# Performance of a Wide-ranging Collection of Black Locust Seed Sources in Western Oklahoma

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## Abstract

Results of a 1987 black locust (*Robinia pseudoacacia* L.) seed source planting in western Oklahoma are reported. The 116 families showed considerable variation in growth. Survival to age 5 remained above 90 percent for all but nine families. Between ages 5 and 10, 40 percent of the surviving trees suffered stem dieback, probably due to hot, dry summers. Consequently, if one is selecting for use in harsh environments, testing should be long term. Correlations of growth with latitude and longitude were found, but they accounted for 10 percent or less of the variation. Greatest variation was among families, and family selection for utilization or improvement is suggested.

## Introduction

Black locust (*Robinia pseudoacacia* L.) is recognized as one of the most versatile tree species in North America, and perhaps also in Europe, if not the world. It has been utilized for firewood, fuelwood, posts, poles, lumber, wood fiber, bioenergy, site stabilization, land reclamation, forage and honey production. It is drought-resistant, tolerates poor soils, fixes nitrogen, and has shown wide site adaptability. It produces a high-energy, stable wood that is decay resistant.

The original range of black locust was confined to the Appalachian, Ozark, and Ouachita Mountains. It has since been planted widely and has become naturalized throughout the United States, southern Canada, and parts of Europe and Asia (Hardin and others 2001). Black locust is reportedly one of the most widely planted hardwoods worldwide (Genys and Harman 1990), yet little information on seed source and family adaptability is available.

A few early survivability reports in Oklahoma (Afanasiev 1947, 1948) did point to the general adaptability of black locust. Some breeding work in Hungary (Keresztesi 1980) demonstrated the potential for improvement in the species. Seed source studies in Georgia (Kennedy 1983), Michigan (Mebrahtu and Hanover 1989), and Maryland (Genys and Harman 1990) all reported considerable variation among sources and families for many traits, but no geographic trends. Bongarten and others (1992) reported that black locust shows considerable potential under short rotation intensive culture management. All these seed source studies reported 1- to 3-yr data, and much remains to be learned about this species.

In this study, black locust seed sources were tested in western Oklahoma to examine growth trends and evaluate utilization of the species in the relatively harsh southern Great Plains. The study was planted in 1987, and 10-yr data are reported.

## Materials and Methods

Open-pollinated black locust seeds were collected from four trees in each of 15 natural or naturalized stands across Oklahoma and one in northwest Arkansas. In addition, seeds from 151 open-pollinated families from the eastern United States and southeast Canada were provided by the Michigan Cooperative Tree Improvement Program, Michigan State University. Some of the Michigan collection consisted of two or more families from a stand; others represented single families from a collection location. Seeds of all 215 trees were acid scarified for approximately 1 h as described by Bonner and others (1974). Seed were stored wet overnight and sown in the nursery the following day, in early June 1986. No germination tests were conducted. Sowing density was 27 seed per $ft^2$ (0.09 $m^2$), and nursery practices were standard for hardwood seedlings. One hundred seed of each family were planted. Seedlings were lifted as 1-0 stock for field planting.

Seedlings were planted near Canton, Oklahoma, on an alluvial soil near the North Canadian River. The soil is a Canadian fine sandy loam. Average annual precipitation is approximately 26 in (66 cm), mean maximum July temperature is 96 °F (70 °C), and mean minimum January temperature, 25 °F (-4 °C). Competition was controlled by mowing.

The planting design was a randomized complete block, with three-tree-row family plots and five replicates. Spacing was 8 × 8 ft (2.4 ×2.4 m), and the planting was surrounded by one border row of mixed leftover seedlings.

Number of seed germinated in the nursery was determined approximately 2 mo after planting the seed. In the field planting, survival and height were recorded at plantation age 1, 5 and 10 yr, and diameter at breast height was measured at age 5 and 10. The number of multiple stems was counted at age 10, and, because considerable dieback had occurred between ages 5 and 10, the number of stems showing main stem death was also recorded. These data were subjected to an analysis of variance with the SAS program GLM (SAS, Cary, NC).

To look for possible geographic trends in growth related to collection location, simple correlations of family means for growth and survival with latitude and longitude were calculated, as well as age/age correlations. Family and single-tree heritabilities were estimated using formulas suggested by Wright (1976), excluding the site component. These estimates were made using expected mean squares estimates from the SAS program "Variance Components Estimation Procedure."

## Results

Average germination for seed planted from the 215 open-pollinated-families was 15 percent, ranging from 0 to 66 percent. Seedling survival after 1 yr in the nursery was 28 percent, ranging from 0 to 42 percent. The reason for poor seedling survival is unknown. A minimum of 15 seedlings per family was required for field planting; thus, only 116 of the 215 families are represented in the field planting.

First-year plantation survival (table 1) was 97 percent; plantation mean height was 4.3 ft (1.3 m). Only three families had survival below 90 percent. Height growth was considerably more variable, ranging from 0.8 to 8.3 ft

**Table 1.** Black locust plantation family and stand means and range.

| | | | FAMILY | | STAND | |
|---|---|---|---|---|---|---|
| **TRAIT** | *N* | — | *Minimum* | *Maximum* | *Minimum* | *Maximum* |
| SURVIVAL (%) | | | | | | |
| Yr 1 | 1658 | 97 | 67 | 100 | 67 | 100 |
| Yr 5 | 1658 | 92 | 40 | 100 | 40 | 100 |
| Yr 10* | 1658 | 60 | 0 | 100 | 07 | 100 |
| HEIGHT | | | | | | |
| Yr 1 (ft) | 1614 | 4.28 | 0.82 | 8.29 | 2.16 | 5.64 |
| (m) | | 1.30 | 0.25 | 2.53 | 0.66 | 1.72 |
| Yr 5 (ft) | 1527 | 13.32 | 1.50 | 20.60 | 7.07 | 14.90 |
| (m) | | 4.06 | 0.46 | 6.28 | 2.15 | 4.54 |
| Yr 10 (ft) | 989 | 20.35 | 0.80 | 32.00 | 11.80 | 27.30 |
| (m) | | 6.20 | 0.24 | 9.75 | 3.59 | 8.32 |
| DIAMETER | | | | | | |
| Yr 5 (in) | 1498 | 1.59 | 0.24 | 3.27 | 0.91 | 2.18 |
| (cm) | | 4.04 | 0.61 | 8.31 | 2.35 | 5.54 |
| Yr 10 (in) | 989 | 2.91 | 0.51 | 6.89 | 1.34 | 4.13 |
| (cm) | | 7.39 | 1.29 | 17.50 | 3.40 | 10.49 |
| AGE 10 | | | | | | |
| % multiple stems | 988 | 26.6 | 0.00 | 100 | 0.00 | 100 |
| % dieback | 988 | 29.9 | 0.00 | 100 | 0.00 | 100 |

* % = number without dieback Yr 10/number alive Yr 5

(0.25 to 2.53 m). Stand data are also presented in table 1. The 116 families represented 54 stand locations, but 29 of these stands are represented by a single seed source. The other stands included 2 to 13 families. Stand range in survival was the same as the family range because the poorest family was a single-family stand.

Fifth-year survival was still high, with a plantation mean of 92 percent. At this age, 9 more families had dropped below 90 percent survival, for a total of 12. Only 3 of these families were below 80 percent survival, and these were the families below 90 percent survival at age 1. Variability in height among families had increased considerably, with a plantation mean height of 13.3 ft (4.06 m), but a range of 1.5–20.6 ft (0.46–6.28 m). The stand height ranged from 7.1 to 14.9 ft (2.15 to 4.54 m), but, except for the two slowest growing stands (the same two with the lowest survival), all stands averaged between 11 and 15 ft (3.3 to 4.6 m) in height. Plantation mean DBH at age 5 was 1.6 in (4.04 cm), with a range of 0.2–3.3 in (0.61–8.31 cm) for families and 0.9–2.2 in (2.35–5.54 cm) for stands. Only trees >4.5 ft (1.37 m) in height are included in the diameter data.

A large number of families suffered from main stem dieback sometime between age 5 and 10. Since most of the trees showing dieback had lower stem or basal sprouts, they were not counted as dead. Therefore, to better reflect the performance of families not exhibiting dieback, age 10 survival was calculated as the number of trees alive at age 5 not showing dieback at age 10. Thus, as shown in table 1, only 60 percent of the trees alive at age 5 did not exhibit dieback by age 10. The family range was 0–100 percent, and the stand range, 7–100 percent.

Trees showing main stem dieback were not included in the age 10 height and diameter data summaries. Age 10 family mean heights ranged from 0.8 ft (suggesting that some trees suffering from dieback were inadvertently measured) to 32.0 ft (0.24 to 9.74 m), while stand means ranged from 11.8 to 27.3 ft (3.59 to 8.32 m). Stem diameter at age 10 for family means ranged from 0.5 to 6.9 in (1.39 to 17.50 cm); stand means were 1.3–4.1 in (3.40–10.49 cm).

Age/age correlations of growth traits (table 2) were high for age 1 with age 5, but were much reduced for age 10 with age 1 and 5 because of the age 5 dieback. Consistent, relatively small, yet generally significant negative correlations were found between most traits and latitude. A generally consistent but, again, relatively small positive correlation was found for correlations of growth traits with longitude.

At age 10, 26 percent of the remaining trees had multiple stems. Number of stems showed a small but significant correlation with longitude ($r = -0.30$) and latitude ($r = 0.27$). Number of stems was also positively correlated with height and diameter at age 1 and age 5, but this was lost at age 10, no doubt due to dieback.

Analysis of variance for growth traits and family and individual tree heritabilities were estimated (table 3), although these estimates are upwardly biased because a single planting is represented. Except for age 1 family in stand survival, family in stand and stand differences were significant for all survival, height, and diameter measurements, as well as percent dieback at age 10. The number of stems was not significant.

## Discussion

Seed germination and seedling survival in the nursery were highly variable among families. Germination rates were no doubt highly influenced by the acid scarification. Olson (1974) reported that predetermined optimum acid soaking times can vary from 10 to 120 min by seed lot. Since we treated all lots similarly, germination data were probably not representative of the true viability of the families, and therefore germination data were not included in further analysis.

Initial survival and growth of virtually all the families in the field were excellent. There was no difference in survival between family and stand means at age 1 because the three poorest performing families (the only families below 90 percent survival) were single-family stands, and many stands and families showed 100 percent survival. Unlike survival, there was considerable variation in height growth by the end of 1 yr in the field, with the best families exceeding 8 ft (2.4 m). As expected, first-year stand height showed less variability than did family height. At age 5, both survival and growth were still excellent for the plantation as a whole, with considerable variability in growth, suggesting that a breeding program to improve growth in black locust would be quite effective. Since survival was still >90 percent, little need to improve survival was suggested. There were, however, several families which exhibited both slow growth and poor survival and were clearly not well adapted to the Oklahoma conditions. These families became more obvious at age 10.

By age 10, a considerable amount of main stem dieback had occurred. This dieback was probably due to one or several exceptionally hot, dry summers. Consequently, initial planting survivability was no longer of concern; rather, families surviving dieback on harsh sites such as the test site would be more important. For black locust planted in harsh environments, such as western Oklahoma, these 10-yr survival data are perhaps the most valuable. It would seem logical to select those families showing little or no age 10 dieback for such sites.

Obviously, black locust possesses a vast amount of variability in growth at both the stand and family levels. There, is however, a very limited apparent geographic pattern or trend among sources to suggest a starting point for a selection and improvement program. The small correlations

**Table 3.** Analysis of variance p values and heritability ($h^2$) estimates.

| | GLM–ANOVA P VALUES (TYPE III) | | | HERITABILITIES | |
|---|---|---|---|---|---|
| **Trait** | **Stand** | **Family (Stand)** | **Rep × F(S)** | **$h^2$ Family** | **$h^2$ Tree** |
| Survival | | | | | |
| Age 1 | 0.0001 | 0.8964 | 0.3500 | 0.32 | 0.12 |
| Age 5 | 0.0001 | 0.0001 | 0.0001 | 0.58 | 0.41 |
| Height | | | | | |
| Age 1 | 0.0001 | 0.0001 | 0.0001 | 0.59 | 0.47 |
| Age 5 | 0.0001 | 0.0001 | 0.0001 | 0.69 | 0.63 |
| Age 10 | 0.0001 | 0.0001 | 0.0001 | 0.58 | 0.47 |
| Diameter | | | | | |
| Age 5 | 0.0001 | 0.0001 | 0.0001 | 0.67 | 0.60 |
| Age 10 | 0.0001 | 0.0028 | 0.0027 | 0.58 | 0.40 |
| % Stems | 0.1634 | 0.1310 | 0.2447 | 0.32 | 0.13 |
| % Dieback | 0.0001 | 0.0001 | 0.0081 | 0.69 | 0.60 |

**Table 2.** Simple correlation coefficients among family means[a] and with latitude and longitude.

| | SURVIVAL | HEIGHT | | | DIAMETER | | PERCENT | PERCENT |
|---|---|---|---|---|---|---|---|---|
| | Age 1 | Age 1 | Age 5 | Age 10 | Age 5 | Age 10 | Multiple stems | Dieback |
| HEIGHT | | | | | | | | |
| Age 1 | 0.2906[b] | | | | | | | |
| | 0.0019[c] | | | | | | | |
| Age 5 | 0.2924 | 0.6795 | | | | | | |
| | 0.0014 | 0.0001 | | | | | | |
| Age 10 | -0.0217 | 0.2819 | 0.3950 | | | | | |
| | 0.8181 | 0.0023 | 0.0001 | | | | | |
| DIAMETER | | | | | | | | |
| Age 5 | 0.1784 | 0.6647 | 0.8059 | 0.4776 | | | | |
| | 0.0554 | 0.0001 | 0.0001 | 0.0001 | | | | |
| Age 10 | 0.0268 | 0.2992 | 0.3454 | 0.7925 | 0.5932 | | | |
| | 0.7761 | 0.0012 | 0.0002 | 0.0001 | 0.0001 | | | |
| % Multiple stems | 0.2875 | 0.1897 | 0.3842 | 0.1526 | 0.2525 | 0.1023 | | |
| | 0.0018 | 0.0422 | 0.0001 | 0.1034 | 0.0065 | 0.2765 | | |
| % Dieback | 0.0457 | 0.0934 | -0.0667 | -0.0878 | -0.1959 | -0.0212 | 0.1176 | |
| | 0.6265 | 0.3186 | 0.4769 | 0.3507 | 0.0350 | 0.8225 | 0.2107 | |
| Latitude | -0.1319 | -0.1051 | -0.1675 | -0.1751 | -0.1952 | -0.2488 | -0.3016 | -0.2062 |
| | 0.1582 | 0.2617 | 0.0723 | 0.0613 | 0.0358 | 0.0073 | 0.0011 | 0.0264 |
| Longitude | 0.0843 | 0.0871 | 0.2361 | 0.2141 | 0.2890 | 0.3386 | 0.2763 | -0.0111 |
| | 0.2681 | 0.3526 | 0.0107 | 0.0216 | 0.0017 | 0.0002 | 0.0028 | 0.9063 |

[a]The number of families = 116 at ages 1 and 5 and 115 at age 10.

[b]Pearson correlation coefficients

[c]Prob >_R_ under Ho: Rho = 0--i.e., the probability that the correlation is not different from 0.

with latitude detected suggests the typical relationship of northern sources growing more slowly, but these correlations account for less than 10 percent of the total variation and are no doubt of limited importance. The correlations with longitude may reflect the original range of black locust, a range split between east and west of the Mississippi River Valley. If origin were known for all sources, the correlation might be greater, as might correlations with latitude. Again, these correlations represent at most about 11 percent or less of the total variation observed and, since native and naturalized stands can no longer be distinguished even in the native range of the species, the correlations are of limited practical value. Good-performing stands and families tend to be scattered among both the native range and naturalized areas, and it seems practical to recommend testing to identify good sources for use in any particular area.

The positive correlation of multiple stem number with growth traits suggests a relationship of fast growth to poor form, which may be a concern, depending on intended use of a planting.

Both family and individual tree heritabilities tend to be quite high for all traits except number of stems. First-year survival heritabilities were also relatively low, probably because survival was uniformly high. Generally high heritabilities suggest that an improvement program would be effective. The low heritability of stem number may alleviate any concern about the possible relationship of stem number to growth.

## Conclusions

These 1, 5-, and 10-yr growth data generally agree with earlier reports on black locust at ages 1 to 3 (Kennedy 1983; Mebrahtu and Hanover 1989; Genys and Harman 1990). That is, there is a considerable amount of genetic variation available in black locust, but there are no important or strong geographic trends. Consequently, selection of "best sources or families" for any particular region will require testing of many sources or families on the sites of interest to determine which sources and families are best for those sites. For example, if selecting the best stands, defined as growth of 20 ft (6 m) in height or better with less than 10 percent dieback at age 10, one stand from each of Oklahoma, Arkansas, Kentucky and Tennessee would be included. With the same criteria, at the family level, 16 families would be selected: 7 from Oklahoma, 2 from Kentucky and Maryland, and 1 each from Tennessee, Arkansas, Michigan, and New Brunswick and Ontario, Canada. Relaxing the dieback criteria to 20 percent, 9 sources from 5 States would be included; at the family level, 29 families, 13 of them from Oklahoma and Arkansas, fit the criteria, coming from 11 States or provinces. Obviously, for finding good sources or starting an improvement program for black locust in Oklahoma, Oklahoma and Arkansas sources would be appropriate. Family selection could be quite effective.

These results suggest the opportunity to greatly improve black locust through selection and breeding. As suggested by Surles and others (1989), a breeding program should focus on family-level selection, as stand selection alone has limited potential for gain.

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