OPERATIONAL PLANTATIONS OF IMPROVED SLASH PINE: AGE 15 RESULTS

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Abstract.--Paired commercial plantations of "improved" and "unimproved" slash pine were compared for volume production and fusiform rust infection at fifteen years from planting at ten locations in the Georgia Flatwoods. The "improved" trees were progeny of an unrogued clonal seed orchard, where the parents were phenotypically selected for volume production, crown and bole characteristics, and disease resistance.

Overall, the "improved" trees could not be shown to be any better than the "unimproved." Our inability to detect a significant difference between "improved" and "unimproved" slash pine may be due to the insensitivity of the test; we were only able to detect differences greater than ten percent in volume and 23% in rust infection. Additional sample stands could not be located and the realized gain from the earliest phenotypic selection practices may never be known.

Separate volume equations were derived for the "improved" and "unimproved" stock used in this study. These volume equations were not significantly different indicating that bole form was not altered by selection either.

Additional keywords: Pinus elliottii, realized gain, volume equations, fusiform rust, tree improvement.

INTRODUCTION

The first plantations of trees established from clonal seed orchard progeny are reaching merchantable sizes and only now can we begin to evaluate the real gains made from early selection methods.

In this study we examine the volume production and fusiform rust resistance of Union Camp's first slash pine "improved" plantations in comparison to adjacent nonimproved plantations. Only from such commercial plantations can actual realized gains be determined. Data was collected in the winter of 1981-82, fifteen years after establishment.

Measurements of this material at ages five years and ten years have been reported by Zoerb (1972, 1977). He recorded height, diameter, and fusiform rust infection finding that the improved trees were four percent larger in height and diameter, but that they had 34% greater rust infection at age five and 17% greater infection at age 10.

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In this update, we have sought to emphasize volume on a per unit area basis as a means for comparison. In order to dc so, volume equations for improved stock had to be developed and compared to those for nonimproved stock.

The improved stock in this study are progeny from an unrogued clonal slash pine seed orchard, where the parents were phenotypically selected for volume production, fusiform rust resistance crown characteristics, and specific gravity. The results of this study apply only to "improved" populations derived from similar selection and propagation practices.

METHODS

Plot Measurements.

The study was made at 10 locations in the Georgia Coastal Plain (Figure 1) at each of which there was an improved and an unimproved stand. In each stand six .05 acre plots were established. Three of the six plots were selected according to the following criteria:

M1. inimal pest and pathogen evidence,
M2. inimal number of wild trees,
M3. inimal forked or otherwise deformed trees, and
4. Similar stand densities between improved and unimproved stands

The other three plots were located randomly, adjacent to the three selected plots, to provide unbiased estimates of stand characteristics.

During the period fall 1981/winter 1982 measurements taken on dbh, total height, fusiform rust stem cankers were recorded for each tree.

Stem Analysis.

Two trees per plot were selected and felled for stem analysis. Selection of the sample trees was such that the range of dbh's over all the plots was represented in the sample. Diameters outside and inside bark were measured at the stump end and at 4 foot intervals along the ' stem, and the volumes of each 4-foot section was calculated using Smalian's formula. Individual tree volumes were obtained by summing the section volumes.

Tree Volume Functions.

Individual tree volume equations were derived for trees in both improved and unimproved stands to estimate stand volumes. The observed tree volumes from the stem analysis were used to determine least squares estimates of the coefficients in the model

$$V = b_0 D^{b_1} H^{b_2}$$

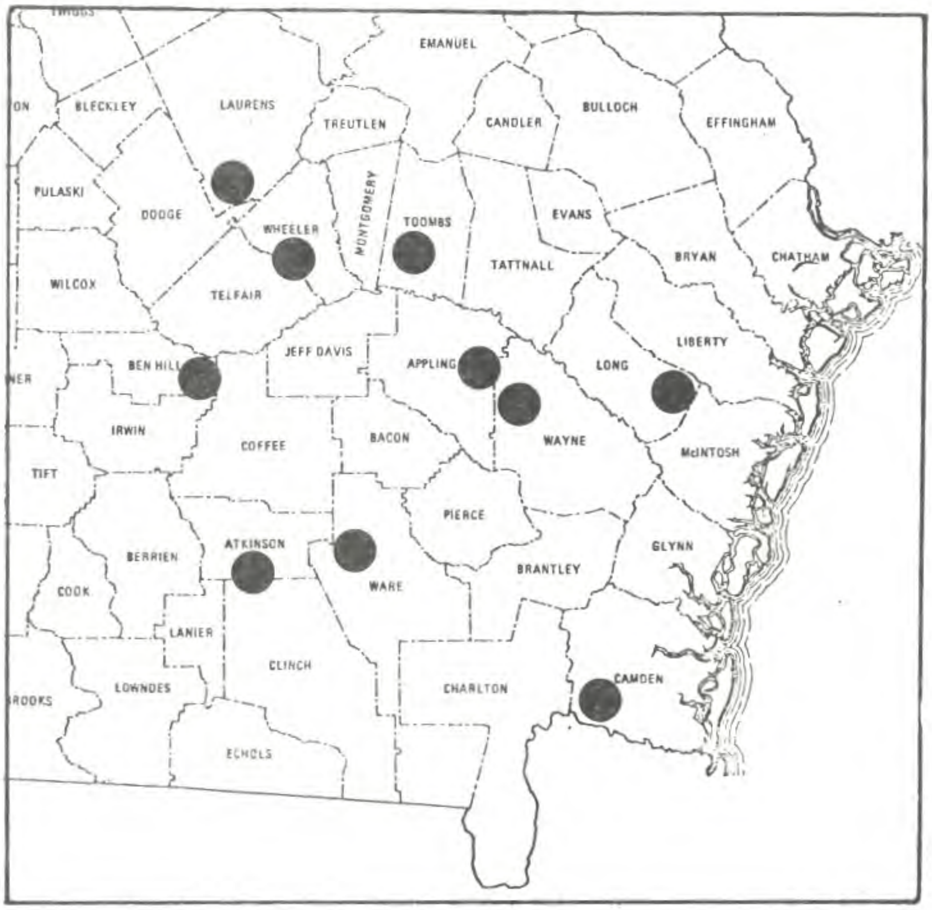

Figure 1.--Geographic location of sample plantations in Southeast Georgia.

where V = total stem volume (i.b. or o.b.) in cubic feet excluding stump
D = dbh in inches
H = total tree height in feet, and
b_0, b_1, b_2 = coefficients estimated from the observed data.

In addition, a taper function was derived from the above coefficients according to the methods of Clutter (1980).

Stand Volumes.

Stand volumes, on a per acre basis, were estimated by stand and stock tables in which the individual tree volume equations were applied to the diameter distribution on each plot.

RESULTS

Volume Characteristics.

Select versus random plots. At each location three improved and three unimproved plots were selected for comparison based primarily on equal plot density. Also three improved and unimproved plots were selected at random to provide unbiased comparisons of stand volumes and fusiform rust infection rates. However, the results from both kinds of comparisons were similar and the results that follow are, therefore, based on the pooled data.

Individual tree volume equations. The individual tree volume equations, both improved and unimproved, derived from the stem analysis, are shown in Table 1.

Table 1.--Estimated total cubic foot volume equations for 'improved' and 'unimproved' stands.

$$TCVOB_i = 0.0052897\ D^{1.9354216} H^{0.8741346}$$

$$TCVOB_u = 0.0068074\ D^{1.97604635} H^{0.78621135}$$

$$TCVIB_i = 0.0012254\ D^{1.9703507} H^{1.1384161}$$

$$TCVIB_u = 0.0013152\ D^{1.96456405} H^{1.11594819}$$

TCVOB = total stem cubic foot volume outside bark, excluding stump

TCVIB = total stem cubic foot volume inside bark, excluding stump

D = diameter breast height in inches
H = total tree height above ground level, in feet
i = 'improved'
u = 'unimproved'

The volume equations are graphed in Figure 2 which emphasizes their close similarity across the range of dbh's and heights found in these stands. The differences between improved and unimproved tree volume equations, both outside and inside bark, were tested in an analysis of covariance and could not be shown to be different at the five percent level (Table 2). This implies that the selection had no effect on tree taper either.

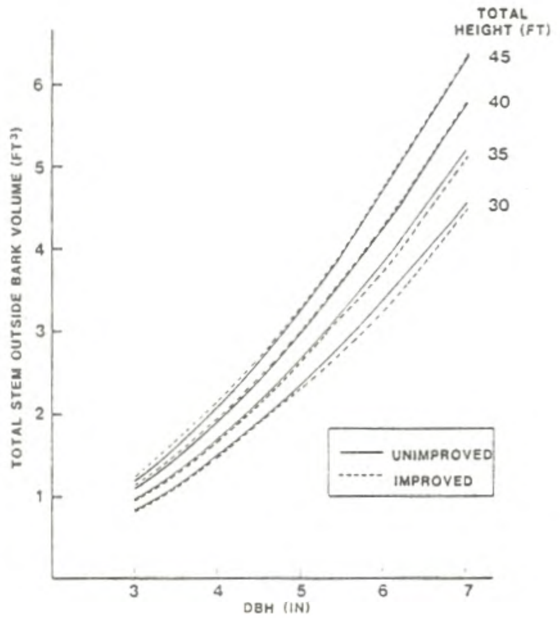

Figure 2.--Total stem: cubic foot outside bark curves for improved and unimproved slash pine.

Table 2.--Analysis of variance for testing seed source effects on volume equation 1.4.

Source	df	Outside Bark MS	F	
lnDbh and lnTotHt	2	51.0318	17010.6**	
Seed Source	3	0.0019	0.633n.s.	R^2 = 0.9933
Error	234	0.0030	-	
Total	239			

Source	df	Inside Bark MS	F	
lnDbh and lnTotHt	2	59.9479	8563.99**	
Seed Source	3	0.0091	1.3n.s.	R^2 = 0.9867
Error	234	0.0070	-	
Total	239			

Stand mean tree characteristics. The mean for all trees on the six improved and six unimproved plots at each locatior was calculated for dbh, total height, volume (inside and outside bark), and bark volume expressed as a percentage of total volume.

For each characteristic the difference between the improved and unimproved means was tested by a t-test at each location and by a paired t-test over all locations. The mean values are shown in Table 3 and significant differences at the five percent level are indicated by an asterisk.

In three of the ten locations the improved trees had significantly larger mean tree volumes while at one location the unimproved mean tree volume was greater. In general, the means for dbh and height follow the same pattern as mean tree volume. In seven out of the ten locations, however, bark percent was significantly less for the improved trees. At no location was mean bark percent greater for the improved trees.

The paired t-test over all locations showed no differences between the means with the exception of bark percent, where improved trees had a significantly smaller amount.

Stand characteristics. The stand characteristics, number of stems per acre, and volume per acre, inside and outside bark, were calculated at each location for the improved and unimproved stands, and the results are presented in Table 5.

The improved and unimproved means at each location were compared by t-tests. No differences were found at any location for these stand characteristics. Mean values over all locations could not be found to be different, either, using a paired t-test.

The number of stands available for this study was limited, and the inability to detect significant increases in volume may be due to the restricted sample size. With our sample size, we could detect a difference in volume per acre of ten percent (at the five percent level of probability). Sample sizes needed to detect smaller differences are shown in Table 5. About 40 pairs of stands would be needed to detect a difference of five percent in volume.

Fusiform Rust Infection.

Trees with fusiform bole cankers were recorded and the numbers expressed as a percentage of surviving trees at age 15. Mean infection rates for improved and unimproved stands are given for each location in Table 4. At each location the improved and unimproved infection rates were not significantly different.

Zoerb's (1972, 1977) five and ten year results show that the improved trees actually had greater fusiform infection. Our inability to show significant differences at age 15 may be due to greater mortality among the improved trees from rust infection at earlier ages.

Table 3.--Mean tree measures at sample locations.

Location	Seed Source	Dbh (in.)	TotHt (ft.)	TCVOB (ft^3)	TCVIB (ft^3)	Bark %
Appling Co.	I	5.3	40.4*	3.67	2.44	34.9
	U	5.5	42.2	4.04	2.66	35.0
Atkinson Co.	I	5.8	44.2	4.72*	3.22*	33.1*
	U	5.6	43.4	4.19	2.78	34.4
Ben Hill Co.	I	5.0	31.7	2.62	1.64	39.2
	U	4.8	32.5	2.49	1.51	40.4
Camden Co.	I	5.8*	44.7	4.63*	3.15*	32.9*
	U	5.4	43.4	4.04	2.70	34.4
Laurens Co.	I	5.4	36.6	3.62	2.37	36.6*
	U	5.8	37.2	4.10	2.62	37.8
Long Co.	I	4.6	32.2	2.42	1.52	39.2
	U	5.0*	34.4*	2.98*	1.88*	39.4
Toombs Co.	I	5.8*	38.2*	4.14*	2.72*	35.7*
	U	5.2	34.8	3.20	2.00	39.1
Ware Co.	I	5.2	41.4	3.62	2.40	34.4*
	U	5.2	41.4	3.51	2.30	35.5
Wheeler Co.	I	4.7	32.0	2.58	1.63	39.3
	U	4.9	34.2	2.70	1.68	39.4
Wayne Co.	I	4.9	38.8	3.03	1.98	35.8*
	U	5.0	37.7	3.07	1.96	37.4
Mean - All Locations	I	5.2	38.0	3.50	2.31	36.1**
	U	5.2	38.1	3.43	2.21	37.3

DISCUSSION

Realized gain in volume production.

To this point in time gains from improved southern pines have been estimated from small plot progeny tests. These results may be misleading when applied to commercial plantations, however. As Cannell (1982) points out, trees which grow largest in small plot progeny tests are superior competitors, and superior competitors may not produce maximal volume in large blocks, such as commercial plantations, because volume production on a stand depends more on the efficient use of limited resources rather than competitive ability.

Table 4.--Mean plot measures at sample locations.

Location	Seed Source	Stems/ Acre	Vol/Acre (ft^3)o.b.	Vol/Acre (ft^3)i.b.	Fusiform %
Appling Co.	I	456	1677	1115	27.3
	U	443	1792	1181	15.4
Atkinson Co.	I	476	2248	1535	16.8
	U	486	2041	1355	13.9
Ben Hill Co.	I	324	849	529	28.9
	U	376	937	570	12.9
Camden Co.	I	486	2252	1534	12.0
	U	520	2102	1402	8.2
Laurens Co.	I	250	905	592	60.4
	U	304	1243	794	73.8
Long Co.	I	350	849	534	16.1
	U	334	994	625	15.2
Toombs Co.	I	260	1076	707	45.2
	U	274	874	546	41.3
Ware Co.	I	486	1760	1171	5.8
	U	494	1734	1135	6.7
Wheeler Co.	(I)	174	447	282	35.9
	(U)	214	577	358	33.0
Wayne Co.	I	484	1466	959	13.2
	U	440	1350	862	10.6
Mean - All Locations	I	375	1353	896	26.2
	U	388	1364	883	23.1

Our primary purpose in this study was to determine realized gain from the earliest improved slash pine in commercial plantations rather than in small plot progeny tests and thereby also determine the actual effectiveness of the phenotypic selection practices used to assemble the improved parents. Unfortunately, our results are indefinitive. Because of the small number of stands available for sampling, we can say that the improved trees produced between ten percent more and eight percent less volume. Forty similar samples would be needed to detect the five percent improvement predicted from progeny test results (Ledig, 1973). To the best of our knowledge, however, the ten stands used in this study are the only ones of early vintage where improved and unimproved trees have been mapped separately.

Table 5.--Least significant differences and sample sizes estimates derived from data set.

Trait	Least significant difference (%)	Sample size needed to detect significant difference of: 5%	10%	15%
dbh	4.6	9	2	2
Total Height	3.4	5	2	2
TCVOB/tree	10.2	43	11	5
TCVIB/tree	11.2	51	13	6
Bark %	1.9	2	2	2
Stems/acre	5.9	14	4	2
TCVOB/acre	9.4	36	9	4
TCVIB/acre	10.3	43	11	5
Fusiform %	23.9	229	58	26

Although we were not able to meet our primary objective, more important is the fact that we may never be able to determine the gains made from the first round of phenotypic selection. This point may seem trivial now that we are well beyond this stage in the improvement of southern pines. However, because the southern pine breeding programs continue to be models for other breeding programs, it is imperative that we monitor the effectiveness of each procedure in the development of improved southern pines.

Differences in bark volume.

While no difference in wood volume was detected, the improved trees were shown to have significantly less bark volume (or thinner bark). Bark thickness was not a criterion for selection, nor is there any apparent biological association between bark thickness and any of the selection criteria (straightness, branch diameter, pruning, wood density, height, crown area/bole volume ratio, and disease resistance). The difference in bark thickness may be due to the geographic origins of the trees. The thinner-barked improved trees were from the moist Georgia-Florida flatwoods, while the thicker-barked unimproved trees were from the drier, and perhaps more fire prone, area around Emanuel County, Georgia.

Resistance to fusiform rust

When the first selections of slash pine were made, resistance to fusiform rust was not a major consideration. Trees with fusiform rust were not allowed, but most selections were made in stands with low infection rates. This amounted to de *facto* selection between stands. Results from this study and others (Goddard and Strickland, 1970, North Carolina State University, 1970, LaFarge and Krause, 1967) indicates that such practice was not effective. Phenotypic selection within heavily infected stands appears to be much more successful (Dinus, 1971).

CONCLUSION

This study is the first to investigate genetic gains in commercial plantations of southern pines. While the results are inconclusive, the need for future studies of this kind is evident. Testing of improved trees in large blocks is now widely practiced in southern pines and should yield more accurate estimates of gain made through genetic selection. However because these studies are designed to measure cumulative gain from several selection practices, the gain, in volume at least, from the early phenotypic selection practices may never be ascertained.

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