EXPLORATION OF ENVIRONMENTAL FACTORS RELATED TO SEED SOURCE X PLANTATION INTERACTIONS IN BLACK WALNUT

Geordie D. Smith 1/

Abstract.--Genotype x environment interactions were found for fifteen year height and dbh of black walnut seed sources grown in seven midwestern U.S. plantations. Correlations between environmental parameter estimates and plantation effects or genotype x environment interaction effects were used to identify environmental factors of importance in the selection of planting sites. Soil pH and amount of available phosphorus were strongly correlated with plantation performance in height and dbh. Average July temperature, length of growing season, and soil pH showed significant relationships with interaction effects of seed sources for height. Latitude, average January temperature, average July temperature, length of growing season, amount of available nitrogen, and silt content of soils showed significant relationships with interaction effects for dbh. These environmental factors merit extra consideration in selection of plantation sites within this region.

Additional keywords: height growth, diameter growth, Juglans nigra L., unbalanced design, sign test, genotype x environment interaction, site selection.

Seed source selections and genetic gains obtained from tree improvement programs are dependent upon the presence or absence of genotype x environment (GE) interactions. When strong interactions exist, seed source and planting site selections should be considered simultaneously in order to maximize advantageous seed source and planting site combinations. Practical application of improved planting stock, however, generally involves plantings on untested sites. The tree grower, therefore, needs to identify a set of criteria for selection of plantation sites which will take advantage of favorable seed source-planting site combinations.

Exploration of the relationships between plantation effects or seed source x plantation interaction effects and environmental factors can be used as an interim guide for selection of planting sites in which the selected planting stock will perform well. Since genetic diversity is often used to protect investors from severe economic losses, more than one seed source is generally selected. The tree grower, therefore, should use this information to select planting sites that are likely to take advantage of favorable GE interactions.

1/ Graduate Research Assistant, Department of Forestry, Southern Illinois University at Carbondale, Carbondale, Illinois 62901. (The author wishes to express gratitude to Professor Fan H. Kung and Dr. Knud E. Clausen for their technical advice, guidance, and encouragement throughout this study.)

The economic value of black walnut _(Juglans nigra_ L.) makes it a good candidate for tree improvement programs, but little information is available concerning the nature and magnitude of GE interactions in this species. Seed source x plantation interactions have been observed in midwestern black walnut plantations (Bey 1973), but actual tests for the presence or absence of interactions have not been conducted.

Seed source x plantation interactions for height and dbh of black walnut are examined in this report. Environmental factors that may be of importance in selection of black walnut plantation sites, within the range of environments encountered, are also identified.

MATERIALS AND METHODS

The black walnut plantations studied are part of a range-wide provenance test established in 1967 in eight midwestern states (Bey 1973). The plantation located in Indiana subsequently suffered severe flood damage and was excluded from the study. No two plantations contained identical sets of seed sources, therefore, the experimental design was an incompletely balanced, or unbalanced, factorial design. Plantation locations and a list of cooperating agencies have been published by Bey (1973). Thirty-nine seed sources were represented in two or more plantations and were used to evaluate GE interactions for height and dbh. Twenty-two of these seed sources were represented in three or more plantations and were used for correlation analysis.

Data Measurements

Measurements of height and dbh were obtained in the winter of 1981-82. Soil samples were collected in mid-April, 1982. Soil depth and depth to mottling were measured to a maximum depth of five feet (1.52 m). Estimates of soil pH and amounts of available nitrogen, phosphorus and potassium were obtained by methods described in the Soil Analysis Outfit, Model AM-31 (La Motte Chemical Products Company, Chestertown, Maryland). Sand, silt, and clay percentages were obtained by the Bouyoucos hydrometer method (Sabey 1969). Estimates of average January temperature, average July temperature, length of growing season, and average annual precipitation were obtained from Kincer (1941).

Statistical Methods

The Statistical Analysis System (SAS) of Barr et al. (1979) was used to conduct analysis of variance, variance component analysis, and correlation analysis. Plot means were used for analysis of variance and variance components, and plantation means were used for the correlations. The GLM procedure was used to perform factorial analysis of variance using fixed effects models. Type IV sums of squares were used as recommended for unbalanced data by Barr et al. (1979) and Goodnight (1978). The VARCOMP procedure was used to estimate variance components using random effects models and typel methods of estimation. Estimates of seed source effects and plantation effects were obtained by an adaptation of the method of Kung (1978) for estimation of parent effects following use of an irregular mating design. Seed source x plantation interaction effects were then calculated by the formula $I_{ij} = X_{ij} - X_{pn} - S_i - P_j$, where:

I_{ij} = the GE interaction effect for the ith seed source in the jth plantation;
$\bar{X}_{ij}$ = the mean of the ith seed source in the jth plantation;
$\bar{X}_{pn}$ = the population mean;
S_i = the ith seed source effect;
P_j = the jth plantation effect.

Correlation analysis was used to examine the relationships between interaction effects for each seed source, or plantation effect, and environmental factors associated with each plantation. A two-tailed sign test (Ostle 1963) was used to evaluate whether the directionality of correlations between interaction effects and environmental factors was significantly positive or negative:

RESULTS AND DISCUSSION

Seed source x plantation interactions were highly significant for both height (table 1) and dbh (table 2).

Table 1.--Factorial analysis of variance for 15-year height of black walnut seed sources in seven midwestern plantations

Source	d.f.	MSQ	F[a]	V.C.	%
Seed source	38	5.51	4.25**	0.00[b]	0.00
Plantation	6	186.14	143.50**	8.03	81.77
S x P	65	3.96	3.05**	0.49	4.99
Error	496	1.30	--	1.30	13.24
Total	605	--	--	9.82	100.00

a/** Indicates significance at the 0.01 level.
b/ Negative variance component actually obtained.

Table 2.--Factorial analysis of variance for 15-year dbh of black walnut seed sources in seven midwestern plantations

Source	d.f.	MSQ	F[a]	V.C.	%
Seed source	38	17.51	4.47**	0.00[b]	0.00
Plantation	6	578.65	147.82**	27.94	81.70
S x P	63	16.55	4.23**	2.35	6.87
Error	484	3.91	--	3.91	11.43
Total	591	--	--	34.20	100.00

a/** Indicates significance at the 0.01 level.
b/ Negative variance component actually obtained.

Variance components indicate that interactions account for about 5% and 7% of the total variation in height and dbh, respectively (tables 1 and 2). Analysis of variance and variance components also suggest that selection of planting site is of greater importance than selection of seed source for these traits. Though the F tests for seed source and plantation main effects are statistically invalid due to confounding of effects in the unbalanced design, in practice it would be foolish to ignore the strength of the message presented in these tables. Variance components indicate that planting site accounts for almost 82% of the total variation in both height and dbh. This is strong justification for careful selection of planting site in order to maximize return from investments.

Estimates of environmental parameters for each plantation are given below (table 3).

Table 3.--Environmental parameter estimates for seven plantations

Environmental Parameter	IL	MO	KS	OH	IA	MI	MN
Latitude (°N)	37.3	37.8	39.2	40.8	41.8	42.3	44.2
Longitude (°W)	89.3	92.2	96.5	81.9	91.7	85.4	92.0
Elevation (m)	134	259	308	315	227	280	241
Soil Depth (cm)	122	152	152	69	125	55	122
Depth to Mottling (cm)	96	152	152	52	120	55	87
Sand Content (%)	15	11	17	27	23	39	33
Silt Content (%)	76	61	62	48	58	41	55
Clay Content (%)	9	28	21	25	19	20	12
Soil pH	5.6	5.9	7.5	6.1	5.9	5.8	6.0
Available N (kg/acre)	4.5	2.6	1.2	4.5	3.4	4.5	4.5
Available P (kg/acre)	4.5	13.2	75.8	11.3	10.2	4.5	17.0
Available K (kg/acre)	45.4	62.6	159.7	61.2	45.8	45.4	135.2
Avg. Jan. Temp. (°C)	1.7	0.4	-1.6	-2.3	-6.2	-4.3	-10.0
Avg. July Temp. (°C)	26.4	25.3	26.7	22.3	23.9	22.8	21.6
Growing Season (days)[a/]	200	182	171	152	165	153	148
Avg. Ann. Precip. (cm)	115.8	111.8	81.0	97.5	87.9	86.9	79.0

[a/] Growing season is given as the average number of days between the last killing frost of spring and the first in the fall.

Significant correlations between environmental parameter estimates and plantation means in height and dbh, and/or plantation effects for height and dbh (table 4) suggest that soil pH and amount of available phosphorus are important environmental factors in selection for overall site quality of black walnut plantations within this region. Amount of available potassium and plantation elevation may also merit some consideration in terms of dbh.

When GE interaction effects for each seed source are correlated with environmental factors, the correlations obtained are often high but, because of small sample sizes, they are usually not significant. However, by looking at the directionality of the correlations, it is possible to identify environmental factors that are likely to maximize benefits from favorable seed source-planting site combinations. If there is no relationship between a

Table 4.--Correlations between performance and important plantation environmental factors

Correlation between	Coefficient of Correlation[a/] Unadjusted Plantation Means	Adjusted Plantation Effect[b/]
Height - soil pH	0.755*	0.705‡
Height - phosphorus content	0.692‡	0.614
DBH - soil pH	0.894**	0.950**
DBH - phosphorus content	0.858*	0.903**
DBH - potassium content	0.485	0.730‡
DBH - plantation elevation	0.528	0.726‡

a/ ** , * and ‡ Indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

b/ Adjusted plantation effects obtained by method of Kung (1978).

particular environmental factor and GE interaction effects, the number of positive coefficients would be expected to equal the number of negative coefficients. The sign test can be used to test this hypothesis (Ostle 1963). Average July temperature and length of growing season show significant directionality in correlations with GE interaction effects for height growth (table 5).

Plantations with higher July temperatures and longer growing seasons should be selected within this region. Soil pH correlations also show a tendency toward unidirectionality, but in the negative direction. This is in opposition to the soil pH correlation with plantation effect (table 4). Correlation coefficients for GE interactions were generally lower than those for plantation effect for height, therefore, selection for higher soil pH is recommended for planting sites within the range of environmental conditions encountered in these plantations.

Latitude, average January temperature, average July temperature, average annual precipitation, length of growing season, amount of available nitrogen, and silt percentage show significant directionality in correlations with GE interaction effects for dbh (table 6).

Correlations with plantation latitude are significantly negative thereby emphasizing selection of more southern planting sites for dbh within the midwestern region. Selections for planting sites with higher January and July temperatures, greater annual precipitation, longer growing season, and more available nitrogen are also likely to take advantage of favorable GE interactions for dbh within this region. Soil textural classes, based upon percentages of sand, silt and clay (table 3), ranged from loam to silty clay loam. Within this textural range, soils with greater silt content should be selected in order to take advantage of GE interactions for dbh.

CONCLUSION

Latitude, elevation, average January temperature, average July

Table 5.--Sign test on correlations of GE interaction effects for height of black walnut with environmental factors of planting sites

Variable	No. of Correlation Coefficients Positive	Negative	Sign Test[a/]
Latitude	13	9	N.S.
Longitude	14	8	N.S.
Elevation	8	14	N.S.
Average January Temperature	11	11	N.S.
Average July Temperature	18	4	**
Average Annual Precipitation	10	12	N.S.
Length of Growing Season	17	5	*
Available Nitrogen	10	12	N.S.
Available Phosphorus	7	15	N.S.
Available Potassium	9	13	N.S.
Soil pH	6	16	‡
Percent Sand	12	10	N.S.
Percent Silt	8	14	N.S.
Percent Clay	7	15	N.S.
Soil Depth	9	13	N.S.
Depth to Mottling	12	10	N.S.

a/ **, *, and ‡ Indicate significance at the 0.01, 0.05, and 0.1 levels, respectively.

Table 6.--Sign test on correlations of GE interaction effects for dbh of black walnut with environmental factors of planting sites!/

Variable	No. of Correlation Coefficients Positive	Negative	Sign Test[a/]
Latitude	3	18	**
Longitude	7	14	N.S.
Elevation	9	12	N.S.
Average January Temperature	18	8	**
Average July Temperature	16	5	*
Average Annual Precipitation	15	6	‡
Length of Growing Season	18	3	**
Available Nitrogen	16	5	*
Avvailable Phosphorus	8	13	N.S.
Available Potassium	8	13	N.S.
Soil pH	10	11	N.S.
Percent Sand	8	13	N.S.
Percent Silt	16	5	*
Percent Clay	8	13	N.S.
Soil Depth	7	14	N.S.
Depth to Mottling	7	14	N.S.

a/ Only 21 seed sources were examined due to lack of dbh data for one seed source in one plantation.

b/ ** , *, and ‡ Indicate significance at the 0.01, 0.05, and 0.1 levels, respectively.

temperature, average annual precipitation, length of growing season, amount of available nitrogen, phosphorus and potassium, soil pH, and silt content are environmental factors that merit consideration in site selection for height and dbh growth of black walnut in the midwestern United States. Site selections based upon these factors will take advantage of the odds that plantation effects and/or GE interaction effects will be favorable.

It should be emphasized that the results presented here must be considered exploratory since this experiment was not designed to confirm the role of particular environmental parameters in the determination of plantation effects or GE interaction effects. In addition, inferences made from unbalanced designs can never be as strong as those from balanced designs (Wright 1977). These results may, however, be used as an interim guide to site selection until experiments with more seed sources in common can be conducted and the role of individual environmental factors in GE interactions of black walnut can be confirmed.

LITERATURE CITED

Barr, A.J., Goodnight, J.H., Sall, J.P., Blair, W.H., and Chilko, D.M. 1979. SAS users guide, 1979 edition. 494 p. Raleigh, N.C.: SAS Institute Inc.

Bey, C.F. 1973. Growth of black walnut trees in eight midwestern states--a provenance test. USDA Forest Serv. Res. Pap. NC-91, 7 p. North Cent. Forest Exp. Stn., St. Paul, Minn.

Goodnight, J.H. 1978. Tests of hypothesis in fixed effects linear models. SAS Tech. Rep. R-101, 15 p. Raleigh, N.C.: SAS Institute Inc.

Kincer, J.B. 1941. Climate and weather data for the United States. In Climate and man, Yearbook of Agriculture, p. 685-1210. USDA, Washington, D.C.

Kung, F.H. 1978. Estimating parent effects in full-sib progeny tests following use of an irregular mating design. Silvae Genet. 27: 196-200.

Ostle, B. 1963. Statistics in research, second edition. 585 p. Ames, Iowa. The Iowa State Univ. Press.

Sabey, B.R. 1969. Introductory experimental soil science. 116 p. Champaign, Illinois. Stipes Publ. Co.

Wright, J.W. 1977. Analysis of variance calculations for irregular experiments. Lake States For. Tree Improv. Conf. Proc. 13:147-157.