Genetic Variation in Ocala Sand Pine and its Implications

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(Received January 1979 / January 1980)

Summary

Open-pollinated progenies of 56 Ocala sand pine selections and check lots of Ocala and Choctawhatchee sand pine were established in a progeny test in Taylor County, Florida. Based on a composite selection system incorporating fifth-year data on individual tree volume, survival, form, and fecundity, the test was converted to a seedling seed orchard having 55 families with from one to 18 trees per family. Specific gravity data were taken during the roguing at age 8 years. Heritabilities were calculated, and genetic gains for three orchard strategies were derived. Genetic potential for improving volume and form and maintaining fecundity appears good. In spite of indications that survival can be increased genetically, Ocala sand pine can generally be expected to survive poorly. The wood density level that can be achieved by breeding is below the level of Choctawhatchee check trees. Overall, genetic improvement is unlikely to produce Ocala sand pine that perform as well as Choctawhatchee sand pine.

Key words: Pinus clausa (Chapm.) Vasey, genetic variation, seedling seed orchard.

Zusammenfassung

Frei abgeblühte Nachkommenschaften von 56 selektierten *Pinus clausa* var. *clausa* (Ward), und Kontrollen von *P. c.* var, *clausa* und *Pinus clausa* var. *immunigata* (Ward) wurden einer Nachkommenschaftsprüfung in Taylor County, Florida unterzogen. Mit Hilfe eines kombinierten Selektionsverfahrens auf der Basis von Volumen, Überlebensfähigkeit, Form und Produktivität wurde nach fünf Jahren die Nachkommenschaftsprüfung in eine Sämlings-Samenplantage mit 55 Familien mit je 1 bis 18 Bäumen umgewandelt. Das spezifische Gewicht des Holzes wurde bei der Durchforstung unterlegener Bäume im achten Jahr ermittelt. Die Heritabilitäten wurden berechnet und der genetische Gewinn für drei Samenplantagen-Strategien abgeleitet. Das genetische Potential zur Erhaltung der Produktivität sowie der Volumen- und Formverbesserung erschien als gut. Trotz der Hinweise, daß die Überlebensrate genetisch verbessert werden kann, ist generell ein geringes Überlebensprozent für *P. c.* var. *clausa* zu erwarten. Das Niveau der Holzdichte, das durch Züchtung erreicht werden kann, liegt niedriger als die Holzdichte der *P. c.* var, *immunigata*-Kontrollbäume. Zusammenfassend ist zu schließen, daß eine genetische Verbesserung an *P. c.* var. *c.* wie an *P. c.* var. *i.* nicht zu erreichen sein wird.

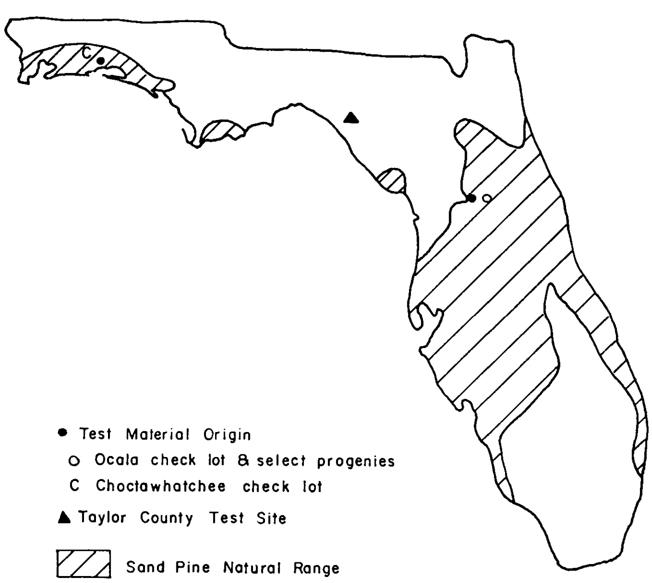

Figure 1. — Natural range of sand pine in Florida, origin of test material, and location of test site.

Introduction

Sand pine [*Pinus clausa* (Chapm.) Vasey] is a scrubby species with a native range almost exclusively in Florida (*Fig. 1*). Its natural occurrence is restricted to excessively well-drained sand hills or coastal dunes. Growth of dense stands of sand pine on these deep, nearly sterile sands is remarkable, and total wood production on such sites is far superior to that of other pine species (Burns, 1973b).

Geographic variation in the species has been noted, including seed characteristics and juvenile traits (Morris, 1967); two races of sand pine have been described (Ward, 1963; Burns, 1973a). The major concentration of Ocala sand pine is on the Ocala National Forest with outlying stands on deep sand sites widely scattered in peninsular Florida. The Choctawhatchee race is concentrated on Eglin Air Force Base in West Florida.

Major differences exist between the races. Most importantly, the Choctawhatchee race has generally better form, more resistance to mushroom root rot (Ross, 1973), higher survival, and denser wood (Taras, 1973) while the Ocala race has larger trees (Burns, 1973b; Rockwood and Kok, 1978). A feature of both races is precocious and abundant flowering; many cones are produced on 5-year-old seedlings.

Because of excellent growth on deep sand sites, sand pine is now widely used for reforestation of scrub oak sites in Florida. While the species typically has rough form, limbiness, and crookedness, very wide phenotypic variation in form and growth has been observed (Goddard and Strickland, 1973). Steps were initiated by the U. S. Forest Service, the Cooperative Forest Genetics Research Program (CFGRP) at the University of Florida, and forest industries in 1965 for genetic improvement of both races. This paper reviews accumulated results with Ocala sand pine, including the development of a seedling seed orchard, and discusses the potential of the race in comparison to Choctawhatchee sand pine.

Materials and Methods

Field Procedures

Natural sand pine stands on the Ocala National Forest and other stands in that vicinity were screened for outstanding sand pine phenotypes. In selection, emphasis was placed on straightness, natural pruning, size of limbs and general limbiness, and relative volume growth. Although good phenotypes were not numerous, approximately 100 individuals with excellent characteristics were located.

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Journal Series Paper No. 1358 of the Florida Agricultural Experiment Station

Cones were obtained from the ortets in 1969. Sufficient seedlings were produced from 56 individuals for the establishement in 1970 of a progeny test on a deep sand site in Taylor County, Florida. Five randomized blocks of 10-tree row plots were planted at a spacing of 6 × 10 feet. Bulk check lots, obtained following large-scale logging operations, were also included to represent the unimproved Ocala and Choctawhatchee races; two plots of each check were planted in each block.

All trees in the test were measured after five years of growth. In addition to total height in feet (TH) and diameter breast height in inches (DBH), trees were scored for form on a qualitative scale of 1 (poor) to 5 (good) in which both straightness and limbiness were considered. Fecundity was also evaluated by the same scale. Individual tree volumes were estimated by the formula Volume Outside Bark (cu. ft.) = $.001818 \cdot DBH^2 \cdot TH$.

At age 8, the progeny test was converted to a seedling seed orchard on the basis of composite evaluations, where combined values for each family were calculated using the following arbitrarily assigned weights for the age 5 traits: 3, 3, 1, and 1 for volume, form, survival, and fecundity, respectively. One family was completely removed. For the remaining families, a maximum of three selections were made per plot for top-rated families, two trees for intermediate families, and one tree per plot for poor families. Over 90 percent of the approximately 117 trees per acre remaining in the seedling seed orchard were derived from 44 families (*Table 1*).

Table 1. — Composition of the Ocala sand pine seedling seed orchard.

Number of Trees Per Family	Number of Families	Total Trees
1 - 5	11	44
6 - 10	27	220
11 - 18	17	219
	55	483

In conjunction with the roguing of the progeny test, wood density data were collected. Up to nine trees per plot were utilized for each progeny in each of three blocks. Check lot trees were also sampled. The basal stem sections were analyzed for unextracted specific gravity.

Statistical Procedures

Analyses of variance for four traits were performed by first calculating within plot variances and degrees of freedom and then utilizing plot means for deriving other values. Least squares procedures were used for volume, form, and fecundity since two plots had no surviving trees. By employing harmonic means for number of trees per plot for these three traits, within-and between-plots analyses were combined to obtain expected mean squares (*Table 2*). The within-plot variance for survival was approximated by (mean survival)·(100 - mean survival). Analysis of specific gravity data was by least squares.

The variance component for open-pollinated families was assumed to estimate 1/4 of the additive genetic variance. Individual tree and family mean heritabilities were calculated for all traits as follows:

$$h^2_I = \frac{4\sigma^2_f}{\sigma^2_w + \sigma^2_e + \sigma^2_f}$$

$$h^2_F = \frac{\sigma^2_f}{\frac{\sigma^2_w}{hr} + \frac{\sigma^2_e}{r} + \sigma^2_f}$$

Standard errors of both types of heritabilities were derived according to documented procedures (Osborne and Peterson, 1952).

Table 2. — Expected mean squares for analyses of variance.

Source	EMS
Survival:	
Reps	$\sigma^2_e + 56\,\sigma^2_r$
Progenies	$\sigma^2_e + 5\,\sigma^2_f$
Error	σ^2_e
Specific Gravity:	
Reps	$\sigma^2_w + 4.7701\,\sigma^2_e + 192.1583\,\sigma^2_r$
Progenies	$\sigma^2_w + 4.9367\,\sigma^2_e + 11.7508\,\sigma^2_f$
Error	$\sigma^2_w + 4.118\,\sigma^2_e$
Within Plots	σ^2_w
Volume, Form, and Fecundity:	
Reps	$\sigma^2_{w/h*} + \sigma^2_e + 55.5989\,\sigma^2_r$
Progenies	$\sigma^2_{w/h} + \sigma^2_e + 4.9642\,\sigma^2_f$
Error	$\sigma^2_{w/h} + \sigma^2_e$
Within Plots	$\sigma^2_{w/h}$

*Harmonic mean equals 5.6766 for volume and 5.70113 for form and fecundity.

Gain estimates for single trait selection were obtained for the seedling orchard under three representative selection regimes: retaining (1) the 17 best families and 26% of the trees in these families, (2) the 44 best families and 20% of the trees, and (3) the 55 best families and 18% of the trees, respectively. Parent trees were assumed to have been selected at one per 1000. Methodology and selection intensities for the three regimes were taken from Shelbourne (Shelbourne, 1969).

Results and Discussion

Considerable variation among family means was observed for volume, form, fecundity, and survival, but not for specific gravity (*Table 3*). For volume per tree, stringent selection of wild trees resulted in a more than 6 percent

Table 3. — Summary of progeny and check performance for five traits.[1]

	Trait				
	Volume Per Tree (ft^3)	Survival (%)	Specific Gravity	Form	Fecundity
Range Among Family Means	.117-.293	34-92	.400-.456	1.6-3.4	1.5-3.3
Standard Deviation Among Family Means	.037	13	.014	.4	.4
Mean of All Families	.203	68	.427	2.6	2.2
Mean for Top 17 Families for Indicated Trait	.247	83	.445	3.0	2.7
Mean of Top 17 Families in Composite Selection	.221	74	.430	3.0	2.1
Ocala Check Mean	.192	51	.414	2.6	1.9
Choctawhatchee Check Mean	.139	72	.478	2.2	2.4

[1]Specific gravity at age 8; all other traits at age 5.

Table 4. — Analyses of variance and variance components for five Ocala sand pine traits.

Source	Volume d.f.	Volume ms	Volume σ^2	Survival d.f.	Survival ms	Survival σ^2	Specific Gravity d.f.	Specific Gravity ms	Specific Gravity σ^2
Reps	4	.02750**		4	1777.**		2	.00046	
Progenies	55	.00657**	.00081	55	798**	72.5	55	.00234**	.000096
Error	218	.00255**	.00111	220	436	217.5	91	.00114**	.000078
Within Plots	1611	.00144	.00820			2178.6	513	.00082	.000822

Source	d.f.	Form ms	Form σ^2	Fecundity ms	Fecundity σ^2
Reps	4	.460		.364*	
Progenies	55	.735**	.096	.628**	.098
Error	218	.259**	.100	.143**	.042
Within Plots	1620	.158	.903	.101	.577

*and ** significant at the 5 % and 1 % levels, respectively

improvement over the Ocala check. Test data show the typical relationship between the two sand pine races (Rockwood and Kok, 1978), with individual Ocala trees being much larger than the Choctawhatchee check trees and average survival of the Ocala families being slightly less.

The average form of progenies was the same as the Ocala check lot, but many families had vastly improved stem straightness and branching characteristics. Surprisingly, the form of the Ocala trees was better than that of the Choctawhatchee trees.

Average fecundity of the progenies was more than the Ocala check, but less than the Choctawhatchee. Since flowering has been prolific and started at an early age, these differences are relatively unimportant.

The mean improvement of select lines over the Ocala check in survival was very notable, as this value approximated the survival rate of the Choctawhatchee check. The range among family means was nearly 60%.

Analyses of variance indicated that progenies were a significant source of variation for all traits (*Table 4*).

Table 5. — Heritability estimates and associated standard errors for Ocala sand pine.

Trait	Individual	Family
Volume	.32 ± .06	.61 ± .37
Survival	.12 ± .04	.45 ± .52
Specific Gravity	.39 ± .14	.49 ± 1.16
Form	.35 ± .09	.65 ± .34
Fecundity	.55 ± .12	.77 ± .22

Table 6. — Relative indices of variation among individuals and family means in five Ocala sand pine traits.

Trait	Among Individuals[1] (%)	Among Family Means[2] (%)
Volume	52.4	18.9
Survival	97.4	24.8
Specific Gravity	7.6	2.7
Form	40.3	14.8
Fecundity	45.3	19.0

1 $\frac{\sigma_I}{\text{Ocala Check Mean}} \times 100$

2 $\frac{\sigma_F}{\text{Ocala Check Mean}} \times 100$

Variation among replications was high for volume, survival, and fecundity, but not specific gravity and form. Progeny x replication interaction was evident for all traits except survival.

Individual and family heritabilities (*Table 5*) in conjunction with relative indices reflecting the level of total variation for the various traits (*Table 6*) suggest the degrees of improvement that can be anticipated. Volume per tree, which is moderately heritable and has a relatively high level of variation, has considerable likelihood for improvement. Tree form is somewhat more heritable, but a slightly lower level of variation is estimated. Because of the generally poor form of Ocala sand pine, improvement of this trait is particularly important.

Fecundity is the most heritable of the five traits and has a moderate degree of variation. While these results indicate that increases in cone productivity are possible, the trait requires little emphasis as 5-year-old trees were prolific cone and seed producers.

Survival and specific gravity, the two traits that are critical to the utilization of Ocala sand pine, exhibited differing combinations of heritability and variation. Survival was less heritable, but the amount of variation was substantial implying that an adequate response could be expected. Specific gravity, on the other hand, was somewhat more heritable, but an extremely low amount of variation was present. Therefore, little increase in wood density will result from selection and breeding.

Theoretical gains possible from the orchard were calculated assuming single trait selection (*Table 7*). Alternative 3 evaluates the potential of the present preliminary orchard. Two additional schemes, somewhat arbitrary yet dictated by the present composition of the orchard, were imposed to evaluate potential improvement under more intensive among-family selection. Neither involves within-family selection beyond what has already been conducted. Alternative 2 retains the 44 best families and reduces orchard density to an average of 106 trees per acre. Alternative 1, using the 17 best families, reduces the orchard to 53 trees per acre. Operationally, Alternative 2 would allow more within-family roguing, avoidance of half-sib mating, and a broader genetic base than Alternative 1.

The expected improvement in each trait, independent of the others under Alternative 3, was 46 percent for volume, 33 percent for survival, 8 percent for specific gravity, 45 percent for form, and 52 percent for fecundity relative to

Table 7. — Predicted selection gains for five traits of Ocala sand pine.

Trait	Alternative 1[a/] Units	%*	Alternative 2[b/] Units	%	Alternative 3[c/] Units	%
Volume	.104 ft³	54	.093	48	.089	46
Survival	22%	43	18	36	17	33
Specific Gravity	.037	9	.034	8	.033	8
Form	1.2	53	1.1	47	1.0	45
Fecundity	1.4	59	1.3	54	1.2	52

*percent relative to Ocala sand pine check.

a)selection of top 17 families (i = 1.16) and 26% of the trees in those families (i = 1.25).

b)selection of the top 44 families (i = .36) and 20 % of the trees in those families (i = 1.40).

c)selection of the top 55 families (i = .05) and 18 % of the trees in those families (i = 1.46).

the selection intensity for wild selection was assumed to be 1 in 1000 (i = 3.40).

the Ocala check. The intense family selection of Alternative 2 would increase the gain by approximately 2 percent for four traits. Very intensive family selection (Alternative 1) would raise the response some 8 percent relative to the current orchard for the same traits. The response of specific gravity to more intensive family selection was minimal.

Predicted volume improvement was appreciable under Alternative 1 for independent selection, but the discrepancy between the averages of the 17 families highest in volume and the 17 families best overall *(Table 3)* suggests that the orchard response will be less. While volume is not significantly related to the other traits *(Table 8)*, the emphasis on other traits in family selection resulted in a sacrifice in volume, as shown in an examination of several top-ranked families *(Table 9)*.

Improvement of survival appears possible based on the results of this study. The better families under composite selection approximated the performance of the Choctawhatchee check, and many top families bettered that standard.

Supplementary evidence (Burns, 1973b; Rockwood and Kok, 1978), however, indicates that the relatively good survival of Ocala progenies in this test is misleading. Also, five of six CFGRP progeny tests, including many of the same progenies, outplanted over the last two years have been failures, averaging less than 10 percent survival. These results make commercial utilization of Ocala sand pine questionable in spite of the indications in this study that survival can be genetically improved.

Good survival of Ocala sand pine appears highly dependent on favorable soil moisture at planting and during the first spring, more so than other races and species. On deep sand sites subject to drought, Ocala sand pine does not have good drought resistance immediately after planting. This may be due in part to the extremely short dormancy of Ocala sand pine seedlings which are frequently in a state of active growth at time of planting (Zelawski and Strickland, 1973). In contrast, well-established trees are very drought resistant.

The low specific gravity of Ocala sand pine is particularly crucial. The large difference between the Ocala and Choctawhatchee checks roughly corresponds to that which has been reported for older trees (Taras, 1973). Collectively, Ocala selections had slightly denser wood than the Ocala check apparently due to an association between specific gravity and tree form *(Table 8)* since density was not a selection criterion for the parent trees.

Desirable increases in wood density appear unattainable, however. The most intensive selection regime proposed for the orchard, Alternative 1, predicts an increase to .451, almost .03 below the Choctawhatchee check. No family had a mean specific gravity within .02 of the Choctawhatchee check. The omission of specific gravity from the overall evaluation of the families for roguing the orchard resulted in the better families having only slightly denser wood than the test average.

Tree form, notably stem straightness and branching characteristics, responded strongly and in agreement with its predictions. Many families exhibited relatively good form, and several trees had exceptionally straight stems and compact crowns compared to checks. Continued emphasis on selection for form should produce very acceptable phenotypes.

Fecundity was characterized as having the highest gain potential, but is a relatively unimportant selection consideration due to the prolific flowering characteristic of Ocala sand pine. Selected families generally flowered more abundantly than the Ocala check. While not significantly so, fecundity was the only trait with inverse associations with all other traits.

Table 8. — Correlations among family means for five traits of Ocala sand pine.

	Survival	Specific Gravity	Form	Fecundity
Volume	-.08	.01	.06	-.19
Survival		-.15	.06	-.15
Specific Gravity			.40**	-.12
Form				-.24

**Significant at the 1 % level of significance.

Table 9. — Some outstanding Ocala sand pine progenies and their performance by trait.

Progeny	Volume Per Tree (ft³)	Survival (%)	Specific Gravity	Form	Fecundity
1	.261	88	.444	2.8	2.6
12	.244	76	.438	2.9	2.1
20	.191	78	.431	3.2	2.4
22	.220	80	.418	3.0	1.7
25	.212	80	.421	2.8	2.2
27	.258	74	.406	2.8	2.5
28	.258	82	.424	3.0	2.0
32	.245	84	.432	2.9	1.6
37	.210	82	.429	2.7	2.3

The potential of the Ocala race for commercial outplanting may be tentatively assessed by comparing improved Ocala sand pine with Choctawhatchee sand pine, the current standard for sand hills reforestation, by incorporating survival, volume per tree, and specific gravity *(Table 10)*. At the planting density used in this study and applying the derived volume and survival figures, the Ocala selects would have nearly 38 percent more volume per acre at age

5 than Choctawhatchee checks. In terms of dry wood production using age 8 specific gravities for converting, the differential drops to a 23 percent advantage. However, this advantage must be taken as an optimum, in view of the uncharacteristically high survival of the Ocala trees in this study. In the more general situation where Ocala survival is very poor relative to Choctawhatchee, the differential could shift drastically in favor of Choctawhatchee, sand pine.

Conclusions

The results of this study are impetus for genetic improvement of Ocala sand pine. Considerable variation occurs for most traits, and calculated potentials for volume, survival, form, and fecundity separately are high. Improvement of wood density appears to be restricted.

In spite of these generally positive indications, the overall potential of the Ocala race for large scala reforestation is suspect. The race's poor survival under less than the best conditions and relatively low wood density, with little likelihood of genetic improvement, make it compare unfavorably with even unimproved Choctawhatchee sand pine.

Table 10. — Comparison of Ocala select trees with Choctawhatchee check trees.

	Ocala Selects	Choctawhatchee Checks
Trees Planted Per Acre	726	726
Trees Per Acre at Age 5	494	523
Volume Per Tree	.203 ft^3	.139 ft^3
Volume Per Acre	100.3 ft^3	72.7 ft^3
Specific Gravity	.427	.478
Solid Wood Per Acre	2,673 lbs.	2,168 lbs.

Appropriate English-Metric Conversions

1 foot	*= .3048 meter*
1 inch	*= 2.54 centimeters*
1 cubic foot	*= .0283 cubic meter*
1 tree per acre	*= 2.471 trees per hectare*
1 cubic foot per acre	*= .06997 cubic meter per hectare*
1 pound per acre	*= 1.121 kilograms per hectare*

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