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Survival, Growth, and Target Canker Infection of Black Walnut Families 15 Years After Establishment In West Virginia

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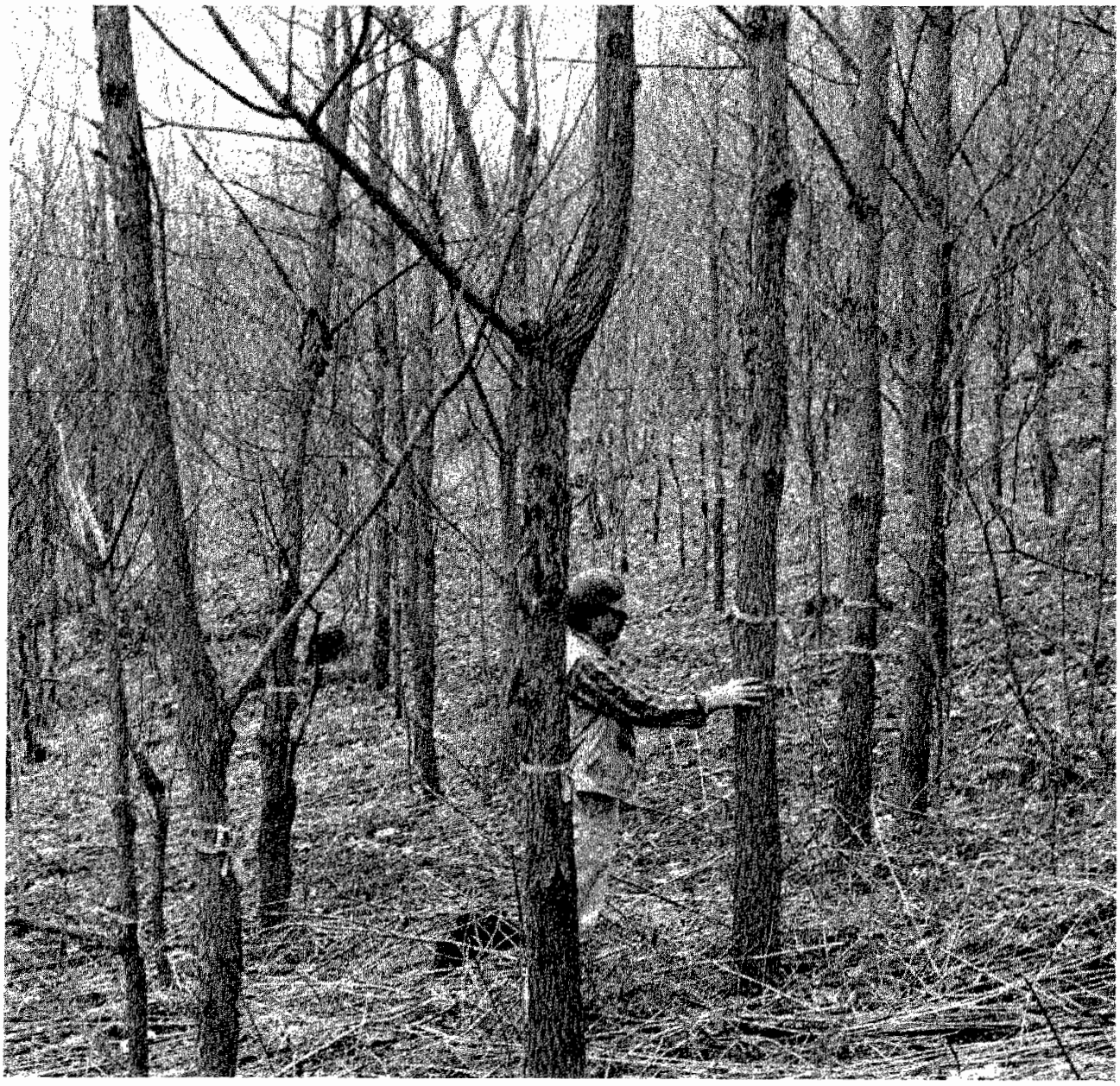

Abstract

The survival, growth, and rate of target canker infection of 34 black walnut (*Juglans nigra* L.) families were evaluated 15 years after establishment in north-central West Virginia. The progenies originated at locations in Pennsylvania, West Virginia, Tennessee, and North Carolina. There were significant differences between families in survival, incidence of target canker infection, total height, and diameter at breast height. The North Carolina and Tennessee sources were less suitable for the growing conditions of the test site; local and slightly more northern sources seem more suitable. Near the northern extremity of the range of black walnut, maintaining a viable native population of this species and using local seed sources in artificial regeneration activities are recommended.

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Introduction

The range of black walnut *(Juglans nigra* L.) extends southward from Ontario, Canada, to Florida in the east and from South Dakota to Texas in the west. It grows on a variety of sites but does best in coves and well-drained bottoms in the Appalachians and Midwest (Williams 1990). Black walnut usually is found in small groups or as individual trees throughout the forest landscape.

The wood of black walnut is highly valued for commercial purposes and, as a result, has been heavily utilized. In the Central Appalachian region, periodic removal of individual black walnut trees from the forest has virtually eliminated most good local seed sources. Those trees that remain are of poor form and do not indicate the potential for this species. Evidence suggests that black walnut grew on sites up to 3,000 feet in elevation with the best development on limestone-influenced soils. The reestablishment of this species to the range of sites it previously inhabited likely will occur only with management intervention.

As might be expected from its extensive natural range, black walnut has considerable genetic variation related to geographic origin (Bey 1980; Waite and others 1988). This variation expressed in growth characteristics affords an opportunity for selecting and breeding superior trees. The objective of this study was to demonstrate the potential for producing genetically improved black walnut seed suited to growing conditions similar to those found in the Central Appalachian region. This can be done by establishing an open-pollinated walnut progeny test that can be converted into a seed orchard. In order for the seed orchard to develop with only the most suitable trees for this region, the first step must be to identify the best families within the test site.

Since this study's inception, there has been an outbreak of the perennial target canker caused by the fungus *Nectria galligena* within the outplanting. *N. galligena* attacks many hardwoods and is particularly virulent in black walnut (Manion 1991). This endemic stem disease, first noted after the 1988 growing season, could become a major factor influencing the viability of the outplanting as a potential seed orchard. Cankers that develop on the stems and branches of trees can cause severe defects, stunting, or death. Development of cankers on the main stem can destroy the economic value of the tree, so any differences in resistance to *N. galligena* among families would be an important selection criterion.

This paper reports the 15-year growth, survival, and resistance of target canker infection of black walnut progenies from Pennsylvania, West Virginia, Tennessee, and North Carolina that were planted in north-central West Virginia. The significance of these results to forest management activities in the Central Appalachian region is discussed.

Methods

The black walnut outplanting was established on the Fernow Experimental Forest (39°2'N, 79°40'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. Because of space limitations, the outplanting was divided into two areas. The first area is at an elevation of 2,800 feet. The soil is a Belmont silt loam derived from the Greenbrier limestone formation. The soil at the second area (elevation of 2,720 feet) is a Meckesville silt loam, which is colluvial in origin. However, the Meckesville soil also has some limestone influence as it lies just downslope from the limestone-derived Belmont series. The site index for both areas is between 80 and 85 for northern red oak.

Both areas previously were forested with 65- to 70-year-old stands of mixed Appalachian hardwoods, including 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 (*Fraxinus americana* L.). There were few scattered black walnut trees near both sites. In preparation for planting, the sawtimber and pulpwood were harvested and all remaining stems were felled. Brush and small stems were removed from the sites to facilitate planting. Both areas have northwest aspects with slopes not exceeding 10 percent.

The outplanting design is a randomized complete-block of open-pollinated families with six rectangular blocks laid out parallel with the contour of the area topography. Four blocks were installed on the Belmont site and two were installed on the Meckesville site. Trees were planted 6 feet apart, in rows 12 feet apart. Each of the 34 families (Table 1) was represented in each of the six blocks by a five-tree plot. A border row of black walnut nursery stock was laid out around the perimeter of the area on each site; an additional buffer of planted yellow-poplar seedlings was established outside the black walnut. The sequence of the family plots on each block was randomized. Nursery 1-0 bare-foot seedlings from 34 families were planted on March 29 and 30, 1976. Average seedling height was 1.0 foot and roots were pruned to 10 inches at planting time. Postplanting site treatment has included several herbicide applications and cuttings that were necessary to control competing herbaceous and woody vegetation.

Total height of the tree, diameter at breast height (d.b.h.), survival, and incidence of target canker infection on the main stem were recorded every 5 years, 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. Plot means of the surviving trees only were used for all analyses (Bresnan and others 1992; Freese 1967; Rink and Kung 1991)

Table 1.—Family code, geographic origin, and mean family percent survival of 34 black walnut families 15 years after establishment in a north-central West Virginia progeny study

Family code	Origin	Latitude N ° ′	Longitude W ° ′	Percent survival
1660	Tucker, WV	39-05	79-40	97
1666	Greene, PA	39-45	80-15	90
1600	Berks, PA	40-30	76-00	90
1627	Lewis, WV	39-00	80-30	83
1638	Pendleton, WV	38-40	79-20	83
1653	Boone, WV	37-50	81-40	83
1654	Boone, WV	38-05	81-50	83
1607	Buncombe, NC	35-45	82-30	80
1632	Braxton, WV	38-40	80-45	80
1649	Monroe, WV	37-40	80-30	80
1630	Braxton, WV	38-40	80-45	77
1589	Alexander, NC	35-50	81-15	77
1655	Kanawha, WV	38-15	81-25	77
1628	Braxton, WV	38-40	80-45	73
1588	McDowell, NC	35-45	82-00	73
1642	Pocahontas, WV	38-15	80-00	73
1646	Greenbrier, WV	38-00	80-25	73
1652	Boone, WV	37-50	81-40	73
1606	Cumberland, PA	40-15	77-15	70
1645	Greenbrier, WV	38-00	80-25	67
1605	York, PA	40-00	76-45	63
1661	Monongalia, WV	39-40	80-00	63
1650	Summers, WV	37-45	80-45	63
1602	Cumberland, PA	40-15	77-15	63
1625	Upshur, WV	39-00	80-15	60
1615	Wayne, TN	35-15	87-45	60
1641	Pocahontas, WV	38-15	80-00	60
1636	Tucker, WV	39-05	79-40	60
1604	Chester, PA	40-00	75-30	60
1578	Morgan, TN	36-10	84-45	57
1633	Gilmer, WV	39-00	80-50	57
1603	Chester, PA	40-00	75-30	57
1658	Clay, WV	38-20	81-10	53
1582	Rowan, NC	35-30	80-30	50

and were given equal weight regardless of the number of trees they represented. Where appropriate, regression analysis was used to estimate relationships between performance factors and family origin. A two-sample t test was used to test for differences in the evaluation criteria among the Meckesville and Belmont sites. Data were analyzed and tested for significance at the 5-percent level. The 7-year results as reported by Wendel and Dorn (1985) were used for contrast where appropriate.

Table 1 summarizes identification information for each family. The distance between the most easterly and westerly family is approximately 600 miles. The distance between the most northern and southern family is about 350 miles. There are two families from Tennessee, four from North Carolina, seven from Pennsylvania, and 21 from West Virginia, including two seed sources from the same county (Tucker) as the outplanting site. The outplanting is about 100 miles north of the center of the collection area. Parent-tree elevation was not recorded for most sources. Elevation estimates from location descriptions were uncertain and were not included in the analysis.

Results

Site Differences

At the end of 15 growing seasons, trees growing on the Belmont site and those growing on the Meckesville site did not differ significantly in survival, incidence of canker infection, total height, or d.b.h.

Survival

Fifteen years after the outplanting was established, overall survival averaged 71 percent. Survival by family ranged from 97 percent for the Tucker County, West Virginia, family (1660) to 50 percent for the Rowan County, North Carolina, family (1582). Ranking of survival for all families is shown in Table 1. Analysis of variance indicated a contrast in family survival rate that was significant, indicating a meaningful genetic component in the variation.

Regression analyses revealed no trends of mean family survival related to latitude or longitude of seed source. Families from three of the four North Carolina sources (1588, 1589, and 1607) had above-average survival rates despite their southern origins from about 250 miles south of the test site. However, trees from both Tennessee families (1578, 1615) had mean family survival rates of 57 percent and 60 percent, respectively. The Tennessee families are at or near the southern limit and the most westerly in origin of the families represented in the study.

Target Canker

Analysis of variance indicated some contrast in the incidence of target canker infection that was significant. The target canker caused by the fungus *N. galligena* has become established in all blocks and all families within the study (Fig. 1). The rate of target canker infection for all blocks and all families was 53 percent. Family infection rates ranged from 18 percent for the Greenbrier County, West Virginia, family (1645) to 86 percent for the Braxton County, West Virginia, family (1630). The family with the second lowest rate of target canker infection also was from Greenbrier County (1646). Similar results for the two Greenbrier families may indicate the presence of a shared genetic component that pertains to the lower canker infection rates observed in these two families. Ranking of infection by family is shown in Table 2.

Neither regression analysis nor plotting revealed correlations between mean canker infection rate and family geographic origin of families expressed as latitude, longitude, or both. Families from the same general latitude and longitude as the test site showed a wide range of canker infection. Families that were more widely separated in geographic origin from the test site had canker infection rates near the median of the distribution of infection rates.

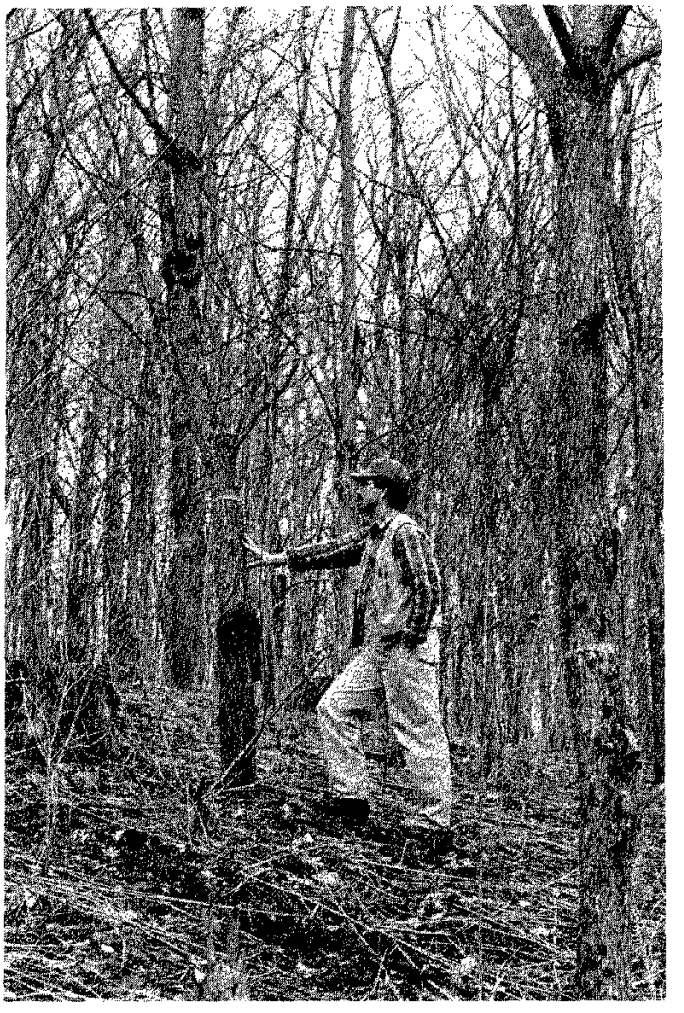

Figure 1. Black walnut plantation 15 years after establishment showing the presence of the target canker.

The relationships between family infection rate and survival and d.b.h. also were examined. Neither relationship exhibited a substantial correlation (Table 3). It is expected that the target canker will become a principal cause of mortality in the future. And while individual trees may not yet be dying as a direct effect of target canker infection, the loss in potential monetary value of an infected tree is great if the target canker develops on the main stem (Fig. 2).

Total Height and Stem Diameter

Mean total height for all blocks and all families was 18.2 feet (average: 22.9 to 13.0 feet). Ranking of height by family is shown in Table 4. Analysis of variance revealed a significant difference in family total height. The family with the tallest mean height (1660) was from a local seed source (Tucker County, West Virginia).

Figure 2. Black walnut stem showing the typical effects of target canker infection caused by the fungus *Nectria galligena*.

The family with the shortest mean total height, from Greenbrier County, West Virginia (1645), also was the family with the lowest observed target canker infection, indicating a possible negative relationship between growth rate or canopy position and canker infection. Further analysis of mean family height and canker infection did not show such a relationship (Table 3). There was no relationship between mean total height and geographic origin, though the family from Wayne County, Tennessee (1615), the most western and nearly the most southern in origin, ranked 33rd in mean family height (14.1 feet).

Height growth has averaged about 1.1 feet per year since establishment. Average annual height growth after 7 years was even less at 0.8 foot. Height growth of the five fastest growing families after the first 7 years was only a little better at 0.9 foot per year. However, average annual height growth of the top five families after 15 years was 1.4 feet. For the past 8 years, these same families have been growing at a rate of 1.8 feet per year. These results show that height growth rate is increasing and that family differences likely will become more apparent as well.

Average d.b.h. for all blocks and families was 2.6 inches. For families, d.b.h. ranged from 3.3 inches for the Tucker County, West Virginia, family (1660) to 1.5 inches for the Greenbrier County, West Virginia, family (1645). Ranking of d.b.h. by family is shown in Table 5. Analysis of variance revealed a significant difference in mean family d.b.h.

As expected after 15 years, mean family d.b.h. and mean total height are highly correlated (Table 3). This suggests that height measurements, being the most time consuming, could be dropped from future analyses. However, Bresnan and others (1992) showed that correlations between total height and d.b.h. declined after 20 growing seasons.

Table 2.—Ranking of 34 black walnut families 15 years after establishment in north-central West Virginia according to mean family target canker infection of surviving trees

Family code	Origin	Percent infected
1645	Greenbrier, WV	18
1646	Greenbrier, WV	25
1642	Pocahontas, WV	29
1638	Pendleton, WV	32
1600	Berks, PA	41
1628	Braxton, WV	42
1641	Pocahontas, WV	43
1653	Boone, WV	44
1650	Summers, WV	44
1666	Greene, PA	46
1615	Wayne, TN	46
1632	Braxton, WV	46
1602	Cumberland, PA	47
1589	Alexander, NC	48
1627	Lewis, WV	49
1660	Tucker, WV	53
1605	York, PA	53
1588	McDowell, NC	53
1636	Tucker, WV	54
1658	Clay, WV	54
1652	Boone, WV	55
1582	Towan, NC	56
1578	Morgan, TN	56
1649	Monroe, WV	58
1604	Chester, PA	58
1603	Chester, PA	58
1661	Monongalia, WV	63
1625	Upshur, WV	66
1654	Boone, WV	74
1655	Kanawha, WV	76
1606	Cumberland, PA	77
1633	Gilmer, WV	81
1607	Buncombe, NC	84
1630	Braxton, WV	86

Table 3.—Correlation matrix of black walnut mean family survival, incidence of target canker infection, total height, and d.b.h. 15 years after establishment in north-central West Virginia.

Item	Survival	Canker infection	Total height
Canker	0.07		
Total height	0.36	0.38	
D.b.h.	0.30	0.39	0.94

Table 4.—Ranking of 34 black walnut families 15 years after establishment in north-central West Virginia by mean family total height of surviving trees

Family	Origin	Total height
		Feet
1660	Tucker, WV	22.9
1600	Berks, PA	21.9
1666	Greene, PA	21.0
1652	Boone, WV	21.0
1655	Kanawha, WV	20.7
1589	Alexander, NC	20.3
1625	Upshur, WV	20.2
1649	Monroe, WV	20.1
1641	Pocahontas, WV	20.0
1638	Pendleton, WV	19.5
1654	Boone, WV	19.5
1642	Pocahontas, WV	19.4
1627	Lewis, WV	19.2
1628	Braxton, WV	19.2
1661	Monongalia, WV	18.9
1578	Morgan, TN	18.8
1646	Greenbrier, WV	18.4
1630	Braxton, WV	18.4
1653	Boone, WV	18.2
1588	McDowell, NC	18.1
1607	Buncombe, NC	18.0
1632	Braxton, WV	17.9
1658	Clay, WV	17.7
1633	Gilmer, WV	16.6
1636	Tucker, WV	16.3
1604	Chester, PA	16.2
1605	York, PA	15.8
1603	Chester, PA	15.7
1602	Cumberland, PA	15.4
1606	Cumberland, PA	15.4
1582	Rowan, NC	15.4
1650	Summers, WV	14.9
1615	Wayne, TN	14.1
1645	Greenbrier, WV	13.0

Table 5.—Ranking of 34 black walnut families 15 years after establishment in north-central West Virginia, by mean family d.b.h. of surviving trees

Family	Origin	D.b.h.
		Inches
1660	Tucker, WV	3.3
1600	Berks, PA	3.2
1655	Kanawha, WV	3.2
1666	Greene, PA	3.1
1625	Upshur, WV	3.1
1652	Boone, WV	3.0
1578	Morgan, TN	2.9
1589	Alexander, NC	2.9
1654	Boone, WV	2.9
1628	Braxton, WV	2.9
1638	Pendleton, WV	2.8
1641	Pocahontas, WV	2.8
1588	McDowell, NC	2.8
1649	Monroe, WV	2.8
1658	Clay, WV	2.8
1661	Monongalia, WV	2.7
1642	Pocahontas, WV	2.7
1653	Boone, WV	2.7
1607	Buncombe, NC	2.7
1627	Lewis, WV	2.6
1630	Braxton, WV	2.6
1632	Braxton, WV	2.5
1646	Greenbrier, WV	2.5
1633	Gilmer WV	2.4
1605	York, PA	2.2
1603	Chester, PA	2.2
1604	Chester, PA	2.1
1606	Cumberland, PA	2.1
1636	Tucker, WV	2.1
1582	Rowan, NC	2.1
1602	Cumberland, PA	1.9
1650	Summers, WV	1.9
1615	Wayne, TN	1.7
1645	Greenbrier, WV	1.5

Discussion

Superior families of this progeny test cannot be identified objectively 15 years after establishment but trends are beginning to emerge. Unlike the results obtained after 7 years that documented significant differences only in family survival rate and stem diameter, the current results reveal significant differences in survival rate, total height, d.b.h., and rate of target canker infection. Using these four traits as criteria, a subjective overall index was developed for the families in this test. 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). To develop the index, the families were ranked in each category, allowing for ties, and then the rankings were summed for each family. The rankings are taken from Tables 1, 2, 4, and 5 and provide a measure of relative fitness as to their suitability for the growing conditions similar to those found on the Fernow Experimental Forest. Because of the high correlation between total height and d.b.h. (Table 3), including both of these in the index essentially weights size at 50 percent of the total weight, survival at 25 percent, and target canker infection at 25 percent. Other weights as well as other selection criteria could be used depending on the sought after characteristics and management objectives (Kucera and others 1975).

The results of the multiple trait index are summarized in Table 6. The first trend made evident by this summary is the relatively poor performance of the more southern families. These families were represented by a total of six families from North Carolina and Tennessee. From this group, only one lies within the top half of the overall ranking. By contrast, past work has shown that seed sources from more southern locations, up to 200 miles south of the planting zone, tend to grow as fast or faster than local seed sources (Bey 1980; Bresnan and others 1992). However, Rink and Kung (1992) suggest this may not hold true for planting sites near the northern extremity of the natural range of a species. Black walnut growing at the latitude and elevation of the Fernow Experimental Forest does belong in this category (Williams 1990). Thus, study results indicate that expected performance gains did not occur when southern seed sources of black walnut were planted on the Fernow.

The second trend made evident by the results of the multiple trait index is that superior families may be found locally or even north of the planting site. This is suggested by the geographic origin of the top four performing families. Of the four, two are northern sources from Pennsylvania and two are local sources. The two local sources consist of one family from Pendleton County, West Virginia, that is immediately next to the county of the study. The second local source is from the same county as the study. The top ranked family, from Berks County, Pennsylvania (1600), ranked second in survival, total height, and d.b.h. It was ranked first overall because it displayed the lowest canker infection rate of any of the faster growing or better surviving families. The family from Tucker County, West Virginia (1660), a local source, ranked first in survival, total height, and d.b.h. It was ranked second overall due to its average target canker infection rate. The third ranked family was from Greene County, Pennsylvania (1666). In addition, being a northern source, this family also is from a county that is in the extreme southwest corner of Pennsylvania and is adjacent to West Virginia. Thus, its origin is closer than many West Virginia families.

Unfortunately, the role of elevation in combination with the latitude of the seed source cannot be evaluated. These attributes in part represent adaptations to cold temperatures. In areas where black walnut grows over a wide range of elevations, latitude alone is an inadequate indicator of cold hardiness. In West Virginia, black walnut

Table 6.—Categorical and overall ranking of 34 black walnut families 15 years after establishment in north-central West Virginia

Family code	Origin	Survival	Canker infection	Height	D.b.h.	Overall sum[a]	Overall ranking
1600	Berks, PA	2	5	2	2	11	1
1660	Tucker, WV	1	13	1	1	16	2
1666	Greene, PA	2	9	3	3	17	3
1638	Pendleton, WV	3	4	9	6	22	4
1589	Alexander, NC	5	11	5	5	26	5
1642	Pocahontas, WV	6	3	10	7	26	5
1652	Boone, WV	6	15	3	4	28	6
1628	Braxton, WV	6	6	11	5	28	6
1641	Pocahontas, WV	10	7	8	6	31	7
1646	Greenbrier, WV	6	2	14	9	31	7
1655	Kanawha, WV	5	21	4	2	32	8
1653	Boone, WV	3	8	15	7	33	9
1649	Monroe, WV	4	17	7	6	34	10
1627	Lewis, WV	3	12	11	8	34	10
1654	Boone, WV	3	20	9	5	37	11
1625	Upshur, WV	10	19	6	3	38	12
1632	Braxton, WV	4	9	18	9	40	13
1588	McDowell, NC	6	13	16	6	41	14
1578	Morgan, TN	11	16	13	5	45	15
1658	Clay, WV	6	14	19	6	45	15
1661	Monongalia, WV	9	18	12	7	46	16
1645	Greenbrier, WV	8	1	28	15	52	17
1607	Buncombe, NC	4	24	17	7	52	17
1630	Braxton, WV	5	25	14	8	52	17
1650	Summers, WV	9	8	26	13	56	18
1605	York, PA	9	13	23	11	56	18
1602	Cumberland, PA	9	10	25	13	57	19
1636	Tucker, WV	10	14	21	12	57	19
1604	Chester, PA	10	17	22	12	61	20
1603	Chester, PA	11	17	24	11	63	21
1633	Gilmer, WV	11	23	20	10	64	22
1615	Wayne, TN	10	9	27	19	65	23
1582	Rowan, NC	13	16	25	12	66	24
1606	Cumberland, PA	7	22	25	12	66	25

[a]Sum of individual rankings for each family.

grows at about the same latitude at elevations ranging from around 500 feet in the eastern panhandle to nearly 3,000 feet in the Allegheny mountains. Further work in selecting superior black walnut families should include both of these environmental factors and their relationship to family characteristics.

The top ranking families and their viability as components of a potential seed orchard cannot yet be determined. For recommendations to be valid, it must be assumed that the number of individual trees infected with the target canker will not continue to increase significantly. In Michigan, rates of black walnut growth were 30 percent less in infected versus uninfected trees (Thomas and Hart 1986). In this study, target canker infection was first noted 13 years after establishment and may have been too recent to evaluate.

Thus, due to the high ranking performance of two local sources in this study, it would seem appropriate to engage in management activities that will preserve local seed sources for black walnut near the northern range of this species. Continued overcutting of local stock may result in a loss of black walnut adaptations to an environment that could not be easily replaced by more southern sources. Forest managers should guard against reducing the natural range of any species. As such, managers of northern black walnut regions should maintain a viable native black walnut population and use local seed sources in plantations and in artificial regeneration activities. Perhaps the most prudent action would be to identify any remaining good local black walnut trees so they can be protected as future seed sources for use in artificial regeneration.

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The survival, growth, and rate of target canker infection of 34 black walnut (*Juglans nigra* L.) families were evaluated 15 years after establishment in north-central West Virginia. The progenies originated at locations in Pennsylvania, West Virginia, Tennessee, and North Carolina. There were significant differences between families in survival, incidence of target canker infection, total height, and diameter at breast height. The North Carolina and Tennessee sources were less suitable for the growing conditions of the test site, local and slightly more northern sources seem more suitable. Near the northern extremity of the range of black walnut, maintaining a viable native population of this species and using local seed sources in artificial regeneration activities are recommended.

Keywords: *Juglans nigra*; artificial regeneration; progeny test; seed sources

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