means (*Table 6*). Correlation coefficients for year 1 vs year 2 were 0.8 or greater, and those for year 1 and year 2 vs year 5 were 0.4 to 0.7. Unexpectedly, the year 1 vs year 5 coefficient was higher than the year 2 vs year 5 in Test I, containing predominantly western Tennessee parents. These coefficients thus substantiate the hypothesis of some major changes in family ranking over time.

Fourteen families well represented in both Test II and Test IV were included in an analysis of variance designed to evaluate family × site interaction. In this analysis neither family nor family × site terms were statistically significant.

Discussion

With the exception of the selfs, survival and growth in all the tests have been within expectations for an operational planting. Family variation exhibited to date over several site conditions offers good opportunities for improving early growth rate.

Despite design problems and some effects of environmental preconditioning, the data provide some guides for the use of yellow-poplar breeding material. The narrow-sense heritability for height (averaging about 0.3) and observed phenotypic standard deviation will give genetic gains of around 14 to 28 percent if the top 10 percent of full-sib families are selected. Though there was an apparent stabilization of heritability (i.e., similar estimates in years 4 and 5), environmental preconditioning is still suspect in this test, and gain estimates are tentative.

Comparison of heritabilities estimated from full-sib and open-pollinated families in this study strongly suggests that the assumption of half-sibs for open-pollinated families is not appropriate for yellow-poplar and that, in fact, open-pollinated progeny tests may have no role in yellow-poplar breeding. It is likely that, because of the predominance of insect pollination and restricted movement of insects during feeding, open-pollinated families range between full-sibs and siblings resulting from a restricted pollen mix, i.e., made up of pollen from a few male parents in close proximity to the female (Thor *et al.* 1976). Therefore, breeding should continue to rely on full-sib progeny tests, and mating should be aimed at identifying parental combinations with high specific combining ability or parents with exceptionally good general combining ability. Orchard design may vary from a number of two clone mini-orchards for the purpose of producing single high-value crosses to a relatively larger orchard with small numbers of clones, all with high general combining ability.

The relatively large contribution of male effects to genetic variance in Test II was an unexpected observation and may be an artifact of the experimental design. Therefore, breeding strategy should not be altered in light of this relationship until it is substantiated by further testing, perhaps via diallel crossing designs.

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Genetic Variation in Traits Important for Energy Utilization of Sand and Slash Pines

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Summary

Half-sib families of Choctawhatchee sand pine and slash pine were utilized to estimate genetic variation for a number of biomass traits including stem, branch, and total green weights; percent stem biomass; stem wood dry weight, volume, and energy content; foliage and branch moisture content, specific gravity, and ash content; and basal stem wood and bark moisture content, specific gravity, and heat value. Variation among families was observed for many traits, although significant differences were not detected for several traits due in part to limited sample size. Heritabilities of biomass quantity traits were moderate to high, and estimated genetic gains from parent plus family selection were appreciable. Biomass quality traits generally had low heritabilities which, coupled with less variation, resulted in limited gain potential. Meaningful increases in sand pine and slash pine productivity in "silvicultural energy plantations" appear possible through selection for increased stem biomass, better survival, and higher biomass density.

Key words: *Pinus clausa* var. *immuginata* Ward, *Pinus elliottii* var. *elliottii* Engelm., biomass production, genetic improvement.

Zusammenfassung

Halbgeschwister Familien von *Pinus clausa* var. *clausa* und *P. elliottii* var. *elliottii* wurden zur Schätzung der genetischen Variation von Biomasse-Eigenschaften verwendet: Stamm, Äste Gesamt-Grüngewicht; Prozent Stamm-Biomasse; Trockengewicht des Stammholzes, Volumen und Energiegehalt; Feuchtigkeitsgehalt, spezifisches Gewicht und Aschengehalt der Blätter und Äste; Feuchtigkeitsge-

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halt, spez. Gewicht und kalorischer Wert vom basalen Stammholz und Rinde.

Viele der erwähnten Charaktereigenschaften zeigten signifikante Unterschiede zwischen den Familien. Mehrere der angegebenen Eigenschaften zeigten keine signifikanten Unterschiede, doch dürfte dies an der ungenügenden Stichprobengröße liegen.

Die Heritabilität von quantitativen Biomasse-Eigenschaften war mittel bis hoch, und der geschätzte genetische Gewinn von Eltern- und Familienauslese bemerkenswert. Qualitative Biomasse-Eigenschaften zeigten allgemein geringe Heritabilitäten, die, verbunden mit geringer Variation, in begrenztem Gewinnpotential resultierten.

Bedeutende Wachstumszunahmen bei *P. clausa* var. *clausa* und *P. elliottii* var. *elliottii* in „waldbaulichen Energie-Plantagen" erscheinen möglich durch Selektion auf höhere Stamm-Biomasse, bessere Überlebensrate und erhöhte Biomasse-Dichte.

Introduction

Choctawhatchee sand pine *(Pinus clausa* var. *immuginata* Ward) and slash pine *(P. elliottii* var. *elliottii* Engelm.) are two promising species for silvicultural energy plantations in Florida (Conde and Rockwood, 1979). Choctawhatchee sand pine grows well on excessively drained sandy soils (Burns, 1973; Rockwood and Kok, 1978) which characterize some 800 thousand hectares of sandhills in northwest and central Florida. Dense plantings of Choctawhatchee sand pine result in high biomass production and have been suggested for production of energy wood (Rockwood *et al.*, 1980). Slash pine, which is well-adapted to nearly flat, moderately-drained, sandy sites, is the major pulpwood species in the extreme southeastern United States with over 2.1 million hectares of plantations established (Boyce *et al.*, 1975). For short rotation energy cropping, biomass yields of closely-spaced slash pines may also be acceptable (Rockwood and Frampton, 1979).

Considerable information exists on genetic variation in traits influencing pulpwood production of sand pine and slash pine (*e.g.*, Goddard and Rockwood, 1979), and some of these traits are likely to be important for biomass production. However, relatively little is known about genetic variability for biomass traits per se of these or other potential species. Significant clonal differences for total branch dry weight, total number of branches, and number of branches per whorl were noted in 5- and 6-year-old Monterey pine *(P. radiata* D. Don) planted at .6 × .6 m (Forrest and Ovington, 1971). Webb *et al.* (1973) found significant family differences but a relatively low heritability for dry weight in sycamore *(Plantanus occidentalis* L.) at a 1.2 × 1.2 m spacing. Matthews *et al.* (1975) reported family differences among 8-year-old Virginia pine *(Pinus virginiana* Mill.) grown at 2.4 × 2.4 m spacing for branch weight and the ratios of branch, stem, and bark weight to total weight. No differences among 14-year-old loblolly pine *(P. taeda* L.) families planted at 2.4 × 2.4 m were detected for total dry matter or its distribution among components by van Buijtenen (1978), but he did note clonal differences in slash pine planted at 4.6 × 4.6 m for stem wood, stem bark, branch wood, branch bark, and needle dry weight. Families of 11-year-old loblolly pine established at 1.8 × 1.8 m spacing differed in total above ground dry weight (Pope and Graney, 1978).

Variation in biomass quantity is of considerable importance in increasing productivity, but variation in biomass quality may also be useful. Calorimetric yields differ among foliage, wood, and bark components with the differences varying slightly with species (Frampton, 1981). Zavitkovski (1978) reported non-significant clonal differences in *Populus* for heat value of wood, bark, and foliage. Extractives content can considerably influence heat value (Shafizadeh, 1977); genetic variability for wood extractives content in slash pine has been observed (Rockwood *et al.*, 1981). Differences in wood specific gravity and moisture content have been well documented in many species *(e.g.*, Zobel, 1970).

Table 1. — Description of sand pine and slash pine experimental material.

Species -Test	Age	No. of Families	No. of Trees Per Family	Total Trees
Sand pine				
-Archer	4	11	15-16	166
-Archer	5	6	1-6	24
-Archer	6	13	4-16	147
Slash pine				
-0-36	8	14	5-16	135
-0-29	9	5	5-13	39
-Olustee	9	8	7-12	72
-0-18	10	5	9-11	54
-0-14	11	8	5-11	63

Materials and Methods

Field

A sand pine seedling seed orchard, originally established with ortet open-pollinated families at a .6 × 4.6 m spacing near Archer, Florida, was sampled for this study in Summer 1978. A total of 23 families were involved in three age groups *(Table 1)*. While no families were common to all three ages, the six 5-year-old families were also represented in the 4-year-old material, and one of the 4-year-old families was present in the 6-year-old set.

The slash pine sample was taken from September 1978 to July 1979 from four tests originally planted as fertilizer × family trials at .3 × 1.2 m spacing near Gainesville, Florida, and one test established as an oleoresin yield study at .5 × .9 m spacing at Olustee, Florida. The 35 orchard open-pollinated families ranged from 8 to 11 years of age *(Table 1)*. A checklot was common to the 0—18, 0—29, 0—36, and Olustee tests, and two families were common to 0—14 and 0—18.

Total sample size in a particular test depended on the trees available in the test and on personnel and time constraints in conducting the sampling. Sand pine families were established with up to 20 replications of 10-tree row plots, but only the 4-year-old trees were available to the full extent. The 5-year-old and 6-year-old sand pine had lesser numbers of trees due to within-family roguing that had been conducted. Slash pine families were typically established with up to 12 replications of 3-to 4-tree row plots, but, at the time of sampling, mortality had reduced the number of trees by about one-third.

Sample trees were randomly selected from the dominant or co-dominant trees available. The total height of each sample tree was measured to .03 m and its outside bark diameters at basal and breast height were determined to .25 cm. An exception was that only basal diameter was taken for the 4-year-old sand pine. After the tree was fell-

Table 2. — Overall means, coefficients of variation among family means, ranges among family means, and significance of family differences for biomass quantity traits of sand pine.

	Test Age								
	4			5			6		
Trait	Mean	CV[1]	Range	Mean	CV	Range	Mean	CV	Range
Total Ht. (m)	1.9			2.8			4.7		
DBH (cm)	1.3			2.5			8.1		
Green Stem Biomass (kg)	.8	29	.5-1.3*[2]	2.8	33	1.2- 4.1	15.5	13	11.7-18.7
Dry Stem Biomass (kg)							4.4	16	3.7- 5.8
Green Branch Biomass (kg)	2.0	27	1.0-3.1*	5.8	31	3.5- 8.2	26.4	17	19.2-35.4*
Green Total Biomass (kg)	2.8	27	1.4-4.4*	8.6	32	4.7-12.7*	41.9	14	26.4-52.4*
Percent Green Stem Biomass	28	9	25-34*	31	10	26-36	38	8	33-44*
Stem Wood Volume (m^3)							.012	14	.009-.014
Stem Wood Energy Content (Kcal)							20,690	35	10,029-31,031

[1] Coefficients of variation are in percent

[2] Significant at the 5% level

Table 3. — Overall means, coefficients of variation among family means, ranges among family means, and significance of family differences for biomass quantity traits of sand pine.

	Plantation Age								
	4[1]			5			6		
Trait	Mean	CV[2]	Range	Mean	CV	Range	Mean	CV	Range
Basal Wood Moisture Content (%)	192	6	176-206	184	6	160-208	159	5	147-153*
Basal Wood Specific Gravity	.362	4	.350-.387*[3]	.358	8	.310-.405	.425	2	.403-.453*
Basal Wood Heat Value (cal/g)							4754	1	4691-4831*
Basal Wood Ash Content (%)							.34	45	.12-.60
Basal Bark Moisture Content (%)	143	15	114-182	130	15	106-154	104	4	98-110
Basal Bark Specific Gravity	.312	5	.285-.335	.314	14	.269-.447*	.335	3	.321-.354
Basal Bark Heat Value (cal/g)							4999	1	4870-5081
Basal Bark Ash Content (%)							2.1	19	1.7-3.3
Foliage Moisture Content (%)	214	10	152-235*	203	18	160-262	217	8	189-248*
Foliage Heat Value (cal/g)							5219	1	4732-5337
Foliage Ash Content (%)							2.2	22	1.6-7.5
Branch Heat Value (cal/g)							4689	2	4531-4785

[1] Ages classes 3, 5, and 6 contained 43-56, 22-25, and 13-147 trees, respectively

[2] Coefficients of variation are in percent

[3] Significant at the 5% level

ed, branches were removed, and the biomass of the stem and the branch plus foliage components was immediately determined to .05 kg. All slash pine trees, all 5-year-old sand pine, and five trees in each 4- and 6-year-old sand pine family were then further sampled by removing disks approximately 2.5 cm thick at the base of the tree and at succeeding 1.2 m intervals up the stem. In addition, a mid-length disk was taken from a representative branch, and a foliage sample was collected. These biomass samples were placed in polyethylene bags and subsequently stored in a cold room or freezer until processed in the lab.

Laboratory

Green weights of the disks were determined after removing the samples from storage. Ovendry weights were taken after the samples reached a constant weight at 103

Table 4. — Overall means, coefficients of variation among family means, ranges among family means, and significance of family differences for biomass quantity traits of slash pine.

	Test														
	0-36			0-29			Olustee			0-18			0-14		
Trait	Mean	CV[1]	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV	Range
Total Ht. (m)	6.6			7.0			11.0			8.4			8.6		
DBH (cm)	5.8			5.8			8.6			6.6			6.9		
Green Stem Biomass (kgs)	10.8	22	7.4-14.7*[2]	13.1	19	10.1-16.3	34.6	14	27.3-43.8	19.3	58	9.0-30.1*	18.6	27	9.4-26.1
Green Branch Biomass (kgs)	4.9	12	4.0-5.9*	5.5	12	4.9-6.8	8.0	26	5.8-12.9	5.0	91	1.5-13.7*	5.4	26	3.4-7.4
Green Total Biomass (kgs)	15.7	18	11.7-20.6*	18.6	17	14.9-23.1	42.6	16	33.1-56.7	24.3	64	10.6-53.9*	24.0	27	12.8-32.7
Percent Green Stem Biomass	65	6	58-70*	68	4	64-72	82	2	78-84	84	3	80-88	76	4	68-79*

[1] Coefficients of variation are in percents

[2] Significant at the 5% level

Table 5. — Overall means, coefficients of variation among family means, ranges among family means, and significance of family differences for stem biomass quality traits of slash pine.

	Test														
	0-36[1]			0-29			Olustee			0-18			0-14		
Trait	Mean	CV[2]	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV	Range	Mean	CV	Range
Basal Wood Moisture Content (%)	102	3	98-107	96	5	88-104	113	8	97-126*	99	7	96-110*	85	4	76-89
Basal Wood Specific Gravity	.470	2	.453-.484	.470	4	.440-.482	.447	6	.420-.507*	.517	3	.500-.549*	534	2	.517-.559*
Basal Wood Heal Value (cal/g)	4687	1	4567-4766*	4706	1	4666-4768	4644	1	4561-4746*	4697	1	4660-4738	4852	2	4721-4983*
Basal Bark Moisture Content (%)	70	5	65-76	82	5	75-87	78	6	74-85	73	10	65-83	73	5	67-81
Basal Bark Specific Gravity	.264	6	.237-.298*	.271	3	.264-.286	.287	5	.272-.321	.268	4	.265-.284	.269	7	.238-.298
Basal Bark Heat Value (cal/g)							4977	2	4870-5085						

[1] Tests 0-36, 0-29, Olustee, 0-18, and 0-14 contained 118-139, 31-38, 8-72, 49-52, and 51-61 trees, respectively

[2] Coefficients of variation are in percents

[3] Significant at the 5% level

± 2° C. Moisture content was expressed as a percent of ovendry weight. Volumes of wood and branch samples for specific gravity calculations were determined by the water displacement method (Astm, 1975). Stem bark volumes were estimated from diameter inside bark, diameter outside bark, and disk width measurements. Heat values for the wood and bark of all stem basal disks were obtained from a Parr Model 1241 automatic adiabatic calorimeter. Upper stem wood heat values were derived for at least one tree in each family.

Numerical

Stem and branch green weights determined in the field were combined to give total above ground green weights. Percent green stem biomass was the proportion of the total contributed by the stem wood and bark.

Total cubic foot inside-bark volumes were calculated for the 6-year-old sand pine by use the STX computer program (Grosenbaugh, 1974). Derived stem section volumes were combined with disk wood properties to obtain total stem wood dry weights and energy contents.

Analyses of variance for all traits were performed with least square techniques using appropriate models, and necessary variance components and heritabilities were derived under the assumption that the families were half-sibs. Genetic gains were estimated assuming selection intensities of 1 in 400 for seed orchard trees and 1 in 4 for families for sand pine. Selection intensities for slash pine were 1 in 1000 for parent trees and 1 in 4 for families.

Results and Discussion

A variety of biomass prediction equations for the two species were developed (Frampton, 1981). Equations for stem, branch, and total green weight as functions of diameters and/or heights had coefficients of determination above .82. Prediction of percent stem biomass was much less reliable. Upper stem wood properties were often adequately predicted by basal or breast height disk determinations.

Within age groups, sand pine family differences were generally greater for biomass quantity traits *(Table 2)* than for biomass quality traits *(Table 3)*. A similar comparison was evident among slash pine families although sample sizes for biomass quantity traits *(Table 4)* were usually greater than for biomass quality traits *(Tables 5* and *6)*.

Table 6. — Overall means and ranges for foliage and branch biomass quality traits of slash pine.

Trait	Mean	Range
Foliage Moisture Content (%)	153	126-177
Foliage Heat Value (Cal/g)	4891	4775-5060
Branch Moisture Content (%)	169	142-203
Branch Specific Gravity	414	.350-.448
Branch Heat Value (Cal/g)	4703	4645-4810

Family differences for biomass quantity traits were found consistently in the 4- and 6-year-old sand pine *(Table 2)* and 8- and 10-year-old slash pine *(Table 4)*. Family differentials for percent green stem biomass were observed in the 4- and 6-year-old sand pine and 8- and 11-year-old slash pine. Relative family differences for biomass quantity traits were comparable but insignificant in the other age and test groups.

Differences among families were observed in certain biomass quality traits *(Tables 3, 5, and 6)*, although the total amount of variation was low. Of most importance was the influence of families on wood specific gravity, wood moisture content, and wood heat value.

Certain biomass trends with age or tree size were notable, but precise responses due to these factors were not possible due to cultural, genetic, and environmental factors confounded with the data. In sand pine, increased tree size resulted in more biomass being concentrated in the stem. Wood and bark specific gravity increased with age, while moisture content of the wood and bark decreased. These trends would be expected to continue with age beyond six years and trees greater than 5 m tall and 8 cm in diameter.

Changes in slash pine biomass traits more accurately reflect the influences of tree age or size because growing conditions across tests were somewhat similar. The amount of branch biomass was remarkably similar in these tests, which coupled with greater stem biomass with increased age and/or size resulted in higher concentration of biomass in the stem. Wood specific gravity generally increased with tree age. Bark properties appeared to be consistent from 8 to 11 years. The higher heat value of the 11-year-old trees may be due to greater extractives content in older trees.

Individual tree heritabilities are reported for the major traits in data sets having adequate family and tree representation *(Tables 7* and *8)*. In sand pine, genetic control of biomass traits generally appears strong. Stem green biomass, and wood specific gravity had high estimates, and heritability of stem wood dry weight also was promising.

Slash pine heritability estimates were lower and less consistent across two tests. In 0—36, stem and total biomass had family heritabilities above .5, while in the Olustee test branch biomass and stem biomass percent had the highest heritabilities. Wood and bark biomass qualities showed low levels of genetic control. The heritabilities of wood specific gravity obtained in this study was comparable to those *(e.g.,* family heritabilities of .27 and .35) estimated from an earlier, more complete sampling of these tests (Rockwood *et al.,* 1981).

The genetic gains calculated for the various traits assumed that the most expedient method of achieving superior planting stock for silvicultural energy plantations would be to collect seed from clones in existing seed orchards that had demonstrated good progeny performance in "biomass" tests. In many cases, clones are also superior for pulpwood production systems and consequently are now established in either rogued orchards or "1½-generation" orchards with other good performing clones.

Calculated gains for such situations confirm that emphasis on biomass quantity traits would be more productive than for biomass quality traits. Sand pine stem green biomass yields may be increased by more than 30%. Further selection for wood specific gravity could also enhance dry weight productivity. For increasing slash pine biomass production, major impetus should also apparently be given to stem green biomass with additional gain to be expected from selecting for wood specific gravity.

Selection for stem biomass and wood specific gravity may also enhance energy yields through indirect selection of other traits. Family mean correlations such as .74 between wood specific gravity and percent stem biomass in sand pine and .52 between wood specific gravity and heat value in slash pine suggest that minor improvements may accrue across traits to produce larger overall increases. The 6-year-old sand pine families assessed for stem wood energy content, for example, demonstrated accumulative differentials due to stem volume, wood specific gravity, and wood heat value factors.

Differentials between unselected planting stock and improved trees of sand pine and slash pine were estimated for short rotation energy cropping systems. At the 2400

Table 7. — Individual tree and family heritabilities and (parental + family) gain estimates for biomass traits of sand pine.

	Age 4			Age 6		
	h_I^2	h_F^2	Gain	h_I^2	h_F^2	Gain
Stem Biomass	.50 ± .32[1]	.73	76%	.55 ± .31	.80	34%
Branch Biomass	.09 ± .16	.32	27%	.38 ± .27	.66	32%
Total Biomass	.63 ± .34	.88	79%	.40 ± .28	.69	28%
Stem Biomass Percent	.07 ± .15	.23	4%	.52 ± .30	.78	18%
Wood Moisture Content	.21 ± .45	.35	6%	.58 ± .32	.80	13%
Wood Specific Gravity	.61 ± .55	.76	8%	.38 ± .27	.66	5%
Wood Heat Value				.22 ± .40	.37	1%
Stem Wood Dry Weight				.53 ± .50	.68	32%

[1] Standard error of heritability

Table 8. — Individual tree and family heritabilities and (parental + family) gain estimates for biomass traits of slash pine.

	0-36/Age 8			Olustee/Age 9		
	h_I^2	h_F^2	Gain	h_I^2	h_F^2	Gain
Stem Biomass	.30 ± .28[1]	.54	45%	.03 ± .28	.08	5%
Branch Biomass	.20 ± .24	.42	17%	.44 ± .44	.69	86%
Total Biomass	.38 ± .30	.65	46%	.12 ± .32	.28	18%
Stem Biomass Percent	.08 ± .22	.20	5%	.54 ± .47	.75	8%
Wood Moisture Content				.03 ± .29	.08	2%
Wood Specific Gravity	.11 ± .24	.23	28%	.23 ± .37	.45	9%
Wood Heat Value	.14 ± .26	.29	1%			
Bark Moisture Content				.19 ± .35	.39	12%
Bark Specific Gravity	.04 ± .27	.08	2%	.07 ± .38	.15	3%

[1] Standard error of heritability

trees/ha density in the sand pine tests reported here, the yield of improved sand pine was 55% greater than for unselected trees. The increase was partitioned to 1) some 20% due to a 67% survival rate of the better families as compared to an average of 57% (Rockwood and Frampton, 1979) and 2) about 35% accruing from greater biomass quantity and better biomass quality of the improved trees. Actual planting densities must be considerably higher, up to 15,000 trees/ha, to attain maximum biomass production in rotations of 6 to 10 years (Rockwood *et al.*, 1980).

Slash pine biomass yields may be similarly increased by use of improved trees. While slash pine is considered to be adversely affected by high planting densities (Collins, 1967), considerable genetic variability for survival was shown in the tests used here. The more competition-tolerant families had a 69% survival rate, the overall average of families was 55%, and an unimproved check had 46% survival in Test 0—36 after seven years (Rockwood and Frampton, 1979). Additional increments from increased biomass quantity per tree and higher wood specific gravity resulted in 85% greater productivity at 8 years for improved trees relative to unselected slash pine.

Such estimates of increased productivity are highly preliminary. To document achievable yields, the better sand pine and slash pine families identified in these studies have been used in operational-level biomass plantings.

Conclusions

There is sufficient genetic variation in sand and slash pines to warrant selection for increased productivity in silvicultural energy plantations. Variation among families and heritabilities were moderate to high for tree stem, branch, and total biomass. Family differences were observed for wood, bark, and foliage moisture contents, specific gravities, ash contents, and heat values, but heritabilities of these traits were usually low.

Primary emphasis should be on selection for individual tree biomass quantity traits, particularly stem biomass. Secondary selection for biomass quality traits, notably wood specific gravity, may be productive. Selection for tolerance to the high competition in dense plantings can enhance per unit area productivity, especially in the density-sensitive slash pine.

Gains possible from use of seed from clones in rogued or $1^1/_2$-generation seed orchards may be appreciable. Sand pine yields can be increased through use of clones whose progenies have greater stem biomass, better survival, and higher wood density. Slash pine productivity may be improved by the use of clones that give higher stem biomass and markedly increased survival.

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