DISTRIBUTION OF DRY MATTER PRODUCTION IN TWENTY FAMILIES OF VIRGINIA PINE (PINUS VIRGINIANA)

by

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INTRODUCTION

Each year, Virginia pine becomes more favored as a commercial species. In Virginia, Virginia pine 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 of its high yield per acre, rapid growth, and ease of natural regeneration, the pulp and paper industries of several southern states have incorporated Virginia pine into their wood procurement, planting, and breeding programs (Thor, 1964).

To further enhance the desirability of Virginia pine as a commercial species, information on the factors determining the rate and distribution of dry matter production is necessary. This information is necessary to identify the controlling factors of rate and distribution of dry matter production and to relate these to the forester's needs. This study considers the partition of dry matter within the tree. Wareing and Matthews (1971) state that even though the rate of total dry matter production within a tree is important, the forester is concerned primarily with the yield of usable wood. In light of the forester's needs, fast-growing trees which have a high percentage of the total dry matter production as stem-wood are desired.

LITERATURE REVIEW

In the past, a large number of studies have been conducted which were concerned with measuring the biomass and productivity of many different forest stands. Much of this work has been summarized by Bray and Gorham (1964), Ovington (1965), and Art and Marks (1971). The many individual papers and the above mentioned summaries make it possible to compare the differences in dry matter production in different forest stands of the world.

A number of the 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). Differences in estimates of stand biomass obtained by using different methods (Baskerville, 1965; Madgwick, 1971) and investigation of the difference between two species in dry matter distribution (Nihlgard, 1972) have also been conducted. Few studies have dealt with the differences in dry matter distribution due to genetic variability among families.

Wareing and Matthews (1971) stated that there have been a number of reports of variation within and between populations of trees in the proportionate distribution of total dry matter. The results of these reports fall into two groups: (1) those showing a constancy within a stand in the distribution of dry matter within individual trees, which suggests a strong internal control; and (2) those showing considerable variation between trees suggesting the possibility of genetic variation.

Six clones of Pinus radiata were examined by Forrest and Ovington (1971). They showed that total crown weights differed significantly between clones. Forrest and Ovington stated that crown weight differences were due to the additive effect of differences of individual branch weight and number of branches per tree, both apparently controlled by genetic factors. Clonal differences were also found in the volume of bole wood produced per unit weight of leaves.

Full and half-sib families have shown genetic variability in photosynthetic efficiency (P.E.), net assimilation rate (NAR), and dry matter accumulation (Campbell and Rediske, 1966; Ledig and Perry, 1969). The same studies showed strong correlation between dry matter production and both P.E. and NAR. But the correlations were found in seedlings, and for the most part the dry matter production measurements were total production and not measurements of the distribution of total production.

In the study of dry matter distribution it is important to have an understanding of the control mechanisms which determine the pattern of dry matter production in the tree (Wareing and Matthews, 1971). Wareing (1970) states that at the present time there is little known about these control mechanisms, but there appears to be a homeostatic mechanism which regulates the distribution of assimilates between shoot and root under any given site conditions.

Ledig and Perry (1965) showed that, for loblolly pine progenies, there is variation in the shoot-root ratio and genetic variation in the relative growth of shoot and root. Differences in the shoot-root ratio are most likely due to the comparison of seedlings of different weight and not due to genetic variation (Ledig and Perry, 1965).

Satoo (1966) showed that among individual trees within a stand the distribution of dry matter was affected by the dominance of the tree in the stand. Satoo also stated that in some cases a significant variation in the distribution of dry matter was 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 if there is not an increase in total dry matter production, by controlling the distribution of dry matter among the component parts of the tree.

MATERIALS AND METHODS

Data Collection

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 were 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 of 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. All branches were removed from the main stem and weighed in the field to give a live crown weight.

4. A 10% random subsample by weight of the crown was taken into the lab and divided into cones, needles, and branches (inclusive of bark).

5. Stem bark and wood were separated.

6. All material was oven dried at 80°C to a constant weight.

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

There was a deviation from the above procedure concerning the first 20 trees sampled. With one tree from each family, 100% of the crown was divided into branches, cones, and needles by age. All other measurements were conducted as listed above. The 10% subsample was used following the first 20 trees in order that a larger number of trees could be sampled.

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 weight, and stem bark weight represented the total amount of dry matter distributed to these three parts of the tree over the 8 years of the stand's existence. Leaf weight and cone weight represented current production only. For this reason, the data analysis of total weight, leaf weight, and cone weight was not emphasized.

The majority of the analyses were concerned with the measurements of branch weight, stem weight, and stem bark weight. These three woody components added together equal the variable total wood-weight. Stemwood weight plus stem bark weight will be termed mainstem.

Methods of Analysis

Analysis of variance tests and Duncan's multiple range tests were used to test for differences between the 20 families in diameter, height, and the absolute amount of branch, leaf, stem, stem bark, cone, and total wood weight.

Regression analysis was used to test for differences among regression equations relating logarithm dry weight of the woody components of the trees to logarithm tree size ($(\text{DBH})^2$ X height). This was done to determine if each family required a separate regression equation to predict dry weight from tree size measurements or if a common equation might be used for all twenty families. Regression equations were tested for significant differences in slope or intercept by using analysis of covariance procedures.

Analysis of variance and Duncan's multiple range tests were used to test for differences between the 20 families in the proportionate distribution of dry matter among the woody components.

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 follows:

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

where: $\delta^2 F$ = variance due to mother tree (1/2 sib family)

$\delta^2 W$ = variance within families (Becker, 1964).

RESULTS

Appendix I lists all measurements and weights taken on the 182 sample trees.

Variations in Tree Dimensions

The sampled trees varied in size; the largest tree of each family was 1.5 to 2.0 times as large asthe smallest tree in stem diameter (DBH) and height. The variation of tree diameter and height within families was greater than between family averages. Family averages for both diameter and height were significantly different (Table 1). Ranking of families for diameter and height (Table 2) was very similar, since diameter and height were highly correlated ($r^2 = .85$).

Variations in Component Dry Weight

Analysis of variance (Table 1) was calculated for branch weight, leaf weight, cone weight, stem weight, stem bark weight, and the total weight of the three woody components (wood-weight). Differences between families in branch weight were significant and are illustrated by the highest family average being over twice as large as the smallest (Table 3). Cone weight was also significantly different among families, with the highest value being more than four times as large as the smallest value (Appendix II). Family averages for leaf weight, stem weight, and bark weight (Appendix II) were not significant at $P = 0.05$ (Table 1).

Total wood-weight did not differ significantly between families (Table 1), even though the highest family mean was nearly twice as large as the smallest. The family differences in total wood-weight were caused primarily by the significant differences in branch weight among families since stem weight did not differ significantly among families (Table 1).

Variations in Regressions Relating Woody Components Dry Weight to Tree Size

Regression relationships were calculated for logarithm branch, stem, bark, mainstem, and total wood-weights against logarithm ($(\mathrm{DBH})^2$ X height) in each family. Regression coefficients did not differ significantly among families in slope, but two equations (branch wt. and total wood wt.) differed significantly among families in equation intercept (Table 4)[1].

Variations in Dry Matter Distribution

The proportionate distribution of dry matter among the woody components was expressed as the per cent of the total wood-weight. There were significant differences among families in the dry matter distribution among the three woody components (Table 5). In each family, branch weight represented a larger proportion of the total wood-weight than stem weight, and in all except four families (2, 4, 6 and 23), branch weight was a greater percentage of total wood-weight than that of stem and bark weight combined (Tables 6, 7).

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[1] Regressions to predict tree component weights were also computed on an arithmetic scale by relating weight to the independent variable ($(\mathrm{DBH})^2$ X height). Tests of hypotheses regarding differences in slopes and intercepts yielded the same results for the regressions computed on arithmetic scales as for those transformed with logarithms.

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 (Table 11). However, proportionate distribution to bark weight was significantly different among the diameter classes.

Heritability Estimates

Heritability (h^2) estimates were calculated for those values which showed significant family difference (Table 9). 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 9) are not possible but may be obtained if assumptions of h^2 calculations are not met. Two assumptions which must be met are (1) that the measured trees arise from a panmictic population and (2) that the selection of parent trees be done completely at random (Falconer, 1960). The first assumption was clearly met with the parent trees having been selected from large, open pollinated stands of Virginia pine. However, the parent trees were not selected at random, since the selection was based on the natural self-pruning ability of each tree. This selection procedure may have caused biased estimates of heritability for the proportionate distribution of woody material since naturally poorly pruned trees have larger and longer branches than naturally well pruned trees (Bailey, 1974).

Parent trees were classified as either naturally poorly or well pruned. Analysis of variance (Table 12) showed that the progeny from poorly pruned parents had a significantly higher percentage of woody material in branch weight, but progeny from well pruned parents had a significantly higher proportion of total woody material in stem weight (Table 10). Well and poorly pruned progeny did not differ in proportionate distribution of bark weight to total wood weight nor did they differ in total wood weight (Table 12).

Table 1: Analysis 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
Cone Wt. (kg)	Family	19 162	0.145	2.53	0.0011
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 means for diameter (cm) and height (m). Means grouped between two asterisks do not differ significantly at P = 0.05.

				Diameter	
				Mean	Family
		*		7.777	42
	*	¦		7.540	4
*	¦	¦		7.400	21
¦	¦	¦		7.333	22
¦	¦	¦		7.330	1
¦	¦	¦		7.300	46
¦	¦	¦		7.190	5
¦	¦	¦	*	6.988	47
¦	¦	¦	¦	6.988	26
¦	¦	¦	¦	6.944	25
¦	¦	¦	¦	6.833	6
¦	¦	¦	¦	6.775	41
¦	¦	¦	¦	6.710	45
¦	¦	¦	¦	6.500	37
¦	¦	¦	¦	6.300	3
¦	¦	¦	¦	6.277	38
¦	¦	*	¦	6.270	48
¦	*		¦	6.133	24
*			¦	5.966	2
			*	5.650	23

				Height	
				Mean	Family
		*		4.833	22
	*	¦		4.811	26
*	¦	¦		4.810	6
¦	¦	¦		4.739	4
¦	¦	¦		4.625	25
¦	¦	¦		4.608	21
¦	¦	¦	*	4.552	46
¦	¦	¦	¦	4.513	42
¦	¦	¦	¦	4.512	47
¦	¦	¦	¦	4.489	5
¦	¦	¦	¦	4.367	37
¦	¦	¦	¦	4.346	41
¦	¦	¦	¦	4.332	1
¦	¦	¦	¦	4.233	48
¦	¦	¦	¦	4.214	38
¦	¦	¦	¦	4.213	45
¦	¦	*	¦	4.212	24
¦	*		¦	4.175	2
*			¦	4.115	3
			*	3.974	23

Table 3: Average branch weight (gms) for trees of the 20 Virginia pine families. Means grouped between two asterisks do not differ significantly at P = 0.05.

			Branch Wt.	
			Mean	Family
		*	8392.	21
	*	¦	7532.	38
	¦	¦	7291.	46
	¦	¦	7071.	42
	¦	¦	6997.	25
	¦	¦	6746.	1
*	¦	¦	6609.	37
¦	¦	¦	6470.	45
¦	¦	¦	6396.	22
¦	¦	¦	6210.	3
¦	¦	¦	6207.	41
¦	¦	¦	6154.	5
¦	¦	¦	6058.	47
¦	¦	¦	6050.	26
¦	¦	¦	5990.	24
¦	¦	*	5742.	4
¦	¦		5182.	48
¦	*		5053.	6
¦			3971.	2
*			3934.	23

Table 4: Analysis of covariance of regressions relating logarithm dry weight of the woody components to logarithm tree size ($(DBH)^2$ X height) for the 20 Virginia pine families.

Source of Variation	F Ratio	Significance
Log Branch Wt. = a + b log (D^2H)		
Slope	1.254	N.S.
Intercept	3.831	P = 0.01
Log Wood-Wt. = a + b log (D^2H)		
Slope	1.133	N.S.
Intercept	3.067	P = 0.01

The following regressions were non-significant in both slope and intercept.

Log Stem Wt. = a + b log (D^2H)

Log Bark Wt. = a + b log (D^2H)

Log Mainstem Wt. = a + b log (D^2H)

Table 5: Analysis 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 6: Family averages of proportionate distribution for branch and stem dry weight (%). Means grouped between two asterisks do not differ significantly at P = 0.05.

					BR/Wood	
					Mean	Family
			*		60.0	38
	*		¦		59.4	3
	¦		¦		58.5	21
*	¦		¦		56.3	37
¦	¦		¦		56.1	45
¦	¦		¦		55.3	46
¦	¦		*	*	55.0	25
¦	*		*	¦	54.4	41
¦	*		¦	¦	53.2	24
¦	¦		¦	¦	53.1	48
¦	¦		¦	¦	52.9	42
¦	¦		¦	¦	52.9	47
¦	¦		¦	¦	52.4	1
¦	¦	*	¦	¦	51.3	5
¦	¦	¦	¦	¦	51.0	26
*	¦	¦	¦	¦	50.7	22
	¦	¦	¦	*	49.8	23
	¦	¦	*		49.6	2
	*	¦			48.0	4
		*			46.6	6

						ST/Wood	
						Mean	Family
				*		44.5	6
		*		¦		42.9	4
*		¦		¦		42.0	2
¦		¦		¦	*	41.7	22
¦		¦	*	¦	¦	41.0	26
¦	*	¦	¦	¦	¦	40.7	5
¦	¦	¦	¦	¦	¦	40.7	23
¦	¦	¦	¦	*	¦	39.7	1
¦	¦	¦	¦		¦	39.1	42
¦	¦	¦	¦		¦	38.6	47
¦	¦	*	¦		¦	38.5	24
¦	¦		¦		¦	38.3	48
¦	¦		¦		¦	37.3	25
*	¦		¦	*	¦	37.3	41
	¦		¦	¦	*	37.2	46
	¦		*	¦		36.7	45
	*			¦		36.1	37
				¦		34.0	21
				¦		33.2	3
				*		32.9	38

Table 7: Family means of proportionate distribution for bark weight (%). Means grouped between two asterisks do not differ significantly at P = 0.05.

			BK/Wood	
			Mean	Family
		*	9.4	23
	*	¦	8.9	4
*	¦	¦	8.8	6
¦	¦	¦	8.4	48
¦	¦	¦	8.3	47
¦	¦	¦	8.3	2
¦	¦	¦	8.2	24
¦	¦	¦	8.1	41
¦	¦	¦	7.9	26
¦	¦	¦	7.9	5
¦	¦	¦	7.8	42
¦	¦	*	7.8	1
¦	¦		7.6	25
¦	¦		7.5	37
¦	¦		7.4	46
¦	¦		7.4	22
¦	*		7.4	21
¦			7.2	3
¦			7.0	45
*			6.9	38

Table 8: Mean and range of family averages for tree dimensions, dry weights, and percent distribution of woody material into the three woody components.

	Mean	Standard Deviation	Family Range
Diameter (cm)	6.8	1.4	5.7 - 7.8
Height (m)	4.43	0.59	3.97 - 4.83
Stem Wood Wt. (kg)	4.39	1.68	3.06 - 5.18
Branch Wt. (kg)	6.22	2.59	3.93 - 8.39
Leaf Wt. (kg)	2.62	1.00	1.79 - 3.35
Stem Bark Wt. (kg)	0.87	0.29	0.64 - 1.06
Cone Wt. (kg)	0.27	0.26	0.11 - 0.47
Total Wood Wt. (kg)	11.48	4.34	7.67 - 14.34
% Branch	53.4	5.7	46.6 - 60.0
% Stem-wood	38.6	4.9	32.9 - 44.5
%Stem bark	8.0	1.6	6.9 - 9.4

Table 9: Estimates 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

Table 10: Mean values of progeny from well-and poorly-pruned parents for tree dimensions, dry weights, and percent distribution of woody material into the three woody components.

	Poorly-pruned	Well-pruned
Height (m)	4.36	4.50
Diameter (cm)	6.8	6.8
Branch Wt. (kg)	6.38	6.05
Leaf Wt. (kg)	2.75	2.49
Stem Wt. (kg)	4.32	4.47
Bark Wt. (kg)	0.87	0.87
Cone Wt. (kg)	0.30	0.25
Wood Wt. (kg)	11.56	11.40
% Branch	54.6	52.2
%Stem-wood	37.6	39.7
% Stem bark	7.9	8.0

Table 11: Analysis of variance for the proportionate distribution of dry matter among the woody components in 1 cm diameter classes.

Variable	Source of Variance	df, error df	Mean Square	F. Value	Probability of Larger F
BR/Wood[1)]	Dia. class	8 173	55.21	1.738	0.50
ST/Wood[2)]	Dia. class	8 173	45.91	1.944	0.18
Bk/Wood[3)]	Dia. class	8 173	12.65	6.343	0.01

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 12: Analysis of variance for total wood weight and the proportionate distribution of dry matter among the woody components between progeny from well- and poorly-pruned parents

Variable	Source of Variance	df, error df	Mean Square	F. Value	Probability of Larger F
BR/Wood[1]	Prune	1 180	248.9	7.879	0.0057
ST/Wood[2]	Prune	1 180	213.9	9.085	0.0033
BK/Wood[3]	Prune	1 180	1.328	0.537	0.5286
Wood Wt. (kg)	Prune	1 180	1.307	0.069	0.7891

[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 13: Analysis of variance for height, diameter, and total wood weight between the two blocks

Variable	Source of Variance	df, Error df	Mean Square	F. Value	Probability of Larger F
Height (m)	Block	1 180	0.605	1.74	0.1858
Diameter (cm)	Block	1 180	0.048	0.02	0.8722
Wood Wt. (kg)	Block	1 180	0.0003	0.00002	0.9921

DISCUSSION

Differences among families, as found in this study, can generally be explained by environmental or genetic differences. The families were planted in two randomized blocks to lessen the chance for possible environmental effects. Height, diameter, and total wood weight values were non-significant between the two blocks (Table 13) indicating that an environmental effect did not exist. Family differences or the absence of family differences may also have been caused by possible inefficiency in the experimental design and by the juvenility of the sampled trees.

Differences in proportionate distribution of dry matter are shown to be independent of tree size. Except for stem bark values, analysis of variance (Table 11) showed non-significant differences between diameter classes in proportionate distribution of stem and branch material. These results, combined with the high heritability estimates obtained for proportionate distribution of dry matter (Table 9), indicate that differences are genetically induced.

Variations in regressions relating component dry weight to tree size (Table 4) have important implications in the estimation of stand biomass and fiber production. There were significant differences among families in regressions relating branch weight to tree size (D^2H). Differences among families in branch weight caused significant differences between the family regressions relating total wood weight to tree size. Total wood weight is the major component of stand biomass. Therefore, to obtain accurate estimates of stand biomass a separate regression equation would have to be used for each family. In some cases, one regression equation could be used for several families with similar component dry weight and tree size.

Estimating fiber production is not as difficult as estimating stand biomass. The family regressions relating stem wood weight to tree size are non-significant in both regression slope and intercept. Consequently, stem wood production for the twenty families can be accurately estimated by one common regression equation.

For a given D^2H, the trees in this study differed in stem wood weight (non-significant) and branch weight (significant at $P = .05$). This implies that even where no significant differences in linear dimensions occur there may be differences in usable produce. The results suggest a need for pulping studies to determine if there are any differences among the families in the physical properties of the wood.

The significant differences in proportionate distribution of total woody material in the three components have several major implications. With a shift in the distribution of woody material a more highly valued product may be a produced even if the total dry matter production per acre is subject to homeostatic control. A more highly valued product will be produced as a larger percentage of dry matter is distributed to the mainstem and less is distributed to branch material. With less branch material there will be a corresponding decrease in the amount of compression wood present in the mainstem and a decrease in residual slash materials after harvest.

The twenty families differed significantly in the percentage of total woody material distributed to the stem (Table 6). Family values ranged from 32.9% to 44.5% (Table 8) with the upper values being 6% above the average. With calculations based on a sample of only 20 families, this suggests that when combined with high heritability a substantial gain in production of stem wood can be made. For example, the families might be manipulated by means of genetic selection in such a way that the family with the largest total production of woody material (i.e., Family 21) would have a high per cent distribution of woody material into stem wood (i.e. Family 6). Combining characteristics of families 21 and 6 would result in an average yield of 14.34 kg of total woody material and a per cent distribution of woody material into stem wood equal to 44.5%. This would yield a family average of 6.38 kg of stem wood, which is 23% greater than the highest family average of 5.18 kg. It might also be possible to combine the stem wood production per unit of foliage of Family 22 with the total production of foliage in Family 21. This would result in a family that produces 2.13 kg of stem wood per unit of foliage. With an average annual foliage production of 3.35 kg., stem wood yield from this combination would average 7.13 kg, an increase of 37.6% over the highest family average of 5.18 kg.

Resampling the 20 families in about five years will be helpful. By resampling and calculating estimates of foliage production and annual dry matter production, information on efficiency of dry matter production per unit of foliage may be obtained. This information can be used in conjunction with dry matter distribution data in a genetic selection program. Resampling in five years will aid in determining if the present differences in proportionate distribution of woody material will persist as the trees increase in age and size.

Timber yield may be increased by either increasing dry matter production itself or by controlling the distribution of dry matter into the components of trees. The results of this study indicate that the latter method of increasing timber yield may be possible through genetic selection.

LITERATURE CITED

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APPENDIX I: BLOCK,FAMILY & TREE NO.,TREE MEASUREMENTS, AND THE WEIGHT OF COMPONENT PARTS OF THE SAMPLE TREES. ALL WEIGHTS IN GRAMS, HT.IN METERS, DIA.IN CENTIMETERS

			HT	DIA	BRANCH	LEAF	STEM	BARK	CONE
BI	1	3	4.70	8.0	6248.0	3577.0	5131.4	968.2	653.0
BI	1	6	4.67	8.5	6264.3	3094.1	5772.1	1029.4	929.4
BI	1	9	3.32	5.9	4601.0	1343.0	3132.7	548.9	209.0
BI	1	12	3.50	4.0	2695.0	744.0	1573.5	241.1	47.0
BI	1	15	5.24	9.6	9591.0	4441.0	8590.1	1210.1	760.0
BI	2	7	3.23	3.6	1332.0	1043.0	1290.0	248.5	0.0
BI	2	1	4.52	7.3	6826.0	2715.0	4507.8	746.3	175.0
BI	2	4	3.30	4.0	1650.0	1147.0	1445.9	266.0	283.0
BI	2	10	5.10	7.6	5435.7	3145.1	5244.8	932.1	187.0
BI	2	13	4.71	7.4	4745.0	2546.0	5003.9	725.5	167.0
BI	3	1	4.59	7.1	8438.0	3309.0	5542.4	1023.1	284.0
BI	3	4	4.62	7.1	10821.0	3031.0	5641.7	748.6	1121.0
BI	3	7	4.71	7.4	9009.8	4396.9	4862.0	1162.4	146.0
BI	3	10	4.79	6.8	4710.0	2174.0	4139.2	750.7	137.0
BI	3	13	3.92	6.3	6545.0	2282.0	3189.4	739.2	54.0
BI	4	2	4.97	7.5	4771.0	1665.0	4933.0	986.7	315.0
BI	4	8	4.91	8.4	8535.6	4151.1	6341.9	1253.4	116.2
BI	4	11	4.19	7.1	5060.0	2211.0	3770.6	640.8	47.0
BI	4	5	5.03	7.8	6542.0	2967.0	6194.5	953.2	365.0
BI	4	14	5.37	8.4	8493.0	2158.0	7059.2	1372.4	407.0
BI	5	2	4.03	7.7	5767.0	2779.0	4309.2	792.7	592.0
BI	5	5	4.72	7.5	6403.0	3185.0	5060.5	628.9	256.0
BI	5	8	4.45	6.6	4124.8	2656.5	3798.9	780.5	355.0
BI	5	11	3.87	4.4	2227.0	965.0	1956.2	382.3	71.0
BI	5	14	4.56	7.5	6919.0	2872.0	5797.6	804.0	765.0
BI	6	3	4.30	7.0	6628.0	2663.0	4592.8	733.6	67.0
BI	6	6	4.02	4.1	1350.0	643.0	1502.5	356.5	17.0
BI	6	9	5.39	7.6	4776.0	3342.7	5290.1	1057.7	76.5
BI	21	2	3.97	4.5	4447.0	1481.0	2211.4	618.6	0.0
BI	21	8	4.19	5.3	4037.5	1951.3	2527.3	549.9	150.2
BI	21	11	4.74	7.3	6535.0	5286.0	5103.1	868.3	50.0
BI	21	14	5.19	8.1	9091.0	3708.0	6066.9	1125.0	923.0
BI	21	5	4.80	7.5	7010.0	2164.0	4110.9	851.5	273.0
BI	22	2	5.51	8.7	11417.0	2857.0	7994.7	1234.3	154.0
BI	22	5	5.64	8.6	7302.4	2714.5	6968.4	1109.7	50.5
BI	22	8	5.22	7.6	5460.0	1799.0	4947.1	610.2	936.0
BI	22	11	4.02	5.3	3100.0	1331.0	3147.1	498.7	227.0
BI	22	14	5.04	8.3	7694.0	3756.0	6506.3	1051.2	764.0
BI	23	10	3.55	5.5	4115.0	1417.0	2991.0	525.4	90.0
BI	23	7	2.03	1.5	194.6	248.2	263.7	81.3	0.0
BI	23	1	4.60	7.1	4604.0	2135.0	4493.5	800.0	151.0
BI	23	4	4.95	6.8	3355.0	2090.0	4082.4	747.2	293.0
BI	23	13	3.77	5.5	3357.0	1451.0	2693.3	567.8	145.0
BI	24	8	5.17	9.4	14634.0	3778.0	8306.6	1151.4	317.0
BI	24	2	4.07	5.4	6350.0	1333.0	2920.1	630.1	21.0
BI	24	5	4.98	7.4	5822.7	3014.9	4893.2	1042.4	275.8
BI	24	11	5.04	8.5	9614.0	3084.0	7229.4	1233.4	269.0
BI	24	14	3.33	5.5	2701.0	1128.0	2338.9	446.9	38.0

DRY MATTER DISTRIBUTION IN 20 VIRGINIA PINE FAMILIES

			HT	DIA	BRANCH	LEAF	STEM	BARK	CONE
BI	25	7	4.17	6.1	6329.0	2265.0	3614.7	653.2	65.0
BI	25	1	4.17	5.2	4965.0	1996.0	2905.9	604.0	346.0
BI	25	4	4.64	6.7	6730.0	2299.0	4805.3	693.7	75.0
BI	25	10	4.73	7.6	9851.5	3606.9	5406.3	1081.8	319.1
BI	25	13	4.90	7.3	7216.0	3148.0	5046.3	842.9	344.0
BI	26	8	5.26	7.3	7478.0	2740.0	5542.5	819.0	266.0
BI	26	2	5.65	9.0	8038.0	2767.0	8590.2	1314.6	72.0
BI	26	5	4.31	5.5	2598.9	1555.2	2304.9	529.2	324.3
BI	26	11	5.96	8.4	6815.0	2854.0	7271.8	1008.2	299.0
BI	26	14	4.46	6.4	4472.0	1891.0	3997.4	687.4	373.0
BI	37	10	4.92	9.4	12769.0	5546.0	8831.0	1290.2	326.0
BI	37	4	5.60	9.2	9507.0	4003.0	8335.0	1041.6	410.0
BI	37	7	3.15	3.5	3661.0	1221.3	1658.5	431.6	657.6
BI	37	13	4.67	7.1	6315.0	2958.0	4266.7	679.0	200.0
BI	33	6	3.77	5.2	3799.0	2060.0	2593.2	515.9	132.0
BI	33	3	4.57	7.7	7786.0	2522.0	5641.6	989.0	929.0
BI	33	9	4.80	6.7	8575.0	3671.5	4359.4	699.3	319.7
BI	36	12	4.41	7.4	9783.0	3338.0	4655.6	836.9	909.0
BI	35	15	3.39	5.6	4677.0	1632.0	2622.4	643.3	78.0
BI	41	2	4.21	7.6	6862.0	2234.0	4621.1	1039.3	286.0
BI	41	5	4.23	5.8	5601.3	2999.3	3195.1	677.1	421.5
BI	41	8	4.40	6.7	6273.0	1977.0	4408.5	1078.0	671.0
BI	41	11	4.24	6.3	4765.0	2202.0	3521.6	749.8	427.0
BI	41	14	4.33	7.4	5980.0	2895.0	5106.3	898.4	82.0
BI	42	2	4.63	8.0	8177.0	2422.0	5641.7	1039.2	564.0
BI	42	5	4.51	7.3	7052.0	2261.0	4876.3	992.5	1119.0
BI	42	8	4.90	8.6	8709.9	4084.7	5633.1	1150.5	195.4
BI	42	11	4.66	7.5	6126.0	2324.0	5386.5	843.7	575.0
BI	42	14	4.57	7.8	5021.0	2549.0	5613.3	771.1	173.0
BI	45	1	3.94	5.9	8346.0	3872.0	3685.5	806.2	260.0
BI	45	4	4.27	6.0	5944.0	1799.0	3770.6	608.2	193.0
BI	45	7	4.50	7.7	8205.0	4940.0	5202.3	914.5	225.0
BI	45	10	3.48	5.5	4485.4	2822.9	3265.9	516.3	19.9
BI	45	13	4.48	6.9	6922.0	2192.0	4436.8	714.8	9.0
BI	46	1	4.75	7.3	9342.0	3133.0	5499.9	974.7	233.0
BI	46	4	4.60	7.5	7305.0	2456.0	4932.9	895.6	273.0
BI	46	7	4.31	7.3	6818.5	3517.3	4439.6	815.3	146.2
BI	46	10	4.38	6.6	5401.0	1844.0	2926.5	819.3	68.0
BI	46	13	4.04	5.3	3915.0	1865.0	2906.7	604.5	74.0
BI	47	3	4.68	6.5	4365.0	1666.0	3810.7	801.3	44.0
BI	47	6	4.20	6.4	4722.6	2260.0	3144.0	672.1	164.0
BI	47	12	4.80	7.2	4866.0	2272.0	4890.5	1136.8	713.0
BI	47	15	3.91	5.5	7821.0	2464.0	3713.9	959.6	396.0
BI	48	7	2.93	3.2	1747.0	671.0	1086.3	311.6	89.0
BI	48	1	5.11	8.5	11028.0	4742.0	7130.1	1188.8	0.0
BI	48	4	4.34	7.3	6069.0	3088.0	4976.2	956.8	231.0
BI	48	10	4.73	7.0	4226.9	2354.0	3523.9	770.5	239.0
BI	48	13	3.56	4.3	1808.0	1180.0	1559.3	360.0	31.0

DRY MATTER DISTRIBUTION IN 20 VIRGINIA PINE FAMILIES

			HT	DIA	BRANCH	LEAF	STEM	BARK	CONE
II	1	1	4.51	7.7	11560.0	4726.0	5755.1	1170.5	516.0
II	1	4	4.39	8.9	9102.0	3652.0	6105.2	1352.7	299.0
II	1	7	4.15	8.2	8409.0	3489.0	6055.1	1092.6	349.0
II	1	10	4.57	7.8	8201.0	3421.0	5641.7	1056.6	643.0
II	1	13	3.77	4.7	1393.0	811.0	1729.4	550.5	247.0
II	2	8	3.75	4.8	3110.0	1697.0	2367.3	557.3	221.0
II	2	11	4.43	5.6	2984.0	1947.0	2701.8	583.0	126.0
II	2	14	4.33	6.3	4911.0	2276.0	3515.5	831.1	0.0
II	2	2	4.20	7.1	4745.0	2732.0	3734.8	902.8	66.0
II	3	3	3.58	3.4	2137.0	612.0	1105.7	320.7	0.0
II	3	6	3.85	4.8	3985.0	1326.0	1956.2	428.7	0.0
II	3	15	3.94	7.6	5349.0	2238.0	2991.0	725.3	177.0
II	3	12	3.04	5.7	4901.0	2288.0	2253.9	627.0	56.0
II	4	1	4.79	7.6	5535.0	2527.0	4564.5	1089.1	366.0
II	4	10	4.54	7.8	4924.0	3058.0	4748.7	1100.5	147.0
II	4	13	4.47	6.5	3075.0	1852.0	3827.5	842.3	254.0
II	4	4	3.62	5.6	3545.0	1956.0	2679.4	774.6	59.0
II	4	7	4.95	8.7	7136.0	3958.0	6676.5	1390.6	137.0
II	5	1	3.74	6.1	3498.0	2108.0	3090.2	918.1	238.0
II	5	7	4.23	7.7	7064.0	3038.0	5953.5	1053.9	186.0
II	5	4	4.94	8.2	8441.0	3555.0	5496.7	1133.9	98.0
II	5	10	5.35	8.1	8843.0	2715.0	7371.1	1194.0	549.0
II	5	13	4.95	8.0	8235.0	2640.0	6010.2	1289.4	35.0
II	6	4	5.37	9.3	10071.0	4626.0	7901.0	1462.7	197.0
II	6	7	4.57	6.3	4092.0	1375.0	3841.4	766.6	336.0
II	6	10	5.21	6.7	3404.0	1213.0	4167.5	844.2	40.0
II	21	2	4.83	6.8	12016.0	4803.0	6492.2	1539.1	167.0
II	21	5	4.75	7.8	10524.0	4067.0	5386.5	1299.9	192.0
II	21	8	4.45	7.6	9126.0	3012.0	4932.9	1145.2	266.0
II	21	11	4.64	7.5	6823.0	4426.0	4394.3	910.7	146.0
II	21	14	5.12	9.5	12237.0	4638.0	7668.7	1687.0	351.0
II	22	3	5.09	7.1	5865.0	2732.0	4904.6	1024.8	425.0
II	22	6	4.14	6.5	4405.0	1746.0	3302.8	682.5	52.0
II	22	9	3.76	5.3	4903.0	1669.0	2935.3	586.2	0.0
II	22	12	4.98	8.1	8313.0	3322.0	5873.5	1178.3	186.0
II	23	3	4.24	6.5	5622.0	2608.0	3884.0	1004.2	0.0
II	23	6	4.03	5.4	3905.0	1969.0	2865.3	826.2	133.0
II	23	9	3.71	4.7	3015.0	1419.0	2158.3	526.7	0.0
II	23	12	3.80	5.5	4586.0	1919.0	2958.3	635.2	94.0
II	23	15	4.55	7.0	5096.0	2627.0	4224.2	1054.9	250.0
II	24	3	[illegible]	5.4	3706.0	1567.0	2976.7	624.0	55.0
II	24	6	2.72	2.3	783.0	498.0	580.4	208.0	0.0
II	24	12	4.14	5.2	4750.0	2198.0	3801.6	825.5	202.0
II	24	15	4.10	6.3	5553.0	2165.0	3756.4	932.1	362.0
II	25	4	5.23	8.1	8676.0	3802.0	6392.9	1463.5	796.0
II	25	7	5.09	8.3	10303.0	4876.0	7215.2	1376.6	296.0
II	25	1	4.10	5.0	1915.0	1196.0	2041.2	559.2	35.0
II	25	10	4.65	8.2	6991.0	3467.0	4252.6	969.0	0.0

DRY MATTER DISTRIBUTION IN 20 VIRGINIA PINE FAMILIES

			HT	DIA	BRANCH	LEAF	STEM	BARK	CONE
II	26	8	4.52	6.3	6302.0	2647.0	4110.9	907.1	350.0
II	26	11	4.39	7.0	9493.0	3553.0	4607.0	1017.6	314.0
II	26	14	4.48	7.0	4203.0	2102.0	4337.6	914.2	424.0
II	26	5	4.27	6.0	5055.0	1855.0	3118.6	897.3	963.0
II	37	3	4.03	5.7	6135.0	2754.0	3035.5	774.0	688.0
II	37	6	4.14	5.7	5191.0	1763.0	3076.0	873.5	552.0
II	37	12	3.45	5.6	2011.0	901.0	1310.8	287.6	13.0
II	37	15	4.97	7.3	7288.0	2594.0	5698.4	1451.7	601.0
II	38	3	4.05	5.4	4058.0	1365.0	2650.8	689.1	313.0
II	38	9	4.53	5.3	10168.0	3374.0	3614.7	916.0	62.0
II	38	12	4.40	7.1	8221.0	1994.0	5471.7	1047.5	550.0
II	38	15	3.96	6.1	10721.0	2987.0	4252.6	879.5	396.0
II	41	7	3.37	6.0	4716.0	2438.0	3405.9	745.1	263.0
II	41	10	4.98	7.8	7620.0	2743.0	5712.6	1267.5	542.0
II	41	13	4.21	6.6	7842.0	3432.0	4039.9	1040.9	672.0
II	42	1	3.94	7.7	4290.0	2227.0	3501.3	788.6	0.0
II	42	10	5.17	8.5	11699.0	3732.0	6988.3	1419.4	387.0
II	42	13	3.98	7.2	4937.0	2392.0	3939.1	912.3	465.0
II	42	4	4.26	7.4	7552.0	3663.0	4110.9	1166.5	315.0
II	45	1	4.74	7.3	5673.0	3135.0	4955.1	926.8	280.0
II	45	10	4.48	7.0	5304.0	2653.0	4323.4	850.8	107.0
II	45	13	4.37	6.7	5023.0	3351.0	4465.2	916.1	3.0
II	45	4	3.53	5.6	3182.0	2482.0	2324.7	511.2	0.0
II	45	7	4.34	9.2	7624.0	4511.0	5032.5	1086.3	0.0
II	46	2	4.49	7.7	9430.0	3818.0	4947.1	1248.4	0.0
II	46	8	5.32	8.0	8216.0	2742.0	6506.4	1216.7	219.0
II	46	14	4.05	7.5	7125.0	2864.0	4805.3	985.5	262.0
II	46	5	4.53	8.3	8072.0	3620.0	5953.6	1162.3	55.0
II	47	3	4.78	7.4	5581.0	2773.0	4054.0	974.5	191.0
II	47	6	4.94	7.5	5326.0	2378.0	4777.1	834.2	1297.0
II	47	15	4.07	6.6	6495.0	2923.0	4493.5	956.4	242.0
II	47	9	4.28	7.1	5602.0	3304.0	3997.4	960.8	771.0
II	47	12	4.95	8.7	7746.0	3306.0	6563.1	1197.4	147.0
II	48	3	4.55	6.6	5661.0	2483.0	4224.2	731.5	236.0
II	48	6	3.80	5.8	4412.0	2151.0	3019.3	629.2	166.0
II	48	15	4.70	7.0	5607.0	2733.0	3912.3	827.6	238.0
II	48	9	3.73	5.2	5071.0	2007.0	2891.8	760.0	131.0
II	48	12	4.80	7.8	6190.0	2943.0	4848.0	1277.1	155.0

(BRANCH, LEAF, AND CONE WEIGHT OF EACH TREE IS BASED ON A 10 PERCENT SUBSAMPLE OF THE CROWN OF THAT TREE)

Appendix II: Family averages for tree measurements and weight of component parts. All weights in grams, height in meters and diameters in centimeters.

Family	Ht	Dia	Branch	Leaf	Stem	Bark	Cone
1	4.33	7.3	6746.3	2929.8	4948.4	922.1	467.2
2	4.18	6.0	3971.2	2116.5	3318.0	643.6	136.1
3	4.12	6.3	6210.6	2406.3	3520.2	725.1	220.8
4	4.74	7.5	5742.7	2665.3	5079.6	1040.4	221.1
5	4.49	7.2	6154.8	2851.4	4794.4	907.8	316.5
6	4.81	6.8	5053.5	2393.8	4549.2	870.2	122.3
21	4.61	7.4	8392.9	3353.6	4890.4	1059.5	252.0
22	4.83	7.3	6396.6	2436.3	5180.9	908.4	311.6
23	3.97	5.7	3934.4	1788.3	3061.2	676.9	116.6
24	4.21	6.1	5990.4	2075.1	4100.4	788.2	171.1
25	4.63	6.9	6997.4	2984.0	4631.2	916.2	252.9
26	4.81	7.0	6050.5	2473.8	4875.6	899.4	376.1
37	4.37	6.5	6609.6	2717.5	4526.2	853.7	431.0
38	4.21	6.3	7532.1	2549.3	3996.7	824.1	409.9
41	4.35	6.8	6207.4	2615.0	4251.4	937.0	420.6
42	4.51	7.8	7071.5	2861.6	5080.1	1009.3	421.5
45	4.21	6.7	6470.8	3175.8	4146.3	792.1	108.8
46	4.55	7.3	7291.6	2875.5	4868.7	969.1	147.6
47	4.51	7.0	6058.3	2594.0	4382.7	943.7	440.6
48	4.23	6.27	5182.0	2435.2	3717.1	783.3	151.6

DISTRIBUTION OF DRY MATTER PRODUCTION IN TWENTY FAMILIES OF VIRGINIA PINE (Pinus virginiana)

by

James A. Matthews

(ABSTRACT)

In the fall of 1963 seed was collected from 20 selected Virginia pine trees. The trees were selected in pairs of well- and poorly-pruned trees. Progeny (half-sib) derived from the 20 parent trees were sampled, at age nine, to determine if differences existed among the 20 families in the distribution of dry matter. Families differed in branch weight and cone weight but not in stem, stem bark, leaf, and total wood weight (stem + bark + branch weights).

Proportionate distributions of stem, branch and stem bark dry weights were significantly different among the 20 families. Differences in proportionate distributions were shown to be independent of tree size but there were significant differences in distributions between progeny from naturally well and poorly pruned parents. Heritability (h^2) estimates were calculated for those values which showed significant among family differences.