# PERFORMANCE OF GREEN ASH PROVENANCES OF THE GREAT PLAINS REGION

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Abstract.--Seven provenances of Fraxinus Pennsylvanica Marsh from the Great Plains Region were planted in North and South Dakota, Nebraska, and Kansas in 1961. A later collection of seed from 24 provenances was planted in 1971 in the same states. Trees originating from Kansas and further south suffered progressively greater winter injury as the distance of the plantation from the origin increased to the north. However, trees from southeast Kansas and central Oklahoma provenances grew faster than average in eastern Nebraska and trees from Nebraska provenances grew faster than average in North and South Dakota. North and South Dakota trees performed better than trees from other sources in the south central Nebraska planting at Hastings.

Additional keywords: Fraxinus pennsylvanica, Height growth, Diameter growth.

Green ash, Fraxinus pennsylvanica Marsh., has become increasingly important for urban and park plantings because of its hardiness and satisfactory performance on adverse sites, even in periodically flooded areas (Broadfoot and Williston 1973). It has been one of the most widely and successfully planted hardwoods in windbreaks native on diverse sites east of the Rocky Mountains from southern Alberta, Canada, to Nova Scotia and Florida on the Atlantic coast (Forest Service 1965).

An earlier provenance study by Wright (1944) revealed ecotypic variation in winter hardiness, growth rate, leaf fall and leaf morphology among collections from the eastern United States and Canada. In the Great Plains Region three ecotypes based on resistance to artificially induced drought were recognized by Meuli and Shirley (1937). More recent research indicates that individual tree variation is as great or greater than variation among provenances (Santamour 1963). Ying, et al. (1972) reported a north-south clinal variation in growth rate, bud break and leaf fall in a nursery study of green ash provenances of the Great Plains Region.

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Provenance test plantations have been established in Nebraska and three other Great Plains states to determine genetic variability of green ash, and to evaluate the adaptability and performance of various seed sources to these plantation sites.

## METHODS

### 1961 Provenance Study

The Plant Materials Division, Soil Conservation Service, collected green ash seed in 1959 from seven native stands in the Great Plains Region and provided seedlings to the Nebraska, Kansas, and South Dakota Agriculture Experiment Stations and the Plant Materials Center, Bismark, North Dakota (Figure 1). The number of trees in each stand from which seed was collected was not recorded, but in most instances was probably only one or two trees. Seedlings were grown at the Plant Materials Center, North Dakota, and distributed in the spring of 1961. The Nebraska plantation was established at Horning State Farm, Plattsmouth, with twelve replications of 4-tree linear plots in a randomized complete block design spaced 1.8 x 3.6 meters (6 x 12 ft.) on an eroded upland silt loam of loess origin with north aspect. Planting designs were different at each of the other locations. Sources that were planted at each location are shown in Table 1.

### 1971 Provenance Study

Green ash seed was collected by Soil Conservation Service personnel in 1968 and 1969. The number of parent trees in each stand ranged from one to ten. In addition, we collected open pollinated seed from each of the seven sources established in the 1961 planting at Horning State Farm. Seeds were planted in June, 1970, in our nursery at Lincoln.

Three plantations were established in the spring of 1971 in Nebraska near Plattsmouth, Hastings, and Lincoln respectively (Figure 1). The randomized complete block design with single tree plots was planted on a level silty clay loam site at Hastings and Lincoln and on a gently sloping silt loam site at Plattsmouth. Progeny seedlings from the 1961 provenance plantation were also planted at Plattsmouth. The Lincoln planting was spaced at 0.6 x 1.8 meters (2 x 6 ft.) and the Hastings and Plattsmouth plantings were spaced at 2.4 x 4.3 meters (8 x 14 ft.).

Seedlings for test plantations in other states were provided to the U.S. Forest Service Experiment Station, Bottineau, North Dakota, and the Agricultural Experiment Stations at Brookings, South Dakota, and Manhattan, Kansas. Number of replications of 4-tree plots varied from 3 (Kansas), 6 (South Dakota), to 8 (North Dakota) in a randomized complete block design. The South Dakota planting on a sandy loam was spaced 2.4 x 3.0 meters (8 x 10 ft.) and the Kansas plantation on a fertile sandy clay loam was spaced 3.6 x 3.6 meters (12 x 12 ft.). Seedlings for the North Dakota planting were lined out in Bottineau for one year before field planting in 1972 in two single row windbreaks on private land with 2.4 meters (8 ft.) between trees.

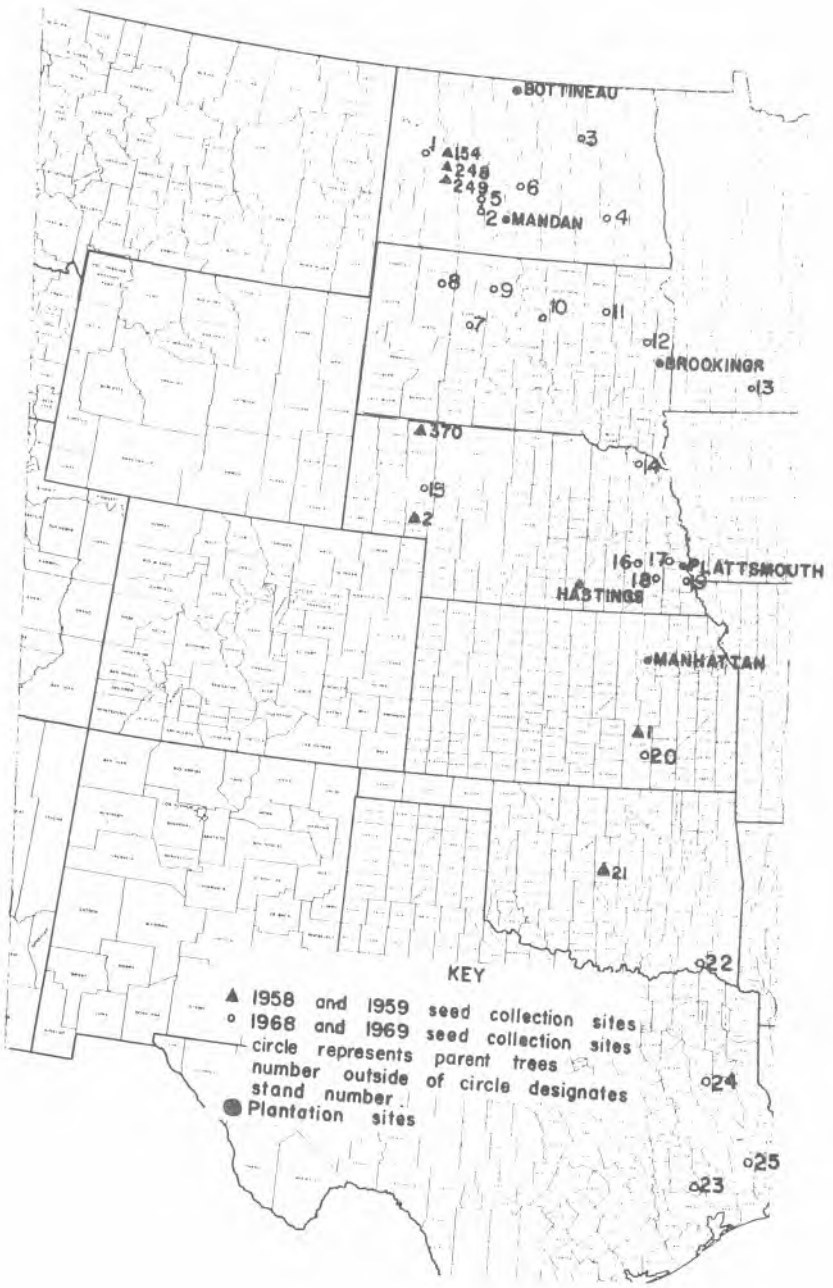


Figure 1. Collection and plantation sites of green ash provenances.

## Analyses

Data from the three 1961 Nebraska plantations were analyzed as a completely random experiment with unequal numbers of replicates because of missing plots. Variance analysis of data from the other plantings followed standard procedure of the randomized complete block design.

# RESULTS

## Mortality and Injury

Survival of green ash seedlings originating from Nebraska and states to the north was over 90 percent in all plantations, except where gophers injured roots and killed trees in the 1971 planting at Plattsmouth. At Bottineau, North Dakota, half of the planting suffered various degrees of damage from rabbits, thereby increasing variability of results, but causing no mortality. Also, over 73% of the seedlings of Oklahoma origin failed to become established at Plattsmouth the first summer. Thirty seven percent failed at Brookings and either all failed at Manhattan or they were not available for planting.

Winter killing was the major cause of mortality to the trees from Oklahoma in the North and South Dakota plantations. Trees of Kansas origin were hardy in Nebraska plantations but suffered winter injury in North and South Dakota. At Manhattan, Kansas, trees of the Oklahoma source in the 1971 planting were injured by cold, but trees of Oklahoma origin in the 1961 planting have not suffered injury at Plattsmouth.

## Growth

### 1961 Plantations

All sources at Plattsmouth, Nebraska, maintained the same relative height at age ten that they had at age two. Correlation between age two and age ten height was 0.97. The diameter growth in this planting closely paralleled height growth.

Eight-year height indicated the strong effect of seed sources, site and site-seed source interaction (Table 1). Trees from Butler county Kansas (K-1) were taller than those from other sources in Kansas, Nebraska and South Dakota plantings but lost that superiority in North Dakota due to cold injury. Diameter at age 15 indicates that the relative size of the various origins had not changed since the height measurements at age eight (Tables 1, 2).

### 1971 Plantations

The below average height growth of the Kansas source in the 1971 South Dakota plantation and the Oklahoma source at Hastings, Nebraska, was probably due to winter injury (Table 3). The Kansas and Oklahoma sources did not survive the first winter in Bottineau, North Dakota.

Table 1. Height of the 1961 green ash provenances at four locations and heights of their progeny at Plattsmouth.

| Source | N. Dakota Mandan | S. Dakota Brookings | Kansas Manhattan | Nebraska Plattsmouth | |
|---|---|---|---|---|---|
| | | | | Original | Progeny |
| Age (years)--- | 8 | 8 | 8 | 8 | 5 |
| | ----------Percent of Experiment Mean---------- | | | | |
| 0-21 | -a/ | 61 | - | 117 | 107 |
| K-1 | 38 | 112 | 116 | 139 | 108 |
| NB-2 | 108 | 113 | 97 | 93 | 96 |
| NB-370 | 125 | 110 | - | 95 | 93 |
| ND-154 | 129 | 98 | 86 | 86 | 95 |
| ND-248 | - | - | - | 90 | 101 |
| ND-249 | - | 103 | - | 79 | 94 |
| Mean (cm) | 268 | 389 | 539 | 518 | 197 |
| LSD (0.05)b/ | 11 | 11 | 19 | 12 | 28 |
| LSD (0.01)b/ | 15 | 15 | 27 | 16 | 38 |

a/ Not planted at locations indicated by -.
b/ Expressed as percent of plantation mean.

Table 2. Diameter at the 1961 Plattsmouth plantation at age 15.

| Source | Diameter (cm) |
|---|---|
| Kans 1 | 13 |
| Okla 21 | 12 |
| Nebr 370 | 9 |
| Nebr 2 | 9 |
| N Dak 248 | 7 |
| N Dak 154 | 7 |
| N Dak 249 | 6 |

Lines connect means that are not significantly different at 5 percent level.

Table 3. Relative height of the 1971 green ash provenances in the nursery and in six plantations in the Great Plains Region.

| Stand | State | County | Parent Trees | Plantation Locations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Nebraska Nursery | Kansas Manhattan | Nebraska Plattsmouth | Nebraska Lincoln | Nebraska Hastings | S. Dakota Brookings | N. Dakota Bottineau a/ |
| ----------Age - Years---------- | | | | 1 | 4 | 5 | 3 | 5 | 4 | 4 |
| | | | no | ----------Percent of experiment mean---------- | | | | | | |
| 3 | ND | Ramsey | 3 | 72 # | 91 | 86 | 83 # | 124 * | 101 | 89 |
| 1 | ND | Dunn | 2 | 93 | 95 | 88 | 98 | 114 | 104 | 107 |
| 6 | ND | Burleigh | 2 | 105 | 83 | 82 | 92 | 101 | 104 | 106 |
| 5 | ND | Morton | 2 | 86 | 93 | 91 | 86 | 106 | 98 | 92 |
| 2 | ND | Morton b/ | 1 | 113 | 96 | 74 # | 101 | 121 | 93 | 97 |
| 4 | ND | Barnes | 2 | 79 | 94 | -- | 96 | -- | 87 | 97 |
| 8 | SD | Perkins | 6 | 105 | 91 | 95 | 88 | 90 | 92 | 97 |
| 9 | SD | Dewey | 4 | 97 | 82 | 78 | 92 | 96 | 84 | 93 |
| 7 | SD | Ziebach | 3 | 113 | 98 | 103 | 84 | 110 | 91 | 106 |
| 10 | SD | Potter b/ | 1 | 104 | 115 | 147 * | 97 | 114 | 116 | 115 * |
| 11 | SD | Spink | 6 | 86 | 94 | 87 | 92 | 120 | 118 | 98 |
| 12 | SD | Hamlin | 2 | 82 | 76 # | 107 | 99 | 110 | 89 | 82 # |
| 13 | MN | Watonwan | 7 | 111 | -- | 105 | 98 | 95 | -- | -- |
| 14 | NB | Cedar | 10 | 116 | 93 | 112 | 111 | 116 | 112 | 113 |
| 15 | NB | Garden | 4 | 82 | -- | 77 | 96 | 75 | -- | 106 |
| 16 | NB | Cass | 5 | 86 | 118 | 107 | 105 | 102 | 105 | 101 |
| 17 | NB | Seward | 6 | 101 | 120 | 118 | 100 | 94 | 119 | 99 |
| 18 | NB | Lancaster | 4 | 112 | 124 | 106 | 106 | 118 | 120 * | 101 |
| 20 | KS | Butler | 10 | 101 | 129 * | 108 | 111 | 110 | 62 # | dead |
| 22 | OK | Choctaw | 10 | 124 * | 113 | 94 | 115 * | 74 # | -- | dead |
| | | Means | | 34 | 332 | 215 | 250 | 187 | 104 | 158 |
| | | LSD (0.05) c/ | | 27 | 20 | 30 | 18 | 27 | 17 | 11 |
| | | LSD (0.01) c/ | | 36 | 27 | 40 | 23 | 36 | 23 | 15 |

a/ Planted in 1972.
b/ Plantation tree of unknown origin.
c/ Expressed as percent of plantation mean.

* Tallest trees.
\# Shortest trees.

Mean plantation height increased from north to south. Generally, height growth for all sources in the two eastern Nebraska plantings was considerably greater than in the south-central Nebraska (Hastings) plantation.

Trees of provenances from eastern Nebraska (stands no. 14, 16, 17, 18) performed very consistently at all locations. Trees of North Dakota and four South Dakota sources were the largest in the south-central Nebraska planting (Hastings). Analyses of data from the three Nebraska plantings showed considerable within-stand variation among most provenances.

Progeny from the 1961 Plattsmouth provenance planting performed very much like their parents in that planting (Table 1). Progeny of the Butler county, Kansas, provenance, the fastest growing trees in the 1961 test in Kansas and Nebraska, were the tallest in the 1971 Kansas planting and were above average in growth rate in all Nebraska plantings.

Correlation between height growth and latitude of seed origin for each plantation were all negative but significant only at the Manhattan and Lincoln (r=0.76) plantations.

Site-seed source interactions were all significant in combined analyses and are reflected in the low correlation of height between plantings (Table 4). Correlation coefficients were generally high between plantations with similar site conditions.

Correlations in height growth between different ages varied from plantation to plantation, but were all statistically significant. Correlation of first and second year height with that of the fifth year height was 0.86 and 0.95, respectively, at the Hastings plantation. The same correlations at Plattsmouth were only 0.57 and 0.48. Second year and fourth year correlations were 0.51 at Brookings; 0.40 at Bottineau; and 0.93 at Manhattan.

Table 4--Correlation of total height among different plantations of 1971.

| | Kansas | Nebraska | | | S. Dakota | N. Dakota | Nebraska |
|---|---|---|---|---|---|---|---|
| | Manhattan | Plattsmouth | Hastings | Lincoln | Brookings | Bottineau | Nursery |
| Age(years) | 4 | 5 | 5 | 3 | 4 | 4 | 1 |
| Manhattan | | 0.57* | 0.10 | 0.60* | 0.17 | 0.49 | 0.29 |
| Plattsmouth | | | 0.12 | 0.42 | 0.24 | 0.35 | -0.03 |
| Hastings | | | | 0.31 | 0.17 | 0.12 | -0.26 |
| Lincoln | | | | | 0.02 | 0.27 | 0.34 |
| Brookings | | | | | | 0.73** | 0.14 |
| Bottineau | | | | | | | 0.38 |

*Significant at 0.05 level.
**Significant at 0.01 level.

## DISCUSSION AND CONCLUSIONS

The 1961 study showed that at least one nursery producing planting stock for establishment of provenance plantations should be located near the middle or southerly portion of the natural range of the species to avoid winter injury to seedlings of the southern provenances.

The observed injury, mortality and growth rate of the 1961 and 1971 studies were very similar. Analysis of the more extensive 1971 collection with more parent trees from each provenance indicated that considerable within stand variation can be expected for green ash. Selection of desirable phenotypes within a stand for seed collection is therefore necessary to attain reasonable uniformity of progeny for planting.

Although the Kansas source grew faster than the average at all Nebraska test sites, and Nebraska sources grew faster than others in North and South Dakota, there were exceptions to the observations that moderate northerly displacement may result in a faster growing plantation than would result from planting trees originating from the same or more northerly latitudes. For instance, northern provenances grew faster than all others at Hastings, Nebraska, a site normally receiving 24 inches precipitation as compared to 28 inches at Lincoln and Plattsmouth. This plus more sunshine and higher wind speeds of longer duration produces a site which places trees under stress many times throughout their life. This apparent ability of northern sources of green ash to grow faster than southern sources where water is often limiting agrees with the findings of Mueli and Shirley (1937) that drought resistance of green ash increases with latitude of origin.

Since performance of open pollinated progeny from the 1961 Plattsmouth provenance plantation was very similar to that of their parent trees, very little, if any, natural crossing occurred among the various provenances. This fact is supported by our unreported spring phenology observations which indicate the existence of differences in date of flowering among the provenances of this plantation. They are apparently large enough to discourage cross fertilization among genotypes of considerable diversity,

All of the easier Nebraska stands, and particularly the Cedar County source, produced progeny that grew faster than average in most locations. Until seed orchards of improved selections can provide seed tailor-made for specific planting sites, the Cedar County, Nebraska, stand ranks high as a source of seed for fast growing trees to be planted in Nebraska and the Dakotas over a wide range of site conditions.

In the future, selected phenotypes of green ash will be vegetatively propagated to establish seed orchards and clone beds in order to attain a predictable response to a specific site while maintaining enough genetic diversity to avoid wholesale loss due to unforeseen pests or environmental stress.

## LITERATURE CITED

Broadfoot, W. M., and H. L. Williston. 1973. Flooding effects on southern forests. J. Forestry 71:584-587.

Forest Service. 1965. Silvics of forest trees of the United States. USDA Agric. Handbook No. 271.

Meuli, L. J., and H. L. Shirley. 1937. The effect of seed origin on drought resistance of green ash in the Prairie-Plains states. J. Forestry 35:1060-1062.

Read, R. A. 1958. The Great Plains Shelterbelt in 1954: Nebr. Agric. Exp. Sta. Bull. 441, 125pp.

Santamour, F. S. Jr. 1963. Thirteen-year growth of some green ash provenances in northeast. U. S. Forest Service Res. Note NE-14, 5pp.

Wright, J. W. 1944. Ecotypic differentiation in red ash. J. Forestry 42:591-597.

Ying, C. C., J. Schultz, and W. T. Bagley. 1972. Genetic variation in a green ash population of the Great Plains Region. Proc. 8th Central States Forest Tree Impr. Conf. p. 47-50.