Genetic Variation in Sand Pine and Slash Pine for Energy Production in Silvicultural Biomass Plantations

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Abstract. - Sand pine and slash pine are candidate species for biomass plantations in Florida. Genetic variation within the species for energy production traits was examined to assess the increments possible through utilization of the most suitable families. Twenty-four sand pine families established near Archer, Florida, and 28 slash pine families established near Gainesville in high density tests were measured for growth traits, above ground biomass, moisture content, specific gravity, ash content, and calorimetric value.

Additional keywords: *Pinus clausa, Pinus elliottii.*

Energy production from woody biomass is receiving increasing emphasis in the United States, with silvicultural biomass plantations as one production alternative. In the Southeast, biomass production potential is very high, and in Florida, in particular, there are some unique opportunities to adapt promising species to the cultural conditions required for biomass generation.

Two species endigenous to Florida that are being examined in our Department of Energy project, Energy and Chemicals from Woody Species in Florida, are sand pine (*Pinus clausa* (Chapm.) Vasey) and slash pine (*P. elliottii* Engelm.). Sand pine is ideally suited to the large areas of dry, infertile, sandhills in the panhandle and peninsular portions of the state, and slash is well adapted to the extensive flatwoods common to north and central Florida.

Genetic improvement of these species has been conducted in the Cooperative Forest Genetics Research Program (CFGRP) at the University of Florida. For commercial forest plantations, sizable gains in volume and fusiform rust resistance of slash pine have been realized (Goddard and Rockwood 1978). Similar increases in volume production and other important traits of sand pine also appear possible (Rockwood and Goddard 1979).

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The potential response of these species to genetic improvement for the high-density, intensive culture regime required for silvicultural biomass plantations has not been previously evaluated. Important differences in the distribution of biomass, particularly its concentration in the stem, have been observed in Virginia pine (P. virginiana Mill.) families planted at commercial spacing (Matthews et al. 1975). Significant genetic differences in dry matter production and distribution of that biomass were found in loblolly pine (P. taeda L.) grown at 8' x 6' spacing and slash pine clones established at 15' by 15' (van Buijtenen 1978).

This paper presents findings concerning variation among sand pine and slash pine families grown under conditions that simulate biomass plantations.

MATERIALS AND METHODS

Field

Sand Pine

Some 50 Choctawhatchee sand pine (P. clausa var. immuginata Ward) families, derived from ortet open-pollinated seed collected from trees selected for superior growth rate and form, were established in a combination half-sib progeny test and seedling seed orchard near Archer, Florida. Planting was staggered over 3 years, 1973, 1974 and 1975. Families were planted two feet apart in 5 tree row plots spaced 15 feet apart in 20 replications.

In 1978, 24 families were sampled: 14 families in the 6-year-old planting, 6 in the 5-year-old planting and 9 in the 4-year-old planting. Up to 15 trees per family were sampled from the 4- and 6-year-old families and up to 6 trees per family from the 5-year-old families. Measurements included stem biomass (lbs.), combined branch and foliage biomass (lbs.), DBH (in.) (basal diameter on 4-year-old families) and total height (ft.). Additional sampling was performed on 5 of the trees sampled per family in the 4- and 6-year-old plantings and all of the trees sampled in the 5-year-old planting. Also, a basal stem disk and disks every 4 feet up the stem (except for 4-year-old trees) were retained for lab processing.

Slash Pine

Twenty-eight slash pine families in fertilizer tests established in 1971, 1972, 1973, and 1974 near Gainesville, Florida were sampled in 1978. The tests were randomized complete block designs involving three replications with split plots; fertilizer treatments were main plots and half-sib families (including a check lot) were sub-plots (5 tree row plots spaced 1 foot within rows and 4 feet between rows).

To make an initial assessment of biomass and energy production traits, one to three trees per family were sampled for the check seedlot and for 16 of the most promising families as determined by previous progeny evaluations. Stem biomass, combined branch and foliage biomass, DBH and total height were measured for all trees sampled. Retained for laboratory processing were a basal disk and disks every 4 feet up the stem.

Laboratory

Moisture content (percent) and specific gravity were evaluated for all of the slash and sand pine wood samples. The calorimetric value (BTU/lb.) and ash content (percent) were also determined for the wood of the basal disks of all the slash pine as well as all of the 6-year-old sand pine sampled.

All laboratory procedures were identical for the slash and sand pine samples. Determinations of moisture content, specific gravity, ash content, and calorimetric value were performed according to standards prescribed by the American Society for Testing and Materials (ASTM 1975 b, ASTM 1975 c, ASTM 1975 a, ASTM 1977) with one modification; burning of ash samples was done at 500°C.

RESULTS AND DISCUSSION

Sand Pine

Green weight biomass concentrations in the stem increased with age and were somewhat variable among families (Table 1). These concentrations, due to the 2' x 15' spacing, may not characterize the stem concentrations likely in similar aged but denser plantings.

Tree age and position in the stem influenced certain wood properties (Table 2). Moisture content decreased with tree age and increased with stem height at the same age; wood density, as somewhat shown by our data, can be expected to have the opposite relationships with age and stem position. Percent ash content was not discernibly related to position in the stem. BTU content was approximately 8600 per pound.

Table 1. Average and range of family means for percent of total above-ground green weight biomass in the stem of sand pine and slash pine.

Sand Pine				Slash Pine			
Age	No. of Families	Average	Range	Age	No. of Families	Average	Range
4	11	29.1	25.9-44.5	8	17	85.5	81.7-90.3
5	6	31.1	26.0-36.2	9	6	84.9	82.0-87.1
6	14	38.0	33.1-43.7	11	8	86.8	84.4-89.4

Table 2. Average wood properties and associated variation among families of Choctawhatchee sand pine stem wood as influenced by age and stem position.

Age	Stem Height 0'	4'	8'	12'
Moisture Content:				
4	194 176-206[1/]			
5	181 160-208	216 198-230	223 178-240	
6	159 147-170**	197 168-235**	219 199-252	218 191-263**
Specific Gravity:				
4	.361 .342-.387			
5	.360 .310-.405	.324 .314-.333	.338 .297-.383	
6	.425 .407-.453*	.366 .317-.404*	.332 .292-.354	.338 .286-.276*
BTU:				
6	8573 8451-8695	8523 8398-8758	8580 8378-8721	8604 8474-8712
Ash:				
6	.0036 .0021-.0065	.0028 .0024-.0034	.0024 .0009-.0030	.0037 .0010-.0058

1/ Range among family means. Significant variation among families noted by * and ** for the 5% and 1% levels, respectively.

Variation among families was observed for important stem wood characteristics at age 6 (Table 2). Moisture content differed by family at most stem positions, as did specific gravity. By utilizing high density, low moisture families, biomass plantations can be established that will yield more desirable stem wood.

Meaningful differences among these families were also noticed for critical growth traits. Fourth-year survival for the 26 families in the oldest planting averaged 67 percent while family means were as low as 20 percent and as high as 86 percent. Height differences at the same age were also significant with family means ranging from 4.1 feet to 10.5 feet.

No pertinent correlations among traits were detected. None of the wood properties were interrelated beyond certain implicit correlations among moisture content and specific gravity, and the growth traits were not related to each other. Further, no correlations among wood properties and growth traits were evident.

Improvement of Choctawhatchee sand pine for biomass production appears to be possible on several fronts. Volume production can be increased by selection for larger tree size in combination with emphasis on higher survival. Selection for wood properties can stress high wood density and low moisture content at the minimum. Characteristics of some of the better families are listed in Table 3.

Estimation of the possible stem wood yield of a sand pine biomass plantation in general, and the improvement due to using superior families in particular, is speculative for a variety of reasons. Although Choctawhatchee sand pine can tolerate a spacing of 2.5' x 3' for at least 17 years (Rockwood et al. 1979),

Table 3. Characterization of some better performing sand pine families.

	Age 6						
	Basal Disk Wood Properties					Age 4 Growth	
Family	Moisture Content	Specific Gravity	BTU	Ash Content	Percent Biomass in Stem	Percent Survival	Height (Feet)
121	147	.437	8512	.0030	37.3	85.7	9.0
147	153	.435	8615	.0037	38.4	79.0	10.1
149	150	.431	8606	.0025	36.6	82.0	9.5
169	156	.435	8451	.0035	40.9	84.3	9.7
181	149	.453	8613	.0043	39.0	64.4	10.2
					Total Mean	67.0	9.1

evidence of its performance at a 2' x 2' spacing is lacking. However, the performance of jack pine at close spacing (Zavitkovski and Dawson 1978) in combination with inferences from the Archer plantings suggests that such a spacing is feasible for short rotation periods. Using the survival observed at Archer and the average tree size, volume, and weight observed by Rockwood et al. (1979) for young trees, a potential dry weight yield of 3.2 tons per acre per year was derived (Table 4).

Yields from utilization of better growing families may result in biomass production gains of nearly 24 percent. The projection for improved sand pine in Table 4 assumes a 10 percent increment for survival and 5.5 percent increases for height and dbh. Any improvements in wood properties would further add to the potential yield.

Biomass plantations of sand pine differ drastically from those proposed for other species in that very little cultural treatment is required. Other than minimal site preparation, most likely double chopping, management is very low intensity. No fertilization, irrigation, weed control, or other practices should be required in the majority of plantings. Further, the sites available for sand pine establishment are very low quality and not given to other agricultural uses.

The ideal rotation time for a sand pine biomass plantation may not necessarily be six years. Observations of older plantings (Rockwood et al. 1979) suggest that yields increase if stands are carried for several more years.

Table 4. Estimated stem biomass yields of unimproved and genetically improved sand pine and slash pine.

	Sand Pine - Age 6		Slash Pine - Age 8	
	Unimproved	Improved	Unimproved	Improved
Spacing	2' x 2'	2' x 2'	2' x 2'	2' x 2'
Survival	67%	74%	55%	69%
Trees/Acre	7,296	8,026	5,990	7,514
Mean DBH	2.0"	2.1"	2.0"	2.1"
Mean Height	14.0'	14.8'	16.5'	20.3'
Ft.^{3}/Tree	.206	.231	.221	.305
Ft.^{3}/Acre	1,503	1,854	1,325	2,292
Ft.^{3}/Acre/Year	251	309	189	286
Lbs./Tree	5.25	5.96	5.90	9.04
Tons/Acre	19.2	23.9	17.7	34.0
Tons/Acre/Year	3.2	4.0	2.2	4.2

Slash Pine

The concentrations of green weight biomass in slash pine stems were considerably higher than those of sand pine (Table 1). The closer spacing of the slash pine produced great uniformity in the stem percentages, as very little variation among families was evident. The differences in concentrations from age 8 to age 11 were minimal; the age at which stemwood percentages first exceed 80 percent could not be determined from our sampling.

For the one age at which within tree variation for wood properties was evaluated, expected relationships between stem height and wood moisture content and specific gravity were observed (Table 5). With the exception of basal specific gravity, wood density decreased with tree height. Moisture content increased with height.

Table 5. Average wood properties and associated variation among 17 8-year-old slash pine families for stemwood.

Stem Height	Wood Property: Moisture Content	Specific Gravity	BTU	Ash Content
0'	105 89-142[1/]	.469 .414-.516	8509 8200-8790	.0028 .0019-.0042
4'	109 93-148	.492 .421-.522		
8'	124 89-139	.457 .397-.512		
12'	136 108-159	.424 .365-.453		
16'	152 112-187	.398 .361-.440		
20'	181 140-216	.355 .281-.420		
24'	185 127-247	.339 .296-.326		

[1/] Range among family means. Family variation was not significant for any trait.

The wood properties of 8-year-old slash pine were generally more favorable than those of 6-year-old pine. Wood density was typically 10% higher and moisture content 10% lower for slash. Ash contents were similar. BTU yields may be slightly lower for slash pine.

As with the sand pine, there were no meaningful correlations noted among the wood properties, but no significant variation among the slash pine families was detected. For certain data, large differences among family means were noted, but may not have been detectable due to the lower number of observations in our sampling.

Variation among families for growth traits was evident (Tables 6 and 7). Survival and height differences were significant by age 3 in all plantings. Families differed for dbh at age 7. Families generally surpassed check lot performance by age 7.

Growth traits were not interrelated nor were they associated with wood properties.

Increased slash pine biomass production can be achieved by utilizing better growing families and capitalizing on families with more desirable wood properties. The projections in Table 4 for unimproved stock are based on the performance of

Table 6. Growth performance of slash pine families in four high density plantings.

Planting	Age	Percent Survival	Height (Feet)
0-14	3		4.3 3.4-5.3[1/]
0-18	3		6.3 5.2-7.5*
0-29	3	95 77-100*	6.4 5.5-8.9*
0-36	3	65 28-95*	7.4 5.9-8.9*
	7	55 25-86*	16.5 11.8-22.9*

[1/] Range among family means. Significant variation at the 5% level as noted by *.

Table 7. Comparison of various classifications of slash pine families at age 7.

Trait	Check	All Families	Top 15 Families
Survival (percent)	46	55 25 - 86	69 58 - 86
Height (feet)		16.5 11.8 - 22.9	20.3 18.8 - 22.9
DBH (inches)	1.7	2.0 1.5 - 2.5	2.1 2.0 - 2.4

the families in the 8-year-old planting in combination with previously derived tree volume and weight estimates (Goddard and Strickland 1968). Due to a lower survival rate than the sand pine, an unimproved slash pine biomass plantation, in spite of a somewhat larger tree size and heavier wood, might be expected to produce a lower dry weight yield.

Use of the very best slash pine families can substantially increase production (Table 4). In the CFGRP, a much larger pool of genetic material may be exploited, and consequently greater increments in survival, height, and wood density can be anticipated. By implementation of the top 15 families as a characterization of the greater potential, a possible dry weight yield of 4.2 tons per acre was projected.

CONCLUSIONS

Choctawhatchee sand pine and slash pine have potential as biomass species for different sites in Florida. Projected yields for the species are comparable to other candidate species (Conde and Huffman 1978). Sand pine can be utilized on extensive areas of non-agricultural land in north and central Florida. Slash pine would be suitable to a larger area of wetter forest lands in north and central Florida. Both species, particularly sand pine, would require relatively low intensity management relative to regimes for other biomass candidates. Utilization of selected families promises to increase yields primarily through higher volume production and secondarily by better wood properties.

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