PROVENANCE x ENVIRONMENT INTERACTIONS IN WHITE ASH

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Abstract. Height growth of 19 white ash provenances at ages 4 and 6 were measured in plantations in Louisiana, Illinois, Ohio and Wisconsin. Both the provenance by plantation interaction and the plantation by year interaction were significant. One-fifth of the variation in height growth could be accounted for by these interactions. The interaction of provenances and plantations is due to the reversal of growth trends among provenances in different plantations, while the interaction of plantations and years is due to the scale of measurement. No significant interaction was found between provenances and years. Practical implications for white ash tree improvement programs are discussed.

Additional Keywords: age-age correlation, logarithmic transformation, site selection, Fraxinus americana L.

The genotype-environment (GE) interaction is the failure of genetic entries to maintain the same relative ranks and level of differences when tested in different environments (Snyder 1972). Unless the magnitude of the GE interaction is known, the tree breeder can neither make a realistic estimate of the rate of improvement nor determine the range of environment to which his results will apply (King 1965). Once the source of interaction is known, one can make a logical choice in seed source recommendations and evaluate selections with greater confidence. If there is no interaction, a few superior genotypes may be selected for the average environment. If there are no changes in ranking but there are changes in levels of difference, common genotypes can still be selected but the predicted genetic gain may not be valid. Finally, if there are changes in both ranking and in levels of difference, one should discard the pooled analysis and look at each plantation separately.

This study examines provenance x environment interactions in white ash (Fraxinus americana L). The objectives of this paper are to quantify and classify interactions among provenances, seedling ages and plantations.

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MATERIALS AND METHODS

Seeds were collected from up to 10 native parent trees per stand throughout the natural range of white ash during 1973-1974. The seeds were sown in the Illinois Division of Forestry Nursery at Jonesboro, Illinois and plantations established in 1976 as randomized complete blocks with 5-tree and 5 replications. Plantations in Louisiana (LA), Illinois (IL), Ohio (OH) and Wisconsin (WI), which had 45 wind pollinated families from 19 provenances in common, were used in this study.

Total height after 3 and 5 years in the field (ages 4 and 6 from seed) were recorded for each tree. Because families within provenance variance was small (Clausen, et. al. 1981), provenance means were used as observations in the data analysis (Table 1).

In order to test whether or not any GE interaction was due to scaling, natural logarithmic transformation of height data was also used in the analysis of variance. A fixed effects model was assumed for testing interactions while a random effects model was assumed for variance component (VC) analysis. Data analysis was processed through the Statistical Analysis System (SAS 1982).

RESULTS AND DISCUSSION

There was no provenance by year interaction (Table 2). There may be two reasons for the lack of this interaction. The first one is that ages 4 and 6 are so close in time that, unless some drastic events have altered the growth trends, there is only a small probability that changes in rank or changes in levels of difference would occur in such a short interval. The second reason is that both ages are within the same stage of growth development, and the age-age correlations are high and positive (Clausen 1982). Namkoong and Conkle (1976) found that age-age correlations are high only when juvenile age classes (age 8 and younger) are compared among themselves or when more mature age classes (age 20 and older) are compared among themselves. Correlations between performance at age 3 and that after 8 years are low and often negative (Namkoong and Conkle 1976). Therefore the provenance by year interaction probably would remain absent until comparison can be made between juvenile and mature ages.

The plantation x year interaction is highly significant when height is measured in the actual units (cm) but is non-significant when height data are transformed to the natural logarithmic scale (Table 2). The discrepancy is due to the multiplicative plantation effect. From age 4 to age 6 the relative growth rate in LA, IL, OH and WI plantations were, respectively, 76, 74, 82 and 59 percent, so the differences are small. But since the Ohio plantation is about 5 times the height of the Wisconsin plantation the difference in actual units becomes significant.

The ranking from high to low for the four plantations remains unchanged from age 4 to age 6. This further strengthens the argument that the plantation by year interaction was due to the change in the levels of difference. Once a proper transformation is used, the interaction vanishes.

Table 1.--Average height of white ash provenances at ages 4 and 6 in four plantations

Seed State	Source No.	Height at age 4				Height at age 6			
		LA	IL	OH	WI	LA	IL	OH	WI
		cm				cm			
TX	6768	82	184	151	24	157	279	208	40
LA	6738	76	153	117	13	154	243	208	42
MS	6737	57	173	130	30	116	252	246	34
MS	6740	63	196	131	37	135	322	275	43
AL	6733	51	135	134	33	89	229	232	38
TN	6728	48	153	157	30	92	244	319	40
TN	6871	50	168	143	29	114	263	302	38
KY	6734	38	167	162	29	88	265	314	35
KY	6792	34	145	183	32	78	250	352	32
IL	6721	47	155	182	34	100	278	323	44
IN	6795	35	144	180	37	73	271	342	46
WV	6778	42	67	157	34	55	141	278	65
IL	6771	52	126	214	49	89	228	361	52
CT	6794	46	88	155	36	64	173	267	64
VT	6782	50	73	187	38	52	140	320	83
ME	6785	43	70	125	37	57	149	237	70
MI	6779	40	70	147	37	52	158	261	55
WI	6723	51	75	164	45	62	162	299	80
MI	6736	43	70	141	37	54	146	261	67
Mean		50	127	156	32	88	221	284	51
Variance		158	2039	621	67	1129	3304	2154	254
St. Dev.		13	45	25	8	34	57	46	16

Table 2.--Analysis of variance for 5-year height in white ash

Source	df	Height in cm			Ln (Height in cm)		
		MSQ	F	VC	MSQ	F	VC
Seed Sources, S	18	2293	8.7[a]	0.23	0.101	2.6[a]	[b]
Plantations, P	3	272414	1034.5[a]	58.41	23.332	598.9[a]	71.75
Years, Y	1	185920	706.1[a]	19.18	11.290	289.8[a]	17.44
S x P	54	2145	8.2[a]	8.49	0.143	3.7[a]	6.11
S x Y	18	204	0.8	[b]	0.016	0.4	[b]
P x Y	3	24120	91.7[a]	11.32	0.040	1.0	0.01
Error	54	263		2.37	0.039		4.69
Total	151			100.00			100.00

[a] Significant at .01 level
[b] Negative variance component

The provenance by plantation interaction was highly significant. Use of natural logarithmic transformation did not remove this interaction. Thus the nature of this interaction is not due to a change in the levels of difference. Using a "mean polish procedure" to remove the population mean from the provenance effect and plantation effect, Kung (1981a) found that in the Illinois plantation the positive interaction terms were common for the southern provenances while in the Louisiana and the Wisconsin plantations, the trend was reversed. Furthermore, using a quadratic curve to fit the height data to latitude, the regression for the Ohio plantation was shown to be convex while the Wisconsin was concave (Kung 1981b). Significant negative correlations among provenance means were found between the northern plantation (WI) and the southern plantations (LA and IL). All these statistical inferences indicated that the provenance by plantation interaction was due to changes in rankings rather than changes in levels of differences.

The combination of provenance by plantation interaction and provenance by year interaction together accounted for about 20 percent of the variance in the original units but only 6 percent of the variance in the transformed units. Furthermore, the largest of the three interaction terms in the original unit was plantation by year, but in the transformed data set it was the provenance by plantation interaction. In contrast to the interaction terms, the ranking by size of variance components for the three primary factors (plantation, year, and provenance) did not change after logarithmic transformation. Thus, logarithmic transformation may or may not change our interpretation. The important thing to remember is that the relationship between variables is strongly influenced by the scales with which these variables are measured. Interpretations of data are valid only with respect to the particular scale adopted in a given instance (Li 1964, p. 445).

Because the standard deviation of height among the four plantations seems to change with the mean height (Table 1), the logarithmic transformation would stabilize the variance and let us meet the assumption requirement. Interpretation of the transformed data would, therefore, be more robust than that without transformation.

RECOMMENDATIONS

Because there was no provenance by age correlation, the ranking of provenance would remain stable. Selection for fast juvenile growth at age 4 from seed appears feasible. Should such interaction still be lacking at the mature age, early selection for mature height would also be possible. The absence of provenance by age correlation indicates that the levels of difference has been maintained. In other words, the annual increment of the periodic growth between age 4 and age 6 were similar for all provenances. The study of genetic difference in annual increment or periodic growth would not be recommended.

The plantation by year interaction is not due to changes in rank. Therefore, site evaluation can be conducted at an earlier age. Since the relative growth rates (growth percentages) are similar, the internal rate of return for white ash plantations would also be similar. In contrast, the absolute increments are different. Thus, planting white ash on good sites

and on poor sites would yield the same interest rate but different monetary return. A forest manager needs to consider both relative and absolute growth potential of the planting site. Planting white ash on a poor site may be justified on the grounds of interest rate but may not be justified on the actual return.

The provenance by plantation interaction is due to changing of ranks, therefore, a tree improvement worker should match seed sources and planting sites very carefully and no common provenances should be recommended for the whole range.

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