandhills sources, these evaluations were made at only one-sixth to one-third of an "average pulpwood rotation." The risk of climatic and/or biotic disaster is always present with sources which are not endemic to their environment. The damage from a late frost, ice storm, prolonged drought, or severe insect or disease attack can easily erase the potential economic gain from higher growth rates. The previously mentioned evidence of genetic divergence within the species suggests that adaptive differences do exist between geographic areas of the state. Certainly some of these differences are in the form of "built-in insurance" for natural hazards to which the trees have been exposed and on which natural selection has acted. Until more definitive results are available from studies of older trees it does not seem advisable to plant non-native seedlings on a commercial basis.

## CONCLUSIONS

1. Within the state of North Carolina, coastal seed sources of loblolly pine have demonstrated the ability to grow more rapidly than sandhills, fall line, or Piedmont sources on a wide range of plantation locations. This faster growth was not associated with any reduction in wood quality.

2. The specific gravity and moisture content of juvenile wood of all sources was affected more by plantation location than by genetic differences between the seed sources.

3. The overall performance of all sources studied is indicative of local genetic differentiation within loblolly pine in North Carolina. There was little evidence of true geographic races.

4. Loblolly was far superior to slash pine in coastal and fall line plantations, producing up to 47 per cent greater volumes and 38 per cent more dry weight.

Table 1. NCSU Study: Growth and wood quality of coastal, sandhills, and Piedmont seed sources by plantation location

| | Plantation Location | Province | | | Plantation Means |
|---|---|---|---|---|---|
| | | Coastal | Sandhills | Piedmont | |
| Total Ht. (Ft.) | Coastal | 17.0 | 16.2 | 15.1 | 16.1 |
| | Piedmont | 16.8 | 16.8 | 15.8 | 16.5 |
| | Province Mean | 16.9 | 16.5 | 15.5 | |
| Dia. @ 1/2 Ht. (In.) | Coastal | 2.2 | 2.2 | 2.0 | 2.1 |
| | Piedmont | 2.0 | 2.0 | 1.9 | 1.9 |
| | Province Mean | 2.1 | 2.1 | 2.0 | |
| Vol. (Cu. Ft.) | Coastal | .494 | .452 | .376 | .440 |
| | Piedmont | .390 | .403 | .342 | .378 |
| | Province Mean | .442 | .427 | .359 | |
| Wood Moist. Cont. (%) | Coastal | 178 | 175 | 175 | 178 |
| | Piedmont | 189 | 193 | 188 | 190 |
| | Province Mean | 184 | 184 | 182 | |
| Wood Sp. Gr. | Coastal | .362 | .366 | .367 | .365 |
| | Piedmont | .350 | .350 | .352 | .350 |
| | Province Mean | .356 | .358 | .360 | |
| Wood Sp. Gr. (Lbs./Cu. Ft.) | Coastal | 22.6 | 22.8 | 22.9 | 22.8 |
| | Piedmont | 21.9 | 21.9 | 22.0 | 21.9 |
| | Province Mean | 22.2 | 22.3 | 22.5 | |
| Dry Wt./Tree (Lbs.) | Coastal | 11.2 | 10.3 | 8.6 | 10.0 |
| | Piedmont | 8.5 | 8.8 | 7.5 | 8.3 |
| | Province Mean | 9.8 | 9.6 | 8.1 | |
| Dry Wt./Acre (Lbs.) | Coastal | 6,696 | 6,187 | 5,165 | 6,016 |
| | Piedmont | 5,112 | 5,284 | 4,510 | 4,968 |
| | Province Mean | 5,904 | 5,735 | 4,837 | |

Note: Each province mean represents the mean value of the two seed source areas within the province.

Table 2. Albemarle Study: Growth and wood quality of coastal, fall line and Piedmont seed sources by plantation location

| | Plantation Location | Source | | | Plantation Means |
|---|---|---|---|---|---|
| | | Coastal | Fall Line | Piedmont | |
| Total Ht. (Ft.) | Coastal | 9.8 | 8.4 | 9.8 | 9.3 |
| | Fall Line | 8.4 | 8.0 | 8.3 | 8.2 |
| | Piedmont | 10.8 | 9.7 | 9.7 | 10.0 |
| | Source Mean | 9.6 | 8.7 | 9.2 | |
| Dia. @ B. H. (in.) | Coastal | 1.25 | 1.00 | 1.24 | 1.16 |
| | Fall Line | .90 | .81 | .92 | .88 |
| | Piedmont | 1.38 | 1.15 | 1.10 | 1.21 |
| | Source Mean | 1.18 | .99 | 1.09 | |
| Vol. (Cu. Ft.) | Coastal | .078 | .059 | .077 | .072 |
| | Fall Line | .055 | .051 | .056 | .054 |
| | Piedmont | .093 | .072 | .068 | .078 |
| | Source Mean | .075 | .061 | .067 | |
| Wood Moist. Cont. (%) | Coastal | 158 | 157 | 160 | 158 |
| | Fall Line | 221 | 209 | 215 | 215 |
| | Piedmont | 187 | 184 | 182 | 184 |
| | Source Mean | 189 | 183 | 186 | |
| Wood Sp. Gr. | Coastal | .388 | .385 | .383 | .385 |
| | Fall Line | .328 | .340 | .335 | .334 |
| | Piedmont | .360 | .358 | .370 | .363 |
| | Source Mean | .358 | .361 | .363 | |
| Wood Sp. Gr. (Lbs./Cu. Ft.) | Coastal | 24.19 | 24.04 | 23.88 | 24.04 |
| | Fall Line | 20.45 | 21.23 | 20.91 | 20.86 |
| | Piedmont | 22.48 | 22.32 | 23.10 | 22.63 |
| | Source Mean | 22.37 | 22.53 | 22.63 | |
| Dry Wt./Tree (Lbs.) | Coastal | 1.88 | 1.42 | 1.85 | 1.72 |
| | Fall Line | 1.13 | 1.08 | 1.17 | 1.13 |
| | Piedmont | 2.08 | 1.60 | 1.57 | 1.75 |
| | Source Mean | 1.70 | 1.37 | 1.53 | |
| Dry Wt./Acre (Lbs.) | Coastal | 1,131 | 853 | 1,109 | 1,031 |
| | Fall Line | 677 | 650 | 670 | 676 |
| | Piedmont | 1,250 | 959 | 944 | 1,051 |
| | Source Mean | 1,019 | 821 | 918 | |

Table 3. Albemarle Study: Growth and wood quality of loblolly and slash pine in two plantations

| | Plantation Location | Species | | Plantation Mean |
|---|---|---|---|---|
| | | Loblolly | Slash | |
| Total Ht. (Ft.) | Coastal | 9.3 | 6.9 | 8.0 |
| | Fall Line | 8.2 | 6.7 | 7.5 |
| | Species Mean | 8.8 | 6.8 | |
| Dia. @ B. H. (In.) | Coastal | 1.16 | .82 | .99 |
| | Fall Line | .88 | .80 | .84 |
| | Species Mean | 1.02 | .81 | |
| Vol. (Cu. Ft.) | Coastal | .072 | .049 | .061 |
| | Fall Line | .054 | .048 | .051 |
| | Species Mean | .063 | .049 | |
| Wood Moist. Cont. (%) | Coastal | 158 | 148 | 153 |
| | Fall Line | 215 | 205 | 210 |
| | Species Mean | 187 | 176 | |
| Wood Sp. Gr. | Coastal | .385 | .408 | .397 |
| | Fall Line | .334 | .348 | .341 |
| | Species Mean | .360 | .378 | |
| Wood Sp. Gr. (Lbs./Cu. Ft.) | Coastal | 24.04 | 25.44 | 24.74 |
| | Fall Line | 20.86 | 21.69 | 21.28 |
| | Species Mean | 22.45 | 23.57 | |
| Dry Wt./Tree (Lbs.) | Coastal | 1.72 | 1.25 | 1.49 |
| | Fall Line | 1.13 | 1.05 | 1.09 |
| | Species Mean | 1.43 | 1.13 | |
| Dry Wt./Acre (Lbs.) | Coastal | 1,031 | 752 | 892 |
| | Fall Line | 676 | 630 | 653 |
| | Species Mean | 854 | 691 | |

Note: Loblolly means = means of all loblolly sources in the respective plantation.

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