Wood Density and Percent Summerwood Variation Among Nine Loblolly Pine Seed Sources Grown in Alabama

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Since the establishment of the Southwide Pine Seed Source Study in 1951, information concerning racial difference in external characteristics of the major southern pines has become increasingly available. Equally important to woodland managers is information on the intrinsic qualities of the wood in the juvenile and mature parts of the trees. Such information can also be obtained from the Southwide Pine Seed Source Study now that most of the plantings have reached an age at which wood properties of the juvenile zone of the tree can be evaluated reliably. Numerous reports indicate that wood properties and anatomical characteristics vary over broad geographic areas (3, 4, 7, 13, 14, 15). This variation has been attributed to climatic and physiographic differences. Until now, few data have been obtained on the influence of racial factors on the intrinsic qualities of wood because of the limited availability of seed source study material. This paper presents data on wood density and percent summerwood variation from one central Alabama. planting of the Southwide Pine Seed Source Study.

PAST RESEARCH

Rees and Brown (8) report results of a 17-year-old red pine study in which the specific gravity of only one of 19 seed sources tested was significantly higher than all others. Echols (1) found highly significant variation in wood den s i ty among 15 seed sources of 17-year-old Scotch pine planted in New Hampshire, but he found no consistent trends associated with physiography or climate of provenances. Five-year-old loblolly from six seed sources examined by Thor and Brown (11) showed the wood density of one seed source to be significantly lower than three other sources. In 1967, Thor (10) re-examined the six seed sources after 10 years' growth and still found a significant difference in specific gravity between seed sources. He stated that the geographical trends did not follow those demonstrated for natural populations. Saucier and Taras (9) compared wood density among six seed sources of 8-year-old longleaf pine planted in Virginia. They found that one seed source (Florida) was significantly lower in wood density than all others, but evidence of frost damage in the plantation suggested that this difference in specific gravity was possibly associated with the lack of frost resistance in the Florida stock. A small but significant variation in wood density was reported by Goddard and Cole (5) in 5-year-old loblolly pine plantings that contained 18 seed sources from Georgia, South Carolina, and Florida. Gilmore **et al.** (2) showed no significant differences between seven loblolly pine seed sources grown in southern Illinois. They concluded that geographic race has little relation to specific° gravity.

Jackson and Strickland (6) reported results of a 22-year-old loblolly pine planting in Georgia that contained 10 seed sources. They found wood density significantly correlated with longitude and latitude of seed source origins. Wood density increased westward with longitude from South Carolina to Texas, and northward with latitude from Georgia and Alabama to Maryland. These geographic trends are the opposite of those found for natural stands by Zobel and McElwee (14) and Wheeler and Mitchell (13). It appears, from the variation in results now on record,' that additional seed source studies of wood density are needed to clarify this situation.

MATERIALS AND METHODS

The samples for this study were obtained from a planting of the Southwide Pine Seed Source Study located in Talladega County, Alabama. The planting was established jointly by TVA and Kimberly Clark Corporation during the 1952-53 planting season, and it has been maintained and periodically measured by Kimberly Clark foresters since that time. Nine seed sources were planted in a randomized, complete-block design with four replications. Each replication consists of 9 squares, each with 72 trees in border rows and 49 interior trees. Spacing is 6 x 6 feet. The seed sources represented in this planting are shown in figure 1 and listed below:

Alabama - Cullman County
Alabama - Jefferson County

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Arkansas - Clark County

Georgia - Wilcox and Crisp Counties

Louisiana - Livingston Parish

Maryland - Somerset County

North Carolina - Pamlico County

North Carolina - Onslow County

Texas - Angelina County

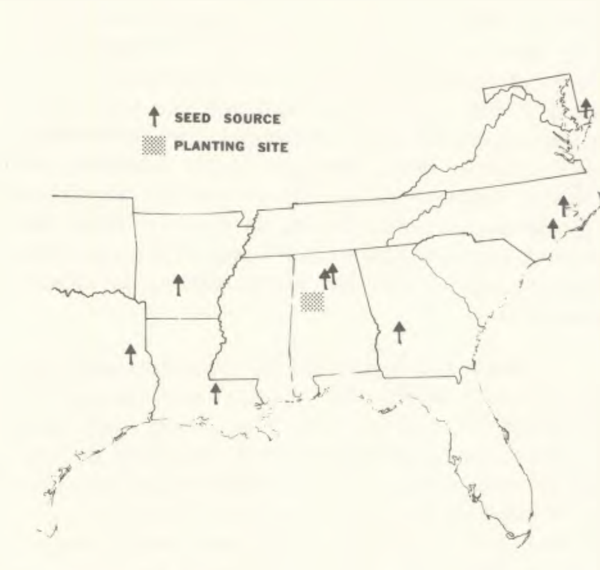

Figure 1.-Location of seed sources and planting site.

Prior to the loss of two replications of this planting in late 1965 from a marble-quarrying operation, 10 trees were randomly selected from all plots for a total study sample of 360 trees. The sample tree s were cut down and a single disc, 3 inches thick, was removed from each tree at a point 5.3 feet above the ground. The d.b.h. and total height measurements were also obtained. The field collection was carried out by personnel from the Institute of Forest Genetics in Gulfport. These s a m p l e s were shipped to the Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, Georgia, for analysis. At the time samples were col lected, the planting was in its thirteenth growing season (14 years from seed).

Percent summerwood and ring width measurements were made a cros s two opposing radii of the sample discs. The radii were chosen, after excluding areas containing compression wood, by randomly selecting a tra n se c t that passed through the pith. Measurements were made to the nearest 0.001 mm on a traversing dual-linear micrometer microscope.

Specific gravity was measured on two 45 degree wedges cut from each sample tree disc. Compression wood and knots were avoided when se l e c t i n g the wedge-shaped samples. Green volume was determined by the water displacement method and the ovendry weight was determined by drying to a constant weight at 105° C. Specific gravity was determined on unextracted material only.

RESULTS

The average d.b.h., total height, annual rings in cross section, and specific gravity of the sample trees a re presented in table 1. The most northern seed source (Maryland) had the highest average specific gravity of 0.435, while the Georgia seed source was lowest with 0.393. Excluding these high and low values, there was only a difference of 0.02 units in specific gravity separating the remaining seven seed source s. Analysis of variance for specific gravity (table 2) indicated a h i gh l y significant difference among seed sources, but a Duncan's multiple range test showed that the significant seed source difference was confined to the extreme values. That is, the Maryland seed source was significantly greater than only the Georgia seed source at the 5 percent level. The percent summerwood varied essentially in the same manner as specific gravity. The Maryland seed source had the greatest percent summerwood with 32 percent, and the Georgia seed source had the lowest with 22 percent. All other seed sources varied between 31 and 28 percent. Analysis of vari-

Table 1.--Average d.b.h., height, annual rings, percent summerwood, and specific gravity

Seed Source	D. B. H.	Hgt.	Rings in cross Sec.	Summer- wood	Specific Gravity 1/
	Inches	Feet	No.	Percent	Wt./vol.
Somerset Co., Md.	4.52	39.1	9.7	32	0.435
Onslow Co., N.C.	4.49	41.9	9.5	28	.426
Clark Co., Ark.	4.72	36.8	9.6	31	.424
Angelina Co., Texas	4.00	35.4	10.2	28	.422
Pamlico Co., N. C.	4.76	40.9	10.0	30	.417
Livingston Par., La.	4.54	40.9	10.2	31	.414
Jefferson Co., Ala. 2/	4.37	38.2	9.6	30	.412
Cullman Co., Ala.	4.46	37.1	10.1	28	.406
Wilcox & Crisp Co., Ga.	4.85	39.0	10.2	22	.393

1/ Green volume on ovendry weight basis.

2/ C-319, Local seed source.

Table 2.-Mean squares and test of significance for the analysis of variance of specific gravity and percent summerwood.

Source	d.f.	Specific gravity Mean squares	Percent summerwood Mean squares
Seed sources	8	0.005114**	0.027434
Replications	3	0.000996	0.013635
Experimental error	24	0.001093**	0.013972**
Sampling error	311	0.000370	0.004633

**Significant at 1 percent confidence level.

ance (table 2) for percent summerwood indicated a significant difference among seed sources at the 10 percent confidence level only. The experimental error for both specific gravity and percent summerwood was highly significant, indicating large individual differences among trees within plots.

Since gross wood yield is of primary importance for many uses, dry weight yields of seed sources were compared. These da to are presented in table 3, which lists seed sources ranked from high to low in mean specific gravity, tree volume, and tree dry weight.

Tree volumes were calculated by using the conical formula $0.001818D^2H$ where D= diameter inside bark of sample discs and H= total tree height. Dry weight per tree was computed as follows:

Dry weight, lbs. = 62.4 x specific gravity x tree volume cu. ft.

Table 3 shows considerable shifting of seed source ranks when specific gravity and tree volume are compared. The Maryland seed source, which ranked first in specific gravity, ranked seventh in tree volume, while Georgia, which ranked last in specific gravity, ranked first in tree volume. There was an overall tendency for seed sources which ranked high in specific gravity to rank lower in tree volume and vice versa. The rank of seed sources by tree dry weight changed slightly from that of tree volume. The east North Carolina source ranked fifth in specific gravity, second in volume, and first in dry weight. Other seed sources changed rank order as they reflected the composite effects of specific gravity and tree volume. Table 4 shows correlations for tree and wood characteristics and several physiographic and climatic factors. The physiographic and climatic factors in these correlations are those found at the points of origin of the respective seed sources. In this group of relationships, specific gravity and percent summerwood were found to be significantly correlated at the 5 percent confidence level (r = 0.758*) as were tree volume and tree dry weight with June-August rainfall (r = 0.654* and r=0.637*, respectively). The relationships between specific gravity and latitude, tree volume and longitude, and tree dry weight and longitude were not significant. In addition, specific gravity was negatively associated, but not significantly, with average annual temperature and January minimum temperature.

DISCUSSION

The nine seed sources in this planting had a

Table 3.- -Comparison of mean specific gravity, volume, and dry weight

Specific gravity		Tree Volume 1/		Tree Dry Weight 2/	
Source	**Wt/vol**	**Source**	**Cu. Ft.**	**Source**	**Pounds**
Somerset Co., Md.	0.435	Wilcox & Crisp Co., Ga.	1.86	Pamlico Co., **N.** C.	47.36
Onslow Co., N. C.	.426	Pamlico Co., N. C.	1.82	Wilcox & Crisp Co., Ga.	45.61
Clark Co., Ark.	.424	Livingston Par.,La..	1.69	Onslow Co., N. C.	43.86
Angelina Co., Texas	.422	Onslow Co., N. C.	1.65	Livingston Par., La.	43.66
Pamlico Co., N. C.	.417	Clark Co., Ark.	1.64	Somerset Co., Md.	43.43
Livingston Par., La.	.414	Cullman Co., Ala.	1.64	Clark Co., Ark.	43.39
Jefferson Co., Ala. 3/	.412	Somerset Co., Md.	1.60	Cullman Co., Ala.	41.55
Cullman Co., Ala.	.406	**Jefferson Co., Ala.**	1.40	**Jefferson Co., Ala.**	35.99
Wilcox & Crisp Co., Ga.	.393	Angelina Co., Texas	1.19	Angelina Co., Texas	31.33

1/ Volume in cubic feet=$0.001818D^2H$.

2/ Dry weight = 62.4 x specific gravity x volume.

3/ C-319, Local seed source.

Table 4.--Correlations among plot means for relation. ships between tree and wood traits and vari. ous physiographic and climatic factors at seed source origin.

Specific gravity x percent summerwood	.758*
Specific gravity x d.b.h.	-.336
Specific gravity x total height	.060
Specific gravity x latitude	.532
Specific gravity x longitude	-.235
Specific gravity x average annual temperature	-.496
Specific gravity x January minimum temperature	-.532
Specific gravity x annual precipitation	-.448
Specific gravity x June-August rainfall	-.1 50
Specific gravity x frost free season	-.144
Volume x latitude	.215
Volume x longitude	-.495
Volume x average annual temperature	.050
Volume x January minimum temperature	.105
Volume x annual precipitation	.193
Volume x June-August rainfall	.654*
Volume x frost free season	.125
Dry weight x latitude	.358
Dry weight x longitude	-.567
Dry weight x average annual temperature	-.082
Dry weight x January minimum temperature	-.033
Dry weight x annual precipitation	.097
Dry weight x June-August rainfall	.637*
Dry weight x frost free season	.006
Percent summerwood x latitude	.387
Percent summerwood x longitude	-.020
Percent summerwood x annual temperature	-.495
Percent summerwood x January minimum temperature	-.477
Percent summerwood x annual precipitation	.060
Percent summerwood x June-August rainfall	-.109
Percent summerwood x frost free season	-.160

*Significant at the 5 percent confidence level.

relatively narrow range of variation in specific gravity and percent summerwood after 14 years. Only two sources varied significantly from each other in specific gravity, and none in percent summerwood. Specific gravity and percent summerwood of the various seed sources tended to be associated with latitude, increasing from south to north (r = 0.532 and 0.387) but these were not significant. These trends are similar to those found by Jackson and Strickland (6) and others. On the other hand, volume tended to be associated with longitude, decreasing from east to west (r = -0.495). Tree dry weight reflects both specific gravity and tree volume, but this factor is more strongly associated with longitude, decreasing from east to west. The correlation of r = -0.567 was not significant.

These two weak trends, that is, specific gravity increasing from south to north, and volume from west to east, suggest that dry weight production should be highest from seed sources obtained in the eastern part of the species range. Such is the case since four of the first five seed sources in order of dry weight production are from this area.

Specific gravity did not vary with physiographic location of seed source origins but tree volume and tree dry weight did. The high values for dry weight were associated with coastal sources while the lower values were from inland sources. Wells and Wakeley (12), in their study of loblolly pine seed sources, showed similar growth responses; that is, trees from areas with wet summers and warm winters grew faster than those from areas with dry summers and cold winters. Areas with wet summer and Moderate winter temperatures were mostly coastal. Of interest also was the significant correlation (r=0.654*) between tree volume and June-Augusi rainfall. Trees from high rainfall seed sources tended to hive greater volume growth, lower percent summerwood, and low specific gravity, but they are superior to other sources on a dry weight basis. Because these data are based on young material, it is likely that this correlation will change as percent summerwood increases with tree age.

SUMMARY AND CONCLUSIONS

In a 14-year-old planting of nine seed sources in Alabama, only the Maryland source had significantly higher specific gravity than one other source (Georgia).. There was no significant difference in percent summerwood, wood volume, or dry weight.

There were no clear-cut trends in geographic variation, but specific gravity and percent summerwood tended to be associated with latitude, increasing from south to north, while volume and dry weight tended tc be associated with longitude, decreasing from east to west.

High volume and, consequently, dry weight were associated with coastal seed sources, while the lower volumes were from inland sources. Trees from high rainfall sources tended to have greater volume growth, lower percent summerwood, and lower specific gravity, but they were superior to other sources on a dry weight basis. Performance of the local seed source was below average in all properties examined in this study.

Performance of coastal North Carolina seed sources was above average in all properties examined. The southwest Georgia seed source ranked first in volume and last in specific gravity, but in spite of its low specific gravity, it ranked second in wood dry weight.

It would be premature at this early plantation age to recommend non-local seed sources for this planting site. As evidence like this begins to accumulate, however, such practices may become advisable for some areas.

The genetic component of geographic variation in specific gravity does not appear to be large. If non-local seed are procured for the purpose of improving dry weight production, attention should be focused on those seed sources that exhibit above average tree characteristics of diameter, height, and taper.

LITERATURE CITED

1. *Echols, R. M.*
   1958. Variation in tracheid length and wood density in geographic races of Scotch pine. Yale Sch. Forest. Bull. 64,52 pp,

2. *Gilmore,* A. *R., S.* G. Boyce, *R. A.* Ryker
   1966. The relationship of specific gravity of loblolly pine to environmental factors in southern Illinois Forest Sci. 12: 399-405.

   Gilmore, A. R., G. E. Metcalf and W. R. Boggess.
   1961. Specific gravity of shortleaf pine and loblolly pine in southern Illinois. J. Forest. 59: 894-896.

4. Goddard, *R. E. and R. K. Strickland.*
   1962. Geographic variation in wood specific gravity of slash pine. TAPPI 45(7): 606-608.

5. *Goddard, R. E. and D. E.* Cole.
   1965. Variation in wood production of six-year-old progenies of selected slash pine TAPPI Third ForestiBiol. Conf. Proc.

6. *Jackson, L. W. R. and R. K. Strickland.*
   1962. Geographic variation in tracheid length and wood density of loblolly pine. Ga. Forest Res. Counc., Res. Pap. 8, 4 pp.

7. *Larson, Philip R.*
   1957. Effects of environment on the percentage of summerwood and specific gravity of slash pine. Yale Sch. Forest. Bull. 63, 89 pp.

8. *Rees, L. M. and R. M. Brown.*
   1954. Wood density and seed sources in young plantation red pine. J. Forest. 52: 662-665.

9. Saucier, *J. R. and M. A.* Taras.
   1966. Wood density variation among six longleaf pine seed sources grown in Virginia. J. Forest. 64: 463-465.

10. *Thor, Eyvind.*
    1967. A ten-year-old labially pine seed source test in Tennessee. J. Forest. 65:326-327.

77. Thor, *Eyvind and Shelby Brown.*
    1962. Variation among six loblolly pine provenances tested in Tennessee. J. Forest. 60:476-480.

12. *Wells, Osborn O . and P.* C. *Wakeley.*
    1966. Geographic variation in survival, growth, and fusiform-rust infection of planted loblolly pine. Forest Sci. Monogr. 11, 40 pp., illus.

13. Wheeler, *P. R. and H. L. Mitchell.*
    1959. Specific gravity variation in Mississippi pines. Fifth South. Conf. on Forest Tree Impr. Proc. pp. 87-96.

14. *Zobel; B. J. and Robert L.* McElwee.
    1958. Natural variation in wood specific gravity in loblolly pine (**Pinus taeda L.)** to growth and environmental factors. TAPPI 41(4): 158-161.

75. Zobel, *B. J., E. Thorbjornsen, and F. Henson.*
    1960. Geographic site and individual tree variation in wood properties of loblolly pine. Silvae Genet. 6: 149-158.