INHERITANCE AND GAINS OF THREE WOOD PROPERTIES IN VIRGINIA PINE

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Abstract. --Wood cores were obtained from a six-year-old open-pollinated Virginia pine heritability test. A total of 738 trees, representing 123 half-sib families from 12 seed sources were sampled to determine wood specific gravity, extractives and diameter growth. The heritability of diameter growth was .267 while there was no evidence of significant genetic effects on extractive content in juvenile wood. Significant gains in wood production may be obtained using seed source selection for specific gravity and within-family selection for diameter growth; even greater gains may be achieved by among and within-family selection for diameter.

Additional keywords: Specific gravity, extractives

This is the third report about the Virginia Pine (Pinus virginiana) Heritability Study of The University of Tennessee. The first report (Thor, 1964) on wood properties included data obtained during selection of parent trees from which open-pollinated seed were collected for the establishment of the heritability test. A second report (Evans and Thor, 1971) contained heritability estimates and genetic gains for height growth based on 1- and 2-year evaluations. The objective of the present report is to present preliminary results of inheritance of wood specific gravity, extractives and diameter growth in Virginia pine in addition to predicted gains from these heritability estimates.

METHODS

Data used in this study were obtained from one of the six plantations which make up the open-pollinated Virginia Pine Heritability Study. The soil was a silty loam underlain by a fragipan at a depth of approximately 18 inches; the site was relatively flat at an elevation of 1000 feet on the Highland Rim in Middle Tennessee.

During August 1972, when the trees were in their sixth growing season, 11 mm wood cores were collected from 738 trees, representing 123 half-sib families from 12 seed sources. The third and seventh trees were bored in each 10 tree family row-plot in 3 of the 10 replications present. In plots where the third or seventh tree was missing the next tree in line was sampled. Cores with pitch pockets, knots or visible amounts of compression wood were not accepted. Since trees were bored between 12 and 18 inches above ground level this meant that trees which were relatively straight and had a fairly clear bole in this stem section were accepted. Trees under 1 inch in diameter at 1 foot above ground level were not sampled since cores from such trees often crumbled upon extraction. Total height and diameter at half-height measurements used in calculation of volumes and weights of wood per tree were obtained from five year data.

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All cores were extracted with alcohol and benzene for 16 hours followed by alcohol for six hours. Extractives in gm/cm were determined by subtracting the specific gravity of each core before and after extraction.

Data were analyzed using the Statistical Analysis System (Barr and Goodnight, 1972) at The University of Tennessee Computing Center. The expected mean squares and the analysis of variance were calculated on an individual tree basis:

Source of variation		Expected mean squares
Replications	2	
Stands	11	$\sigma^2_w + w\sigma^2_{f(s)r} + wf\sigma^2_{rs} + wrf\sigma^2_s + wr\sigma^2_{f(s)}$
Replications x stands	22	$\sigma^2_w + w\sigma^2_{f(s)r} + wf\sigma^2_{rs}$
Families in stands	111	$\sigma^2_w + w\sigma^2_{f(s)r} + wr\sigma^2_{f(s)}$
Families in stands x reps	222	$\sigma^2_w + w\sigma^2_{f(s)r}$
Within plot	368	σ^2_w

The heritability as derived by the variance components method was

$$h^2 = \frac{4\sigma^2_{f(s)}}{\sigma^2_w + \sigma^2_{f(s)r} + \sigma^2_{f(s)}}$$

Using parent-offspring regression and correlation the heritabilities were h = 2b and h = 2r, respectively. Within-family gains were computed using methods of Falconer (1960) and selection intensity tables of Namkoong and Snyder (1969).

RESULTS AND DISCUSSION

Extracted Specific Gravity

Both replication and stand effects were significant at the 1% level of probability while family within stand effects were only significant at the 10% level. The low family variance component is rather surprising, If, as with other species of southern pines, specific gravity were a strongly inherited complex trait, the family component should be relatively high (Zobel et al., 1972). The low family and high stand mean square are the reverse of the natural variation pattern in Virginia pine where extracted specific gravity had a significant among tree component but was non-significant among stands (Thor, 1964). Apparently specific gravity in Virginia pine is strongly affected by environment with different populations reacting differently to changed environments. The highly significant among replication component would tend to confirm this strong environmental effect.

A New Duncan's Multiple Range Test distinguishing among stand means and the geographic source of each stand is presented in Table 1. The test shows that, in general, the stands can be separated into two groups, those with high wood densities and those with low densities. Stand numbers 2, 12, 9 and 4 fall into the high category and are also the stands which fall into the extremes of the species range in Tennessee and Kentucky while the five stands with low specific gravity are all from the central part of the range sampled. The coefficients of variation (Table 1) for each stand indicate that the magnitude of wood density variation within stands is approximately equal.

Table 1.--Duncan's New Multiple Range test for specific gravity and coefficients of variation for open-pollinated progeny from 12 stands

No.	Stand Location	Stand Mean	C.V.%
2	West Kentucky (Dawson Springs)	0.41015	5.33
12	Great Valley (Newport, Tn.)	0.40643	5.60
9	Cumberland Plateau (Morehead, Ky.)	0.40544	5.35
4	Eastern Rim (Rock Is., Tn.)	0.40536	5.94
1	West Tenn (Clinton)	0.40250	5.90
13	Great Valley (Elizabethton, Tn.)	0.40237	5.93
10	Great Valley (Etowah, Tn.)	0.39615	4.87
7	Eastern Ridge (Pineville, Ky.)	0.39380	6.62
11	Great Valley (Vonore, Tn.)	0.39356	4.87
8	Cumberland Plateau (London, Ky.)	0.39201	5.92
6	Cumberland Mts. (Wartburg, Tn.)	0.39189	5.99
3	Cumberland Plateau (Sewanee, Tn.)	0.38633	6.65

Heritabilities for extracted specific gravity were estimated at .162 by the variance component method, .129 by the regression method, and .183 by the correlation method. These estimates are low in comparison with values obtained for other species. In the case of the variance components method this result is a reflection of the low family and the high stand variance component. However, the estimates obtained by the three methods seem to be in fairly close agreement. All three methods have their drawbacks as enumerated by van Buijtenen (1962).

Extractive Content

Since the analysis of variance showed a very low and statistically non-significant family effect, no heritability value was computed for this characteristic. The stand component also was non-significant.

The trees in this plantation were in their sixth growing season at the time cores were extracted and heartwood depositions were not expected; therefore, the extractive content should be low. Extractive percent ranged between 2.6 and 10.3% of extracted wood, considerably higher than the 2 to 4% obtained by Zobel et al. (1972) for juvenile wood of loblolly and slash pine, but similar to that produced between the 10th and 25th growth ring in young Virginia pine (Thor, 1964). Virginia pine stands older than 50 years have from 2 to 3 times the amount of extractives observed in younger stands indicating that heartwood initiation is rather late in this species.

Only the replication effect was significant in the analysis of variance, indicating strong environmental control over extractive content. Stonecypher and Zobel (1966) obtained similarly high replication and low among family mean squares for extractive percentages in loblolly pine.

Diameter Growth

Diameter heritabilities were calculated using half-height measurements obtained at age five. Both replication and family mean squares were significant at the 5% level indicating both genetic and environmental control over this character. The heritability estimate of .267 is in agreement with the heritability of diameter inside bark of five-year-old loblolly pine, $h^2 = .28$, as obtained by Stonecypher and Zobel (1966). Variation in diameter growth among stands was not significant.

Correlations among characteristics

Table 2 lists correlation coefficients between various characteristics. The most noteworthy of these is the significant positive correlation between progeny specific gravity and progeny diameter at one foot above ground level, r = .235. With the exception of Thor and Brown (1962) who obtained a similar positive correlation for juvenile loblolly pine (r = .201) most reports show negative correlations between diameter and wood densities of southern pines. In the present case, although this correlation was significant, only 5.5 percent of the variation in offspring wood specific gravity was accounted for by variation in progeny diameter. By itself, diameter would not be a very efficient indirect selection criterion for high wood density, but it is encouraging that selection for rapid juvenile diameter growth will not result in decreased specific gravity.

A similar situation exists for the correlations between progeny wood specific gravity and the remaining progeny and parent characters. All of these correlations are statistically significant, but none accounts for much of the variation in specific gravity of progeny trees.

Table 2.--Relationships among wood properties of progeny and parent trees

Relationships	Correlation Coefficient
Progeny specific gravity x progeny extractives	.135*
Progeny specific gravity x progeny d.i.b. a/	.235*
Progeny specific gravity x parent sp. gr.	.091*
Progeny specific gravity x parent extractives	.087*
Progeny extractives x progeny d.i.b.	.078*
Progeny extractives x parent sp. gr.	.025 NS
Progeny extractives x parent extractives	-.053 NS
Progeny d.i.b, x parent sp. gr.	-.083*
Progeny d.i.b. x parent extractives	.010 NS

a/ Progeny diameter inside bark data from measurements of core lengths obtained at 1 foot above ground level.

Gains

One objective of most experimental breeding programs is to demonstrate the amount of genetic gain or advance which can be achieved by the program. In the Virginia pine project it was anticipated at the time of initiation that one of the six plantations would be sacrificed for the purpose of creating a seedling seed orchard. This means that the selection intensity used in the calculation of gains will be governed by practical considerations of the spacing desirable in the orchard. The trees in this plantation were planted at a spacing of 4 x 8 feet, each tree occupying 32 square feet. If we assume a desired spacing in our orchard of 30 x 30 feet or 900 square feet per tree, we will rogue about 30 trees for each selected orchard tree.

We may initiate the program by selecting trees from the four stands with high wood density (Table 1), or a proportion saved of 1/3 (this stage is similar to a seed source selection).

The next stage of the selection program is determined by the need to avoid inbreeding. Since a family within each replication is represented by ten half-sib trees in a row plot, only one of these trees can be retained leaving us the final desired number of trees. Selection of individual trees at this within-family level will be for greatest rate of diameter growth. This characteristic is of great economic importance, its heritability is adequate, the within plot variance is large, and the measurement is cheap to obtain.

Mean values of five-year growth and wood density variables with and without stand selection are shown in Table 3. Based on five-year data it is apparent that no gain in yield of wood per tree is achieved by stand selection alone. Although specific gravity is increased by stand selection, it seems to be offset by mild losses in height and diameter. It should be remembered that significant differences among stands were obtained only for specific gravity and not diameter growth. Although there was a positive correlation between wood density and diameter, this correlation was on an individual tree basis; the non-significant correlation between stand means of specific gravity and diameter was negative. r = -.166.

Cable 3.--Mean values-[a/] for height, diameter[b/], wood specific gravity, volume/tree[c/] and weight/tree with and without stand selection

Source	Ht (ft)	Diam (in)	Sp. Gr.	Vol/Tree (ft3)	Wt/TreE (lbs)
Mean from four selected stands	9.90	1.48	.4069	.133	3.39
Mean for all 12 stands	10.01	1.51	.3988	.142	3.53

a/ Height, diameter and volume per tree are from five-year measurements
b/Diameter outside bark measured at half total height.
c/The volumes per tree were derived from volume prediction equation of Perry and Roberts (1964), V = (10.62 D H)/1728.

The projected gain resulting from within-family selection for diameter growth was .13 inches (with i= .75; o =.27; h^2=.267). Using data from Table 3 this gain in diameter increases the mean volume of wood per tree from .142 to .159 cubic feet cubic feet per tree after both stand and within-family selection. Adjusting for specific gravity gains from stand selection, the selected trees represent a gain of 14.4 percent or .51 pound of wood per tree.

Although this gain represents increases of both specific gravity and diameter, these data indicate that much greater gains can be achieved by selection for diameter growth than by selection for specific gravity. Of the .51 pound gain in wood per tree only .08 pound was the result of higher specific gravity from stand selection. By using the multistage method of among-family and within-family selection for five-year half-height diameter (Namkoong, Snyder and Stonecypher, 1966), selecting the one third families with best diameter growth and the individual within each family plot with highest rate of diameter growth, a gain of 25 percent over the mean tree weight may be obtained. This gain of .87 pound will result in trees with 4.40 pound of wood per tree.

It should be emphasized that these gains do not take into account height growth changes resulting from among and within-family selection, differential survival of individual families or correlated response of wood density from within family selection (resulting from the positive wood density-diameter correlation). An attempt was made to estimate the correlated response of specific gravity; the resulting response was low and the omission of this response from the gain in weight of wood per tree probably has no measurable effect. However, there was a highly significant phenotypic correlation between family means of height and half-height diameter at age five (r=.79). Such a high positive correlation is indicative of a correlated response in height growth from among-family selection and that expected gains are underestimated.

CONCLUSIONS

1. If higher specific gravity wood were the goal of a Virginia pine breeding program, data from this young plantation indicate that most improvement may be achieved by stand selection. Heritability estimates for juvenile wood ranged from .129 to .183.

2. Extractive content in juvenile wood of Virginia pine is primarily influenced by environmental variables. There was no evidence of any significant genetic effect.

3. The heritability of diameter growth (.267) is comparable with heritabilities of other southern pines.

4. A significant positive correlation between extracted specific gravity and diameter growth was indicated on an individual tree basis.

5. A gain of 14 percent in yield of dry wood can be achieved in Virginia pine by a combination of stand selection for wood specific gravity and within-family selection for diameter growth. However, the gain achieved by among and within-family selection for diameter was 25 percent.

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