DIVERSITY IN THE NORTHERN SEED SOURCES OF LOBLOLLY PINE

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ABSTRACT.--Nine seed sources of Loblolly pine (Pinus taeda) from the northern parts of its range (Maryland and Delaware) and two commercial seed lots were studied in a tree nursery and in Coastal, Piedmont, and Appalachian plantations of Maryland. Significant variations were found in speed of germination, cotyledon-number, bud-set, secondary growth, straightness of seedlings, height in the nursery, and height and survival at age of 11 to 15 years in the field. Trees from commercial seed lots and from Chincoteague Island grew slowly. Four of five sources from Maryland's Eastern Shore had 5% to 8% larger heights than the mean heights of all sources. At the coldest research site (Allegany County, MD), survival was significantly correlated with the latitude of the seed source (r = 0.73).

Loblolly pine (Pinus taeda L.) is the most important of the southern pines. Its total timber volume is larger than the volume of all other pines combined (Dorman 1976). In the north, P. taeda extends to northeastern Maryland, central Delaware, and to some sites along the southern shore of New Jersey. Climate in the northern range is marked by uniform rainfall in late winter to midsummer, with only a slight decrease in late summer. In Maryland, loblolly pine can grow well on a variety of soil types, and is the most planted forest tree (Genys, 1965). The Buckingham State Forest Tree Nursery grows over three million seedlings of P. taeda each year. Therefore, it is important to select the best Tea sources and to establish seed orchards.

The first study of different geographic sources of loblolly pine was established in Louisiana in 1926. Thirty-five years after planting, a local Louisiana progeny was found to be superior in growth rate to sources from Georgia, Texas and Arkansas (Wakely and Bercaw 1965). Other small studies were conducted in Louisiana at a later date, but northern sources were not included (Crow 1964). Also, in Arkansas the experiments were based on seed lots from southern states (Dorman 1976). The first range-wide seed source study, which included only one seed lot from Maryland, began in 1951. The Maryland Forest Service received seeds from nine sources, grew seedlings in the State Forest Nursery, and

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established a research plantation in Somerset County, Maryland (Eastern Shore) in March 1953. Five years after planting, the trees ranged in height from 2.0 m (Louisiana source) to 3.1 m (Maryland and South Carolina sources) (Little and Tepper 1959). Ten years later, Little (1969) reported again that the seed source from Somerset County, Maryland was most outstanding and recommended that local seed sources from Maryland be used in the State's planting program. Also, loblolly pine from Maryland was best of six sources studied in southern Illinois (Woerheide, 1959).

In addition to growth rate, loblolly pine can vary in resistance to pests (Powers and Zobel, 1978). Studies in Alabama showed that loblolly pine from Maryland, in comparison to other sources, had the highest average specific gravity (0.435) and the greatest proportion of summerwood (32%), though it ranked only seventh in stem volume. In Georgia, trees from Maryland suffered less damage by wet snow than trees from Alabama or North Carolina. On the basis of all south-wide studies of P. taeda, Wells (1969) identified four seed collection and planting zones. The northern zone (No. 3) includes Maryland, Delaware and Virginia.

The present experiment was arranged to learn more about the trees from the northern range of P. taeda, and to test the variability of seed sources from a small section of the species range.

MATERIALS AND METHODS

Cones of P. taeda for this experiment were collected in fall 1966. Nine seed lots of known origin included five from the Eastern Shore of Maryland (east of Chesapeake Bay), three from Southern Maryland (Western Shore), and one from central Delaware (Table 1). Each source was represented by collections from three or more trees. Ten open cones per sample, selected at random, were used for measuring and calculating their mean length (Table 1). Seeds of each source were extracted manually and stored over winter at 1° C. One commercial seed lot was added to represent seed of unknown origin which was used for production of a portion of seedlings in Maryland's nursery in 1966.

In March 1967, these ten seed lots were sown in four randomized blocks at the State Forest Tree Nursery in Harmans, Maryland. Each source in each block was represented by a 1.2 m long row of seedlings spaced 3 to 5 an apart; rows were spaced 15 cm apart. While in the nursery, the specimens were studied with respect to their speed of germination, number of cotyledons, stem straightness, bud formation, tendency for secondary growth, and one-year height.

Next spring, in March 1968, the ten populations of one-year-old trees from research plots and one additional source of unknown origin grown in the nursery, were planted in three physiographic regions of Maryland: Coastal Plain, Piedmont Plateau, and

Allegheny Mountains (Table 2). The Coastal and Piedmont plantations were arranged in four randomized blocks, where each population was represented in each block by a square 4-tree plot, with trees spaced at 2.4 x 2.4 m. In these two plantations, heights of trees were measured at the age of 11 years. The Allegheny plantation was arranged in a similar design but included only two blocks and was measured at age 15.

Statistical analysis of the data from the four blocks in the nursery or from the four blocks in the Coastal plantation was based on plot means. Depending on the total number of sources, the analysis was structured as follows: 39 degrees of freedom (df) for total, 9 df for different sources, 3 df for blocks, and 27 df for interaction. Because of poor survival, the heights of specimens in the Piedmont and Allegheny plantations were analyzed by considering each tree as a plot of a completely randomized experiment. Duncan's multiple range test was used to estimate the most applicable least significant differences (LSD).

Correlation coefficients (r) were calculated to estimate the relationships between different characteristics, and their relationship to geographic factors such as latitude, longitude and elevation of the seed source.

RESULTS

Phenotypic variation in cone length

Average cone length for collections from different stands ranged from 8.4 cm (Caroline County) to 10.2 cm (Kent County, Delaware). Both extremes were from a similar area east of the Chesapeake Bay (Table 1). A large portion of this variation may have been caused by environmental factors. The absolute range of individual cone lengths in this northern region was from 6.6 an to 11.4 am.

There was a significant correlation (r = .78) between the cone length and the percent of seedlings with a large number (> 7) of cotyledons (Table 5).

Speed of germination

Speed of germination was recorded on April 25, 1967. Nine populations had seedlings just emerging from the soil (grades from 8 to 12), while the seedlings of population No. 876 from Caroline County were fully developed and in the process of shedding their seed coats (Table 3). Also at this date, the number of germinated seedlings varied. The fewest seedlings had germinated in population No. 80, and the largest number in No. 876 from Caroline County. The speed of germination and the abundance of germinated seedlings (on 4/25/67) were strongly correlated, r = 0.81.

Number of cotyledons

Cotyledon-numbers of individual seedlings varied from 4 to 10, but such extreme numbers were very rare. Out of 880 seedlings studied, only 3 specimens had 4 cotyledons, and only 2 had 10. Three percent had 5 cotyledons, 29% had 6, 42% had 7, 22% had 8, and only 3% had 9.

The number of cotyledons in different populations was varied. The largest percentage of trees with high number of cotyledons (8 or more) was among those from Delaware (48%) and Somerset County, MD (44%). The fewest seedlings with high numbers of cotyledons were among the trees from two islands; Assateague Island (8%) and Tilghman Island (10%). On the other hand, the Delaware and Somerset populations included only 10% to 11% seedlings with small numbers of cotyledons (6 or less), while the Chincoteague and Tilghman sources included 61% and 59%, respectively.

The percentage of seedlings with "small" numbers of cotyledons (< 7) were correlated with the percentage of creeping seedlings (r = 0.58) and the late bud set (r = 0.57). Unlike in Pinus strobus L., the large cotyledon numbers in P. taeda sources showed no significant relationship to their potential for rapid growth (r = 0.17).

Stem straightness of nursery seedlings

The largest number of creeping seedlings in the nursery was in the population from Assateague Island (30%); the fewest were found in populations from Somerset (3%) and Caroline (4%) Counties. The percentage of creeping seedlings was correlated with the percentage of seedlings with small numbers of cotyledons (r = 0.56), and was inversely correlated with one-year heights (r = -0.71). Also, the high percentage of crooked seedlings in the nursery was inversely correlated with the heights of trees in the field (r = -.63). Sources from the west had somewhat smaller percentages of creeping seedlings than those from the east (western longitude versus the percent of creeping seedlings, r = -0.51).

Bud set

On October 4 (1967), most seedlings in the nursery had their terminal buds set. The percentage of growing seedlings (which had no terminal buds) ranged in different populations from 2% to 10%. Strains with the highest number of seedlings without terminal buds were from Assateague and Tilghmam islands. This delayed bud set was inversely correlated with one-year heights (r = -0.63), and with a tendency for secondary growth (r = -0.68). Also, it was more evident in populations with small numbers of cotyledons (r = 0.57).

Secondary growth

After terminal buds were formed, some seedlings flushed out again and began secondary growth. The highest numbers of seedlings showing this characteristic were among trees from Caroline and Charles counties, MD. This tendency for secondary growth was correlated with the speed of germination (r = 0.67), and was inversely related to the lateness of bud set (r = -0.68). Apparently, trees which formed terminal buds early had a stronger tendency for secondary growth.

Survival

The survival rates of trees in three different regions, Coastal Plain, Piedmont and Allegheny Mountains, showed no significant relationships (Table 5). In Maryland's coastal plain, where loblolly pine is native, the survival rate of trees from all sources was outstanding, ranging from 67% to 100% (Table 4). Analysis of variance showed no significant differences among the different sources, and survival rates were not related to any studied factors.

In the Piedmont Plateau, ten years after planting, only about one-fifth (22%) of the trees survived. The cause of this high mortality has not been determined. One of the factors could have been occasional drought periods in summer. The survival rates of different populations ranged from 10% (from St. Mary's County, and from commercial source #882) to 37% (from Queen Anne's County). These extreme values of survival rates were significantly different (at 0.05 level).

In the Allegheny Mountains, about 150 miles northwest of P. taeda range, more than half (58%) of the planted trees died. Survival rates of different populations ranged from 10% to 70%, and were significantly correlated with the northern latitude of the seed source (r = 0.73). Also, there was a significant correlation between the survival rate and the percentage of seedlings that developed secondary growth in the nursery (r = 0.55).

Height growth

One-year old seedlings in the nursery had an average height of 16.5 cm (Table 1). Height of different populations ranged from 12.7 cm to 18.2 cm, or 77% to 110% of the experimental mean (= 100%). Some of these differences were significant at 0.01 level.

In the Coastal Plain, 11-year old trees had an average height of 9.5 m (= 31 feet). Height of trees from different seed sources ranged from 8.8 m to 10.1 m, and some differences were significant at 0.05 level (Table 4). The slowest growing population (#881) came from the Assateague Island, located on the Atlantic Coast. The best seed source was from Princess Ann township in Somerset

County; these trees were 7% taller than the average. Except the source from Assateague Island, all sources from the Eastern Shore were either average or above average. All sources from the Western Shore of Maryland were below average. Heights of trees in this plantation were not correlated with either the longitude or the latitude of the seed source, but were inversely related to the percentage of creeping seedlings in the nursery (r = -0.61).

In the Piedmont Plateau, 11-year old trees were on the average 8.1 m (= 26.5 feet) tall. Individual populations ranged in height from 7.3 m to 8.8 m, or from 90% to 109% of the plantation mean. According to Duncan's multiple range test, these two values were significantly different (though the F-value was low). The rank of heights in this plantation was somewhat similar to that in the Coastal Plain (r = 0.67). However, the trees from St. Mary's County (the most southern seed source) were exceptionally tall. Heights of different sources were inversely correlated with the percentage of creeping nursery seedlings (r = -0.53) but were not related to any geographic factors (latitude, longitude, or altitude).

At Mount Savage in the Allegheny Mountains, the trees at age 15 were only 7.6 m (24.9 feet) tall. Individual populations in this plantation showed the widest range of variation, ranging from 4.2 m to 8.9 m (or from 55% to 117% of the population mean). The smallest were some southern (St. Mary's Co.) and eastern (Chincateaque) sources, and trees grown from the commercial seed lots.

DISCUSSION

These data from the three study plantations provide both, some common and some unique trends. (1) The trees from Assateague Island were poor in all plantations (a maritime source). (2) All other sources from Maryland's eastern shore had average or above average height. (3) Trees from central Delaware were average. (4) Trees from Maryland's western shore were most variable depending on where they were planted. (5) Trees from commercial seed lots were average in the Coastal plain and Piedmont, but notably poor in the mountains. (6) In the mountains, trees from the most southern sources showed the poorest survival. (7) One of the best seed sources for all regions would be #876 from Caroline County, and the best for the coastal plain would be #877 from adjacent Somerset County.

A significant variation was in the number of cotyledons of the germinating seedlings. Rowan (1979) found that individual seedlings with less than seven cotyledons were less susceptible to fusiform rust, caused by Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. fusiforme Burdsall and Snow. The present study indicated that the greatest percentage of seedlings with low numbers of cotyledons were in population from Assateague Island

(61%). The Assateague seedlings, however, had a strong tendency to develop non-erect stems. In addition, the Assateague source and another source from the Tilghman Island (in the Chesapeake Bay) had a tendency to remain in active growth late in the fall. This characteristic may be related to the moderate maritime climate of their provenance. When planted in a more continental climate they may present a higher risk for injury by early frost.

LITERATURE CITED

Crow, A. B.
1964. Ten-year results from a local geographic seed source study in southeastern Louisiana. Louisiana State Univ. For. Notes 57. 4p.

Dorman, K. D.
1976. The genetics and breeding of southern pines. U.S.D.A. Forest Service Agric. Handbook 471. 407p.

Genys, J. B.
1965. Analysis of productivity of loblolly pine grown on different soil series in Maryland. Forest Research Notes of NRI of University of Maryland No. 65-5. 3p.

Little, S.
1969. Local seed sources recommended for loblolly pine in Maryland, and shortleaf pine in New Jersey and Pennsylvania. USDA Forest Service Res. Pap. NE-134. 16p.

Little, S. and H. B. Tepper
1959. Six-year results from a Maryland planting of loblolly pines from different sources. Proc. 6th Northeastern Forest Tree Improvement Conference (1958):26-29.

Powers, H. R., Jr., and B. J. Zobel
1978. Progeny of specific loblolly pine clones vary in fusiform rust resistance according to seed orchard of origin. Forest Sci. 24(2): 227-230.

Rowan, S. J.
1979. Number of cotyledons affects susceptibility to fusiform rust within, but not among families of slash and loblolly pines. Plant Dis. Reptr. 731-734.

Wakely, P. C. and T. E. Bercaw
1965. Loblolly pine provenance test at age 35. Jour. Forestry 63: 168-174.

Wells, O. O.
1979. Results of the southwide pine seed source through 1968-1969. Proc. 10th Southern Conference For. Tree Improv.:117-129.

Woerheide, J. D.
1959. Loblolly seed from Maryland best of six sources tested in southern Illinois. USDA Forest Service CSFE Station Note No. 129. 2 p.

Table 1. Origin of seed sources and cone lengths of loblolly pines (Pinus taeda) studied in Maryland.

Seed Lot I.D.	Origin of seed lots County and location	Lati-tude	Longi-tude	Alti-tude	Cone length
				m	cm
	Maryland's Eastern Shore				
875	Queen Anne's Co., Kent Island	39°00'	76°18'	3	8.6
876	Caroline Co., Burrsville	38°54'	75°44'	15	8.4
828	Talbot Co., Tilghman Island	38°41'	76°20'	2	8.9
877	Somerset Co., Princess Anne	38°12'	75°43'	3	9.9
881	Worcester Co., Assateague Island	38°18'	75°06'	3	--
	Delaware				
874	Kent Co., Hartley	39°19'	75°41'	10	10.2
	Maryland's Western Shore				
878	Charles Co., Indian Head	38°34'	77°10'	6	9.1
879	Anne Arundel Co., Mount Zion	38°50'	76°37'	60	9.9
880	St. Mary's Co., Point Lookout	38°02'	76°20'	3	8.9
	Maryland's Canmercial Seed				
80	Origin unknown	---	---	--	--
882	Origin unknown	---	---	--	--

*based on measuring ten or more dried open cones

Table 2. Sites of research plantations of loblolly pines (Pinus taeda) in three physiographic regions of Maryland.

Region	County of MD	Location	Altitude	Site Characteristics
Coastal plain	Charles	Smallwood State Park, near Rison	30 m	Level, deep sandy loam soil site is within the species range.
Piedmont Plateau	Howard	Hugh Thomas Wildlife Research Center	120 m	Level, medium deep loam soil. Outside of the species range (± 100 km).
Allegheny Mountains	Allegany	Bruce Farm, near Mount Savage	500 m	Southeast slope (8%), shallow soil. Outside of the species range (± 250 km).

Table 3. Variation in loblolly pine (Pinus taeda) seedlings from different seed-sources, studied in Maryland's Forest Tree Nursery, Harmans, Maryland, in 1967. Also given are average lengths of cones from different stands. Highest values are underlined.

Data	Code	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Seed Lot I.D. No.	Origin of seedlots County of Maryland or Delaware	Germination April 25th advance	Germination April 25th abundance	Cotyledon numbers 6 or less	Cotyledon numbers 8 or more	Creeping seedlings	Delayed bud set	Trees with 2nd growth	Height, one-year
				- - percent of seedlings - - - -					% M
	Eastern Shore								
875	Queen Anne's Co.	10	10	46	13	13	4	31	106
876	Caroline Co.	19	20	40	24	4	4	41	109
828	Talbot Co.	9	10	59	10	5	10	16	102
877	Somerset Co.	10	15	11	44	3	6	23	104
881	Worcester Co.	10	10	61	8	30	10	20	77
	Delaware								
874	Kent Co.	11	14	10	48	6	7	26	87
	Western Shore								
878	Charles Co.	10	10	19	34	6	2	38	99
879	Anne Arundel Co.	11	11	13	30	5	5	28	109
880	Saint Mary's Co.	10	12	15	29	8	2	23	110
	Commercial								
80	Origin unknown	10	7	61	15	11	7	28	99
882	Origin unknown	10	10	25	31	10	6	23	97
Least significant difference (0.05)		5	4	23	24	12	14	14	14
F-value		5.4	6.5	16.4	6.1	8.9	1.4	5.6	10.1

(2) Germination advance scored as follows: 4 = no germination, 8 = seedlings pulling up from ground, 12 seedlings nearly straight up; 16 = seedlings strong; 20 = seedlings shed their seed coats.

(3) Germination-abundance of germinated seedlings - scored as follows: 4 = none, 8 = very few, 12 = average for the experiment; 16 = abundant; 20 = germination complete.

Seedlings which had no terminal buds on October 4th (1967).

Seedlings which formed buds but later in the fall, resumed growth again.

(9) M (mean height of all populations) = 16.5 cm.

Table 4. Growth rates of loblolly pine (Pinus taeda) from different seed sources of its northern range, studied in Maryland's Coastal Plain, Piedmont Plateau and the Allegheny Mountains.

Seed Lot No.	Origin of seed County	Trees Survived			Average Height			Joint Rank
		Coastal Plain	Pied-mont	Alle-gheny	Coastal Plain	Pied-mont	Alle-gheny	
	Age from seed, years:	11	11	15	11	11	15	
	Plantation mean height, m:				9.45	8.08	7.59	
		--- percent - - -			% of plantation mean			
	Eastern Shore							
875	Queen Anne's Co.	92	37	70	100	102	116	106
876	Caroling Co.	92	20	50	104	103	117	108
828	Talbot Co.	67	30	40	103	109	104	105
877	Somerset Co.	100	13	30	107	102	112	107
881	Worcester Co.	83	37	20	93	90	82	88
	Delaware							
874	Kent Co.	92	13	40	100	102	101	101
	Western Shore							
878	Charles Co.	75	23	50	94	94	103	97
879	Anne Arundel Co.	92	17	60	98	95	116	103
880	St. Mary's Co.	75	10	10	98	108	95	100
	Commercial							
80	Origin unknown		27	60		104	83	94
882	Origin unknown	83	10	30	101	101	55	86
Least Sign. Diff.			27		10	18	36	
F-value		.9	2.4*	.8	2.1*	1.2	3.8**	

*Significant at 0.05 level; **Significant at 0.02 level

Table 5. Relationships between different characteristics of loblolly pine (Pinus taeda) from the northern range, expressed by correlation coefficients (r). Data from Tables 1, 2 and 4.

Characteristics-X_1	Code	Characteristics - X_2 (1)	(2)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
		correlation coefficients (r)														
Cone length	(1)	1.00														
Germination speed	(2)	-.39	1.00													
Cotyledons, <7(Z)	(4)	-.73*	-.06	1.00												
Cotyledons, >7(%)	(5)	.78*	.07	-.92**	1.00											
Seedlings, creeping (Z)	(6)	-.38	-.24	.56*	-.58*	1.00										
Late budset (Z)	(7)	.29	-.26	.57*	-.39	.43	1.00									
Growth, secondary (%)	(8)	-.34	.67*	-.17	.18	-.29	-.68*	1.00								
Height, 1-year	(9)	-.53	.27	-.28	-.09	-.31**	-.63**	-.34	1.00							
Survival, Coastal Plain	(10)	.40	.35	-.37	.44	-.11	-.11	.30	.06	1.00						
Survival, Piedmont	(11)	-.55	-.13	.82**	-.82**	.60*	.40	-.01	-.30	-.19	1.00					
Survival, Mountains	(12)	-.12	.18	.20	-.17	-.25	-.15	.55*	.31	.31	.39	1.00				
Height, 11 yrs., Coast	(13)	.01	.30	-.13	.27	-.62*	.08	-.07	.47	.39	-.34	.07	1.00			
Height, 11 yrs., Piedmont	(14)	-.38	.04	.05	.00	-.53*	-.05	-.21	.52*	-.22	-.26	-.07	.67*	1.00		
Height, 15 yrs., Mountains	(15)	-.12	.35	-.19	.11	-.44	-.29	.40	.49	.34	.15	.44	.27	.08	1.00	
Height, joint rank	(16)	-.25	.37	-.20	.17	-.63**	-.26	.28	.64**	.31	-.03	.35	.60*	.43	.92**	1.00
Latitude of seed source	(17)	.11	.31	.01	.12	-.23	.08	.37	-.07	.29	.12		.12	.01	.45	.33
Longitude of seed source	(18)	-.15	-.24	-.32	.11	-.51*	-.60*	.33	.56*	-.40	-.13	.43	-.18	.08	.36	.21
Altitude of seed source	(19)	.38	.19	-.35	.16	-.24	-.12	.19	.30	.30	-.26	.42	-.09	-.32	.48	.14

*significant at 0.05 to 0.01 level; **significant et 0.01 level