Inherent Vigor Influences Growth of Slash Pine More than Intensive Cultural Treatments

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Individuals of a species often exhibit wide differences in growth rate due to inherent and environmental influences. Such variations are important in natural and artificial selection and greatly influence efforts in tree improvement. To maximize tree growth, it is necessary to determine thc relative effects of these factors under varying conditions for a particular species.

Breeding is a practical approach to improving tree growth. BARBER (1961) noted that 8-year-old slash pine progenies ranged from 19 to 25 feet in height and from 4.2 to 5.4 inches in d.b.h. Average volumes of 13-year-old slash pine progenies ranged from 6 to 9 cubic feet per tree (SQUILLACE and BENGTSON 1961). Fifteen-year-old clones of Pinus radiata D. DON varied in size from a maximum of 9.8 inches d.b.h. and 49 feet in height to a minimum of 3.7 inches and 20 feet (FIELDING and BROWN 1961). ZOBEL (1969) estimated that breeding can increase southern pine volume growth by 10 percent or more over a rotation.

Although environmental manipulation through fertilization, drainage, and other cultural treatments affects tree growth, only during recent years have genotype-environment interactions been closely studied. Slash pine progeny lines showed significant seed source X fertilization and seed source X cultivation interactions for height and diameter growth (PRITCHETT and GODDARD 1967, KAUFMAN 1968). A strong clone X fertilizer interaction was observed for diameter and height in 1-year-old Populus detoides BARTR. (CURLIN 1967). Numerous other genotype-environment interactions are summarized by SQUILLACE (1970).

The present study was designed to evaluate the long term effects of intensive culture on selected slash pine clones and to provide a better understanding of the relative influences of inheritance and environment on the growth of slash pine.

Experimental Design and Treatments

The study area was located in northeast Florida on a well-drained flatwoods soil (Klej fine sand) formerly under cultivation. The study was installed in 1957 and 1958 in a split-plot 2^3 factorial design. Cultural treatments, begun in 1960, were as follows:

Irrigation (split plot):

A. No addition to the average 52 inches of rainfall per year.

B. Irrigation to provide at least 2 inches of total water (rainfall plus irrigation) per week from March through November, and at least 1 inch per week from December through February.

Fertilization:

A. No fertilizer.

B. Uramite was hand broadcast around each tree at the rate of 0.2 lbs. N/tree in April 1960 and 0.3 lbs./tree in April 1961; superphosphate (20 percent) was spread at 50 lbs. P/acre in April 1962; ammonium nitrate was spread at 150 lbs. N/acre, both in the spring of 1964 and in May 1967.

Soil Cover:

A. Disking to a depth of 5 inches four times annually until 1965, but only twice annually from 1965 to 1969.

B. Cover crop of hairy indigo (Indigofera hirsuta L.), mowed once annually.

There were no untreated control plots; comparisons were made among the factorial combinations of treatments.

A set of 18 ramets (1 from each clone) comprised a plot for the environmental treatments. The experiment was replicated three times; thus, it contained a total of $18 \times 8 \times 3 = 432$ ramets. The plots were separated by 1 or 2 rows of commercial seedlings, and all trees were planted at 20- X 20-foot spacing.

The clonal stock was air layered from 11-year-old ortets of known parentage. All ortets were grown in a nearby progeny test plantation and were control-pollinated or wind-pollinated progeny of trees growing within 100 miles of the study area.

In October 1969, d.b.h. and total height were measured on the 12-year-old experimental ramets, as well as on the 23-year-old ortets and 212 commercial seedlings separating the treatment plots. Per-tree volumes to a 4-inch top diameter were then calculated from the formula of BENNETT et al. (1959) for plantation-grown trees.

Results and Discussion

Genetic Effects:

Inherent growth differences were statistically significant at the 1 percent level of probability (figure I). The following tabulation summarizes the average tree size by clone for all cultural treatments combined:

Material	Height	D.B.H.	Volume
	(Feet)	(Inches)	(Cubic feet)
Smallest clone	37	7.1	4.1
Average clone	42	9.2	9.2
Largest clone	46	10.4	12.8

Four of the 18 clones averaged 12 or more cubic feet of merchantable volume per tree. Eight clones averaged from 9 to 10 cubic feet while 6 others averaged less than 8 cubic feet per tree. The two largest air layers were each 48 feet tall, 12.1 inches d.b.h., and had 18 cubic feet of merchantable volume. There were no apparent differences in stem and crown form between the fast and slow growing air layers. Slow growing clones had the least variation in individual ramet volumes, rapid growing clones had the greatest variation.

The broad-sense heritability for merchantable volume, based on the intraclass correlation of ramets, was 0.59 (with a 95 percent confidence interval of 0.23 to 0.95). The ortet-ramet correlation for volume was 0.60 (with a 95 percent confidence interval of 0.14 to 0.83) (figure 2). There was also a strong height correlation between the 23-year-

Figure 1. — Comparison of ramets from slowly vs. rapidly growing clones. The fastest growing clone had more than 3 times the wood volume of the slowest grower, indicating wide genetic differences among individual trees.

old ortets and the ramets at 4 years of age (r = 0.56 with a 95 percent confidence interval of 0.11 to 0.80). The height of ramets at 4 and 12 years of age, were very closely correlated (r = 0.80 with a 95 percent confidence interval of 0.50 to 0.91).

These results indicate that rapidly growing ortets have rapidly growing vegetative propagules. This demonstration of genetic effects suggests that we can put more emphasis on early clonal performance in judging the genetic potential of field selections. However, when selections are evaluated on the basis of ramet performance, it should be recognized that differences in the age of ortets may have to be taken into account (Franklin 1969).

The broad-sense heritability, as well as the ortet-ramet correlations may have been biased upward by non-genetic "c" effects associated with cloning (Libby and Jund 1962). Squillace and Bengtson (1961) estimated narrow-sense heritability for volume to be 0.31 to 0.35, based upon the progeny plantation in which ortets for this study were growing. The difference between narrow-sense and broad-sense heritability was probably due to both non-additive genetic variation and "c" effects — which cannot be separated in this study. However, it appears that "c" effects were relatively small because the ortets were of the same age and were grown under rather uniform conditions.

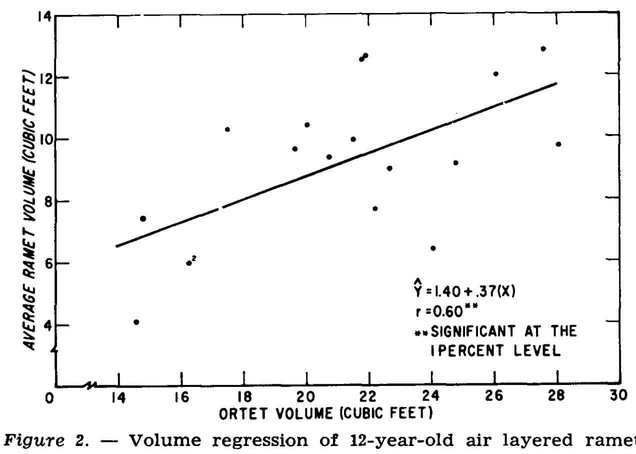

Figure 2. — Volume regression of 12-year-old air layered ramets with 23-year-old ortets grown from seed.

Table 1. — Effects of cultural treatments on merchantable volume of 12-year-old slash pine ramets[1]).

	Irrigation		No irrigation	
	Disking	Cover crop	Disking	Cover crop
	------ Cubic feet per tree ------			
Fertilization	9.5	9.5	9.1	9.7
No fertilization	8.3	9.8	9.2	8.3

[1]) Each number is the average of 54 trees — three trees from each of 18 clones.

Cultural Effects:

Merchantable tree volume was significantly affected (.01 level) by the interaction of irrigation, fertilization, and cover cropping. Plots which were irrigated and cover cropped but not fertilized had the greatest merchantable volume — 9.8 cubic feet per tree. This was only 1 to 3 percent greater than the volumes of three other intensive treatment combinations *(table 1)*, but was 18 percent greater than both cover cropping only and irrigation + disking + no fertilization. The generally rapid growth of all trees can be attributed to the relatively fertile old field site. Growth differences due to cultural treatments (other than irrigation) would probably have been greater on untilled flatwood sites which have lower nutrient reserves and poorer drainage.

Irrigation interacted with cover cropping in the same general manner as the above-mentioned three-way interaction. Irrigation + cover cropping yielded 6 to 8 percent more volume than did the other treatment combinations. This interaction showed up as early as age 4, when irrigated cover cropped trees had greater heights and diameters than nonirrigated cover cropped trees (Bengtson 1969). It is possible that the legume competed with the trees for soil moisture during the first few years of plantation establishment.

Of the main treatment effects, fertilization increased volume over no fertilization by 6 percent. Although this difference was statistically significant, the actual effect of fertilization was questionable because of the significant treatment interactions. There were no significant differences in volume among the other main treatments.

There were no significant treatment × clone interactions.

Isolation trees grown from seed and experimental trees grown from vegetative propagules had almost identical volumes after 12 years in the field. Air layers growing on plots that were cover cropped or disked without fertilization or irrigation averaged 8.7 cubic feet of merchantable volume per tree, whereas seedlings surrounding these plots averaged 8.4 cubic feet. This difference was not statistically significant. Seedlings and air layers under other treatments could not be compared directly; however, average tree volumes were similar. These results suggest that the growth of vegetative propagules, from relatively young ortets, is at least as fast as the growth of trees produced from seed.

Conclusions

Under the conditions of this study, inherent growth differences were much greater than the effects of intensive culture. Ramets produced from rapidly growing ortets grew faster than those from slowly growing ortets. This suggests that more emphasis can be placed on early clonal performance in judging the genetic potential of field selections. Rapidly growing clones had up to three times more merchantable volume than slowly growing clones after 12 years in the field. Propagules air layered from young ortets grew as rapidly as commercial seedlings.

Although there were no untreated controls to compare with the cultural treatments, results suggest that trees will grow best under the most intensive cultural treament combinations. A summer cover crop without irrigation or supplemental fertilization may reduce tree growth by competing with trees for available water and nutrients. The cost of establishing and maintaining an irrigation system, coupled with relatively small increases obtained in tree growth, indicates that irrigation is not practical for slash pine plantations in the flatwoods.

Abstract

Growth of eighteen 12-year-old slash pine (*Pinus elliottii* ENGELM.) clones that received intensive care for 10 years was compared. Cultural treatments included a factorial arrangement of irrigation vs. no irrigation, fertilization vs. no fertilization, and disking vs. cover cropping. Statistically significant differences in volume resulting from clonal and treatment effects were found, but clonal effects were much greater. Overall, the clones averaged 9.2 cubic feet of merchantable volume per tree. Trees of the fastest growing clone averaged 12.8 cubic feet per tree; those of the slowest averaged only 4.1 cubic feet. The ortet-ramet correlation for merchantable volume was relatively strong ($r = 0.60$), indicating that rapidly growing ortets tend to have rapidly growing ramets. Intensive culture increased tree growth over limited culture by 14 to 18 percent. Air layered propagules grew at the same rate as commercial trees grown from seed.

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