GEOGRAPHIC VARIATION IN THE ROSEMOUNT, MINNESOTA NC-99 EASTERN COTTONWOOD PROVENANCE TEST - A FINAL REPORT - 1/

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__Abstract.__ In this cottonwood provenance test, mortality between the 6th and 17th year in the field was high in many sources originating between 38 and 42 degrees north. Seventeenth year survival exceeded 75 percent only in the Minnesota and northern Ohio sources, and growth differences among origins were non-significant. The results suggest that local populations may be the most appropriate source of breeding materials for use under Minnesota condition.

__Additional Keywords:__ Provenance effects, mortality, height growth, diameter growth, diameter-height ratio, __Populus deltoides.__

This paper summarizes the development of cottonwood (__Populus deltoides,__ Bartr.) provenances over a 17-year period under the severe conditions near the northern limits of the species range. The data were obtained from the most northerly test (45° N. latitude) in the series established as a part of the regional project, NC-99. Mortality within several sources has now reached a level that precludes future evaluation of provenance effects, and this paper represents a final report on that aspect of the test.

MATERIALS AND METHODS

Planting stock consisted of 1-0 seedlings from 108 open-pollinated families. Mother trees were located in natural stands between the 80th and 100th meridian (Pennsylvania to South Dakota) and between 30 and 46 degrees north latitude (Texas to Minnesota). In evaluating the test, the open-pollinated families were placed in the following 11 "geographic groups or provenances":

Geographic Group	Latitude (°N)	Longitude (°W)	Nr. Families
Minnesota	44 - 46	91 - 93	26
South Dakota	44	99	1
No. Illinois	41 - 42	90	16
Nebraska	40 - 41	96 - 99	3
No. Ohio	40 - 41	80 - 81	4
Indiana	40 - 41	87	4
Missouri	38 - 39	92 - 93	15
So. Ohio	38 - 39	81 - 83	8
Kansas	37 - 39	96 - 98	2
So. Illinois	37 - 38	88 - 90	7
<37 degrees	37	88 - 96	22

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The seed collection for this and the other NC-99 cottonwood provenance tests was coordinated by J.J. Jokela of the University of Illinois. It was completed in 1964, and this test was planted in the spring of 1965 at the University of Minnesota's Rosemount Agricultural Experiment Station using stock grown in an Illinois nursery.

The planting site was an old field which had been prepared by disking. The soil, a sandy loam, is relatively fertile, but the site is underlain by coarse gravel and is rated as poor to fair for cottonwood because of moisture stress in dry years.

The planting design was a randomized complete block with the 108 families as treatments, one seedling per plot and 5 replications. Spacing was 10 x 10 feet and post-planting care consisted of pruning seedling to a single stem during the first growing season and controlling weeds for two season's by disking and mowing.

Data considered in this paper are restricted to those related to growth and survival. Variables evaluated statistically included height after the 2nd year in the field, height and diameter after the 6th, 12th, and 17th years in the field and two derived variables for the last three measurement years: diameter squared x height and diameter as a percent of height. Heights were measured to the nearest tenth foot in the 2nd and 6th year and to the nearest foot in later years. Diameters at breast height (4.5 feet) were measured to the nearest tenth inch.

Because of the extensive mortality, data were analyzed on the basis of a completely random design. Analysis of Variance was used to test for differences in the performance of the "geographic groups" listed above and source means were compared using Duncan's multiple range test with adjustments for the number of observations per treatment. Tests of significance were carried out at the .05 level.

RESULTS

Survival over the 17 years in the field, as summarized by figure 1, strongly reflects the influence of seed origin. High latitude materials clearly had the highest survival. From a practical viewpoint, 17th-year survival could only be considered satisfactory (above 75 percent) in the Minnesota and northern Ohio groups. The rapid elimination of materials from south of 38 degrees was expected. The high level of mortality occurring between the 6th and 17th year in several of the middle latitude sources (38-42 degrees north) was not.

The extent of this delayed mortality is illustrated by the data for the Missouri, Southern Ohio and South Dakota sources. All had survival in excess of 80 percent six years after planting and below 33 percent 11 years later. When computed on the basis of the number of trees living at the beginning of a measurement period, mortality in the South Dakota, southern Ohio and Indiana sources was higher for the 12-17 year period than for the 6-12 year period. Given this trend, additional losses in the middle latitude sources can be expected.

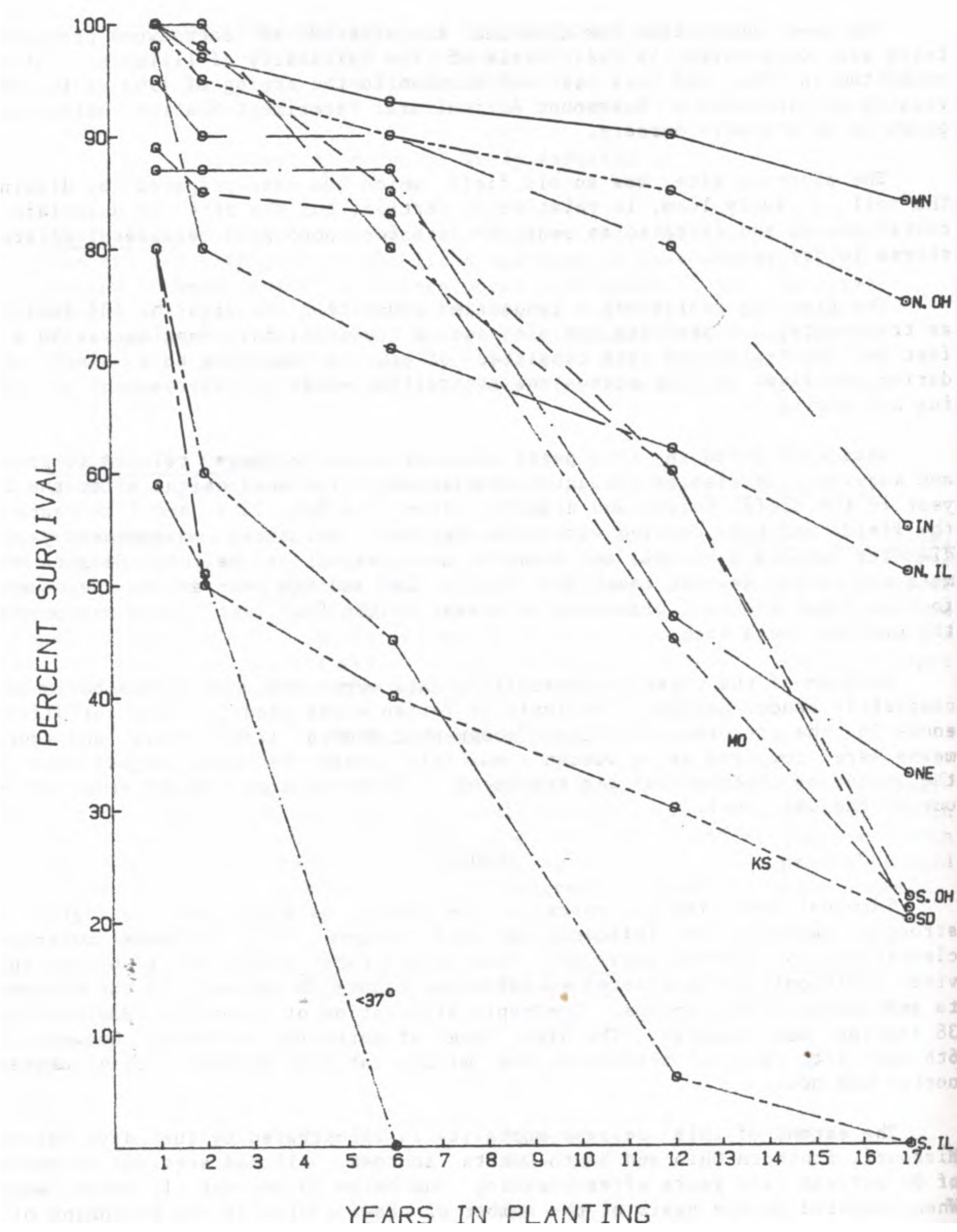

Figure 1. Survival of 11 NC-99 geographic sources of eastern cottonwood over 17 years at Rosemount, Minnesota.

Height data are summarized in table 1. Significant differences among sources in height were found for 2nd, 6th and 12th year measurements. Through year 12, Nebraska, Missouri and Minnesota sources were consistently in the tallest group of sources. Between the 12th and 17th year, rankings shifted and differences in height among sources were no longer significant.

Table 1. Mean heights (feet) of 11 geographic sources of cottonwood in the Rosemount, Minnesota, NC-99 test 1, 6, 12 and 17 growing seasons after planting. [a,b]

	SECOND YEAR			SIXTH YEAR	
Source	Nr. Obs.	Height	Source	Nr. Obs.	Height
Nebraska	13	9.8	Nebraska	13	24.2a
Missouri	64	8.9a	Minnesota	122	22.9a
Minnesota	126	8.9a	Missouri	61	22.7a
So. Ill.	21	8.5ab	No. Ill.	57	20.6b
Indiana	18	8.3ab	Indiana	18	20.3bc
No. Ohio	19	8.3ab	So. Ohio	34	19.5bc
So. Ohio	39	8.1ab	So. Ill.	11	19.4bc
Kansas	5	8.1ab	No. Ohio	18	19.1c
No. Ill.	66	7.8b	*** Sources below not included in analysis ***		
So. Dakota	5	7.0b			
<37 degrees	56	7.0b	Kansas	4	20.3
			So. Dakota	4	18.0

	TWELFTH YEAR			SEVENTEENTH YEAR	
Source	Nr. Obs.	Height	Source	Nr. Obs.	Height
Nebraska	7	39.7a	So. Ohio	9	47.1a
Missouri	34	36.8ab	Nebraska	5	46.6a
Minnesota	117	36.7ab	No. Ill.	41	45.2a
No. Ill.	50	35.4b	Minnesota	108	44.7a
So. Ohio	24	34.1bc	Indiana	11	44.6a
Indiana	16	33.6bc	Missouri	15	44.5a
No. Ohio	17	33.5c	No. Ohio	15	41.1a
Sources below not included in analyses					
Kansas	4	33.2	Kansas	2	34.0
So. Ill.	1	37.3	So. Dakota	1	29.0
So. Dakota	3	36.7			

a/ All surviving trees listed in table; sources with fewer than 5 surviving trees not included in analysis.

b/ Means within a year followed by the same letter do not differ at the .05 level.

Differences among sources in mean diameter were significant for all measurement years (table 2). However, differences were generally found only when extreme values were compared. Nebraska, Minnesota and Missouri sources tended to have greater diameters which was consistent with the height data. In contrast, the Indiana collection was consistently above average in diameter even though its height was not outstanding.

Table 2. Mean diameters breast height (inches) of geographic sources of cottonwood in the Rosemount, Minnesota, NC-99 test 6, 12 and 17 growing seasons after planting. [a,b]

	SIXTH YEAR			TWELFTH YEAR	
Source	Nr. Obs.	Diameter	Source	Nr. Obs.	Diameter
Nebraska	13	3.8a	Nebraska	7	7.0a
Indiana	18	3.6a	Minnesota	117	6.6a
Minnesota	122	3.6a	Indiana	16	6.6ab
Missouri	61	3.5a	Missouri	34	6.2ab
No. Ohio	18	3.2ab	No. Ill.	50	5.8ab
So. Ill.	11	3.1ab	So. Ohio	24	5.6b
No. Ill.	57	3.1b	No. Ohio	17	5.6b
So. Ohio	34	3.1b			

	SEVENTEENTH YEAR	
Source	Nr. Obs.	Diameter
Indiana	11	8.9a
Nebraska	5	8.6ab
Minnesota	108	8.5ab
Missouri	15	7.9ab
No. Ill.	41	7.9ab
So. Ohio	9	7.7ab
No. Ohio	15	7.1b

[a] Only those sources with 5 or more surviving plants were consider

[b] Means within a year followed by the same letter do not differ at the .05 level.

Means for diameter squared x height, an approximation of volume, are found in table 3. Significant differences among groups were found for years 6 and 12, but no clear pattern was evident. By the 17th year difference among sources were not significant.

Table 3. Means of diameter² x height in cubic feet after 6, 12 and 17 years in the field for selected cottonwood sources in the NC-99 test at Rosemount, Minnesota. a,b/

SIXTH YEAR		TWELFTH YEAR		SEVENTEENTH YEAR	
Source	Product	Source	Product	Source	Product
Nebraska	2.53a	Nebraska	13.72a	Indiana	27.61a
Missouri	2.19ab	Minnesota	11.62a	Nebraska	25.49a
Minnesota	2.17ab	Indiana	11.13ab	Minnesota	23.95a
Indiana	2.09abc	Missouri	10.95ab	Missouri	21.41a
No. Ohio	1.61bc	No. Ill.	9.07ab	No. Ill.	21.10a
No. Ill.	1.58c	No. Ohio	8.65ab	So. Ohio	20.34a
So. Ohio	1.42c	So. Ohio	7.99b	No. Ohio	17.02a

a/Only data for sources with 5 or more trees living in year 17 are presented. See table 1 for number of trees per source.

b/ Means within a year followed by the same letter do not differ at the .05 level.

Substantial differences among sources in their diameter relative to their height were suggested by the sixth-year data (Dhir and Mohn, 1974). Table 4 presents the results of analyses of the variable diameter as a percent of height obtained from current data. The results confirm diameter-height ratio differences observed previously. The highest ratio was found in the Indiana source, but it was not statistically different from the values for other vigorous sources -- Minnesota, Nebraska and Missouri.

Table 4. Ratio of diameter (ft) to total height (ft) after 6, 12 and 17 years in the field for selected cottonwood sources in the NC-99 test at Rosemount, Minnesota.a,b/

SIXTH YEAR		TWELFTH YEAR		SEVENTEENTH YEAR	
Source	Ratio x100	Source	Ratio x100	Source	Ratio x100
Indiana	1.41a	Indiana	1.58a	Indiana	1.64a
Nebraska	1.29ab	Minnesota	1.46a	Minnesota	1.54ab
So. Ohio	1.28ab	Nebraska	1.43ab	Nebraska	1.54abc
Minnesota	1.25ab	Missouri	1.35b	Missouri	1.47abc
Missouri	1.21ab	No. Ohio	1.33b	No. Ill.	1.42bc
No. Ill.	1.14ab	So. Ohio	1.31b	No. Ohio	1.40bc
No. Ohio	.92b	No. Ill.	1.31b	So. Ohio	1.34c

a/ Only data for sources with 5 or more trees living in year 17 are presented. See table 1 for number of trees per source.

b/ Means within a year followed by the same letter do not differ at the .05 level.

DISCUSSION AND CONCLUSIONS

Conclusions based on the above data must be made with caution because of the limited number of populations sampled, the small number of observations for many of the sources and the single test site. Despite these limitations, the data are the best available, and the trends noted appear strong enough to serve as useful guidelines for continuing our work with cottonwood in Minnesota.

Previous publications related to this test include a report on growth, survival and winter injury during the first two years after planting by Mohn and Pauley (1969) and a summary of the survival, growth, stem form and flowering to age six by Dhir and Mohn (1974). In addition, six-year data from the test were included in a review of geographic variation of eastern cottonwood by Jokela and Mohn (1976). The early results indicated that materials from a number of natural populations located north of 38 degrees latitude could be considered for selection and direct use under Minnesota conditions. The Missouri, Nebraska and Indiana groups were considered particularly promising, because of their satisfactory survival and rapid growth (Dhir and Mohn, 1974).

Serious doubts about the value of these materials for direct use in Minnesota are raised by the levels of mortality in these sources during the two most recent measurement periods. In Minnesota, the performance of mid-latitude sources seems to parallel the rapid early growth and short life spans exhibited by many hybrid poplar clones. Such materials are not suited for many uses.

The cause of delayed mortality in this test has not been determined. It was clearly related to latitude of origin, and climatic injury is suspected to be the underlying cause. During the first two years of the test, the level of observable winter injury was associated with latitude (Mohn and Pauley, 1969). The effects of such injuries may be cumulative, and the actual incidence of such injury probably exceeds that which can be easily observed. While climatic injuries may not be the direct cause of mortality, they could predispose materials to diseases and/or other lethal agents.

Whatever its cause, the mortality between years 6 and 17 indicates that most mid-latitude materials are poorly adapted to condition at the test site. There is a strong possibility that the mortality trends illustrated by figure 1 may continue. Under these circumstances, it would be prudent to limit materials selected for immediate use to those of local (Minnesota) origin.

Non-local materials surviving to date cannot be discounted as possible source of valuable germplasm for the future. While most of the outstanding phenotypes surviving in the test were of Minnesota origin, some were not. The largest surviving tree in the test (58 feet in height and 13.8 inches diameter at 17 years) was of Indiana origin. Continuing work with these outstanding individuals of non-local origin is justified, but testing and breeding efforts should recognize the potential for problems in their adaptation.

The growth data provide no clear answer to which segments of the natural population should be targeted in developing the base populations needed for a long-term improvement program. Ideally, both the means and variances of sub-populations should be considered when addressing this question. However, the data are not adequate for considering variances and marginal for evaluating means.

A further complication is the possible upward bias of the growth data for many of the seed sources. Except in the Nebraska source which is represented by a very small sample, mortality in mid-latitude sources appears to have removed smaller than average trees (table 5). As a result, means for the mid-latitude populations may not be comparable to the local (Minnesota) population in which mortality was not a factor.

Table 5. Comparisons of sixth-year height of trees within geographic sources classified as living or dead after 12 or 17 years in the Rosemount, Minnesota, NC-99 cottonwood test.

Source	Latitude (° north)	Years in Field when Classified	Nr. Living Trees	Nr. Dead Trees	Difference 6-year Height Between Living and Dead Trees (feet)
Minnesota	(44 - 46)	17	108	14	-.4
No. Ill.	(41 - 42)	17	41	16	3.1*
Nebraska	(40 - 41)	17	5	8	-1.2
Indiana	(40 - 41)	17	11	7	3.3
No. Ohio	(40 - 41)	17	15	3	3.3
Missouri	(38 - 39)	12	34	27	3.1*
So. Ohio	(38 - 39+)	12	24	9	3.3*
So. Ill.	(37 - 38)	12	3	8	2.4

* Differences between 6-year heights of groups within sources are significant at .05 level.

The statistical analyses do not provide evidence suggesting that productivity gains would be achieved by using non-local sources (tables 1-3). However, only relatively large differences among sources were detected by these tests. Both the Indiana and Nebraska sources had mean diameters and relative volumes which substantially exceeded the Minnesota source at age 17 (tables 2 and 3), and it is difficult to completely ignore those differences.

When mortality and growth data are both considered, the data point to Minnesota sources as the most reasonable source of base population materials for developing vigorous well-adapted materials for use in environments similar to those of the test. The observations made to date may justify the inclusion of a limited amount of materials from the most promising non-local sources. However, our evaluation of the data suggests that allocating the bulk of the available resources to assembling materials from local populations will maximize the opportunities for gain.

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