RACIAL VARIATION IN ROOT FORM OF LONGLEAF PINE SEEDLINGS

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The study reported here was directed at detecting geographic variation in inherent root form in the main part of the range of longleaf pine (Pines palustris Mill.). It indicated that the roots of 1-year-old longleaf pines from seed sources in southeastern Georgia are more fibrous than those of seedlings representing sources farther west.

Of what interest could variation in root characters be to tree breeders? Laitakari (1929) reported that a fibrous root system, with 90 percent of its absorbing roots in the humus layer, resulted in fast initial growth, and Derr and Enghardt (1957) found that fibrous roots increased resistance to windthrow. Enchanced planting success is also expected of fibrous-rooted stock. Little and Somes (1951) proposed breeding for a fibrous root system. For drought areas, on the other hand, Righter and Duffield (1951) advocated hybridizing pines for tap-roots. In genetics research, a distinctive root habit could serve as a useful "marker" in studies of inheritance.

Has evidence of root variation in longleaf pine previously come to light? Wakeley (1953) reported that in 1928 seed collected somewhere in southern Georgia yielded seedlings strikingly more diffuserooted than those from other sources, In personal correspondence he noted the some but less striking phenomena from the Soperton, Georgia, material of the Southwide Pine Seed Source Study of 1951, and several nurserymen reported it to him for this area in the 1955 phase of the Southwide Study. Dorman noted (personal correspondence) that, at the establishment of the Southwide Study plantation at the Franklin Forest Research Center, Virginia, the Florida source had notably less root development and greater needle development than sources from other States, including Georgia.

Methods

Cones were collected in 1957 from three trees at each of the following locations. 20 locations in south Georgia at about 20-mile intervals on the periphery and through the middle of the slash-longleaf forest type; 1 in southern Mississippi; I at the Birmingham Research Center, Brewton, Alabama; and 1 at Hodges Gardens and Experimental Area, Many, Louisiana. The Alabama and Louisiana collections were made by cooperators. The Louisiana collection was from longleaf-like Sonderegger pines.

After being weighed, seed from each location was sown during March 1958 in three randomized 6- by 24-inch row-plots in the nursery of the Harrison Experimental Forest, in southern Mississippi. The soil was a fine sandy loam. The seedlings were thinned to 10 trees per plot, fertilized, and sprayed to control brown spot disease. In January 1959 their heights were measured to the nearest 1 mm; then they were lifted with a long-bladed shovel a Taproots were pruned to 10 inches, Green weights per plot were taken to the nearest 5 g and a single plant was selected as representative of the root form of the 10 seedlings in the plot. The nine remaining seedlings were outplanted for further study. The root systems of the selected seedlings were photographed in natural size by a shadow method on 10- by 10-inch contact paper; virtually no lateral roots extended off the paper.

On these prints were measured: (1) the total length of the lateral roots, to the nearest 1 cm; (2) the number of lateral roots per seedling; and (3) the average angle of lateral root attachment to the nearest 1 degree. In analysis, numbers of roots per seedling were transformed to log of true number, minus 1, to render distribution normal.

Results

Progenies of the patent trees growing east of a north-south line joining Laurens with Echols Counties, Georgia, had a mean number of 37 roots per plant. Progenies of parents west of this line averaged 29 roots per plant (fig. 1, table 1). The difference is highly significant.

The progenies having the greatest total root lengths (average 166 cm, as against 138 cm for all others) corresponded largely but not entirely with those having the greatest number of roots per plant (fig. 1). This fact indicates a lack of perfect coincidence between number and total length of roots. Analysis of covariance of mean total root length and mean root number led to the conclusion that significant variations existed in total root length over and above that contributed via number of roots--that is, that both number and average length of roots contributed significantly to variations in total root length. Differences among average root lengths were significant, and corresponded closely to the total root lengths adjusted by covariance.

Root angle differences were not significant, but more precise experiments might detect angle variation.

Table 1 .--Root and other characteristics of sampled locations

Location or Type	Wt. per M Seeds	Germination	Seedling Ht.	Wt.	No.	Root Mean lth.	Tot. lth.	Angle
	Grams	Pct.	Mm.	Grams	Log(n) - 1	Cm	Cm	Degrees
Bainbridge, Ga.	108	67	27.7	43.4	25	7.0	122	50
Boston, Ga.	108	72	26.6	42.4	31	6.8	139	51
Valdosta, Ga.	115	83	26.8	46.8	31	7.2	149	61
Statenville, Ga.	116	67	29.4	51.8	36	6.7	156	56
Stockton, Ga.	112	79	25.9	44.6	32	8.5	172	64
Douglas, Ga.	106	64	26.9	49.3	39	6.6	164	59
Pearson, Ga.	114	79	23.5	38.4	36	6.4	150	54
Homerville, Ga.	120	72	26.0	44.6	39	6.1	150	52
Argyle, Ga.	112	82	27.0	39.6	36	6.1	138	55
Blackshear, Ga.	110	80	23.7	40.1	35	5.8	133	53
Ludowici, Ga.	109	74	28.8	45.4	37	7.4	177	56
Glennville, Ga.	118	86	24.8	39.2	37	5.7	133	54
Reidsville, Ga.	127	78	25.3	48.1	35	7.2	165	52
Soperton, Ga.	112	83	26.3	43.6	38	6.7	158	51
Milan, Ga.	105	77	24.0	35.6	31	8.1	173	55
Pitts, Ga.	109	82	24.4	34.0	33	6.9	149	58
Ashburn, Ga.	101	82	26.9	41.2	27	7.1	133	50
Sylvester, Ga.	98	75	23.6	39.6	31	6.2	130	49
Moultrie, Ga.	95	69	23.6	40.6	28	6.9	131	59
Camilla, Ga.	126	59	32.6	49.2	27	7.1	132	51
Birmingham, Ala.	116	75	26.2	42.4	31	6.2	149	61
Brewton, Ala.	98	58	27.5	39.9	31	7.2	125	58
Saucier, Miss.	112	75	27.3	39.7	29	7.4	144	53
Sonderegger (Many, La.)	108	84	28.1	35.8	24	8.0	144	55
Mean	111	75	26.4	42.3	32	6.9	146	55
Probability level	-	-	.01	.01	.01	.05	.05	NS
Standard Error	-	-	1.5	2.6	3.1	.40	12	--

Possible Underlying Relationships

Do the data reveal additional influences affecting root form?

Hypothetically, progenies might have great total root length simply because of great size, expressed as green weight. Weight of progeny was underlain by seed weighty r =+.46**. Total root length, however, proved to be only weakly correlated with either seedling weight (r =+.14) or seed weight (r =+.13). Evidently great total root length was not dependent upon over-all size.

Similarly, total root lengths were not closely related to root angles. The correlation between the two is +.31, non-significant. Among the progenies from Georgia sources, the 4 with the greatest root angles were equally divided between the zones characterized by high and by low total root lengths. This suggests both that angle and total length are relatively independent of each other, and that the lifting procedure had not affected the results. If lifting had introduced a bias, roots with wide angles presumably would have suffered more breakage, which would have resulted in a negative correlation instead of the positive one observed.

Could introgression with loblolly account for the variations observed? Introgressants might be recognized by similarity to the progenies of the three longleaf-like Sondereggers included in the test, i. e., by greater height than longleaf but less green weight in the nursery, Seedlings from no other location had this combination of characters and hence there is no evidence of additional Sondereggers.

Conversely, low green weight in the absence of height growth may indicate selfing; this is a possibility because, in several locations, cone-bearing trees were widely separated. Progenies representing 6 locations showed low weight and no height growth, and 5 of the 6 localities were among those characterized by the lesser total root lengths. Two of these 5 did have high root numbers. Here, perhaps, inbreeding had reduced average root length; if so, some of the discrepancies in figure 1 may indeed be attributed to inbreeding. An alternate hypothesis is that the low weights result from inherently shorter roots irrespective of inbreeding.

Environmental Factors

It appears that one of the main bases of racial root differences is soil condition. Toumey (1929) found that the initial root systems of trees are closely correlated with the particular site conditions under which the species has evolved. Lenhart (1934) found that longleaf seedlings from a single seed source varied relatively little in foot form even when subjected to different soil and moisture conditions; his finding suggests that the results of the present study were unaffected by the particular nursery soil in which the seedlings were grown.

Of the soil factors, Turner (1936) considered moisture the most important for root growth as well as height growth of pines. However, Reed (1939) emphasized that roots and shoots of pine showed markedly different immediate response to environmental factors, particularly moisture and temperature. One of the differences is that root growth is mainly restricted to the spring and fall (Pessin, 1939). Coale (1936) showed that, in the portion of Georgia covered by the present study, slash and longleaf top growth are correlated with the rainfall of the previous summer. He theorized that "This may be due to effect on elaboration and storage of foods that are used in the rapid building of new woody tissue the following spring." Top growth is necessarily preceded by root growth, which in turn is affected by summer soil moisture. Summer droughts are specified by Toumey (1929) as conducive to the evolution of tap-rooted species.

Does the summer rainfall pattern fit the distribution of root form noted in this paper? Visher's (1954) climatic maps and those of Squillace and Kraus (1959) indicate that, in the area studied, summers and falls tend to be drier to the west than to the east and that to the west periods of relative drought occur earlier in the season.

However, lack of a completely consistent root-form gradient indicates that simple environmental relations are unlikely. Squillace and Kraus (1959) are probably correct in stating that a solution to such problems will entail a thorough regression analysis of many factors. It is **time** that ecologists join forces with geneticist's in attacking such problems. Soil moisture contents and other factors should be sampled periodically throughout the range. Although broad soil types (U. S. Dept. Agriculture, 1938) appeared to have no relation in this study, finer subdivisions might. The vegetation of the various locations sampled should be considered; e.g. Pessin (1939) noted the drastic effect of certain grass species on soil moisture content and root growth of longleaf pine. Paleontological conditions, possible migrations of the species, and a study of adaptation to fire might offer further clarification.

Summery

Roots of longleaf pine seedlings from eastern Georgia seed appeared more fibrous than those from collections further west. The number of lateral roots was greater on seedlings from seed collected east of a line joining Laurens and Echols Counties in Georgia. Differences in this character were highly significant, and appeared to be modified less by influences such as possible inbreeding than differences in average length of roots, though significance

was shown for the totter character also. No significant differences were found in the angle of attachment of the laterals to the taproots.

It is hypothesized that the more fibrous-rooted type evolved under the typically wetter summers and falls to the east.

LITERATURE CITED

Coile, T. S. 1936. The effect of rainfall and temperature on the annual radial growth of pine in the southern United States. Ecol. Monog. 6:535-562, illus.

Derr, H. J., and Enghardt, H. 1957. Some forestry lessons from Hurricane Audrey. South. Lumberman 195(2441)1 42-144, illus.

Laitakari, E. 1929. The root system of pine (Pinus slvestris). A morphological investigation. Acta Forest. Fenn. 33:1-380, illus.

Lenhart, D. Y. 1934. Initial root development of longleaf pine. Jour. Forestry 32:459-461.

Little, S., and Somes, H. A. 1951. No exceptional vigor found in hybrid pines tested. U. S. Forest Serv. Northeast. Forest Expt. Sta. Res. Note 10, 4 pp.

Pessin, L.J. 1939. Root habits of longleaf pine and associated species. Ecology 20:47-57 illus.

Reed, J F. 1939. Root and shoot growth of shortleaf and loblolly pines in relation to certain environmental conditions. Duke Univ. School Forestry Bul. 4, 52 pp., illus.

Righter, F., L, and Duffield, J. W. 1951. Hybrids between ponderosa and Apache pine Jour. Forestry 49:345-349, illus.

Squillace, A. E., and Kraus, J. F. 1959. Early results of a seed source study of slash pine in Georgia and Flordia. Proc. Fifth South. Forest Tree Improvement Conf., pp.21-34 illus.

Toumey, J. W. 1929. Initial root habit in American trees and its bearing on regeneration. Internatl. Cong. Plant Sci. Proc. 1:713-728.

Turner, L. M. 1936. A comparison of roots of southern shortleaf pine in three soils. Ecology 17:649-658, illus.

U. S. Department of Agriculture. 1938. Soils and men. U. S. Dept. Agr., 1232 pp. illus.

Visher, S. S. 1954. Climatic atlas of the United States. Harvard Univ. Press, 403 pp.

WakeIey, P. C. 1953. Progress in the study of pine races. South. Lumberman 187(2345): 137-140, illus.