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Survival and Growth of White Ash Families and Provenances 15 Years After Establishment in West Virginia

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Abstract

The survival, growth, and stem form of 45 white ash (*Fraxinus americana* L.) families nested within 22 provenances were evaluated 15 years after establishment in North Central West Virginia. Geographic family origins encompassed a wide area in the eastern and central United States, including locations from Maine in the North to Mississippi in the South to Nebraska in the West. Significant differences were identified among provenances for survival, stem form, total height, and stem diameter and among families within provenances for stem form and total height. Latitude was a significant indicator of provenance performance with performance declining north and south of the plantation latitude. Performance gains may be realized by using proper provenances then identifying superior families within these provenances for white ash artificial regeneration activities.

The Author

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COVER PHOTO.--A white ash tree from Jackson County, Illinois, included in a rangewide provenance and progeny evaluation in West Virginia 15 years after establishment.

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Introduction

White ash (*Fraxinus americana* L.) is a species native to a wide geographic area in the eastern and central United States and Canada. This range extends southward from Nova Scotia to Florida in the East and from Minnesota to Texas in the West. White ash is known to be genetically variable (Wright 1944). To capitalize on the genetic variability found in any species, estimates of various levels of genetic variation must be developed. Thus, a rangewide white ash provenance and progeny test was initiated in 1976 (Clausen 1984). The white ash tree improvement program included the establishment of 22 plantations throughout the eastern United States and Canada. This paper reports on the 15-year results of the West Virginia plantation that was included in the rangewide evaluation. The West Virginia plantation includes 45 families nested within 22 provenances. Provenance and family survival, stem form, total height, and stem diameter at breast height (d.b.h.) are described and are related to the geographic origin of the planting stock. White ash seed collection guidelines are suggested for artificial regeneration ventures in the central Appalachian region.

Methods

The West Virginia white ash outplanting was established on the Fernow Experimental Forest (39.03° N, 79.67° W), near Parsons, West Virginia. Mean annual precipitation on the Fernow is about 58 inches and is distributed evenly throughout the year. Mean annual temperature is 48°F., and the length of the frost-free season is approximately 145 days. The elevation of the outplanting is 2,700 feet. The soil is a Meckesville silt loam (fine-silty, mixed, mesic Typic Fragiudults), which is colluvial in origin and has some limestone influence. Meckesville soil is well drained, 3 to 4 feet deep, and is one of the more productive forest soils in the region. Northern red oak site index for the plantation is between 80 and 85.

Before plantation establishment, the site was forested with a 65- to 70-year-old stand of mixed Appalachian hardwoods that included a high proportion of black cherry (*Prunus serotina* Ehrh.), yellow-poplar (*Liriodendron tulipifera* L.), northern red oak (*Quercus rubra* L.), sugar maple (*Acer saccharum* Marsh.), and white ash. In preparation for planting, the sawtimber and pulpwood were harvested and all remaining stems were felled. The brush and small stems were removed from the site to facilitate the planting. The area has a northwest aspect with a slope not exceeding 10 percent.

The outplanting design is a randomized complete block of 22 provenances with 45 families laid out in 5 contiguous blocks. Trees were planted 10 feet apart, in rows 10 feet apart. Each of the 45 families (Table 1) was represented in each of the five blocks by a five-tree linear plot. A border row of yellow-poplar seedlings was planted around the perimeter of the area. The sequence of the family plots on each block was randomized. Nursery 1-0 bare-root seedlings from each of the 45 families were planted on April 2, 1976. The measurements also include growth that occurred during the first year in the nursery. Thus, the individual trees have had 16 growing seasons. Postplanting site treatment has included several herbicide applications and weedings that were necessary to control competing herbaceous and woody vegetation.

Total tree height, d.b.h., survival, and remarks pertaining to the form of the main stem were recorded periodically, most recently, in January 1991, 15 years after establishment. Data were analyzed by analysis of variance using linear model procedures incorporating the randomized block design with families nested within provenances. Plot means of the surviving trees were used for tree height, d.b.h., and stem form analyses (Bresnan and others 1992, Freese 1967, Rink and Kung 1991) and were weighted by the number of trees they represented to account for unequal variances. Differences in survival and stem form were tested for following arcsin transformation. Regression analysis was used to estimate relationships between performance factors and provenance latitude, longitude, and elevation. Data were analyzed and tested for significance at the 5 percent level. The 7-year results, as reported by Wendel (1985), were used for contrast where appropriate.

An overall provenance ranking or index was developed using the performance criteria where significant differences were identified. Multiple-trait selection is not uncommon and has been used by others to evaluate two or more traits simultaneously (Sprague 1966; Bey and others 1974; Schuler 1993). To develop the index, the provenances were ranked in each category based on overall provenance means and the rankings were summed for each provenance. The rankings provide a preliminary evaluation of suitability for each of the provenances as to their fitness for the growing conditions similar to those found on the Fernow Experimental Forest.

Table 1 summarizes the identification information of each family, including provenance designation. The families originated from 15 states, covering much of the botanical range of white ash.

Results and Discussion

At the end of 15 years, analysis of variance revealed significant differences among mean provenance survival, stem form, total height, and d.b.h. Families within provenances also differed significantly with respect to stem form and total height.

Survival

Average provenance survival 16 years after plantation establishment was 50 percent (Table 2). Survival after 7 years was 61 percent (Wendel 1985). Provenance survival ranged from 88 percent to 0 percent and accounted for 52 percent of the variation in survival. Families within provenances did not differ significantly and accounted for only 4 percent of the total variation. The provenances from Mississippi, Louisiana, and Alabama had a mean survival rate of approximately 9 percent. In contrast, the two

Table 1.--White ash families and provenances planted in West Virginia

Family number	Provenance number	State	County	Latitude (N)	Longitude (W)	Elevation
				---------degrees---------		---feet---
672010	1	NE	Nemaha	40.5	96.3	760
672102	2	IL	Williamson	37.8	89.1	400
672104	2	IL	Jackson	37.7	89.3	420
672110	2	IL	Jackson	37.7	89.4	620
672309	3	WI	Forest	45.7	89.0	1,675
672602	4	IL	Pike	39.8	90.7	700
672809	5	TN	Franklin	35.2	85.9	1,180
672810	5	TN	Franklin	35.2	85.9	1,160
673201	6	OH	Wayne	40.8	81.9	910
673302	7	AL	Madison	34.5	86.5	1,000
673303	7	AL	Madison	34.5	86.5	1,000
673404	8	KY	Trigg	36.8	88.1	490
673405	8	KY	Trigg	37.1	88.1	510
673501	9	AR	Boone	36.4	93.0	850
673502	9	AR	Marion	36.4	92.8	850
673504	9	AR	Marion	36.4	92.8	800
673705	10	MS	George	30.5	88.8	250
673802	11	LA	East Baton Rouge	30.5	91.0	30
673803	11	LA	East Baton Rouge	30.5	91.0	30
673805	11	LA	East Baton Rouge	30.5	91.0	30
674002	12	MS	Oktibbeha	33.4	88.8	380
674004	12	MS	Oktibbeha	33.4	88.8	380
674005	12	MS	Oktibbeha	33.4	88.8	380
674006	12	MS	Oktibbeha	33.4	88.8	380
677109	13	IL	Effingham	39.1	88.4	600
677110	13	IL	Shelby	39.3	88.6	630
677804	14	WV	Randolph	38.9	79.6	3,300
677806	14	WV	Randolph	38.9	79.7	3,200
677808	14	WV	Tucker	39.1	79.5	2,500
678605	15	ME	Penobscot	44.8	69.0	280
678607	15	ME	Penobscot	44.8	69.0	280
679305	16	NY	Cortland	42.7	76.1	1,900
679410	17	CT	New Haven	41.3	73.0	10
679503	18	IN	Washington	38.6	86.1	800
680605	19	WV	Barbour	39.1	80.1	1,580
680606	19	WV	Harrison	39.2	80.2	1,010
680609	19	WV	Taylor	39.3	80.2	1,320
686206	20	TN	McMinn	35.3	84.5	825
686212	20	TN	McMinn	35.3	84.5	825
686404	21	TN	Overton	36.5	85.4	1,180
686405	21	TN	Overton	36.5	85.4	1,180
686406	21	TN	Overton	36.5	85.4	1,160
687304	22	TN	Marshall	35.4	87.7	800
687305	22	TN	Marshall	35.4	87.7	800
687306	22	TN	Marshall	35.4	87.7	800

Table 2.--White ash mean provenance survival, crop trees, total height, d.b.h., and performance index of 22 provenances at the end of 15 growing seasons in West Virginia

Provenance	Center of Geographic Origin[a]	Survival	Crop trees	Total Height	D.b.h.	Performance Index
		--percent--	--percent--	---feet---	--inches--	
18	Southern IN (Salem)	88	21	19.3	2.7	1
19	North Central WV (Bridgeport)	87	23	19.0	2.6	2
14	North Central WV (Harman)	72	20	19.8	3.2	2
16	Central NY (Cortland)	68	31	19.6	2.5	4
2	Southern IL (Marion)	76	14	18.5	2.6	5
6	Central OH (Wooster)	84	12	16.0	2.0	6
4	West Central IL (Rockport)	72	10	17.1	2.5	7
13	East Central IL (Shelbyville)	60	11	15.4	2.2	8
17	Central CN (New Haven)	60	13	13.4	1.5	9
21	Northeast TN (Livingston)	67	8	13.2	1.6	10
20	Southeast TN (Athens)	48	13	12.3	1.3	11
8	Southwest KY (Golden Pond)	38	7	15.5	1.7	11
22	South Central TN (Lewisburg)	37	9	15.1	1.7	13
9	North Central AR (Harrison)	39	9	12.9	1.5	14
12	Central MS (Starkville)	15	24	10.0	1.0	14
15	Northern ME (Millinochet)	58	7	12.3	1.1	16
5	Southern TN (Winchester)	30	13	10.3	1.1	16
11	Southeast LA (Baton Rouge)	8	33	8.2	0.8	18
1	Southeast NE (Auburn)	48	0	12.0	1.2	18
3	Northeast WI (Crandon)	40	5	7.2	0.7	20
7	Northern AL (Meridianville)	14	7	8.8	1.0	21
10	Southern MS (Lucedale)	0	0	0.0	0.0	22
Provenance Mean		50	12	13.4	1.7	

[a]Center of geographic origin is represented by a regional description of location within a state and a centrally located community within that region.

provenances from West Virginia had a mean survival rate of approximately 79 percent. These results are consistent with a region-wide study that found local white ash provenances usually performed either at average or above average levels for the plantation (Clausen 1984).

Stem Form

Overall, plantation stem form was quite poor, although provenances and families within provenances were significant predictors of stem form. Provenances accounted for 18 percent of the total variation in stem quality while families nested within provenances accounted for 24 percent of the variation. Twelve families did not have any potential crop trees. A potential crop tree was defined as a tree that could develop a grade 1 or 2 butt log (Lamson and Smith 1989). Trees with poor stem form characteristics such as a low fork, epicormic branches, or a broken top were considered unsuitable as potential crop trees. The families with the best averages were from Harrison and Randolph Counties in West Virginia. However, less than 50 percent of the trees from these two families were potential crop trees (Table 3).

Poor stem form characteristics within the plantation may be related to the number of provenances and families that probably are unsuitable for the growing conditions of the Fernow. Poor performance of these families has resulted in a longer than usual delay of crown closure. Typically, crown closure would occur in 7 to 8 years following overstory removal. However, the 15-year-old ash plantation has yet to reach this stage of development. This is due partially to the continued weedings necessary to maintain growing space for the slower growing individuals in the plantation. Yet, in the absence of crown closure many of the larger trees are developing forms more typical of open-grown trees. Lack of crown closure also has resulted in the persistence of shrubs. The most common shrub within the plantation is blackberry (*Rubus* sp.). This, too, has intensified stem form problems by attracting bears that damage plantation trees while feeding on the blackberries. Common problems associated with bear damage include broken tops and limbs and bark wounds.

Table 3.--Average crop trees (percent) and total height of 45 white ash families at the end of 15 growing seasons in West Virginia

Family code	Family origin State	County	Total height	Crop trees
			---feet---	--percent--
680606	WV	Harrison	21.2	45
677806	WV	Randolph	21.2	45
677804	WV	Randolph	20.8	44
679305	NY	Cortland	20.4	32
672102	IL	Williamson	20.0	19
673405	KY	Trigg	19.3	7
679503	IN	Washington	19.0	21
680609	WV	Taylor	18.4	14
680605	WV	Barbour	18.3	13
672110	IL	Jackson	18.1	20
677110	IL	Shelby	17.4	10
673504	AR	Marion	17.3	7
672602	IL	Pike	17.1	10
677808	WV	Tucker	16.4	7
672104	IL	Jackson	16.4	0
673201	OH	Wayne	15.4	12
686405	TN	Overton	14.6	20
686406	TN	Overton	14.2	7
679410	CT	New Haven	14.0	13
686206	TN	McMinn	13.6	10
677109	IL	Effingham	13.6	7
687304	TN	Marshall	13.5	20
687305	TN	Marshall	12.8	0
678605	ME	Penobscot	12.5	7
672010	NE	Nemaha	12.0	0
673501	AR	Boone	11.4	0
673302	AL	Madison	11.0	20
678607	ME	Penobscot	11.0	5
687306	TN	Marshall	10.5	0
686404	TN	Overton	9.6	0
672809	TN	Franklin	9.4	13
686212	TN	McMinn	8.8	0
674002	MS	Oktibbeha	8.0	10
672309	WI	Forest	7.2	5
674006	MS	Oktibbeha	6.7	20
673502	AR	Marion	5.8	24
672810	TN	Franklin	5.4	0
673802	LA	East Baton Rouge	5.3	20
673404	KY	Trigg	4.9	7
674004	MS	Oktibbeha	3.5	0
673803	LA	East Baton Rouge	3.0	10
673303	AL	Madison	2.8	0
674005	MS	Oktibbeha	2.4	0
673805	LA	East Baton Rouge	2.0	20
673705	MS	George	0.0	0
Family Mean			12.1	11

Tree Height

Average tree height differed significantly for both provenances and families nested within provenances. Provenances accounted for 27 percent of the total variation in tree height while families within provenances accounted for 18 percent of the variation. Mean provenance total height was 13.4 feet. The provenance with the best height growth of 19.8 feet was a local provenance from north central West Virginia and was 70 percent greater than the mean for all provenances (Fig. 1). These results clearly illustrate that the selection of the correct provenance is critical for height growth of white ash in West Virginia. Additional improvements in height growth may be possible through identification and use of superior families and gains may be proportionately larger with increasing age.

D.B.H.

Mean d.b.h. for all provenances 15 years after establishment was 1.7 inches with the largest diameter of 3.2 inches recorded for the north central West Virginia provenance (Table 2). Provenances accounted for 23 percent of the total variation in d.b.h. and were significant, while families within provenances accounted for 11 percent of the variation but were not significant--illustrating again, the importance of proper provenance selection of white ash in West Virginia. As expected, the results for mean provenance d.b.h. were highly correlated with the results for mean provenance total height (Spearman correlation coefficient r = 0.94).

Performance Index

An overall provenance performance index was developed based on survival rate, stem form, total height, and d.b.h. Including total height and d.b.h. in the index, essentially weights the size as 50 percent, survival as 25 percent, and stem form as 25 percent of the total. In some cases, more than one provenance occupies a particular rank (Table 2). Although the basis for the index is subjective, some general trends are suggested. Perhaps most evident is that the best performing provenances have geographic origins from about the same latitude as the test site. The top three provenances include two provenances from West Virginia and one from Indiana. All are from virtually the same latitude as the test site. Two families within these provenances also had the best stem form characteristics (Table 3) and were local in geographic origin. However, the high ranking of the Indiana provenance suggests that longitude may be less critical than latitude as a potential performance criteria and that superior families may be found in locations not local to the planting site or even part of the central Appalachian mountain region.

Based on the results from the performance index, stepwise multiple regression was used to evaluate provenance performance as related to latitude, longitude, and elevation of the provenance. Latitude-squared and longitude-squared terms were included as potential independent variables. Latitude and latitude-squared were significantly related to survival and total height and accounted for 69 and 68 percent

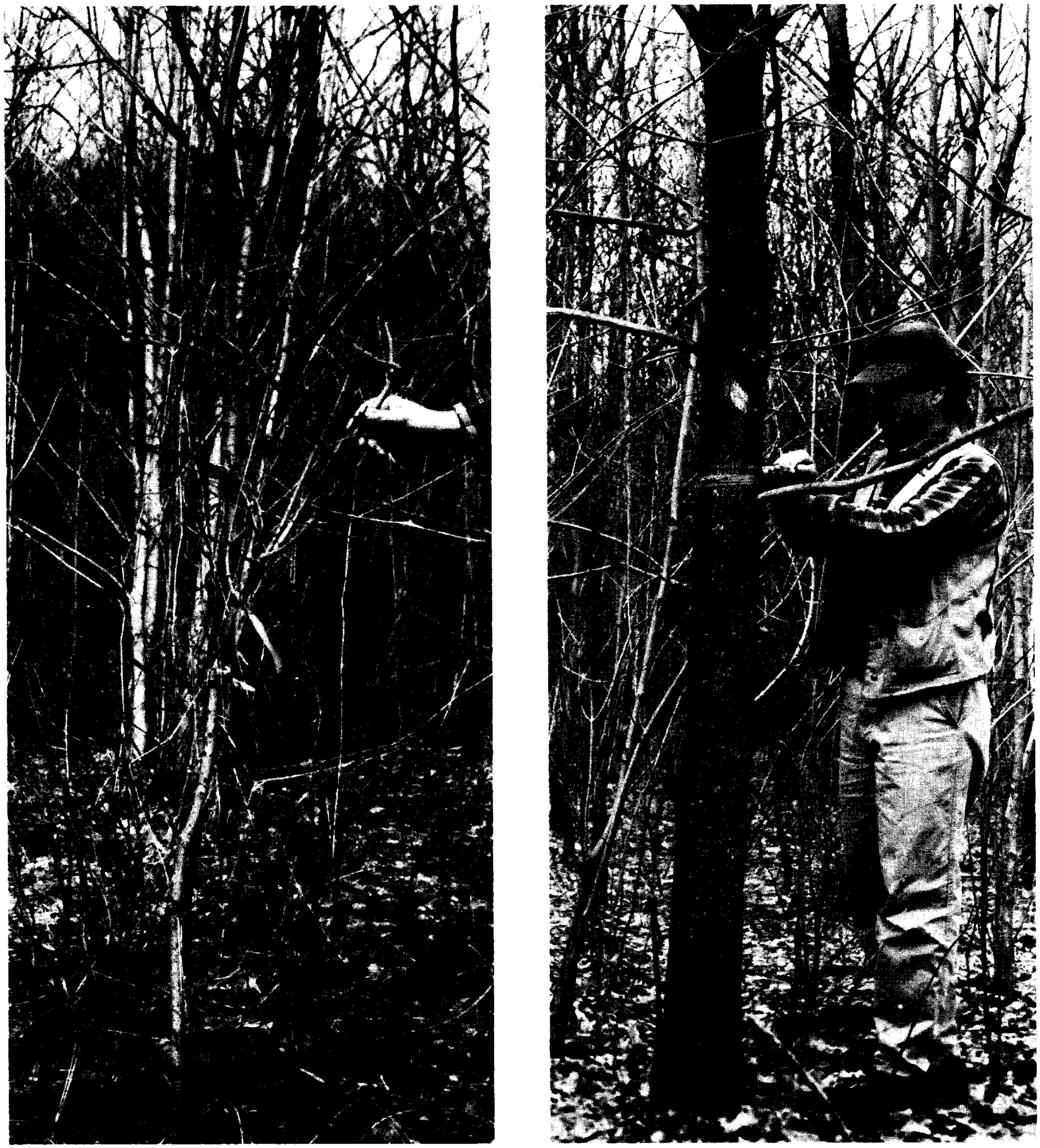

Figure 1.--Range of tree sizes present in white ash plantation in West Virgina 15 years after establishment. Tree height differed significantly for both provenances and families within provenances and latitude was a significant predictor of provenance performance.

of the variability for survival and total height, respectively, when used as the independent variables in quadratic equations (Table 4). Stem form was not related to any of the independent variables and d.b.h. was more closely related to elevation. The distribution of the survival and total height data suggest an optimal latitude for each criterion (Fig. 2), with performance declining north and south of the optimum. The quadratic equations predict optimal latitudes of 41.0° N for survival and 39.5° N for total height. Higher survival rates of slightly more northern provenances may be related to the timing of leaf abscission. Clausen (1982) found dieback of the main stem was closely related to the latitude of the seed origin and the presence of trees still growing at the time of the first killing frost in an Ontario white ash plantation. Thus, performance gains through longer leaf retention may be achieved at the risk of frost injury. On the Fernow, it appears that such risks are too great to realize performance gains by using southern seed sources.

Table 4.--Equations describing white ash provenance survival rate (S) and total height (H) (feet) as a function of latitude and latitude-squared (LS).

Equation	R^2	SE[a]
S = -10.8542 + 0.56293(L) - 0.00687(LS)	0.69	0.15
H = -246.715 + 13.3245(L) - 0.16867(LS)	0.68	2.91

[a]Standard error of estimate.

Conclusions

Preliminary recommendations for planting of white ash in West Virginia suggested it was both safe and advantageous to plant trees originating 100 to 200 miles south and west of the planting site (Clausen 1984). Wendel (1985), reporting on the 7-year results of the Fernow white ash plantation, refined this recommendation by finding that only families from the same general latitude (38° to 40° N) as the test site performed well. This translates to a zone of about 70 miles north and south of the planting site. However, Rink and Kung (1991) found that no significant improvements in height growth were observable in West Virginia, although rangewide studies of white ash have shown that height growth improvements of 25 to 50 percent are possible through proper provenance selection.

The results of this study suggest that white ash performance gains in West Virginia are possible by using proper provenances and superior families within these provenances, but the provenances and families probably will originate within a narrow latitudinal range. Equations developed from the provenance survival and total height observations (Table 4) predict an optimal provenance latitude of 2 degrees north of the plantation for survival and virtually the same latitude as the outplanting for maximizing height growth.

These findings clearly illustrate that white ash seed collection zones for mountainous locations in West Virginia should be restricted to a narrow latitudinal range. Longitudinal seed collection zones appear to be less critical and may provide opportunities for identification of superior families and realization of performance gains by using superior seedlings in artificial regeneration activities.

Improper selection or use of poorly suited sources of white ash in artificial regeneration should be carefully avoided. As seen here, the consequences could result in a complete regeneration failure of the desired species. The risk of using unsuitable sources is increasing in conjunction with the increased use of tree shelters and nursery grown planting material. As this practice becomes more common, both the user and the nursery manager need to be well informed about the origin of their sources and develop guidelines for localized use.

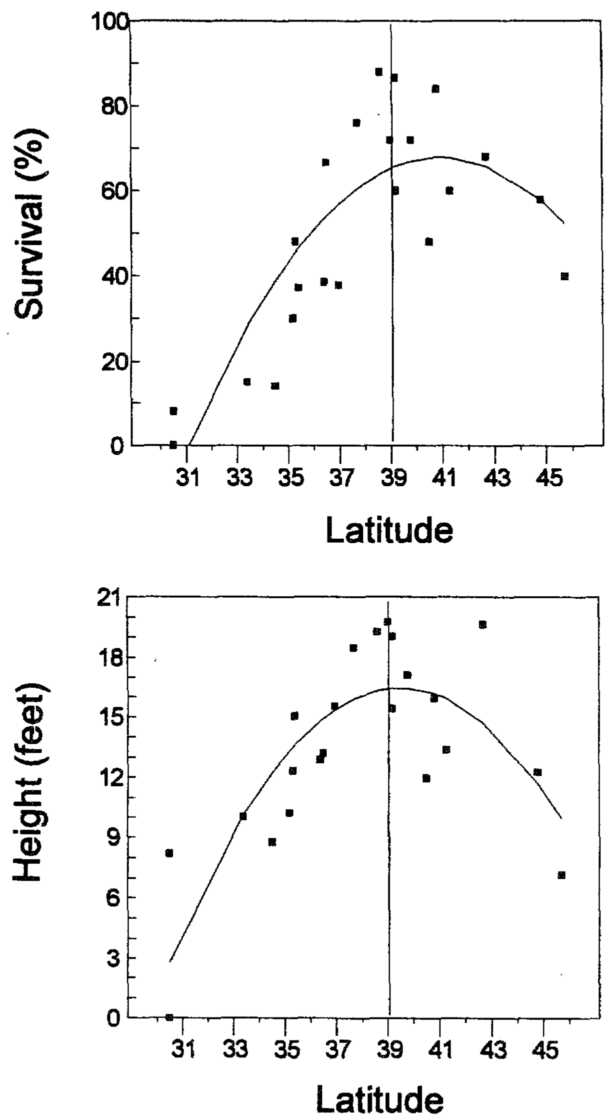

Figure 2.--White ash mean provenance survival and total height as a function of provenance latitude. Vertical line represents latitude of outplanting in West Virginia.

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Keywords: Fraxinus americana, progenies, performance gains, seed collection zones

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