A METHOD FOR SELECTION OF SEED SOURCES AND PLANTING LOCATION FOR BLACK WALNUT IN THE CENTRAL STATES[1]

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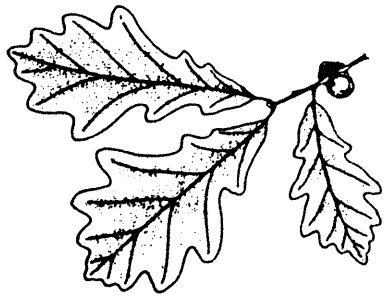

ABSTRACT.--In a range wide provenance test, 39 seed sources of black walnut from Texas to Iowa were grown in 7 central states for 15 years. Response surface models were used to fit height growth, diameter growth and survival percentage. All three models were highly significant. Selection for planting location showed greater importance than seed source selection for each of the three traits though it was more critical for height and dbh growth than for survival. To obtain the best performance, seed sources from 33 to 39 degrees of north latitude should be planted in area ranged from 38 to 39 degrees of north latitude.

INTRODUCTION AND OBJECTIVES

Species with very large natural ranges such as black walnut tend to have greater genetic diversity than species with very limited ranges. Although each local population may be best adapted to a particular set of environmental conditions, adaptation may not be perfect due to lag in response to selection and lack of effective isolation barriers. Bey (1980) has reported that black walnut provenances can be moved as much as 200 miles northward without likelihood of cold damage and that the southern seed sources generally grow taller. The objective of this paper is to answer the following questions:

1. Where should the black walnut seed be collected and where should these seeds be planted within the central hardwood region?

2. How far can you move a seed source and what is the gain or loss in performance due to relocation?

BLACK WALNUT PLANTATIONS

The black walnut plantations were established in 1967 in a range-wide provenance test. Each provenance (seedlot) was grown from seed collected from an average of six parent trees within a mixed hardwood stand. Each plantation consisted of a randomized complete block design with six replicates (blocks) and four trees per row plot. Plantation locations are listed in Table 1 and the locations of seed sources are summarized in Table 2.

TABLE 1.--Plantation locations for seven black walnut provenance study outplantings.

State	County	Latitude (°N)	Longitude (°W)
IL	Alexander	37.3	89.3
MO	Pulaski	37.8	92.2
KA	Pottawatomie	39.2	96.5
OH	Wayne	40.8	81.9
IA	Johnson	41.8	91.7
MI	Kalamazoo	42.3	85.4
MN	Winona	44.4	92.0

RESPONSE SURFACE MODEL

Within the central hardwood region, climatic and other environmental gradients seems to be correlated with latitude, hence the geographic variation is mainly latitudinal in nature (Rink and Coggeshall, 1983; Clausen, 1981; Carter, 1981). For simplification, we assume that latitude is a major component of environmental variation for the selection pressure which acts on seed sources as well as on planting location. A quadratic surface can then be constructed by using latitude of seed sources and of plantations as independent variables and growth as the dependent variable. However, the technique need not be limited to two-dimensional, quadratic functions. The reader may find that other polynomial regression models may better fit his

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TABLE 2.--Seed source origin summary table.

State	Stand	Latitude (°N)	Longitude (°W)	Elevation (m)
IA	1803	42.3	91.2	274
MI	2403	42.0	85.8	256
IA	1802	41.8	94.9	214
IL	1605	41.4	88.1	184
PA	3502	41.0	77.2	195
IN	1705	40.2	86.9	183
PA	3503	40.0	77.1	195
IN	1702	39.8	87.0	223
MO	2702	39.6	86.1	268
KS	1903	39.1	94.9	274
IN	1709	39.1	86.9	149
IN	1704	39.0	86.1	238
IN	1701	38.7	86.5	195
KS	1902	38.3	95.2	297
MO	2708	38.3	94.1	244
IN	1708	38.2	86.6	236
KY	2002	38.0	83.5	305
WV	4202	37.9	80.2	598
MO	2703	37.9	93.9	282
VA	4101	37.8	79.5	305
KY	2005	37.6	84.3	336
IL	1601	37.4	89.3	165
VA	4104	37.1	76.9	37
KY	2004	37.0	84.3	351
KY	2001	36.9	86.8	159
VA	4103	36.9	78.7	140
KY	2003	36.7	84.1	518
MO	2707	36.6	94.4	274
TN	3804	36.4	82.0	622
TN	3803	36.3	83.7	389
NC	3101	36.0	81.7	458
AR	1101	35.8	92.3	366
NC	3105	35.5	82.6	671
NC	3102	35.4	83.7	884
NC	3103	35.3	82.8	762
MS	2602	34.0	88.9	122
SC	3601	33.9	82.1	156
MS	2601	32.3	89.5	137
TX	3901	31.6	96.0	110

data. A quadratic function may produce a peak or a valley, while polynomial regression models of higher degrees may result in several maxima and minima. The presence of minima indicates unique sources to avoid rather than unique sources to choose as seed origins for particular planting latitude. Unfortunately, interpretation becomes more complicated with more complex models.

Let $Z_{ij} = aX_i^2 + bX_iY_j + cY_j^2 + dX_i + eY_j + f + E_{ij}$

where:
- Z_{ij} is the vigor of the jth seed source at the ith plantation.
- X_i is the latitude of the ith planting site.
- Y_j is the latitude of the jth seed source.
- a is the quadratic effect of the planting site latitude.
- b is the joint effect or interaction of seed source and planting site.
- c is the quadratic effect of the seed source latitude.
- d is the linear effect of the plantation latitude.
- e is the linear effect of the seed source latitude.
- f is the intercept of the model.
- E_{ij} is the residual error of fitting individual observation to the response surface.

We assume that vigor and latitudes are measured without error and that the residual errors are normally and independently distributed with a zero mean and a common variance. The unknown parameters (a through f) are first derived from known observations (vigor and degree of latitude) by the method of least squares, then a response surface is drawn by substituting various values of X_i and Y_j. The regression analysis and the contour plot were processed by the Statistical Analysis System (Ray, 1982). The plotted response surface appears as a series of ellipses with different shading. Darker areas represent greater values. The contour lines used in this paper were drawn from the top 10% ellipses generated by the computer using the fitted model.

Tests of normality were performed for height, dbh, and survival percentage data. The test statistic used was a modified version of the Klomogorov-Smirnov D-statistic, where the null hypothesis is rejected for large values of D. The D values obtained for black walnut height, dbh, and survival percentage in these plantations were 0.08, 0.14, and 0.21, respectively. The probability that these data were not drawn from normally distributed populations was less than 1% for each trait, therefore, no data transformations were necessary, even for survival percentage data.

RESULT AND DISCUSSION

All three response surface models were highly significant. However, growth models were better fit than the survival model (Table 3). Theoretically, if both a = c and d = e were true in the response surface model, the local seed source would be the best. In Table 3 we can see that these two conditions were not true, hence local seed source would not be superior, but where can we find a better seed source or a better planting latitude?

When individual models were considered, the maximum height growth of 907 cm at age 15 could be expected by collecting seed from 38.3 degree and planting them at 40.0 degree of north latitude. The tallest 10% of the rank in height (8 meters or above) were represented by the contour line for height in Figure 1.

The picture for diameter growth is similar to that of height growth. The expected maximum dia-

TABLE 3.--Response surface model for height growth, diameter growth and percent survival.

Coefficient	Dependent Variable Height	Diameter	Survival
a	-0.45[a]	-0.84[a]	-1.40[a]
b	0.10[a]	0.21[a]	1.12[a]
c	-0.04[a]	-0.07[a]	-0.43[a]
d	31.91[a]	59.08[a]	66.34[a]
e	-0.98	-3.12	-12.41
f	-609.82[a]	-1103.89[a]	-931.49
Mean Square			
Model	421.70	1211.16	29270.84
Error	4.44	16.46	847.26
F value	94.92[a]	73.59[a]	34.55[a]
R square	0.44	0.38	0.20

[a]Significant at the 1% level.

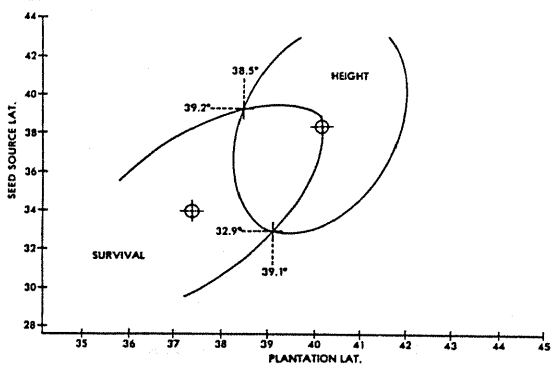

FIGURE 1.--Superimposition of ellipses of optimum height growth and survival.

meter (15.1 cm at age 15) could be obtained by collecting seed from 38.4 degree and planting them at 39.9 degree of north latitude. The largest 10% of the rank in diameter (13 cm or above) could be found within the ellipse for diameter in Figure 2.

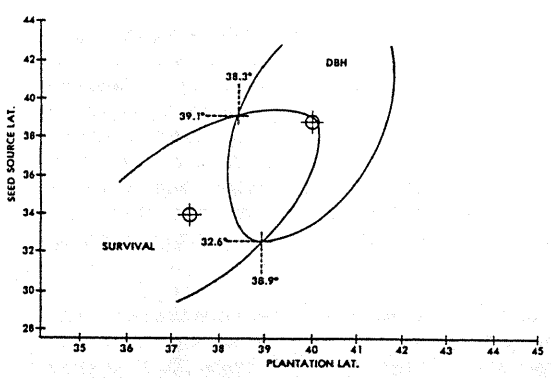

FIGURE 2.--Superimposition of ellipses of optimum dbh growth and survival.

The picture for survival is different. The center of optimum survival is located further southward (34.0° N for seed source and 37.4° N for plantation latitude). However, selection for seed source is again less critical than for planting location. The ellipse for survival in Figure 1 and 2 represents survival rate better than 76 percent.

By superimposing the ellipses for best height growth and best survival (Figure 1), and/or best dbh growth and best survival (Figure 2), the overlapping region defines the area of optimum response for the two traits (Kung and Clausen, 1984). By comparing Figure 1 with Figure 2 it can be seen that the overlapping regions are similar to each other. This illustrates the point that selection for height growth often means selection for dbh also. In fact, the correlation between height and dbh in this study was 0.9181. As can be seen from Figure 1, for height and survival, seed sources from 32.9° north latitude would be the best ones to use if plantations were planned at about 39.1° north latitude. Seed sources from 39.2° north latitude would be expected to do well in planting location between 38.5° and 39.5° north latitude. From the point of view of planting location, when plantations are planned at about 38.5° north latitude seed sources ranging from 34.5° to 39.2° north latitude would be expected to perform well. Similar inferences can be made from the superimposition of ellipses for dbh and survival (Figure 2). Seed sources from 32.6° north latitude would be expected to perform well if planted at 38.9° north latitude, whereas seed sources from 39.1° north latitude would be expected to do well in plantations located between 38.3° and 40.0° north latitude.

Based on the response surface model used for each trait, there is a global maximum for all combinations of seed sources and planting sites and a local maximum for a given seed source or planting site. The global maximums for three traits were discussed earlier, the next question would be how to identify the best seed source for a given planting latitude and how to identify the best planting location for a given seed source?

To find the best seed source for a given planting location, we first obtain the differentiation of the model with respect to the seed source:

$$dZ/dY = bX + 2cY + e.$$

The second step is to substitute the known latitude for planting site and solve the following equation:

$$Y = -(bX + e)/2c.$$

For example given the plantation latitude at 37° and the values of b, e, and c in Table 3, the best seed source for height should be obtained from $-(0.1 \times 37 - .98)/(2 \times (-0.04)) = 34°$ north latitude.

By the same procedure, from $dZ/dX = 2aX + bY + d$ we have $X = -(bY + d)/2a$. For example, to

obtain the best height growth, seed sources from 41° latitude should be planted at $-(0.1 \times 41 + 31.91)/(2x - 0.45) = 40^{o}$ north latitude.

The penalty of not using the right seed source at the right planting location can be calculated by the difference between two predictions from the response surface model. For example, given the plantation latitude at 37° north and the optimum seed source from 34° north, the expected height would be 558 cm. However, if local seed sources were used (X = Y = 37), the estimated height would be 535 cm; the loss in this case would be 23 cm.

CONCLUSION

The method of using a two-dimensional, quadratic response surface model for seed source selection and planting location selection is demonstrated in this paper. To obtain the best growth, seed sources from 33 to 39 degrees of north latitude should be planted in an area ranging from 38 to 39 degrees of north latitude.

Because the centers of all three elipses were located below the diagonal line, southern seed sources on the average would outperform local or northern seed sources (Kung and Clausen 1984). Thus, it would be possible to obtain some growth gains from moving black walnut provenances northward as recommended by Bey (1980).

Based on the overlapping areas in Figure 1 and 2, the range for plantation latitude was narrower than the range for seed source latitude. Therefore, selection for planting latitude should be more critical than provenance selection for black walnut.

The present method of selecting seed source and planting location latitudes explained about 20 to 44% of the variation in growth traits. As pointed out by the reviewers, some additional variables such as longitude, site index, elevation and blocking may be considered for inclusion in the quadratic model. Furthermore, response surfaces with more complicated models, higher order polynomials and nonlinear models are other possibilities in a continuation of this study. Thus, the findings here should be considered only as preliminary results.

LITERATURE CITED

BEY, C. F. 1980. Growth gains from moving black walnut provenances northward. J. Forestry 78: 640-641, 645.

CARTER, K. K. 1981. Early results from a range-wide green ash provenance test. Proc. North Cent. Tree Improv. Conf. 2: 95-99.

CLAUSEN, K. E. 1981. Variation among white ash families in flushing and spring frost susceptibility. Proc. North Cent. Tree Improv. Conf. 2: 86-94.

KUNG, F. H., and K. E. CLAUSEN. 1984. Graphic solution in relating seed sources and planting sites for white ash plantation. Silvae Genetica 33: 46-53.

RAY, A. A. 1982. SAS User Guide: Statistics 1982. SAS Inst. Inc. Cary, N. Carolina. 584 pp.

RINK, G. and M. V. COGGESHELL. 1983. Geographic variation in white oak acorn volume. Proc. North Cent. Tree Improv. Conf. 3: 221-227.