GENETIC CONTROL OF DRY MATTER DISTRIBUTION IN TWENTY HALF-SIB FAMILIES OF VIRGINIA PINE

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Abstract.--Half-sib progeny derived from 20 Pinus virginiana parent trees were sampled, at age eight, to determine presence of significant among family differences in the distribution of dry matter. Families differed in branch weight but not in stem wood, stem bark, leaf, or total wood weight. Proportionate distributions of dry weights for stem, wood branch and stem bark were significantly different among the 20 families. Differences in proportionate distributions were independent of tree size. Heritability (h2) estimates were high for the stem weight and wood weight proportion of dry weight but only moderate for height, diameter and branch weight.

Additional keywords: Biomass, Pinus virginiana, dry matter distribution.

INTRODUCTION

In Virginia, Virginia pine (Pinus virginiana Mill.) accounts for approximately 28% of the softwood growing stock (Sternitzke and Nelson, 1970) and about 44% of the total softwood acreage (Knight and McClure, 1967). Because Virginia pine can provide high per acre yields, has a rapid juvenile growth, and is easily regenerated, industries and state forestry groups in several southern states have incorporated Virginia pine into their procurement, planting and breeding programs (Thor, 1964).

Genetic improvement of Virginia pine requires basic knowledge of the genetic control of tree characteristics important for growth and yield improvement. Because yield of stemwood remains the single most important factor in measuring the results of tree improvement efforts, an understanding of the genetics of dry matter distribution is important if efficient selection methods are to be chosen for breeding improved trees. This study was designed to investigate the genetic control of dry matter production and distribution in twenty Virginia pine half-sib families at age eight years.

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LITERATURE REVIEW

A number of dry matter production studies have dealt with the distribution of dry matter in stands. These studies have been carried out for a variety of reasons, including investigations of the differences between stands growing under different stocking density (Johnstone, 1971) and investigations of the effect of age (Forrest and Ovington, 1970; Hegyi, 1972). Studies have been conducted to provide information for tree nutrition studies (Ovington and Madgwick, 1959; Keay and Turton, 1970; Forrest and Ovington, 1971) and to provide information on differences caused by fertilization (Keay and Turton, 1970).

Satoo (1966) states that in some cases significant variation in the distribution of dry matter has been found among dominant trees in a stand. If this variation in distribution is shown to be genetically controlled, it may be possible to increase the timber yield (stem-wood), even where no increase in total dry matter production occurs. No studies have dealt directly with genetic differences in dry matter distribution among families of plantation-grown Virginia pine.

MATERIALS AND METHODS

In the fall of 1963 Bramlett (1965) collected cones from 20 selected Virginia pine trees. The trees were selected in pairs of naturally well- and poorly-pruned trees and each pair was similar in age, height, diameter, and surrounding stand density. After extraction, seed was sown on May 5, 1964 in nursery beds on the Lee Experimental Forest in Buckingham County, Virginia and outplanted in two randomized blocks in March, 1965. Each family was represented in each block by one 3-tree by 5-tree plot with all seedlings planted at an 8 x 8 foot spacing (Bramlett, 1965).

Five trees from each family in each block were used as the sample for this study. Every third tree in each row in the stand was cut at ground level. One hundred eighty two sample trees were cut during the winter of 1972; 10 from each of the 20 families, less 18 dead and missing trees.

The following measurements were made on each sample tree:

1. Diameter at 1.35 meters (DBH) to the nearest mm.
2. Total height to the nearest cm.
3. Total live crown fresh weight at time of felling.
4. The fresh weight of a random subsample of the crown, representing approximately 10% of the live crown.
5. The total dry weight of stem bark and stem wood.
6. The dry weight of needles and branches in the subsample.

Weights were taken to the nearest 0.1 gram for all samples except stem-wood, which was weighed to the nearest 14 g.

At the time of sampling, crown closure within the stand had just begun and loss of branch material due to natural pruning was negligible. It was assumed that branch weight, stem wood-weight, and stem bark-weight represented the total amount of dry matter (called total wood-weight) distributed to these three parts of the tree over the 8 years of the stand's existence. Leaf weight represented current production only.

Analyses of variance were used to test for differences among the 20 families in diameter, height, the absolute amount of branch, leaf, stem, stem bark, and total wood-weight and for differences in proportionate distribution of woody material.

Heritability (h^2) estimates to determine the relative amount of genetic control over the measured parameters and the distribution of dry matter among the woody components were calculated as folio s:

$$\frac{4\delta^2F}{\delta^2F + \delta^2W}$$

where: δ^2F = variance due to mother tree (1/2 sib family)
δ^2W = variance within families (Becker, 1964)

RESULTS

Variation In Tree Dimensions and Component By Weight

The sampled trees varied in size; the largest tree of each family was 1.5 to 2.0 times as large as the smallest tree in stem diameter (DBH) and height. The range of values for tree diameter and height within families was greater than between family averages. Analysis of variance was performed for branch weight, leaf weight, stem wood-weight, stem bark-weight, and the total wood-weight and results are presented in Table 1. Differences between families in branch weight were significant and varied by a factor of 2 (Table 2). Differences among family averages for leaf weight, stem wood-weight, and stem bark-weight (Table 2) were not significant at P = 0.05 (Table 1).

Table 1: Analyses of variance for height, diameter, leaf weight, cone weight, weight of woody components, and total wood-weight for 20 families of Virginia pine.

Variable	Source of Variance	df, Error df	Mean Square	F. Value	Probability Of Larger F
Height (m)	Family	19 162	0.578	1.790	0.0275
Diameter (cm)	Family	19 162	3.127	1.678	0.0445
Leaf Wt. (kg)	Family	19 162	1.360	1.41	0.1293
Branch Wt. (kg)	Family	19 162	11.05	1.78	0.0285
Stem Wt. (kg)	Family	19 162	3.640	1.33	0.1698
Bark Wt. (kg)	Family	19 162	0.122	1.57	0.0682
Wood Wt. (kg)	Family	19 162	25.60	1.42	0.1242

Table 2: Family averages for tree measurements and weight of component parts. All weights in Kilograms, height in meters and diameters in centimeters. Means not followed by the same letter are significantly different at P = 0.05.

Family	Ht	Dia	Branch	Leaf	Stem	Bark
	(M)	(cm)	KILOGRAMS			
1	4.33abcd	7.3abc	6.75ab	2.93	4.95	0.92
2	4.18bcd	6.0cd	3.97c	2.12	3.32	0.64
3	4.12cd	6.3abcd	6.21abc	2.41	3.52	0.73
4	4.74abc	7.5ab	5.74abc	2.66	5.08	1.04
5	4.49abcd	7.2abc	6.15abc	2.85	4.79	0.91
6	4.81abc	6.8abcd	5.05bc	2.39	4.55	0.87
21	4.61abc	7.4abc	8.39a	3.35	4.89	1.06
22	4.83a	7.3abc	6.40abc	2.44	5.18	0.91
23	3.97d	5.7d	3.93c	1.79	3.06	0.68
24	4.21abcd	6.1bcd	5.99abc	2.07	4.10	0.79
25	4.63abc	6.9abcd	6.99ab	2.98	4.63	0.92
26	4.81ab	7.0abcd	6.05abc	2.47	4.87	0.90
37	4.37abcd	6.5abcd	6.61abc	2.71	4.53	0.85
38	4.21abcd	6.3abcd	7.53ab	2.55	4.00	0.82
41	4.35abcd	6.8abcd	6.21abc	2.61	4.25	0.94
42	4.51abcd	7.8a	7.07ab	2.86	5.08	1.01
45	4.21abcd	6.7abcd	6.47abc	3.17	4.15	0.79
46	4.55abcd	7.3abc	7.29ab	2.88	4.87	0.97
47	4.51abcd	7.0abcd	6.60abc	2.59	4.38	0.94
48	4.23abcd	6.3abcd	5.18bc	2.43	3.72	0.78
MEAN	4.43	6.8	6.20	2.61	4.40	0.87
Std. Dev. of the mean	0.59	1.4	2.59	1.00	1.68	0.29

Variation In Dry Matter Distribution

The proportionate distribution of dry matter among the woody components Lm expressed as the percent of the total wood-weight. There were significant differences among families in the dry matter distribution among the three woody components (Table 3). In each family, branch weight was larger than stem wood-weight, and in all but four families (2, 4, 6, and 23), branch weight was greater than the total of stem wood-weight and stem bark-weight combined (Table 4).

The sample trees were divided into 1 cm diameter classes (i.e. 3.5 to 4.4, 4.5 to 5.4, etc.). Proportionate distribution of woody material into branches and stem was shown to be non-significant among the diameter classes (P = .50 and .18, respectfully). However, proportionate distribution to bark weight was significantly different among the diameter classes (P = .01).

Table 3: Analyses of variance for the proportionate distribution of dry matter among the woody components in 20 families of Virginia pine.

Variable	Source of Variance	df, error df	Mean Square	F. Value	Prob. of Larger F
BR/Wood[1)]	Family	19 162	115.004	4.967	0.0001
ST/Wood[2)]	Family	19 162	85.828	4.928	0.0001
BK/Wood[3)]	Family	19 162	3.962	1.731	0.0356

1) BR/Wood = (Branch weight/Wood weight) X 100.
2) ST/Wood = (Stem weight/Wood weight) X 100.
3) BK/Wood = (Bark weight/Wood weight) X 100.

Table 4: Family averages for total wood weight (kg) and proportionate distribution of woody material into branch, stem, and stem bark. Means not followed by the same letter are significantly different at P = 0.05.

Family	Total Wood Wt.	% Branch	% Stem	% Bark
1	12.62	53.5cdef	39.2abcdef	7.3abc
2	7.93	50.1efg	41.8abc	8.1abc
3	10.46	59.4ab	33.7g	6.9c
4	11.86	48.4fg	42.8ab	8.8ab
5	11.86	51.9cdefg	40.4abcdef	7.7abc
6	10.47	48.2g	43.4a	8.3abc
21	14.34	58.5ab	34.1g	7.4bc
22	12.49	51.2cdefg	41.5abcd	7.3bc
23	7.67	51.3defg	39.9abcdef	8.8a
24	10.88	55.1cdef	37.7bcdef	7.2abc
25	12.54	55.8abcd	36.9cdef	7.3bc
26	11.82	51.2cdefg	41.2abcde	7.6abc
37	11.99	55.1abc	37.8fg	7.1bc
38	12.35	61.0a	32.3g	6.7c
41	11.39	54.5bcde	37.3cdefg	8.2abc
42	13.16	53.7cdef	38.6bcdef	7.7abc
45	11.41	56.7abc	36.3efg	6.9c
46	13.13	55.5abc	37.1defg	7.4bc
47	11.38	53.2cdef	38.5bcdef	8.3abc
48	9.68	53.5cdef	38.4cdef	8.1abc
MEAN	11.47	54.1	38.3	7.6
Std. Dev. of the Mean	4.34	5.7	4.9	1.6

Heritability Estimates

Heritability (h^2) estimates were calculated for those values which showed significant among family differences (Table 5). Height, diameter, and branch weight had moderate heritability values. Heritability estimates for proportionate distribution of dry matter among the three woody components varied from 0.30 to 1.21. Theoretically, heritability values greater than 1.00 (Table 5) are not possible but may be obtained if assumptions of heritability calculations are not met. One assumption which must be met is that the selection of parent trees be completely random (Falconer, 1960). For this study, the parent trees were not selected at random, since the selection was based on the natural self-pruning ability of each parent tree. Consequently, the selection procedure may have caused biased estimates of heritability especially for the proportionate distribution of woody material since naturally poorly-pruned trees have thicker and longer branches than naturally well-pruned trees (Bailey, 1974).

Table 5: Esimtates of heritabilities (h^2) for measured parameters and distribution of dry matter among the woody components.

Variable	h^2
Height	.32
Diameter	.28
Branch Wt.	.32
Branch Wt./Wood-Wt.	1.21*
Stem Wt./Wood-Wt.	1.21*
Bark Wt./Wood-Wt.	.30

*See text for explanation.

Sampled trees were classified into two groups, those from naturally poorly-pruned parents or from well-pruned parents. Analysis of variance showed that the progeny from poorly-pruned parents had a significantly (P = .006) higher percentage of woody material in branch weight. Conversely, progeny from well-pruned parents had a significantly (P = .003) higher proportion of total woody material in the stem. The two progeny groups did not differ significantly in the ratio of bark weight to total wood-weight nor did they differ significantly in total wood-weight.

DISCUSSION

The results of this study indicate that total wood mass in the eight-year-old Virginia pine population studied here is subject to only minor genetic influence. Consequently, improvement of total woody biomass productivity of this Virginia pine population will be relatively slow. The results do suggest that improvement can be made in the proportionate distribution of dry matter to the stem. For example, if the total average wood productivity of the trees in the stand could be genetically manipulated so that proportionate distribution of dry matter to the stem was as great as in family 6, the yield of dry stem would increase approximately 13%. If the family with the greatest total wood productivity (Family 21) could be manipulated such that it produced a percent stem wood comparable to family 6, productivity of stem wood would be 30% greater than the plantation average.

Resampling the families included in this study at varying intervals to maturity will provide needed information on the temporal stability of characters measured in this study, on the variations in foliage efficiency, and more reliable estimates of heritability. Knowledge of the genetics of biomass distribution may increase understanding of the mechanisms responsible for individual tree productivity and through such an understanding, contribute to the efficiency of tree breeding programs.

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