SURVIVAL AND EARLY GROWTH OF DIPLOID WHITE ASH PLANTED IN THE CENTRAL HARDWOOD REGION

Knud E. Clausen[1/]

Abstract.--A white ash progeny test was established with seeds collected throughout the natural range of the species. Survival and height growth of 44 diploid families were recorded 3 years after planting in 10 plantations in the Central Hardwood Region. Survival ranged from 98 percent in eastern Kansas to 56 percent in southern Wisconsin. Individual families varied greatly between and within plantations with the greatest among-family variation observed in the Ohio plantation. Height ranged from 158 cm in Ohio to 41 cm in Wisconsin and was strongly affected by site and management practices. The best growth was recorded in plantations that were cultivated during the first 2-3 years. The families with the best overall growth were from Tennessee, Kentucky, and southern Illinois. However, some families from the same areas either had below-average growth or were among the shortest families. Individual families varied greatly in height from plantation to plantation, indicating that strong genotype-environment interactions exist.

Additional keywords: *Fraxinus americana*, progeny test, variation, genotype-environment interaction, tree improvement.

White ash (*Fraxinus americana* L.) is a hardwood species that grows rapidly and has higher-than-average market value. It occurs from Texas to Minnesota and Nova Scotia to Florida. Extreme climatic and soil differences within this wide natural range have led to much genotypic variation within the species (Wright 1944). Therefore, we are conducting a provenance/progeny test to determine the relative importance of between- and within-provenance variation as a first step in the genetic improvement of white ash.

METHODS

The provenance/progeny test was begun in 1975 by the North Central Forest Experiment Station at Carbondale, Illinois. Seed was collected from 35 geographic areas throughout the natural range of white ash and the seedlings were grown in a southern Illinois nursery for 1 year (Bey *et al*. 1977). In 1976, the families were established in 22 plantations throughout the eastern United States and Canada. The plantations contained various numbers of families in 5-tree plots and 5 replications. However, this paper is only based on data from the 10 plantations within the Central Hardwood Region (table 1).

Part of the genetic variation in white ash appears to be due to the fact that trees can be diploid, tetraploid, pentaploid, or hexaploid; i.e. they have 2, 4, 5, or 6 pairs of chromosomes (Clausen, Bey and Kung 1980). Ploidy level of about 100 parent trees were determined cytophotometrically on the basis of relative DNA content by Schaefer and Miksche (1977) and Leser (1978). Because

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[1/] Principal Plant Geneticist, North Central Forest Experiment Station, USDA Forest Service, Forestry Sciences Laboratory, Carbondale, Illinois 62901.

Table 1.--Location of plantations and number of white ash families included

State	County	Lat.	Long.	Families Diploid	Families Total
		Deg.	Deg.	No.	No.
Alabama	Cullman	34.1	86.8	8	42
Arkansas	Montgomery	34.6	93.6	7	42
Tennessee	Wayne	35.1	88.0	6	42
Illinois	Union	37.5	89.3	12	52
Kentucky	Rowan	38.2	83.4	11	42
Indiana	Crawford	38.2	86.3	8	39
Kansas	Jefferson	39.0	95.2	9	44
Ohio	Muskingum	40.0	82.0	13	49
Missouri	Adair	40.1	92.6	10	42
Wisconsin	Iowa	43.0	90.1	11	40

diploids appear to be much more common than trees of higher ploidy levels, this paper only deals with the early performance of 44 diploid families.

Survival and height of the families were recorded after three growing seasons in the field and the data subjected to analysis of variance. Percentage values used in the calculations were first converted by arcsin transformation.

RESULTS

Average survival of the families after 3 years in the field ranged from 98 percent in the Kansas plantation to 56 percent in the Wisconsin plantation (table 2). Individual family survival varied greatly within plantations but the differences were only significant in 4 of the 10 plantations (table 2). The greatest among-family variation occurred in the Ohio plantation where survival of the 13 families ranged from 24 to 97 percent. In contrast, survival of 12 of the same families in the Illinois plantation only varied from 68 to 100 percent (table 2).

Family survival averaged 78 percent and varied greatly among the 44 families (table 2). Ten of the families only occurred in one plantation each and had from 65 to 100 percent survival. The rest of the families occurred in from two to five plantations and their average survival ranged from 46 to 98 percent. The individual families varied greatly in how well they survived in different plantations. A few families consistently had either high or low survival at all locations but most families varied from plantation to plantation. Kentucky family 3403, for example, survived very well in the Illinois and Ohio plantations but had the lowest survival of the 11 families in the Kentucky plantation.

Height growth of the families was strongly affected by site and management practices and also by geographic location of the plantations. The best growth occurred in the 4 plantations that were cultivated during the first 2 or 3 years. Mean height of the diploid families ranged from 158 cm in the Ohio plantation to 41 cm in the Wisconsin plantation (table 3).

Table 2.--Survival of 44 diploid white ash families after 3 years in 10 plantations[1/]

Family No.	Origin County and State	Plantation AL	AR	TN	IL	KY	IN	KS	OH	MO	WI	Mean
		Percent										
3707	George, MS		72							36		54
3710	George, MS	80						100				90
4001	Oktibbeha, MS	68	56			76		96			50	69
4002	Oktibbeha, MS			80			76				35	64
4006	Oktibbeha, MS	96								44		70
4007	Oktibbeha, MS				88				27			58
4010	Oktibbeha, MS		48	92		84		96				80
3306	Madison, AL				68				24			46
2803	Franklin, TN	92				84	56					77
2804	Franklin, TN				100				73	84		86
2805	Franklin, TN				100				97			98
2806	Franklin, TN	88	88									88
2810	Franklin, TN							100				100
6211	McMinn, TN										65	65
6212	McMinn, TN										65	65
3502	Marion, AR	92										92
3506	Marion, AR		72			56		100		80		77
3508	Boone, AR			76			68				35	60
6408	Overton, TN						72			84	70	75
6409	Fentress, TN									88	75	82
3401	Lyon, KY				100				57			78
3402	Trigg, KY				100				76			88
3403	Trigg, KY				100	48			93			80
9210	Christian, KY	100		92							35	76
2202	Gallatin, IL							100			75	88
2208	Gallatin, IL		88	84								86
2210	Gallatin, IL	76		96								86
2101	Jackson, IL					72	80					76
2102	Williamson, IL					64	92					78
2103	Williamson, IL					100	92			64		85
2113	Jackson, IL				96			100	85	84		91
9804	Warren, OH					80						80
7810	Tucker, WV				96				77			86

Table 2.--Continued.

Family No.	Origin County and State	Plantation AL	AR	TN	IL	KY	IN	KS	OH	MO	WI	Mean
		Percent										
7101	Effingham, IL									64		64
7106	Effingham, IL		80					96				88
7110	Effingham, IL					76						76
3201	Wayne, OH								73			73
9402	New Haven, CT				92				95			94
9405	New Haven, CT				100				65			82
9304	Onondago, NY					64	88					76
9306	Onondago, NY							92			45	68
8609	Penobscot, ME										65	65
2303	Forest, WI				100				80			90
2309	Forest, WI									80		80
Mean		86	72	87	95	73	78	98	71	71	56	78
Significance Level		NS	NS	NS	.01	.01	NS	NS	.01	.01	NS	

1/ Families and plantations are listed from south to north.

Table 3.--Height of 44 diploid white ash families after 3 years in 10 plantations[1/]

Family No.	Origin County and State	Plantation AL[2/]	AR	TN[2/]	IL[2/]	KY	IN	KS	OH[2/]	MO	WI	Mean
		Percent										
3707	George, MS		124							76		100
3710	George, MS	104						106				105
4001	Oktibbeha, MS	108	97			95		91			95	97
4002	Oktibbeha, MS			111			67				93	90
4006	Oktibbeha, MS	88								98		93
4007	Oktibbeha, MS				132				68			100
4010	Oktibbeha, MS		122	92		89		99				100
3306	Madison, AL				104				90			97
2803	Franklin, TN	100				86	77					88
2804	Franklin, TN				96				111	103		103
2805	Franklin, TN				129				98			114
2806	Franklin, TN	109	89									99
2810	Franklin, TN							101				101
6211	McMinn, TN										111	111
6212	McMinn, TN										104	104
3502	Marion, AR	96										96
3506	Marion, AR		88			82		93		115		94
3508	Boone, AR			108			117				104	110
6408	Overton, TN						92			94	94	93
6409	Fentress, TN									106	124	115
3401	Lyon, KY				128				95			112
3402	Trigg, KY				121				103			112
3403	Trigg, KY				126	100			106			111
9210	Christian, KY	100		90							77	89
2202	Gallatin, IL							113			123	118
2208	Gallatin, IL		88	82								85
2210	Gallatin, IL	94		117								106
2101	Jackson, IL					118	126					122
2102	Williamson, IL					123	88					106
2103	Williamson, IL					122	116			114		117
2113	Jackson, IL				123			96	103	111		108
9804	Warren, OH					100						100
7810	Tucker, WV				55				107			81

Table 3.--Continued.

Family No.	Origin County and State	Plantation AL[2]	AR	TN[2]	IL[2]	KY	IN	KS	OH[2]	MO	WI	Mean
		Percent										
7101	Effingham, IL									94		94
7106	Effingham, IL		92					100				96
7110	Effingham, IL					111						111
3201	Wayne, OH								116			116
9402	New Haven, CT				67				100			84
9405	New Haven, CT				62				100			81
9304	Onondago, NY					73	117					95
9306	Onondago, NY							99			88	94
8609	Penobscot, ME										88	88
2303	Forest, WI				56				103			80
2309	Forest, WI									88		88
Mean (cm)		109	53	127	133	91	54	75	158	58	41	
Significance level		NS	.05	.01	.01	.05	.01	NS	.05	NS	NS	

1/ Families and plantations are listed from south to north; height is expressed as percent of plantation means for diploids.

2/ Plantations cultivated during first 2-3 years.

Individual family heights varied greatly within plantations and the differences were significant in 6 of the 10 plantations (table 3). The greatest among-family variation occurred in the Illinois plantation where heights ranged from 55 to 132 percent of the mean. In comparison, heights of the same families in the Ohio plantation only varied from 68 to 111 percent of the mean (table 3). As expected, average family height varied greatly among the 44 families. Southern Illinois family 2101 had the best growth and northern Wisconsin family 2303 had the poorest (table 3).

To better evaluate the height growth of individual families in different plantations, we standardized each family mean (subtracted the plantation mean and divided by the standard deviation among family means in that plantation). On this basis, excluding the 10 families that only occurred in 1 plantation each, southern Illinois family 2101 again ranked first (table 4). It was followed closely by southern Illinois families 2210, 2103, and 2202 and by Tennessee family 6409. In contrast to the good performance by these families, some families from the same general areas had the poorest growth. Southern Illinois family 2208, for example, ranked last. Other poor performers were Wisconsin family 2303 and families from Connecticut, New York, and West Virginia.

DISCUSSION

As expected, the geographic origin of the families affected their survival and height growth. The best survivors usually originated within 200 miles south or north of the plantation locations. In 7 of the 10 plantations the families with the poorest survival came from areas well south of the plantation location. For example, in southern Illinois only those families from more than 200 miles south of the plantation had low survival while those originating closer had excellent survival. Similarly, in the Ohio and Missouri plantations the families with the poorest survival came from Mississippi and Alabama.

Most families from 200 miles south or north of the plantations had above-average height in the Ohio, Alabama, and Tennessee plantations. The best families in the Kentucky and Indiana plantations originated within 100 miles of the planting sites. Local or more southern families had the best growth in the southern Illinois plantation. The best families in the four westernmost plantations all originated south of these locations. Indeed, the poorest family in the Arkansas plantation came from the same State. Movement from east to west was detrimental in the Kentucky and Illinois plantations where families from Connecticut, New York, and West Virginia showed poor growth. The shortest families in five of the plantations all originated in Mississippi.

Differences in site quality, site preparation, and plantation maintenance appeared to be at least as important as geographic origin for survival and early growth of the families. A few families performed consistently in all plantations--Tennessee family 2805 always had excellent survival, families 2804 and 2806 always had above average survival, and Alabama family 3306 and Arkansas family 3508 always had poor survival--but survival of most families varied from plantation to plantation.

For height growth, too, variable performance was much more common than consistent performance. As an example, Mississippi family 4007 was the tallest

Table 4.--Relative height of white ash families after 3 years in 10 plantations[1/]

Family No.	Origin County and State	Plantation AL[2/]	AR	TN[2/]	IL[2/]	KY	IN	KS	OH[2/]	MO	WI	Mean
		Height[3/]										
3707	George, MS		.75							-.44		.16
3710	George, MS	.47						.13				.30
4001	Oktibbeha, MS	.72	-.21			.06		-.23			-.53	-.04
4002	Oktibbeha, MS			1.25			-.52				-.61	.04
4006	Oktibbeha, MS	-.53								.08		-.22
4007	Oktibbeha, MS				1.34				-1.85			-.26
4010	Oktibbeha, MS		.70	-.37		-.21		-.03				.02
3306	Madison, AL				.34				-.50			-.08
2803	Franklin, TN	.27				-.34	-.32					-.13
2804	Franklin, TN				.03				.83	.19		.35
2805	Franklin, TN				1.25				.00			.62
2806	Franklin, TN	.77	-.46									.16
2810	Franklin, TN							.01				.01
6211	McMinn, TN										.41	.41
6212	McMinn, TN										.01	.01
3502	Marion, AR	.00										.00
3506	Marion, AR		-.53			-.56		-.18		.49		-.20
3508	Boone, AR			1.01			.46				.00	.49
6408	Overton, TN						-.03			-.02	-.58	-.21
6409	Fentress, TN									.27	1.21	.74
3401	Lyon, KY				1.18				-.18			.50
3402	Trigg, KY				.92				.34			.63
3403	Trigg, KY				1.11	.27			.50			.63
9210	Christian, KY	.19		-.49							-1.57	-.62
2202	Gallatin, IL							.29			1.14	.72
2208	Gallatin, IL		-.50	-1.18								-.84
2210	Gallatin, IL	-.14		1.81								.84
2101	Jackson, IL					1.11	.64					.88
2102	Williamson, IL					1.36	-.11					.62
2103	Williamson, IL					1.30	.44			.48		.74
2113	Jackson, IL				.99			-.11	.31	.40		.40
9804	Warren, OH					.29						.29
7810	Tucker, WV				-1.46				.55			-.46

Table 4.--Continued.

Family No.	Origin County and State	Plantation AL[2]	AR	TN[2]	IL[2]	KY	IN	KS	OH[2]	MO	WI	Mean
		Height[3]										
7101	Effingham, IL									-.02		-.02
7106	Effingham, IL		-.35					-.01				-.18
7110	Effingham, IL					.78						.78
3201	Wayne, OH								1.09			1.09
9402	New Haven, CT				-1.02				.11			-.46
9405	New Haven, CT				-1.20				.14			-.53
9304	Onondago, NY					-.96	.46					-.25
9306	Onondago, NY							-.04			-.88	-.46
8309	Penobscot, ME										-.91	-.91
2303	Forest, WI				-1.39				.33			-.53
2309	Forest, WI									-.15		-.15
Mean		.12	-.08	.34	.17	.28	.13	-.02	.13	.13	-.21	

1/ Families and plantations are listed from south to north.

2/ Plantations cultivated during firest 2-3 years.

3/ Expressed in standardized units.

family in the Illinois plantation but the shortest family in the Ohio plantation. However, a few families performed consistently--four southern Illinois families and Tennessee family 6409 always had good growth and Illinois family 2208 always had poor growth.

CONCLUSION

Because the performance of progenies of individual trees from the same stands or local areas varies greatly, it is clear that strong genotype-environment interactions exist in white ash. Therefore, it is not enough to collect seed for regeneration purposes from particular geographic areas or provenances that generally produce trees with good survival and growth. A tree improvement program for white ash should concentrate on testing many individuals to identify those that produce the fastest growing progenies. Skilled site selection, intensive site preparation, and good maintenance are also essential for successful white ash plantations.

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