Twenty-year Results of a Shortleaf Pine Seed Source Study in Oklahoma

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Twenty-year Results of a Shortleaf Pine Seed Source Study in Oklahoma[1]

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Shortleaf pine (*Pinus echinata* Mill.) has the largest geographic range of the four major southern pines. It also has a large elevational range, growing from near sea level to about 3,300 feet. Generally, a species with such a large and varied range can be expected to possess substantial genetic variability. In the multitude of environments in which shortleaf pine grows, much of the variation the species displays may be due to the environment or the interaction of genotype and environment. Thus, it is necessary to conduct controlled tests to determine what amount of the variation observed is genetic and what is environmental. A common method used to make this distinction is provenance (seed source) testing. This is a report of the twenty-year results of such a seed source test of shortleaf pine grown in Oklahoma.

The material used in this study is a part of the Southwide Pine Seed Source Study initiated in 1951 by the Committee on Southern Forest Tree Improvement. The objective of the committee was to determine the degree to which inherent geographic variation in the four major southern pines is associated with geographic variation in climate and physiography. Information derived from seed source studies is useful in determining if local sources are the best to use in developing tree improvement strategies, and in identifying appropriate seed sources for growing planting stock. Since shortleaf pine is a major component of much of Oklahoma's commercial forests, this information can be very useful in improving the productivity of these forests.

Materials and Methods

Two shortleaf pine plantings representing transects of the Southwide Pine Seed Source Study were established in Oklahoma in 1957-58 by the late Dr. Michel Afanasiev. The Pushmataha County planting, established in 1957 with 1-0 seedlings, represents a north-south transect across the shortleaf pine range. The McCurtain County planting, established in 1958 with 1-1 stock, represents an east-west transect

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across the range of shortleaf pine. Six seed sources are represented in each planting (see Table 1), with an Ashley County, Arkansas and a Clarke County, Georgia source common to both plantings. The location of and climatic factors at the ten shortleaf pine seed sources are presented in Figure 1 and Table 1.

The plantation design employed was a randomized complete block with four blocks. Seed sources were represented by square plots of 11 by 11 trees spaced six by six feet. The Ashley County, Arkansas plot in block four of the McCurtain County planting was not planted because of a shortage of seedlings.

Data were collected from these two plantations as follows: tree heights at age 3, 5, 10, 15, and 20; DBH at age 10, 15, and 20; percent rust infected and specific gravity at age 10 and 20; and flowering and trachied length at age 10. The ten-year data have been reported by Posey and McCullough (1969).

For specific gravity determination at age twenty, one 5 mm increment core was taken at DBH from each of ten dominant or co-dominant trees in each plot. Specific gravity for each source in each planting was thus based on a sample of 40 cores. Specific gravity was determined by the maximum moisture content method (Smith, 1954). The cores were then resaturated under vacuum and extracted with alcohol-benzene using a modified ASTM (1954) procedure as described by Goggans (1962). Extractive free wood specific gravity was then determined by the maximum moisture content method. Extractives include all resin acids, essential oils, fats, fatty acids, and unsaponifiable water removable through the extraction process. This was the same procedure Posey and McCullough (1969) used to determine specific gravities at age ten, except that their core samples were taken at one foot and they took two cores per tree.

All statistical tests were conducted at the .05 level of significance. Data of each parameter were subjected to analysis of variance, with plot means as the analysis units. Simple correlations of twenty-year plot mean data with earlier measurements and with climatic factors of the seed source origins were computed. Cubic foot volume was computed using the formula:

$$\text{Vol} = -.32 + .00226\ D^2H$$

developed by Gingrich (1962) for estimating merchantable volume with a minimum top diameter of three inches.

Since the two plantations were established in different years with different age planting stock, data were analyzed and will be presented separately by plantation. All discussion relates to twenty-year data unless otherwise stated.

Results and Discussion

Survival

Ten-year survival was discussed by Posey and McCullough (1969). They noted an east-west trend in the McCurtain County planting with western sources showing higher survival. Survival ranged from 67 percent for the Clarke County, Georgia sources in the east to 84 percent for the local source in the west. No north-south trend in survival was noted in the Pushmataha County planting, with survival by source ranging from 86 to 92 percent. Since the plantations were thinned immediately follow-

Table 1. Location and climatic factors of the shortleaf pine seed origins by plantation and transect.*

Seed Source	Latitude	Longitude	Annual Temp °F	January Minimum Temp °F	Annual Precip Inches	Jan-Apr Precip Inches	June-Aug Precip Inches	Frost Free Season Days
McCurtain planting: E-W transect								
Pushmataha Co., OK	34°03′	94°48′	61.8	32.0	54.0	18.5	12.6	227
Ashley Co., AR	33°02′	91°56′	64.8	36.2	49.1	20.5	9.4	228
Tallapoosa Co., AL	32°45′	85°40′	65.2	39.1	52.8	21.6	13.8	237
Clarke Co., GA	34°00′	83°30′	60.2	33.3	53.7	20.5	14.0	213
Putnam Co., GA	33°15′	83°25′	62.7	34.8	49.9	19.7	12.6	217
Union Co., SC	34°50′	81°40′	63.2	34.1	46.7	16.3	13.4	221
Pushmataha planting: N-S transect								
Cherokee Co., TX	31°45′	95°00′	65.6	38.8	48.3	17.8	9.2	236
Ashley Co., AR	33°02′	91°56′	64.8	36.2	49.1	20.5	9.4	228
Clarke Co., GA	34°00′	83°30′	60.2	33.3	53.7	20.5	14.0	213
McCurtain Co., OK	34°03′	94°48′	61.8	32.0	54.0	18.5	12.6	227
Anderson Co., TN	36°12′	84°05′	59.3	31.1	45.5	17.7	11.6	217
Franklin Co., PA	39°52′	77°33′	53.0	23.6	36.0	10.7	10.6	201

*Source: Posey and McCullough (1969)

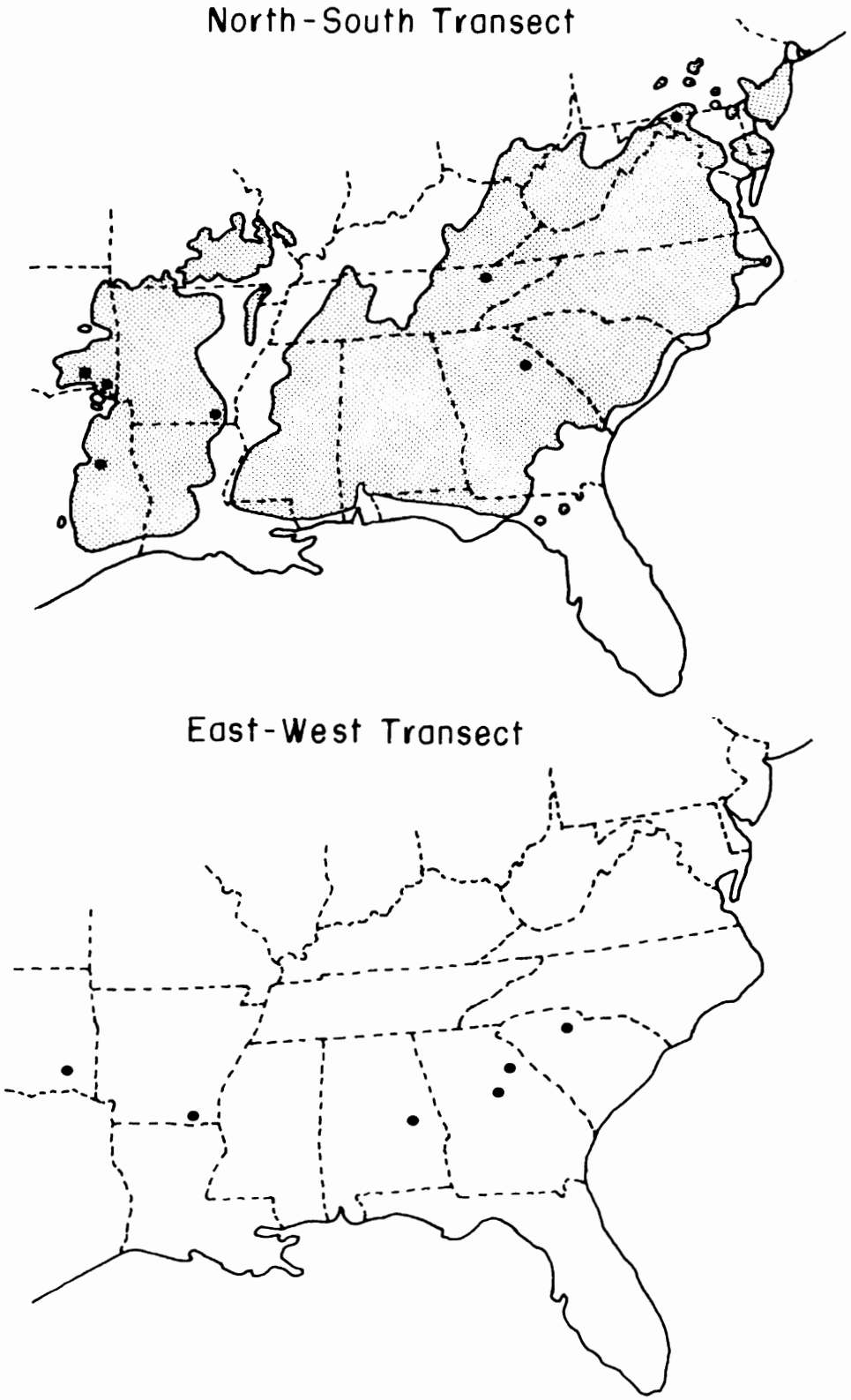

Figure 1. Seed sources (large black dots) by transect, and on the North-South Transect map planting location (black square) and species range (shaded area).

ing collection of the ten-year data, further information concerning source survival is not available. Also, because of thinning, volume and wood yield comparisons at age twenty were not made on a per acre basis.

Height and Diameter Growth

Average height and diameter by seed source for both plantations are shown in Table 2. In the McCurtain County plantation, mean seed source height at age twenty ranged from 35.4 feet for the Tallapoosa County, Alabama source to 40.2 feet for the Ashley County, Arkansas source. The differences among seed sources was determined to be significant by analysis of variance. Duncan's new multiple range test was used to separate the means and is included in Table 2. The Ashley County, Arkansas seed source was significantly taller than the two Georgia and the Alabama seed sources, but was not significantly taller than the local Pushmataha County, Oklahoma source.

Diameter growth in the McCurtain County plantation ranged from 7.8 inches for the Clarke County, Georgia source to 6.9 inches for the Putnam County, Georgia source. Analysis of variance showed these differences to be significant, and means were separated using Duncan's new multiple range test (Table 2). The largest diameter source from Clarke County, Georgia was significantly larger than the local source. It was not taller, however, and the tallest source was similar to the local source in diameter.

Height growth in the Pushmataha County plantation ranged from 41.3 feet for the Franklin County, Pennsylvania source to 48.7 feet for the Ashley County, Arkansas source. The differences among seed sources were significant, and means were separated using Duncan's new multiple range test (Table 2). The Ashley County, Arkansas source was again the tallest, but again was not significantly taller than the local Oklahoma source. The Franklin County, Pennsylvania source, the most northern source by 3° 40′ latitude, was significantly shorter than all other sources. Performance of all sources from west of the Mississippi River was approximately similar.

Diameter growth in the Pushmataha County plantation ranged from 6.5 inches in the Tennessee and Pennsylvania sources to 7.2 inches for the Clarke County, Georgia source. This Clarke County, Georgia source was significantly larger in DBH than the local, Oklahoma source, as it was in the McCurtain County plantation. Again, however, it was not taller than the local source and again the tallest source was not larger in DBH than the local Oklahoma source.

Correlations of twenty-year growth data with latitude, longitude, and climatic factors of seed source origins were computed to look for growth trends along the transects the plantations represent. The McCurtain County planting, representing an east-west transect, showed no significant correlations of growth data with latitude or any of the climatic data listed in Table 1.

In the Pushmataha County plantation, which represents a north-south transect across the range of shortleaf pine, a significant and very high negative correlation ($r = -.958$) was found between height and latitude. This relationship is depicted in Figure 2. Latitude accounts for 92 percent of the variation observed in height growth among the sources represented. A significant and positive correlation of longitude with height was also noted, but was discounted by partial correlation analysis as being an artifact of a chance high simple correlation between latitude and longitude. The relationship of

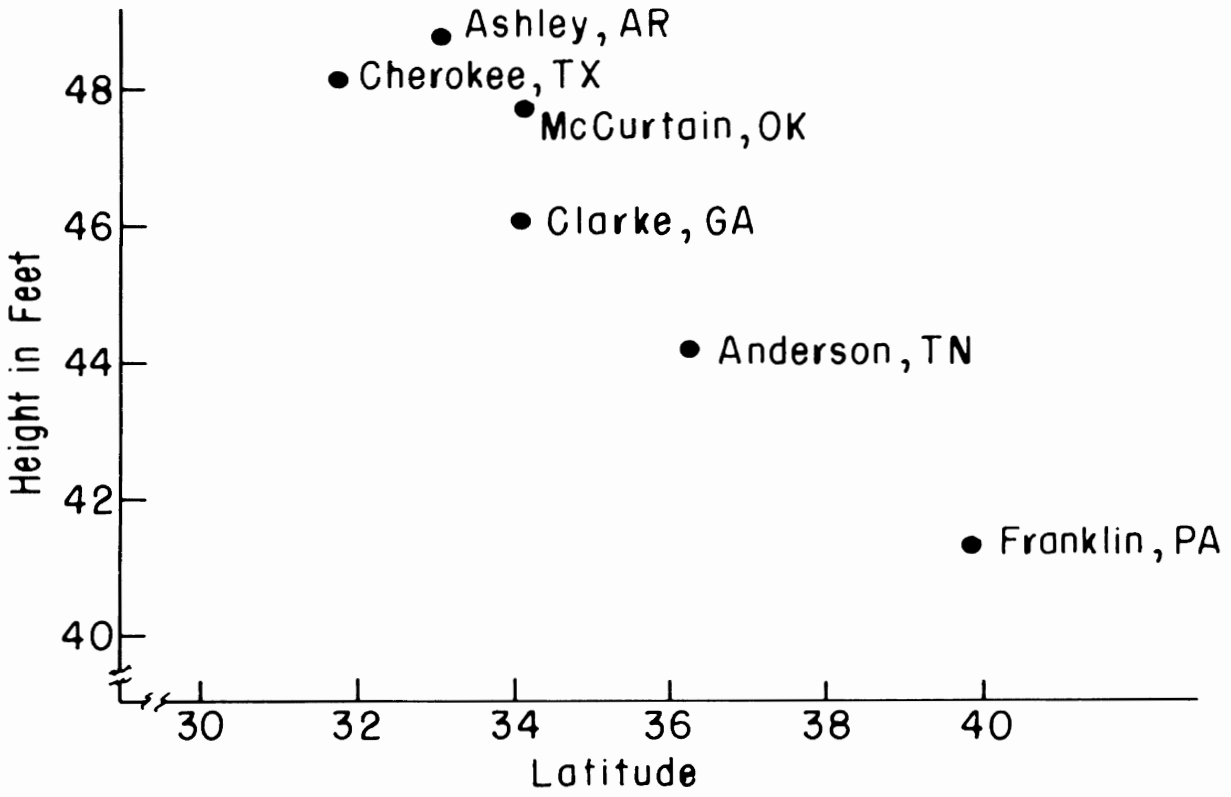

FIGURE 2: Relationship of latitude of seed origin and tree height in the Pushmataha County plantation.

height with latitude suggests a north to south trend in growth rate. The further north a seed origin is from the planting site, the less it grew in height at the Oklahoma site. Height was also correlated with average annual temperature (r = .962), January minimum temperature (r = .908), frost-free days (r = .908) and January to April precipitation (r = .828). These same relationships were reported by Wells (1973) for all 16 of the Southwide Study sources. All these relationships seem to reflect the same north-south growth trend.

Eastern Gall Rust

Eastern gall rust (*Cronartium quercuum* Berk.) was noted in the plantations and a summary of percent trees infected is presented in Table 2. Percent trees infected in the Pushmataha County plantation ranged from zero percent on the Oklahoma and Pennsylvania sources to 2.1 percent on the Anderson County, Tennessee source. These differences were not significant. Considerably more rust was noted in the McCurtain County planting. Infection ranged from 15.6 percent on the South Carolina source to 27.1 percent on the local Oklahoma source. Percent infection was significantly and positively correlated with longitude (r = .936), suggesting the more western sources were more susceptible to infection. The large difference in infection levels between the two plantations is probably environmental, as the two sources common to both plantations were infected in the McCurtain County planting and not infected in the Pushmataha County planting.

Specific Gravity and Extractives

Source average specific gravity values are based on 40 increment core samples taken from 40 trees at DBH. Gilmore *et al.* (1961) have shown a correlation of 0.80 between single core (at DBH) and whole-tree specific gravity estimates for young trees (age 17 years). As the trees in this study were 20 years old, and the specific gravity estimates are based on a large sample of cores, these values should be good estimates of the relative specific gravities of the seed sources.

Specific gravities of unextracted and extractive free wood of the seed sources in the Pushmataha County plantation are presented in Table 3. No significant differences among sources in either unextracted or extracted specific gravities were found. The correlation between specific gravity and latitude was very low ($r = .284$) and was not significant. This supports the observation by Gilmore (1963), that north-south differences in specific gravity are due to physiography and climate, rather than genetics. Posey and McCullough (1969) reported significant differences in specific gravity among these sources at age ten using cores taken at one foot. Possibly, their data reflects juvenile differences not carried over to mature wood, or their larger sample size provided a more sensitive test. Also, there were real changes in the rank of sources by specific gravity since age ten. The Ashley County, Arkansas source, with the highest specific gravity at age ten, dropped to third highest at age twenty, and is now exceeded by the local source and the Pennsylvania source.

Specific gravities of unextracted and extractive free wood for the seed sources in the McCurtain County planting are given in Table 4. Analysis of variance showed specific gravity to be significantly different among seed sources both before and after extraction. Duncan's new multiple range test (Table 4) of extracted mean specific gravity data showed the Ashley County, Arkansas source to have significantly higher specific gravity than all other seed sources in the planting, except for the local Pushmataha County, Oklahoma source. As in the Pushmataha County planting, the Ashley County, Arkansas source in this planting, at age 20, no longer holds the obvious superiority in specific gravity to local sources that it held at age ten.

The influence of extractive content on ranking of seed sources by specific gravity was slight, inverting the rank of several sources in each plantation. These data do, however, agree with the observation by Posey and McCullough (1969) that comparisons of specific gravity among seed sources may not be valid for unextracted specific gravity data.

Volume and Wood Yield.

The plantations were thinned at age ten, so differences in survival at age 20 do not necessarily reflect real source differences. Therefore, volume and wood yield were computed on an average per tree by source basis. Wood yield was computed to account for differences in specific gravity among sources by multiplying volume by extracted specific gravity by 62.4 lbs. Volume and wood yield data are presented in Table 5.

Volume was significantly and negatively correlated with latitude ($r = -.819$) in the Pushmataha County plantation. This relationship was lost when volume was converted to wood yield, reflecting specific gravity's independence of latitude. Volume and wood yield were not correlated to climatic or physiographic factors in the McCurtain County east-west transect plantation.

Table 2: Seed source mean height, diameter, and percent *Cronartium* infection for McCurtain and Pushmataha plantations.

McCurtain County Plantation				Pushmataha County Plantation			
Seed Source	Height (ft.)*	DBH (inches)*	Percent Cronartium	Seed Source	Height (ft.)*	DBH (inches)*	Percent Cronartium
Pushmataha Co., OK	37.6^{ab}	7.0^{bc}	27.1	Cherokee Co., TX	48.1^{a}	6.8^{bc}	1.1
Ashley Co., AR	40.2^{a}	7.4^{abc}	21.3	Ashley Co., AR	48.7^{a}	7.0^{ab}	1.1
Tallapoosa Co., AL	35.4^{b}	7.0^{bc}	18.5	Clarke Co., GA	46.1^{ab}	7.2^{a}	1.1
Clarke Co., GA	36.3^{b}	7.8^{a}	18.1	McCurtain Co., OK	47.7^{a}	6.7^{bc}	0
Putnam Co., GA	35.8^{b}	6.9^{c}	18.7	Anderson Co., TN	44.2^{b}	6.5^{c}	2.1
Union Co., SC	37.1^{ab}	7.5^{ab}	15.6	Franklin Co., PA	41.3^{c}	6.5^{c}	0

*Means not followed by the same letter are significantly different by Duncan's test.

Table 3: Specific gravity of unextracted and extractive free wood of six seed sources at age 20, Pushmataha Co. plantation.

Seed Source	Unextracted Sp. Gr.	Rank	Extractive Content	Extracted Sp. Gr.	Rank	Extracted Sp. Gr. Rank at age 10*
McCurtain Co., OK	0.480	1	0.056	0.424	1	3
Ashley Co., AR	0.472	2	0.053	0.419	3	1
Franklin Co., PA	0.466	3	0.044	0.422	2	2
Clarke Co., GA	0.458	4	0.043	0.415	4	5
Cherokee Co., TX	0.455	5	0.047	0.408	5	6
Anderson Co., TN	0.453	6	0.047	0.406	6	4

*From Posey and McCullough (1969); cores taken at 1 foot above ground.

Table 4. Specific gravity of unextracted and extractive free wood of six seed sources at age 20, McCurtain Co. plantation.

Seed Source	Unextracted Sp. Gr.	Rank	Extractive Content	Extracted Sp.Gr.*	Rank	Extracted Sp. Gr. Rank at age 10**
Ashley Co., AR	0.456	1	0.042	0.414[a]	1	1
Pushmataha Co., OK	0.450	2	0.046	0.404[ab]	2	2
Union Co., SC	0.436	3	0.041	0.395[b]	3	3
Putnam Co., GA	0.434	4	0.051	0.383[b]	6	5
Clarke Co., GA	0.432	5	0.046	0.386[b]	4-5	6
Tallapoosa Co., AL	0.426	6	0.040	0.386[b]	4-5	4

*Means not followed by the same letter are significantly different by Duncan's test.
**From Posey and McCullough (1969); cores taken at 1 foot above ground.

Table 5: Average Volume and Wood Yield per Tree by Plantation and Seed Source.

McCurtain County Plantation			Pushmataha County Plantation		
Seed Source	**Vol. (cu.ft.)***	**lbs. Wood***	**Seed Source**	**Vol. (cu.ft.)***	**lbs. Wood***
Ashley Co., AR	4.929[ab]	126.9[a]	Clarke Co., GA	5.491[a]	141.2[a]
Clarke Co., GA	5.034[a]	120.9[a]	Ashley Co., AR	5.299[a]	138.6[a]
Union Co., SC	4.711[ab]	116.5[ab]	McCurtain Co., OK	4.779[a]	126.4[a]
Pushmataha Co., OK	4.107[ab]	104.2[ab]	Cherokee Co., TX	4.937[a]	125.5[a]
Tallapoosa Co., AL	3.881[b]	93.6[b]	Anderson Co., TN	4.051[b]	102.3[b]
Putnam Co., GA	3.869[b]	92.6[b]	Franklin Co., PA	3.808[b]	100.5[b]

*Means not followed by the same letter are significantly different by Duncan's test.

Table 6: Simple correlations of twenty year data with earlier measurements.

McCurtain County Plantation					Pushmataha County Plantation				
	20 Year Data					20 Year Data			
Height at	Ht.	DBH	Vol.	Sp.Gr.	Height at	Ht.	DBH	Vol.	Sp. Gr.
age 3	.34	.11	.16	-.04	age 3	.38	.17	.27	.27
5	.53*	.37	.43*	.04	5	.73*	.40*	.57*	-.09
10	.83*	.63*	.76*	.31	10	.90*	.38	.63*	-.05
15	.90*	.60*	.76*	.32	15	.93*	.55*	.75*	-.14
DBH at					DBH at				
age 10	.50*	.86*	.81*	.21	age 10	.66*	.64*	.73*	-.14
15	.59*	.96*	.91*	.13	15	.62*	.92*	.91*	-.18

*Significant at .05 level or lower.

Analysis of variance showed both volume and wood yield to differ significantly among seed sources in both plantations. Duncan's new multiple range test was used to separate means for these parameters, and the results are presented in Table 5. The Ashley County, Arkansas and Clarke County, Georgia sources, which happened to be common to both plantings, yielded the highest per tree pounds of wood in both plantings. In the McCurtain County plantation, the best source exceeded the local source in wood yield by 23 percent. In the Pushmataha County plantation, the best source exceeded the local source by 12 percent. In both plantations, however, the best sources were not significantly better than the local sources. Since drought is a critical regeneration problem in Oklahoma, the lower survival of eastern sources reported by Posey and McCullough (1969), coupled with the twenty-year growth data, suggest one should favor use of western sources (probably west of the Mississippi) for planting in Oklahoma. These observations are in agreement with the seed zone recommendations established and discussed by Wells (1969, 1978).

Correlations of Growth Over Time

Simple correlations computed between twenty-year data and earlier measurements are presented in Table 6. The correlations increased with age for height, diameter, and volume, as expected, since such measures are summations of annual effects. Of note is the fact that measures preceding age five did not reliably reflect growth at age 20. Only from age five on were height, diameter, and volume significantly correlated with twenty-year data. Of particular interest was the lack of relationship between specific gravity and the growth parameters, suggesting no relation between growth rate and specific gravity, in agreement with a Missouri study reported by Ralston and McGinnes (1964) and a range-wide study by Wells (1973).

Conclusions

The relative performances of the seed sources in this study at age 20 have not changed substantially since age 10 as reported by Posey and McCullough (1969). There is a definite north-south trend in height/growth and volume produced with sources from further north producing less when grown in Oklahoma. There is no discernible east-west trend. However, considering ten-year survival, the data suggest seed zones and seed interchangeability for shortleaf pine, as outlined by Wells (1969, 1978), are quite appropriate.

There are no apparent geographic trends in specific gravity which are genetic, although some real differences among sources exist. The specific gravity data also suggest that at least for the shortleaf pine sampled, specific gravity is independent of growth rate, an important consideration in tree improvement.

The local seed sources were statistically as productive as all other sources tested when comparing both volume and actual pounds of wood produced. However, some sources of similar latitude to the local sources have, since age ten, consistently produced as much or more wood than the local sources. Use of these sources, provided high survival can be obtained, will provide additional useful genetic variation in a breeding program in Oklahoma. The Ashley County, Arkansas source appears especially productive on the Oklahoma sites tested.

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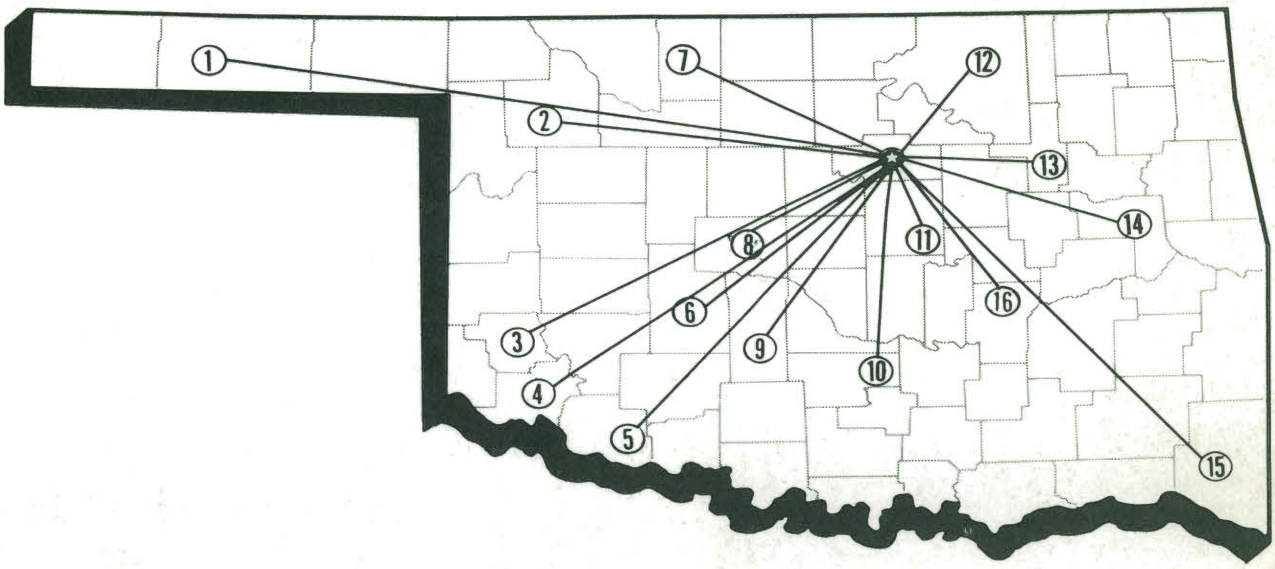

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