DELINEATING SEED COLLECTION ZONE BASED ON MULTI-PLANTATION PROVENANCE TESTS

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Abstract.--In a white ash provenance test, height and survival at age three were found to be correlated with the latitude of the seed source. Regression curves can be useful in delineating the seed collection zone for each plantation. Local seed source was the best for Ohio. Southern seed sources grew taller and survived better in Wisconsin. In Illinois, the southern seed sources grew taller but the northern seed source survived better. The contour plot was useful to project suitable seed collection zone over a broad region. Illustrative examples are given in this paper.

Additional keywords: Height growth, survival, white ash, regression, response surface.

The choice of seed sources is one of the most important factors affecting the establishment and productivity of the tree plantation. Provenance studies can be helpful in making the best choice. In the practice of silviculture we either make generalized planting recommendations or specify a certain stand, based upon the results from the progeny test. If the geographic variation is predominantly clinal, generalized seed sources are recommended. For example, Bey (1973) found that using seed sources two hundred miles south of the planting sites to be most desirable. On the other hand, if the geographic variation is predominantly ecotypic, then a specific seed source is recommended. For example, Wright (1976) preferred the Spanish variety of Scotch pine for high quality Christmas trees.

Besides the pattern of geographic variation, another factor that influences the seed source recommendation is the significance of the provenance x plantation interaction. In the absence of this interaction a few superior genotypes may be recommended over a broad area. Conversely, if the interaction is significant, one would select from each test plantation the best seed source for each corresponding planting site.

Other problems related to seed source recommendations are multiple-trait evaluation and general projections from the multiple-plantation provenance test. In this paper I will use a white ash geographic study to illustrate these problems.

MATERIALS AND METHODS

The material used in this paper is part of a provenance/progeny test of white ash initiated in 1975 by the North Central Forest Experiment Station at Carbondale, Illinois. Seed was collected in 1975 and seedlings were grown in a southern Illinois nursery for one year. A total of 22 plantations were established but only four of them with a balanced complete design were used here (table 1).

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Table 1.--White ash outplanting summary

No.	State	County	Lat.	Long.	Cooperator
1	LA	St. Landry	30.4	92.0	John Toliver
7	IL	Union	37.5	89.3	Fan Kung
11	OH	Muskingum	40.0	82.0	Dan Houston
19	WI	Oneida	46.6	89.5	Hans Nienstaedt

Height and survival at age three were recorded. Plantation means of each stand in four plantations were presented in table 2. Results from the analysis of variance (table 3) indicated a strong seed source x plantation interaction. Thus, no single seed source should be recommended for all plantations. In other words, the best seed source should be selected individually for each plantation.

Table 2.--Performance of nineteen stands in four outplantings

Seed source			Height in plantation					Survival in plantation				
State	Stand no.	Lat. deg.	LA	IL	OH (cm)	WI	Mean	LA	IL	OH (%)	WI	Mean
TX	6768	30.3	82	184	151	24	110	91	92	69	18	68
LA	6738	30.5	76	153	117	13	90	67	61	22	20	43
MS	6737	30.8	57	173	130	30	98	66	76	67	40	67
MS	6740	33.4	63	196	131	37	107	83	91	58	31	66
AL	6733	34.5	51	135	134	33	88	76	78	41	56	63
TN	6728	35.3	48	153	157	30	97	95	100	83	65	86
TN	6871	35.5	50	168	143	29	97	88	100	68	72	82
KY	6734	36.9	38	167	162	29	99	81	100	75	60	79
KY	6792	37.3	34	145	183	32	98	84	94	90	80	87
IL	6721	37.7	47	155	182	34	105	89	99	85	71	86
IN	6795	38.3	35	144	180	37	99	84	97	92	85	90
WV	6778	38.9	42	67	157	34	75	61	92	77	60	73
IL	6771	39.0	52	126	214	49	111	96	100	97	96	97
CT	6794	41.3	46	88	155	36	81	71	96	77	85	82
ME	6785	44.9	43	70	125	37	69	84	95	57	73	77
MI	6779	45.2	40	70	147	37	73	68	88	60	64	70
VT	6782	45.4	50	73	187	38	87	56	92	76	68	73
WI	6723	45.7	51	75	164	45	84	64	100	80	88	83
MI	6736	46.6	43	70	141	37	73	63	96	72	73	76
Plantation Ave.			50	127	156	34		78	92	71	63	
Population Ave.							92					76

Table 3.--Analysis of variance for height and survival

Source	df	Height MSQ	Height VC	Height %	Survival MSQ	Survival VC	Survival %
Plantation	3	715805**	3362	72.3	21663**	95	16.1
Seed source	188	11423*	97	2.1	4050**	52	8.8
Interaction	54	7158**	591	12.7	1741**	129	21.9
Residual	768	597	597	12.9	314	314	53.2
Total	843		4647	100.0		590	100.0

*,**, significant at 5% and 1% level, respectively

Since the data in table 2 suggests that clinal variation more appropriately describes the pattern of growth than ecotypic variation, a second degree regression curve based on seed source latitude is used to predict survival and height growth in each of the four plantations.

SEED SOURCE RECOMMENDATION FOR OHIO

In the Ohio plantation the height growth (Ht) and the survival percentage (Su) of the various seed sources can be expressed as a function of the latitude of the seed source (Lat).

Ht = -644.58 + 40.90 Lat - 0.513 Lat*Lat,with r = .60

Su = -506.57 + 29.40 Lat - 0.367 Lat*Lat,with r = .61

The regression curves were plotted in figure 1. Since the peak for height growth and the peak for survival rate coincide with the latitude of the plantation (i.e. 40 degrees north), the seed source recommendation would be simply selection for the local race.

From the shape of the curve it can be seen that using a seed source within two degrees of the latitude of the plantation does not seriously impair the performance. In other words, it is safe to use seed within a 60 mile range of the plantation and still obtain less than a two percent reduction in performance as compared to the local seed source.

SEED SOURCE RECOMMENDATION FOR WISCONSIN

The regression models for height growth and survival based on the latitude of the seed source are Ht = -129.69 + 7.65 Lat - 0.087 Lat*Lat, with r = 0.73, and Su = -736.46 + 39.27 Lat - 0.471 Lat*Lat, with r = 0.88. From these regression curves (figure 2) we find the peak of survival at 42 degrees north while the peak of height growth is at 44 degrees north; both of which are south of the plantation (46.6 degrees north). So for the seed source recommendation in Wisconsin, stands 100 to 150 miles to the south of the plantation offer the greatest growth and survival.

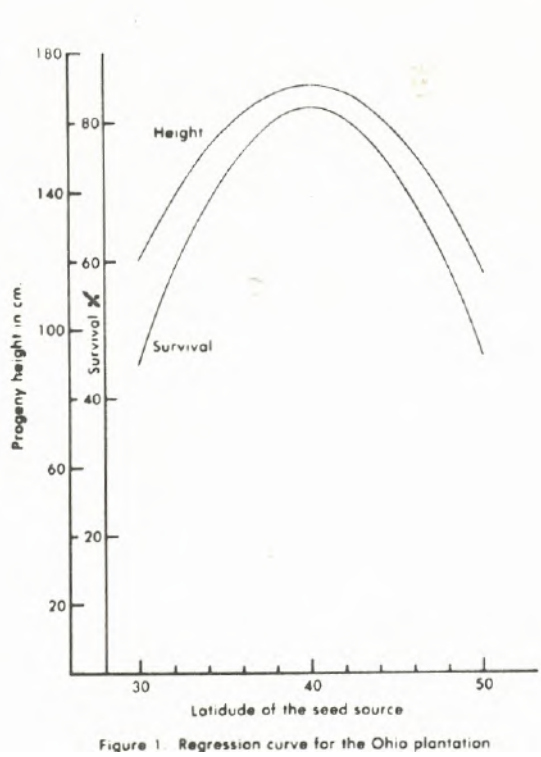

Figure 1. Regression curve for the Ohio plantation

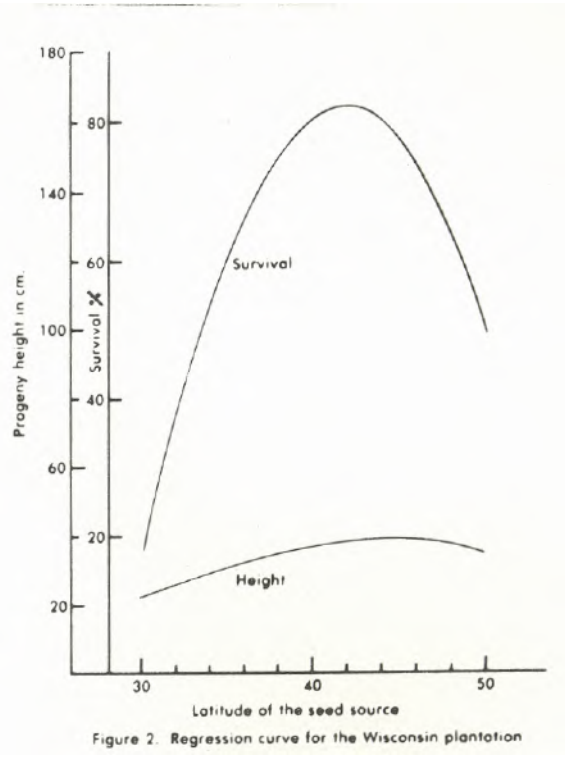

Figure 2. Regression curve for the Wisconsin plantation

SEED SOURCE RECOMMENDATION FOR ILLINOIS

The regression curves for height and survival in the Illinois plantation are Ht = 148.21 + 6.45 Lat - 0.180 Lat*Lat, with r = 0.89, and Su = -235.50 + 16.36 Lat - 0.200 Lat*Lat, with r = 0.69. The peak of survival is at 41 degrees north latitude but the peak of height growth is out of the range in figure 3. Therefore, we can define the best seed source for survival but not for height growth. For survival we can recommend local seed or seed from stands up to 200 miles to the north of the plantation. For height growth it would become a laughing matter if one would recommend the stands at 18 degrees north as the best seed source based on the maximum of the regression formula. No white ash stand has been known to grow at that latitude.

SEED SOURCE RECOMMENDATION FOR LOUISIANA

The regression models for the Louisiana plantation are Ht = 533.45 - 24.07 Lat + 0.293 Lat*Lat, with r = 0.85, and Su = -108.43 + 11.08 Lat - 0.159 Lat*Lat with r = 0.63. While the survival curve is similar to the previous three plantations, the height growth curve has taken an unusual turn. It turns upside-down. Thus, for survival we can recommend local seed or seed from stands up to 250 miles to the north of the plantation. We cannot recommend the best seed source for height. However, from the curve we can see where to avoid seed collection. Trees from 40 degrees north grow slower than others.

MULTI-TRAIT CONSIDERATIONS

When we consider only one trait at a time, a regression curve can be a

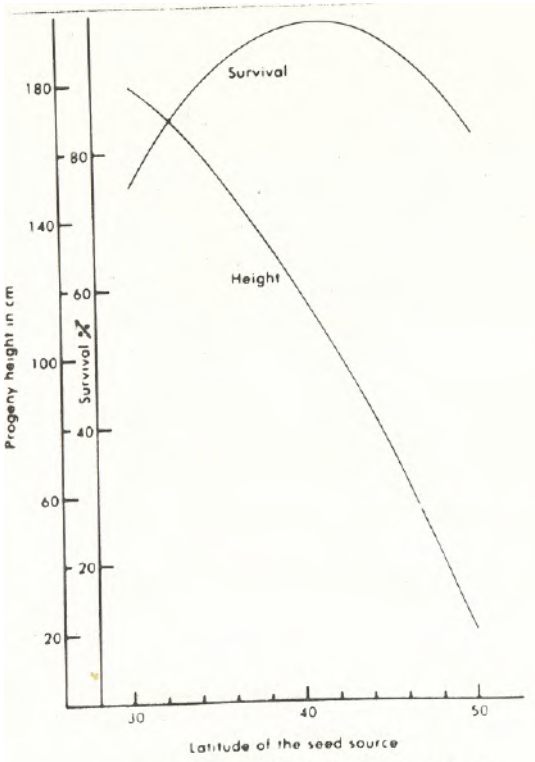

Figure 3 Regression curve for the Illinois plantation

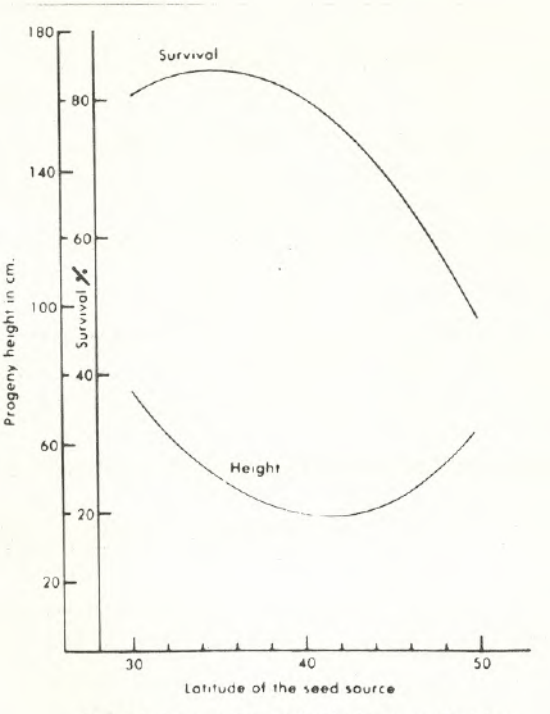

Figure 4 Regression curve for the Louisiana plantation

useful tool to set the range of suitable seed source. If the peak can be found within a reasonable range, such as all the curves for the survival data in this paper, we can define the best seed source or the range of the best seed source. But if the projected peak is out of the natural range of the species, or the curve has a minimum but no maximum, the regression curve would be worthless. Therefore, if we consider several traits simultaneously, each trait must have a usable peak so that the peak of the multivariate observations can become meaningful.

In the case of the Ohio plantation, where the peak for height growth and the peak for survival coincide, the problem of defining seed source for two traits can be reduced simply to that for a single trait. In the case of the Wisconsin plantation where the two peaks differ in location, a single peak can be found by combining two regression formulas into one: W = X(-129.69 + 7.65 Lat - 0.087 Lat*Lat) + Y(-736.46 + 39.27 Lat - 0.471 Lat*Lat), where W is the combined worth of the two trait selection, X is the weight assigned to height growth regression model, and Y is the weight assigned to the survival model. Depending on the value given to X and Y, the peak for W should fall between the peak for X and the peak for Y. Therefore, if we expand this combining method to cover many traits the composite peak must fall within the range of the individual peak for each trait.

PROJECTION OVER A BROAD REGION

As we compared the peaks from the survival curves in the four plantations, we found that the local seed source survived best in Ohio, while the peak shifted to the south in Wisconsin and moved to the north in the Illinois and the

Louisiana plantations. Can we make a general projection of which latitude of seed source can effect the best survival in which latitude of the planting site? I found it to be extremely helpful to use the contour plot techniques (SAS 1979) to study the latitudinal effect of the seed source and that of the planting site. Figure 6 was plotted using the following response surface model: $W = aXX + bXY + cYY + dX + eY + f$, where W = survival percentage, X = latitude of the seed source, Y = latitude of the planting site, and a,b,c,d,e, and f = regression coefficients. The contour plot is constructed in such a way that the darker the area, the higher the survival percentage. It can be easily seen from the contour plot which seed sources are the best for which planting site, and how wide a range of superior seed sources can be used for a given plantation.

For example in figure 5, the seed sources which would give the best survival percentage for a plantation located at 31 degrees of latitude are those from 35 to 39 degrees. As another example, seed sources from 35 to 43 degrees north should be planted between 30 to 41 degrees north.

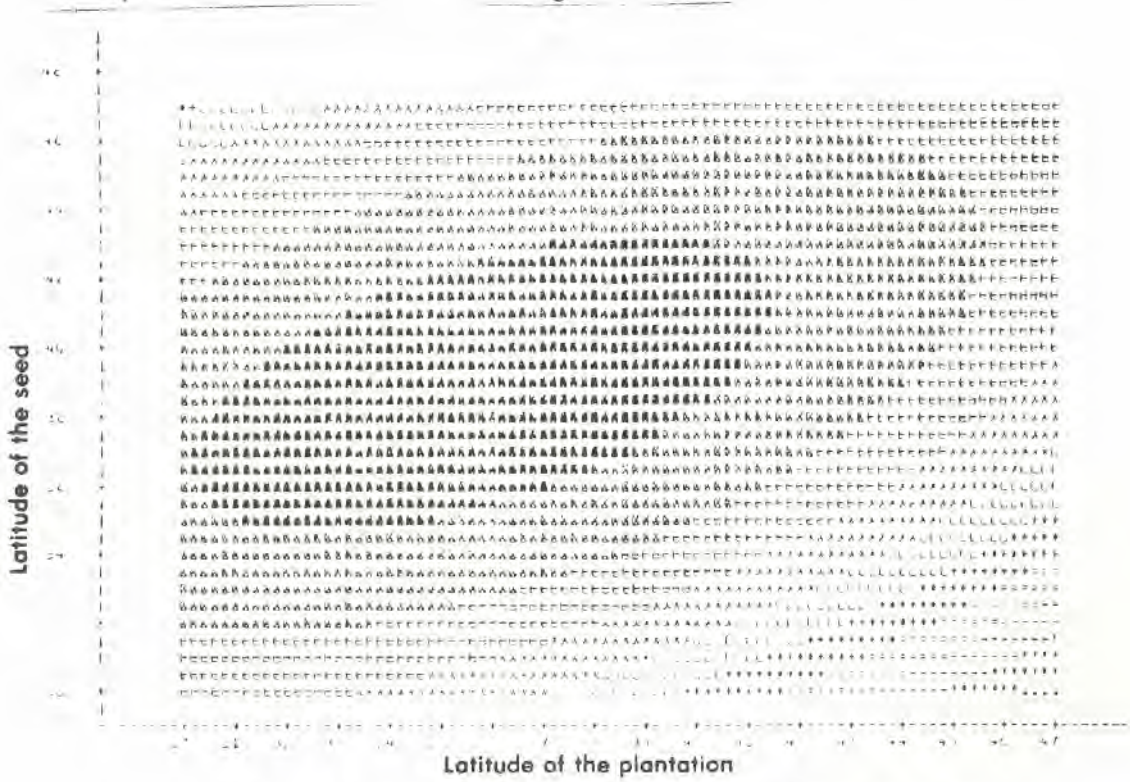

Figure 5. Contour plot for the white ash survival percentage

DISCUSSION

The second degree regression curve is useful to indicate the peak and the range of latitude of the seed source suitable for a specific plantation. The response surface model shows a general view of the seed collection zone over a broad planting range. Although the given examples deal with the latitudinal zoning for white ash, other limiting factors such as longitude, elevation, temperature or moisture zoning may be more suitable for some other species. The primal contribution of this paper is to introduce the readers to the use of regression curve or response surface in seed zone delineation. Since the validity

of the model depends on the nature of the data used, the readers are urged to explore all possible alternative variables in the process and discard the unreasonable model.

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