PROGENY TESTING FOR INTENSIVE MANAGEMENT

R. E. Goddard and W. H. Smith[1/]

Trends in commercial forestry in the South are towards intensification of forest management. Rising taxes, soaring wages, increases in mill capacity, reduction of land area devoted primarily to timber production, and mechanization of forestry practices from planting to harvest force us to seek maximum yields from managed forests.

Programs for forest tree improvement are one phase of this effort to produce more and better timber per acre. Similarly to produce more wood, intensive silviculture is now the rule rather than the exception. Conversion from natural to planted stands, site preparation prior to planting including bedding of thousands of acres, and water control are common practices. A procedure not yet used on an appreciable scale is application of chemical fertilizers to planted stands. Forest fertilization can be expected to expand rapidly as forest-soil fertility is understood and as procedures and prescriptions are developed.

The parallel development of genetic improvement and intensification of cultural measures we are experiencing in plantation forestry is similar in many respects to the agricultural explosion during the 20 century. An example is hybrid corn. Although there were several decades of prior development, widespread acceptance of hybrids by farmers did not begin until about 1940. Current corn yields per acre are many-fold higher than 30 years ago. However, the genetic improvement of corn and modern farming practices are so closely meshed that the effects of genetics and cultural practices cannot be separated. We can expect a comparable compounded progress in forest trees with the greatest gains achieved by development of strains that take fullest advantage of improved cultural practices.

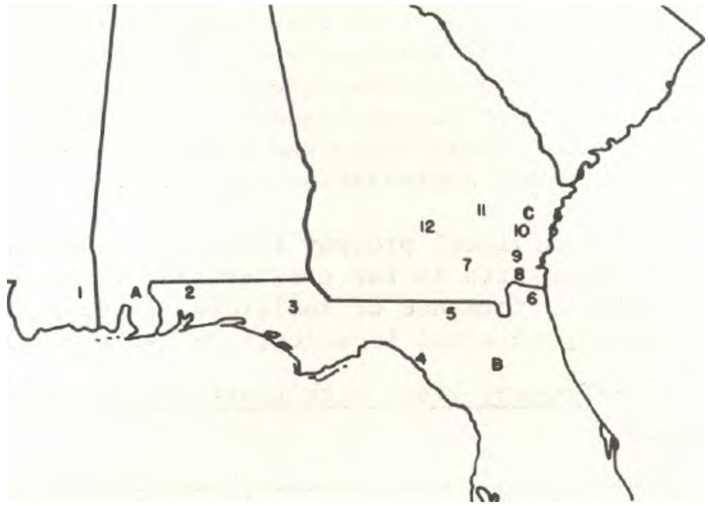
GENOTYPE X ENVIRONMENT INTERACTIONS

The differential response of various genetic entities to changes in environment, or in statistical terms, the genotype X environment interaction, is a common biological phenomenon and can be expected to occur with forest tree species. This is one of the main reasons for establishing geographic seed source studies. The sources best for planting in Florida may not be the best for use in Texas. A study established in 1965 in the Florida cooperative program illustrates some interactions between progeny lines and general environment.

Seed from approximately 90 slash pine clones were collected in seed orchards. Some 12 geographic areas within the natural range of slash pine were represented by up to 12 ortets (mostly 5-10 ortets per area). (See Figure 1). In January 1965, outplantings were established in Alachua County, Florida, Baldwin County, Alabama, and Long County, Georgia. Site preparation in each location was standard practice for the area and in no case was particularly thorough. The Florida and Georgia sites are flatwoods and had a single harrowing plus bedding. The Alabama site is rolling hillside and was only

---

[1/] Associate and Assistant Professor, respectively, University of Florida, School of Forestry, Gainesville, Florida.



1. George-Jackson, Miss.
2. Escambia-Santa Rosa, Fla.
3. Holmes-Calhoun, Fla.
4. Taylor-Dixie, Fla.
5. Madison-Hamilton, Fla.
6. Nassau-Duval, Fla.
7. Atkinson-Clinch, Ga.
8. Charlton-Camden, Ga.
9. Brantley, Ga.
10. Wayne, Ga.
11. Telfair-Appling, Ga.
12. Worth-Turner, Ga.

Planting Sites

A. Baldwin, Ala.
B. Alachua, Fla.
C. Long, Ga.

Figure 1.--Ortet locations and outplanting sites for slash pine select tree provenance trials.

---

chopped although a front-end blade was used to clear away debris during the planting operation. Because of variable quantities of seedlings available, it was not possible to establish all progeny lines at each planting site, but 30 lines are common to all sites.

Table 1.--Mean third-year height on three test sites by area of ortet location

Alachua, Florida Test Site			Baldwin, Alabama Test Site			Long, Georgia Test Site		
Ortet Location	No. of progeny lines	mean ht. (ft)	Ortet Location	No. of progeny lines	mean ht. (ft)	Ortet Location	No. of progeny lines	mean ht. (ft)
5	4	4.5	1	7	4.6	7	7	4.1
4	7	4.2	9	3	4.6	8	5	4.0
8	4	4.1	7	7	4.6	1	6	3.9
6	10	4.0	8	5	4.5	10	9	3.8
7	8	3.9	11	7	4.3	9	2	3.8
9	9	3.8	6	9	4.3	6	7	3.8
11	9	3.7	4	1	4.2	4	5	3.8
10	12	3.6	3	4	4.1	11	7	3.7
12	6	3.5	10	10	4.1	5	3	3.7
1	10	3.5	12	1	4.1	3	3	3.6
2	7	3.3	2	6	4.0	2	2	3.5
3	6	3.3						

Total tree heights three years after establishment were measured in January 1968. Results at this stage indicate some effect of ortet location (Table 1). At the Alachua County site, trees from the nearer areas grew better on the average than trees of more distant origin. The same trend was true for the Georgia and Alabama sites, except for the poor performance of West Florida trees on all sites and the good growth of Mississippi progenies on both Alabama and southeast Georgia sites.

When individual progeny lines are examined, it is obvious that variation within provenances is far greater than differences between provenance averages. The performance of individual lines at the three test sites shows little relationship to ortet location. In Table 2, the dozen lines at each site with greatest mean height are listed. Some individual lines from distant sources grew faster than many relatively local lines. Also, several lines are among the top performers at two different test locations.

Table 2.--Progeny lines with greatest mean third-year height on three test sites

Alachua, Florida Test Site			Baldwin, Alabama Test Site			Long, Georgia Test Site		
Ortet Location	Progeny line	mean ht. (ft)	Ortet Location	Progeny line	mean ht. (ft)	Ortet Location	Progeny line	mean ht. (ft)
5	222-56	5.3	9	263-56	5.7	8	265-55	5.3
6	106-56	5.3	7	143-56	5.5	7	89-56	4.9
5	283-55	5.0	1	89-57	5.3	7	16-57	4.6
4	248-56	449	1	34-58	5.3	1	88-57	4.4
6	262-55	4.8	11	38-56	5.3	10	240-55	4.4
11	11-57	4.8	7	89-56	5.1	10	286-56	4.3
4	1-56	4.7	6	113-56	4.9	1	89-57	4.2
8	97-56	4.5	1	41-58	4.8	5	222-56	4.2
7	16-57	4.4	7	87-56	4.8	7	87-56	4.2
10	33-56	4.4	8	97-56	4.8	6	121-56	4.1
6	114-56	4.3	8	100-56	4.7	11	77-56	4.1
7	48-56	4.3	10	235-55	4.7	4	1-56	4.0

Analysis of variance involving the 30 lines planted on all three sites (Table 3) indicated highly significant differences among all major effects, i.e. sites, provenances, and lines within provenances. In addition, the provenances X sites and the lines within provenances X sites interactions were significant. This later interaction indicates that all lines within a provenance did not react to site differences in the same manner. Some lines grew well in only one location while others shawed very satisfactory growth at all sites.

In older slash pine progeny tests there is good correlation (r=.88) between third year progeny mean height and fifth year volume (Goddard and Strickland, 1968). Thus, if the various progeny lines continue development in the pattern indicated in these tests, clones for a slash pine orchard for any specific area can be selected from much of the species range and need not be limited to the area served by the orchard. However, the specific clones that will produce the best-growing planting stock for an area must be determined by progeny tests. Orchards established on the basis of progeny-test results should achieve improvement substantially above current orchards.

Table 3.--Anal sis of variance. Third year height of 30 slash pine progeny lines on three sites

Source of variation	Degrees of Freedom	Mean Square
Sites	2	23.90**
Lines	29	4.19**
Provenances	10	5.66**
Lines/Provenances	19	3.42**
Lines X Sites	58	1.89**
Provenances X Sites	20	1.13*
Lines/Provenances X Sites	38	2.29**
Experimental Error	27	.48

* Significant at 5% level of probability.
** Significant at 1% level of probability.

GENOTYPE X CULTURAL TREATMENT

Just as various groups of genetically related plants react differently to changes in climatic, edaphic and other factors of the general environment, comparable interactions with cultural treatments occur. Studies of differential responses of slash pine lines to cultural measures have been underway for several years in the University of Florida cooperative program. The first, established in 1961, included fertilization, irrigation, cultivation and seed parent as variables and has been previously reported (Pritchett and Goddard, 1967). In this study, magnesium ammonium phosphate was applied annually to individual trees, irrigation was applied during spring and fall dry periods and cultivation consisted of light rototilling between rows.

All treatments had significant effects on tree growth, particularly during the last two years of the five-year study. Irrigation increased mean total height at five **years** by 2.9 feet and d.b.h. by 0.6 inches. Cultivation increased average total growth to a smaller but statistically significant amount. Fertilization affected growth significantly only the last two years--total height averaged 0.3 feet less on fertilized plots.

The small average response to fertilization can be largely attributed to the highly variable response of individual progeny lines. Total height response of individual lines varied from -2.3 to +2.8 feet. During the last two years response varied from -0.8 to +1.8 feet in height growth and -0.14 to +0.92 inches in diameter growth.

There were also significant interactions between progeny lines and irrigation. All lines responded positively but line differences in height growth during the final two years between irrigated and non-irrigated plots varied from 0.5 to 3.0 feet. These results imply, as do results of the geographic source test discussed above, genetic variation in environmental requirements or in degree of response to more favorable conditions.

FERTILIZATION TRIALS

The cultural treatment of pine plantations most likely to find wide application, other than intensive pre-planting site cultivation, is fertilization. For this reason, continuing emphasis was placed on distinguishing progeny lines which show a strong positive response to added nutrients. A trial of this type was planted in 1963, with eight-tree rowplots of 15 select progeny lines and 3 control lots established in 10 blocks. In 1964 and again in 1965, 300 pounds per acre of diammonium phosphate (1.8-56-0) were applied to half of each block.

From measurements recorded at age 5, dry weight of bole wood inside bark was determined. Mean dry weight per tree on fertilized plots was 4.5 pounds as compared to 4.1 pounds without fertilizer, not significantly different. Again, the average effect of fertilizer was obscured by highly varied responses of the individual lines (Table 4). Response by lines varied from

Table 4.--Mean dry weight per tree at 5 years in fertilized and unfertilized plots by progeny line

Progeny line	Mean dry weight per tree (lbs.)		
	unfertilized	fertilized	response
240-55	4.7	4.8	0.1
244-55	5.2	6.5	1.3
254-55	4.5	4.5	0.0
284-55	3.8	3.7	-0.1
289-55	4.3	4.2	-0.1
60-56	4.1	5.2	1.1
67-56	4.2	5.0	0.8
110-56	5.0	4.5	-0.5
121-56	3.6	4.6	1.0
269-56	3.5	4.0	0.5
18-57	3.4	3.7	0.3
21-57	4.6	4.6	0.0
60-57	**4.1**	4.9	0.8
67-57	4.3	4.7	0.4
89-57	4.1	3.8	-0.3
Controls	3.7	4.2	0.5
Mean	4.15	4.51	.36

-10% to +25% of weight of trees in untreated plots. Five of the select progeny lots showed a relatively strong response to the added fertilizer, one showed a negative response and the remainder of the lots were little affected by treatment.

In 1967 a screening program was initiated with the goal of determining the reaction of progenies of all slash pine clones used in the Florida program to nitrogen and phosphorus. Blocks were laid out and divided into four plots each. Treatments randomly applied were untreated control, N, P, and NP. Both N and P were broadcast at the rate of 50 pounds per acre and lightly tilled into the soil prior to planting. Sub-plots consisted of individual progeny lines planted at 2 X 2-foot spacing. Three annual measurements were planned.

Grass and weeds responded so vigorously to fertilizer treatments the first year that effects on tree seedlings were obscured. In 1968 plots were planted at 1 X 4-foot spacing and vegetation between rows controlled by light tilling twice during the growing season. To establish the 1968 study, seed of 60 progeny lines were planted in small peat pots and seedlings transferred to the field after they became well established. At the same time, to see if the screening trials could be shortened, freshly germinated seedlings of the same lines were established in half-gallon milk cartons, fertilized at rates comparable to the field test and retained in a greenhouse.

Basal diameters and heights of seedlings in the 1968 field and greenhouse studies were measured after one year and these measurements used to compute seedling volume, assuming the stem to be a right cone. Data on height, diameter and volume were subjected to analysis of variance.

Treatments, averaged over all lots, had significant effects on height growth in the field plots and on diameter and volume in the greenhouse (Table 5). Most of the treatment effect was due to nitrogen (Table 6) although the

Table 5.--Summary of results of statistical analyses of measurements of year-old slash pine progenies under 4 fertilization treatments

Source of Variation	Greenhouse			Field		
	Height	Diameter	Volume	Height	Diameter	Volume
Treatments		**	**	*		
N_0 vs N_1		**	**	**		
P_0 vs P_1		*	**			
N X P			*			
Lines	**			**	**	*
Lines X Treatments	**					

* Means different at 5% level of probability.
** Means different at 1% level of probability.

Table 6.--Measurement means of year-old slash pine seedlings by treatment in field and greenhouse

Treatment	Height (cm)		Diameter (mm)		Volume (cc)	
	Greenhouse	Field	Greenhouse	Field	Greenhouse	Field
Control	18.7	17.9	2.8	4.4	0.4	1.2
N	18.3	24.3	2.9	5.8	0.4	2.3
P	18.7	20.5	2.9	5.6	0.4	2.1
NP	18.0	24.2	3.2	5.7	0.5	2.5

influence of phosphate can also be seen. Diameter increment was increased by N in both field and greenhouse. The field design was a split plot experiment and consequently of low sensitivity in detecting differences among the major treatment plots although trends are apparent.

There were significant differences among progeny lines in all traits measured in the field test, but lines varied significantly only in height growth in the greenhouse. Individual lines varied in volume from 0.83 to 4.74 cc in the field and from 0.32 to 0.64 cc in the greenhouse. Field grown seedlings had substantially larger diameters than greenhouse seedlings.

The major objective of the trials was determination of differential responses to fertilization. A significant line X treatment interaction was observed only with height growth in the greenhouse. In this case, response of individual lines varied so much as to nullify over-all treatment effects (Table 7).

Table 7.--Example of lines showing opposite response to nitrogen

line	mean ht. (cm) Control	N	P	NP	mean
A	26.2	14.7	30.0	27.7	24.7
B	13.9	27.9	18.2	32.2	23.1

Examples of varying response to treatment in other attributes measured were found in both greenhouse and field tests but the interactions were not statistically significant.

Correlation coefficients between field and greenhouse volume means for each line under the four treatments were calculated. No relationship between the relative field and greenhouse performance of progeny lines was indicated (Table 8). Lines failed to react similarly to treatments in the two locations. This may relate to pathogen problems encountered in the greenhouse.

Table 8.--Correlation between mean volume per line in field and greenhouse trials

Treatment	
Control	0.014
N	-0.026
P	0.142
NP	-0.163
All	0.104

Establishing seedlings in fertilized, unsterilized, potted soils proved difficult because pathogens seemed to be favored by the nutrients. This fact accounted for much of the variability among and within lines. For example, one line had to be discarded because of its high susceptibility to damping-off. Techniques are under development for avoiding this problem during the highly susceptible period of seedling development. Techniques of interest concern soil sterilization and re-inoculation with mycorrhizae cultures and fertilizing after seedling establishment. Further it is believed that a single "optimum" fertilizer treatment should be chosen for screening trials such that experiments are not limited by inadequate replication and physical problems. For example, this greenhouse experiment involved 900 pots but only 3 replications.

Results to date in attempts to screen numerous lines for response to fertilizer have not suggested any short-cut procedures. However, nutrient accumulations, which are to be determined, may represent variable reserves for growth in a second year. Experience with older tests indicates that three years or more may be needed to show definite differential responses to treatments in field tests. The lack of relationship between field and greenhouse performance does not encourage reliance on short-term pot trials. Hopefully, observation for three years in the intensive field plots and refinement of short-term techniques will provide a means of identifying progeny lines responsive to fertilizer treatment. With so many lines in hand, the task will not be simple. However, only a few lines identified as responsive can be considered a success.

SUMMARY

Results of several tests suggest that slash pine lines vary in their responses to different natural and culturally altered environments.

Variation within geographic areas is greater than variation between areas. Lines from relatively distant sources may grow as well or better than lines from local selections.

Differential response to cultural measures such as fertilization, detected in field tests 3-5 years old, were not strongly indicated by simple measurements of year-old seedlings. Greenhouse performance of lines was not related to growth in the field. These results indicate that present short-term screening trials to determine superior response to fertilization have not proven reliable and longer field trials may be required.

LITERATURE CITED

Goddard, R. E., and Strickland, R. K. 1968. Cooperative Forest Genetics Research Program 10th Prog. Rept. University of Florida School of Forestry Res. Rept. No. 15, 17 p.

Pritchett, W. L., and Goddard, R. E. 1967. Differential Responses of Slash Pine Progeny Lines to Some Cultural Practices. Soil Sci. Soc. Am. Proc. 31:280-283.