COMPETITIVE ABILITY OF SLASH PINE ANALYZED BY GENOTYPE X ENVIRONMENT STABILITY METHOD

E. B. Snyder and R. M. Allen 1/

Early genetic gains in growth rate may be offset by differential competitive ability when progeny test plantations close. Few tests are old enough, but one by Derr and Dell (1960) in a 22-year-old geographic slash pine (Pinus elliottii Engelm.) seed source plantation illustrates what may happen. There variation in diameter among sources was inversely correlated with 10-year survival. One can conclude that volume gains were reduced by stagnation of diameter growth caused by competition.

We followed Lazenby's (1965) suggestion that the genotype x environment stability method be used to study competitive ability and we adopted the methods of Perkins and Jinks (1968).

We observed the responses of 200 half-sib families of slash pine to favorable and unfavorable nursery conditions. Light and water were in short supply in the unfavorable environment, as they would be in a plantation with heavy intertree competition. Results, therefore, are interpreted as indicative of competitive ability; the best competing families will be retested through crown closure in plantations.

ANALYTIC METHODS

A given environment is quantified relative to other environments by the average performance of all the entries. Thus, an environment is described without defining or analyzing the complexly interacting edaphic and climatic factors. The deviation of each environmental value from the experimental mean are plotted on the abscissa of a graph. The environmental value is also subtracted from each phenotypic reading at that environment to establish the genotypic ordinate at the environment (Fig. 1).

Using the genotypic ordinate values of an entry across environments the entry's G x E mean square is determined. The genotypic values of each entry are also regressed against the environmental values, and the gross G x E mean square is subdivided into MS due to regression and MS

1/ — Principal Plant Geneticist at the Institute of Forest Genetics, Southern Forest Experiment Station, USDA, Gulfport, Mississippi, and Belle W. Baruch Professor of Forestry, Department of Forestry, Clemson University, Clemson, South Carolina, respectively.

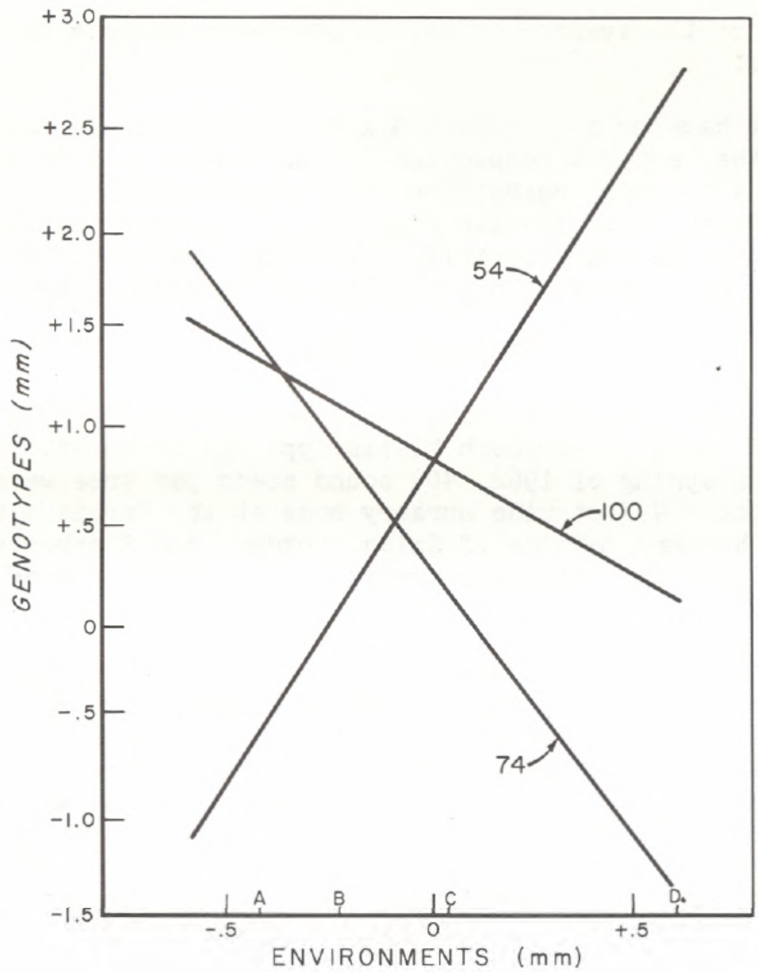

Figure 1.--Types of genotype x environment responses for diameter growth. A, B, C, D are the four environments.

due to deviations from regression. We wish t o emphasize the separate regression analyses for each entry rather than the overall analysis. For the separate analyses, tests are made to determine whether each entry's response is linear. The error variance of the mean, calculated from the overall analysis of variance, is used to test the deviation MS, while the deviation MS of each entry is used as error for the respective regression MS. Tests for statistical significance were made at the 0.05 level of probability.

This regression analysis provides a prediction of relative performances in a range of environments; it does not have the disorderly behavior conveyed by the gross G x E interaction which has not been partitioned. An entry is regarded as desirable if it has a negative regression coefficient significantly different from zero. This condition signifies that the genotypic values of the entry are better, relative to that of the average entry, in poor environments than in good environments.

Entries that have no significant G x E interaction are less desirable since they are not responding to the environment in ways different from the average (regression coefficient = 0). Still less desirable are entries which deviate significantly from regression since their response is unpredictable. From our viewpoint, the least desirable entries were those with a significant positive regression.

BIOLOGICAL METHODS

In 1960 and 1961 wind-pollinated cones were collected from 200 randomly selected trees in southern Mississippi and southeastern Louisiana. In the spring of 1962, 400 sound seeds per tree were sown in 16 106-foot-long x 4-foot-wide nursery beds at the Harrison Experimental Forest. Nursery methods of Smith, Snyder, and Scarbrough (1963) were used, and the beds were treated with methyl bromide for weed control.

Adverse nursery treatments were imposed by either restricting light, water, or both, on each bed. The four combinations of light and moisture were each replicated four times and 200 families were assigned as plots to each bed. In each plot 25 seeds were sown in rows 12 inches apart running across the bed; each half row was a plot. A row of bulk slash pine seed was sown as a temporary buffer between each row of experimental material. Pretreatment height differences caused by faulty weed control persisted to the end of the experiment but were minimized by covariance regression adjustments.

In early August the study seedlings were thinned to **six** per plot and the shade-moisture treatments were imposed. Buffer rows were removed in mid-September and each plot was thinned to five seedlings.

Treatments were imposed by suspending polyethylene sheeting 30 inches above each bed. The sheeting was raised to 5 feet the second year. For the shade treatment the sheeting was covered with Saran shade cloth, which, with the sheeting, excluded two-thirds of the light. The high moisture beds were watered whenever available moisture in the surface 6 inches, as determined by Bouyoucos blocks, dropped below 95 percent. During the second season soil moisture dropped as low as 16 percent in the unwatered beds.

After 2 years average heights and diameters in the four environments were:

	Diameter (mm)	Height (cm)
A. Low light - low moisture	16.4	139.2
B. Low light - high moisture	16.6	134.6
C. High light - low moisture	16.8	143.9
D. High light - high moisture	17.4	143.4

Diameter values coded by subtracting the overall mean are shown on the abscissa of figure 1.

RESULTS AND DISCUSSION

The frequencies of the significant mean squares of interest from the 200 families were:

	Diameter	Height
Negative regression coefficient	7	6
Positive regression coefficient	8	2
Deviations from regression	10	11

For three families only the gross G x E mean square for height and diameter was significant. Entries having average response, not significantly different from zero, made up 86 to 89 percent of entries per character.

A yield-competition ability index was set up with mean diameter growth as the primary criterion. The best 25 percent, 50 candidates, were preliminarily selected (34 are shown in table 1). Half of these will be retained for additional testing. The half retained have one or more of the following attributes: (1) competitive ability in diameter as indicated by significant negative regression, (2) competitive ability in height, or (3) upper quartile rating in height. Those having significant deviations from regressions, i.e.,nonlinear response, were not selected.

Three examples, graphed in figure 1, illustrate both the selection logic and the potentiality of the regression approach for uses other than screening for competitive ability (Morgenstern and Teich, 1969). Entry 54 with a slope of +2.59 was rejected because it grew poorly in adverse environments. It would be desirable where moisture and light are plentiful--the opposite of conditions in a dense stand.

Table 1.--Families in upper quartile class for mean diameter growth.

Entry no.	Mean (mm)	Regression coefficient: Diameter	Regression coefficient: Height	Nonlinear G x E response: Diameter	Nonlinear G x E response: Height	In upper quartile for height growth	Selected
53	20.7	0	-0.72	--	--	+	+1/
11	19.1	0	0	--	--	-	+
4	18.8	0	0	--	--	+	+
102	18.8	0	0	--	--	+	+
94	18.3	0	0	--	--	-	+
76	18.2	0	0	--	--	+	+
190	18.2	0	0	Sig	--	-	-2/
158	18.2	0	0	Sig	--	+	+
178	18.2	0	0	--	--	-	+
6	18.2	1.01	0	--	--	+	+3/
162	18.1	0	0	--	--	+	+
55	18.0	0	-0.37	--	--	+	+1/
70	18.0	0	0	--	--	+	+
86	18.0	0	0	Sig	--	+	+4/
78	17.9	0	0	--	--	+	+
45	17.8	0	0	--	--	+	+
96	17.8	0	0	--	--	+	+
36	17.8	0	0	--	--	+	+
104	17.7	0	0	--	--	+	+
25	17.7	0	0	Sig	--	-	-
13	17.7	2.33	0	--	--	-	-
54	17.7	2.59	0	--	--	-	-
14	17.7	0	0	--	--	+	+
51	17.6	0	0	--	--	+	+
137	17.6	0	0	--	--	+	+
120	17.6	0	0	Sig	--	-	-
37	17.6	0	0	--	--	+	+
77	17.6	0	-0.39	--	--	-	-5/
93	17.6	0	0	--	--	+	+
90	17.6	0	0	Sig	--	-	-
118	17.6	3.52	0	Sig	Sig	-	-
100	17.5	-1.16	0	--	--	+	+6/
101	17.5	0	0	--	--	+	+
160	16.6	-1.06	0	--	--	+	+6/

1/ Good competitors for height.
2/ Rejected because of significant G x E and mediocre height.
3/ Poor competitor but high mean diameter.
4/ Selected in spite of significant G x E.
5/ Although a good height competitor, has low mean height.
6/ The only good competitors with reasonably high mean diameters. Entry 160, however, is slightly below the 25th percentile class for mean diameter.

The most successful competitor on the graph was entry 74 with a slope of -2.82. Breeding for families with a G x E interaction characterized by such a high negative slope appears to be a reasonable way of isolating good competitors. Unfortunately, this particular entry had mediocre mean growth which eliminated it. On the other hand, entry 100 was selected because it had a significant negative slope coupled with reasonable mean yield. Its slope is close to -1, which means that its phenotypic value is fairly constant from environment to environment. Such unvarying types have often been sought by plant breeders for planting over a range of sites.

Since we were selecting for performance under severe conditions, one might ask why we did not limit our progeny testing to severe conditions. The answer is that we wanted to determine if there are genotype x environment interactions. If there are none, conditions of the test are immaterial. If they exist, however, it is important to know whether the G x E interactions include three predictable types of responses: (1) strong negative regression coefficients--adaptation to competition; (2) coefficients near -1--adaptability to a range of environments; or (3) strong positive coefficients--adaptation to the more favorable environments. If genotypes are adapted to particular environments, we then agree that, as a next step, the conditions of the progeny tests should simulate only the special environments being bred for unless the -1 (stable) types or several simultaneous types are desired.

LITERATURE CITED

Derr, H. J., and Dell, T. R. 1960. Where should we get slash pine seed for Louisiana? Forests and People 10(2): 30-31.

Lazenby, A. 1965. Genotype and environment. J. Nat. Inst. Agr. Bat. 10: 274-287

Morgenstern, E. K., and Teich, A. H. 1969. Phenotypic stability of height growth of jack pine provenances. Can. J. Genet. Cytol. 11: 110-117.

Perkins, J. M., and Jinks, J. L. 1968. Environmental and genotype-environmental components of variability. III. Multiple lines and crosses. Hered. 23: 339-356.

Smith, L. F., Snyder, E. B., and Scarbrough, N. M. 1963. Care of pine seedlings used in breeding at Institute of Forest Genetics. USDA Forest Serv. Res. Note SO-2, 4 pp.