U.S. Department of Agriculture
Forest Service
Research Paper SO-155

Family Differences Influence the Aboveground Biomass of Loblolly Pine Plantations

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SUMMARY

We compared the aboveground biomass of 4 half-sib families of loblolly pine (*Pinus taeda* L.) 11 years after planting. Total dry weights differed significantly among families in plantations on the same soil type with the same site index. Differences in biomass resulted from differences in stem form and branch size. Distribution of growth -the proportion of tree weight in wood, bark, branches and foliage — was not significantly different by family. Average total dry matter and distribution of dry matter were similar to results achieved in other studies, but average annual production by family differed substantially from previously reported plantation data.

1979

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

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INTRODUCTION

Loblolly pine (*Pinus taeda* L.) is one of the most important tree species in the southeastern United States. The increasing demand for wood fiber has resulted in greater utilization of harvested trees, including complete aboveground harvesting. However, only limited information is available on the accumulation of biomass in either natural stands (Clark and Taras 1976, 1975) or plantations (Wells and Jorgensen 1975; Switzer and Nelson 1972; Ralston and Prince, 1963; Larsen *et al.* 1976) and does not include data from intermediate-aged plantations of genetically improved seed sources.

Our objective in this study is to determine the effect of family differences on the aboveground biomass of loblolly pine and to compare these results with published data for plantation-grown trees.

PROCEDURE

Seeds from four families of loblolly pine were collected from individual parent trees in natural stands in southern Arkansas. Selection of parent trees was based on rapid growth rate (height and diameter).

Seedlings, separated by family, were grown at the Arkansas State Tree Nursery at Little Rock, Arkansas, and planted as 1-O stock at the Livestock and Forestry Branch Station, Batesville, Arkansas, in the winter of 1964. Planting design consisted of two 0.20 hectare plots located at random for each family, a total of eight plots. Seedlings were located on a 1.83 x 1.83 m spacing (6 ft. x 6 ft.) in a flat ridge-top position of a Nixa soil (loamy-skeletal, siliceous, mesic Glossic Fragiudults). The site was an unimproved pasture that had been abandoned several years earlier, Based on the sample trees, at age 11 these unthinned stands averaged 14.2 cm d.b.h. and 9.8 m in height and had a stocking equivalent to 2990 stems/ha. Site index for sample trees was 20.73 m (68 ft.) at age 25 by the curves of Clutter and Lenhart (1968) and 18.29 m (60 ft.) after Smalley and Bower (1971). Average live crown ratio of sample trees was 27 percent and was not significantly different by family.

In April, 1975, before the 12th growing season, all trees, excluding border rows, were numbered and height (h), diameter at breast height (d), and diameter at base of live crown (d,) were recorded. Before thinning, six sample trees (10% sample) were selected at random from each plot; care was taken to avoid losses in biomass during felling and subsequent handling. Forty-eight harvested trees, *12* from each family, were sampled. Average height, diameter, stocking, and basal area are presented in table 1.

Table 1.— *Average tree and stand characteristics in four families of 11-year-old loblolly pine*

Family	Height m	D.b.h. cm	No. of Trees per ha	Basal Area m^2/ha
1	9.9	14.7	2990	50.96
2	10.0	14.4	2990	49.22
3	9.5	12.9	2990	39.39
4	9.9	14.9	2990	52.73
Mean	9.8	14.2	2990	47.93

Harvested sample trees were separated into foliage, branch, and stem components, and fresh weight of each component was determined. A ten percent subsample (by weight) was collected from foliage and branch components to determine dry-to-fresh weight and foliage-to-branch weight ratios. Branch subsamples were collected by removing one branch from each whorl along the stem. The amount of branch material collected at each internode position was based on the average diameter of the internode and its length.

Stems of sample trees were cut into 1.5 m lengths beginning at ground line. A 5 cm thick

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disc was removed from the base of each section to determine diameter and to estimate dry-to-fresh weight and bark-to-wood weight ratios. Fresh weights of stem sections and discs were determined, and subsamples were dried at 65°C to a constant weight.

We conducted an analysis of variance (ANOVA) to determine the effect of family on total dry matter accumulation and a Duncan's multiple range test for those variables significant in the ANOVA test.

The regression model used to estimate component dry weight values for each family was

$$\log Y = a + b \log X$$

where the lower case letters were constants and X was the combined variable d^2h (diameter at 1.37 meters x total tree height) for stem and foliage and d_c (diameter at the base of the live crown) for branch components (Madgwick 1971). All estimates of weight using regressions incorporated the multiplicative correction for bias suggested by Finney (1941).

$$e^{1/2 S^2}, 1 - \frac{S^2(S^2+2)}{4n} + \frac{S^4(3S^4+4S^2+84)}{96n^2} + \ldots]$$

were S^2 is the variance of logarithm weight and n is the number of observations.

RESULTS AND DISCUSSION

Basal Area

Eleven-year-old stands grown from open-pollinated seed of four loblolly pine trees differed significantly in diameter at breast height (d.b.h.) and basal area (table 1).

Dry Matter

Average total dry matter accumulation was 88.5 x 10^3 kg/ha (fig. 1). Stand data for individual families vary significantly from the overall average. Families l-4 differed from average total biomass by +8, -11, -22, and +25x 10^3 kg/ha with a difference of 47 x 10^3 kg/ha for families with highest (4) and lowest (3) means. Differences in total dry weight result mainly from differences in dry weight of stem and branch components. Family 4 accumulated the greatest dry weight for each component, followed in order by 1, 2, and 3.

Compared to the overall average component weights of 56.25 x 10^3 kg/ha for stem, 7.3 x 10^3 kg/ha for bark, 19.0 x 10^3 kg/ha for branches, and 6.06 x 10^3 kg/ha for the foliage, the difference from average dry weight by family (l-4 in order) was +5.4, -7.85, -14.80, and +17.15 for stem; +0.11, -0.57, -0.77, and +1.26 for bark; +1.44, +0.21, -7.37, and +5.70 for branches, and +1.06, -2.84, +0.79, and +1.06 for foliage.

Differences in stem weight seem to be related more to tree diameter and form than to variation in specific gravity. Values for specific gravity (green volume and oven dry weight basis) taken at d.b.h. averaged 0.46 and were not significantly different (a =.05) among families. Average height to a S-inch top for families l-4 is 8.62, 8.75, 7.78, and 8.99 meters. Stem taper appears to be affected by family and can substantially affect dry weight yields of merchantable stem wood. A similar relationship exists between average branch diameter and total branch weight by family. As average branch diameter increased, so did total dry weight, in the order family 4, 1, 2 and 3.

Valid comparisons with published data for loblolly pine are difficult because of varying age, site index, stocking, stand condition, and method of data collection. Stand data for average total biomass and biomass by component, except for foliage, are in agreement with data presented by Larsen et al. (1976) for l&year-old loblolly pine plantations in the hilly Coastal Plain of Alabama. Foliage weight exceeds by about 20 percent the average value reported for stands of about the same age and site index (such differences could result from the high stocking levels of our study) but is 34 percent less than the average reported by Larsen *et al.* (1976) and 21 percent less than that reported by Wells *et al.* (1975). Those studies were conducted in late summer before needle fall while ours was completed in early spring before needle formation.

Our measurements of average annual and total biomass of plantations are similar to estimates reported for stands of similar age and site index (SI) throughout the South and Southeast (table 2). However, under the same soil and environmental conditions, stands of different genetic makeup having the same site index differ significantly in annual and total biomass production. Comparing our data by family to data reported in other studies indicates that plantations of families 4 and 1 exceed production for genetically unimproved plantations while families 2 and 3 are average or below average in production. Results support the conclusion that yield data for genetically unimproved plantations

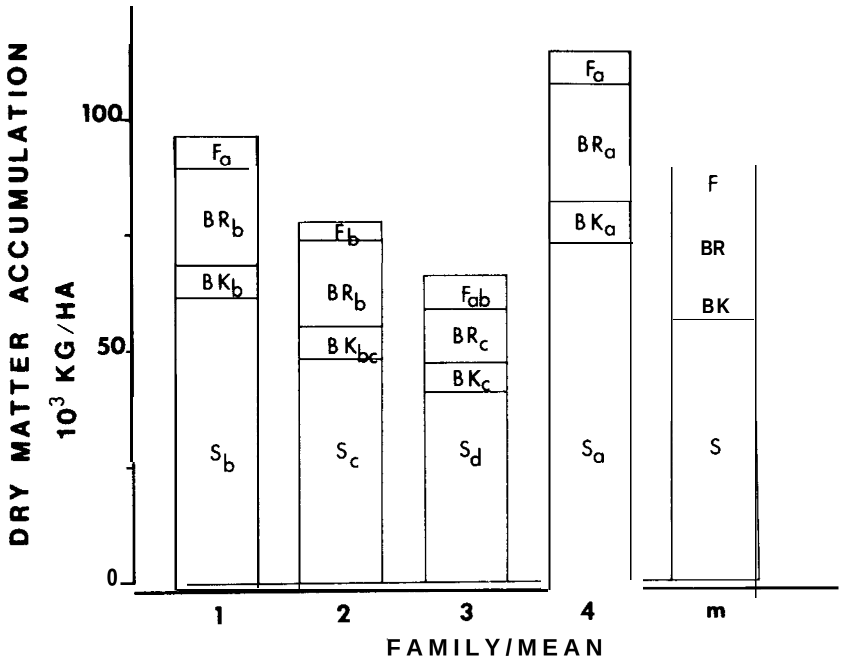

Figure 1.— *Dry matter accumulation and currentfoliage mass per hectare by plant component **forfourfamilies** of 1 l-year-old loblolly pine. Tree components are stem (S), bark (BK), branches (BR), andfoliage (F). Tree components not followed by the same letter are significantly different (a = .05).*

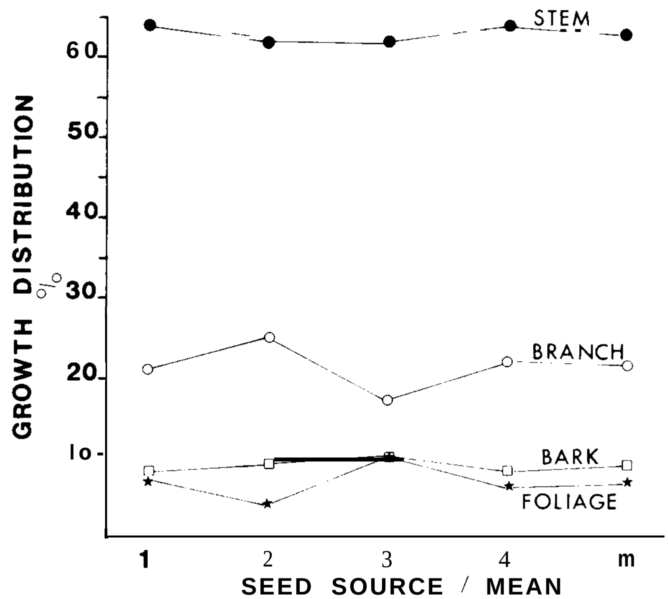

Figure 2.— *Effect of seed source* (family) on *distribution of growth to stem, branch, bark and foliage* components *for 11-year-old loblolly pine plantations.*

Table 2.— *Comparison of aboveground biomass in loblolly pine stands at various locations*

Location and Reference	Age	Biomass: Total	Biomass: Annual	Biomass: Current	Site index: Clutter & Lenhart, 1968	Site index: Smalley & Bower, 1971
		t/ha	----------t/ha/yr----------		----------**meters**----------	
Ala., Larsen et al. (1976)	13	88.5	6.81	.	19.82	
S.C., Metz and Wells (1965)	13	52.6	4.05	. .	18.29	
Miss., Smith et al. (1971)	4	6.3	1.6	. . . .	. . . .	
	5	15.7	3.1	9.4	. . . .	
Miss., Switzer et al. (1966)	18	70.0	3.9	.	18.29	
N.C., Wells et al. (1975)	16	148.0	9.25	. .	20.73	
N.C., Nemeth (1972) and	14	77.4	7.0	. . . .	. . .	
Wheeler (1972)	15	90.6	7.6	12.2	. . . .	
Ralston et al. (1972)	14	75.5	5.4	. . . .	. .	
	15	91.1	6.1	. . . .	. .	
Present Study (Mean)	11	88.5	8.05		20.73	18.29
Family						
1	11	**96.5**	8.77		20.73	18.29
2	11	77.5	7.05		20.73	18.29
3	11	66.5	6.05		20.73	18.29
4	11	113.5	10.32		20.73	18.29

Table 3.— Dry matter distribution (%) of the aboveground biomass of loblolly pine plantations at various locations

Location and Reference	Age	Growth Distribution (%): Stem	Live branch	Dead branch	Bark	Foliage
N.C., Wells et al. (1975)	16	70	9	7	10	5
S.C., Metz & Wells (1965)	13	55.7	19.7[1]	19.7[1]	12.9	9.7
Ala., Larsen et al. (1976)	13	58	14	9	9	11
Ark., Ku & Burton (1973)	19	72	9	5	9	4
Present Study	11	63	21[1]	21[1]	9	7

[1]Total represents live and dead branches combined.

cannot be applied where genetically improved material is planted even though site indexes might be equivalent. These data also suggest that yield tables for specific families or seed sources may be necessary to predict dry matter or volume production.

Growth Distribution

The largest percentage of dry matter is in bole wood, followed in order by branches, bark, and dormant season foliage (table 3). Relative percentage of foliage in growth distribution rankings wil! increase after development of first-year needles, making the amount of growth distributed to the bark the least. On the average, 63 percent of dry matter is in bole wood, 9 percent in bark, 21 percent in branches, and 7 percent in dormant season foliage (fig. 2). Distribution of dry matter among stem wood and bark is not significantly (a = .05) different between families, though the variation was 2-6 percent for stem wood and 3-5 percent for bark. Similar results were obtained for branch and foliage components; however, family 3 had a significantly higher percentage of dry matter in foliage and a lower percentage in branches.

Production of foliage has been estimated from values of standing biomass which assume that production is equal to weight of one-year-old needles on the tree at the end of the growing season. Such an assumption overlooks both decline (if any) in weight of individual leaves at the end of the growing season and actual foliage loss (Bray and Gorham 1964). Using weight of leaves on trees at the end of the growing season will lead to underestimates. However, estimates of stand canopy mass based on logarithmic regressions such as we used tend to overestimate foliage biomass between 1 and 9 percent (Satoo 1965). Madgwick (1971) reported that estimates of needle biomass using either trees of mean basal area or a random sampling were not improved when compared to the regression approach but were significantly underestimated.

Branch biomass reflects many factors, including annual production, death, and decay rates. Accurately estimating branch productivity of stands is difficult (Madgwick 1970), but estimates of live branch biomass using d_c as the regressor variable can be expected to give only slight underestimates (Madgwick 1971). Madgwick (1971) reported that mean estimated stand weights of boles were within 2 percent of actual stand weights regardless of sampling technique or regression variable used.

Dry matter distribution among aboveground tree components reported in our study is similar to that reported elsewhere (table 3). For well-stocked, intermediate-aged stands of a similar age and site quality, genotype apparently has little influence on relative distribution of dry matter. Growth distribution may be more a function of stand age and spacing. Previously established yield tables and biomass distribution by tree component for genetically unimproved plantations could be appropriate for estimating percentages of dry matter distribution in genetically improved plantations.

SUMMARY

For well-stocked stands of similar age and site quality, family differences affect the total production of dry matter but apparently do not affect the distribution of dry matter among bark, branches, and stems.

On genetically improved plantations, dry matter production can differ substantially from that on genetically unimproved plantations, even when site index, age, and level of stocking are equivalent. Our results suggest that yield tables for specific genotypes may be necessary to predict fiber yields.

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Additional keywords: Genotype, biomass, growth distribution, *Pinus taeda*

☆ U.S. Government Printing Office: 1980-676-109