

Performance of Select Walnut in Indiana After 10 Years

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Abstract: Ten-year growth and stem quality of seedlings were compared among seven black walnut (*Juglans nigra*) populations and one half-sibling ("half-sib") family. Seed was collected and sown in the fall of 2001 in the Indiana Division of Forestry (IN DoF) Vallonia Nursery, and 1-0 seedlings were out-planted at two central Indiana sites in 2003. A companion planting of half-sib seedlings from a single phenotypic plus-tree selection was planted adjacent to each test planting by direct seeding in May 2003. Growth varied significantly between sites but was not statistically significant among populations at either site after ten years. Population, however, had a highly significant effect on timber-form quality. Significantly better stem quality was observed for the two select seed sources and the companion half-sib family. Average performance of the two select orchard populations was 13 percent above the plantation mean based on a compilation of all measured criteria.

Key Words: plus-tree selection, forest tree improvement, plantation forestry, progeny testing, seed source testing

Introduction

Black walnut (*Juglans nigra* L.) has historically been one of the most valuable timber species in the Central Hardwood Region of the US (Funk 1973), used to produce fine furniture, cabinetry, molding, and paneling (Cassens 2004). Throughout the last century, it was believed that the genetic quality of black walnut had been eroded due to high grading (Schmidt and Kingsley 1997; McGuire and others 1999). The supply of merchantable walnut logs was in decline by the early 1970s (Hoover 1995). State and federal agencies, partnered with Land Grant Universities in an attempt to mitigate this scarcity, and improve the genetic quality of future walnut timber. The shared goal among groups was to develop both high-quality and faster growing walnut seedling stock. By the 1970s and 1980s, regional cooperatives, supported by the U.S. Forest Service, began testing regional provenances and half-sibling families of walnut to identify geographically adapted, superior genetic sources for seed orchards (Bey 1980; Beineke 1989). All initial accessions in these programs were phenotypic plus-tree selections based on wild trees with very straight apically dominant stems with few defects, and high growth rates.

Walnut seed collected for forestry purposes is rarely collected from natural forest stands. Seed collectors typically harvest walnut seed from more accessible street, yard, park, and cemetery trees. Collectors view mowed lawns where understory vegetation is absent as ideal. Most collectors harvest trees that are accessible to a vehicle in order to facilitate loading seed, since black walnut is among one of the heaviest hardwood seeds. Only seven to eight fresh walnut seeds weigh one pound (Bonner and Karrfalt 2008). More importantly, forest conditions present severe challenges to both walnut seed production and collection since small tree crowns, low light conditions, and intense predation all combine to reduce the number of harvestable walnuts. Instead, walnut collectors prefer mostly open grown trees with large crops to maximize their labor return.

Many of the early black walnut progeny tests were planted “off-site” on soils that were not suited to vigorous walnut growth (Victory and others 2004). Little useful information was obtained from these studies beyond the admonition to only plant future progeny tests on land well suited to walnut. The present study was established on two moderately suitable walnut sites based on the recent black walnut suitability index (Wallace and Young 2008). This study is designed to demonstrate the increase in performance for some of the top-ranked selections in Indiana from an Indiana Division of Forestry (IN DoF) seed orchard and from a Purdue University clone bank (West Lafayette, IN) compared to seeds provided by local collectors in the area. In contrast to the bulk mixed seed of multi-tree populations, we also included a single open-pollinated half-sib family, from a previously untested plus-tree selection in the Purdue collection, to examine the performance of the progeny from a single select parent.

Methods

Plant Material

Seeds were collected from trees representing seven discrete populations in the fall of 2001 (table 1). Populations of seed were identified during 2000 and 2001 to represent typical black walnut collection sites that supply the IN DoF State Nursery (Vallonia, IN), a wild-type forest source, and two select genetic sources composed of grafted clones selected as phenotypic plus-trees: the IN DoF Vallonia Subline 1 seed orchard and the Purdue University Martell Black Walnut Clone Bank 1. Additionally, about 1,000 open-pollinated seeds from clone #226 were harvested from the Martell Clone Bank 2 and stratified in 2002, to provide a single half-sib family with a low level of genetic variation. This seed was pre-germinated and direct seeded adjacent to each provenance test site one month after the larger populations were planted.

Nursery Production

Seeds from each population were bulked at harvest and hulled in a commercial walnut huller to remove husks. The seed was sown in uniform beds at the IN DoF State Nursery, in the fall of 2001, among other black walnut production beds. All seedlings were grown following standard IN DoF nursery practices including: pre-plant soil fumigation, winter mulching, hand and chemical weed control, fertilization, tap-root undercutting, and pest control. Prior to lifting, the stems of each population were painted a unique color to avoid misidentification in the field prior to lifting. A tractor drawn, PTO driven Fobro lifter was

set to an approximate 16 in (40.6 cm) depth to maximize the amount of root retained as the beds were lifted.

Outplanting Experimental Design

Seedlings of the seven bulk populations were planted at two central Indiana locations, near the cities of Fishers and Martinsville, in a randomized complete block design, with ten replicates of 30 seedlings per population at each site. Each randomly assigned population was planted as adjacent 15 tree row-plots at Fishers, or as 30-tree row-plots at Martinsville. White pine (*Pinus strobus*) was used as a single tree perimeter border at Fishers and green ash (*Fraxinus pennsylvanica*) was used as a single tree perimeter border at Martinsville.

Seedlings were planted in April 2003 as dormant 1-0 stock with a Whitfield mechanical tree planter. At the Fishers site, rows were spaced 9 ft (2.7 m) apart and trees within rows were spaced an average of 6 ft (1.8 m) apart. The layout was a rectangle with straight rows but the spacing within rows varied from ± 2 ft (0.6 m) as a consequence of using the mechanical planter without any spacing control. At the Martinsville site, the spacing was adjusted to accommodate additional plantings. Row and tree spacing was 7 ft by 7 ft (2.1 m X 2.1 m) and rows were contoured as the field was a narrow bottom-land hollow, bordered by curving hills. Like the Fishers site, in-row spacing fluctuated ± 2 ft (0.6 m). At each site, 400 sprouted seeds of the half-sib family (#226) were planted by hand one month later, adjacent to each plot, in 5 blocks of 80 trees at the same spacing as the seedlings within each block bordered by the species indicated above.

Soil Types

The soil at Fishers is an Ockley silt loam, fairly uniform, with a slight slope toward a creek. The NRCS Black Walnut Suitability Index (BWSI) characterizes this soil type as “well suited for walnut.” At Martinsville, two soil types occur: a Wilbur silt loam that the BWSI characterizes as “moderately well suited” for black walnut, and an Ava silt loam that the BWSI characterizes as “somewhat suited” for walnut. Unlike the Fishers site, the soil is quite variable with gravel and clay deposits in places, and neighboring hillsides that cause intermittent flooding during heavy rainfall events throughout the year. At Martinsville, trees grew dramatically different between the two soil types. Six blocks of the bulked populations that were planted on the Ava silt loam were ultimately discarded from the analysis as the soil proved unsuitable for walnut, leaving four blocks grown on the Wilbur soil to analyze. The half-sib family was planted on the Ava soil and the poorest half of those seedlings was discarded from the analysis.

Table 1. Location and number of trees for each Indiana walnut seed populations tested.

Black Walnut Seed Sources	Timber Quality of Mother trees	Type of Location	Approximate # of Trees in Population	County	Field Color Code
Vallonia Subline 1	Excellent*	Seed Orchard	30	Jackson	Orange
Martell Clone Bank 1	Excellent*	Clone Bank	5	Tippecanoe	Yellow
Seymour Woods	Excellent	Forest	100	Jackson	Red
Seymour Home	Above average	Yard	75	Jackson	White
State School	Average	Yard	14	Jennings	Blue
SEPAC Plantation	Average	Plantation	20	Jennings	Green
Div. of Forestry Check	Unknown	Various	>300	State-wide	Pink
#226	Excellent*	Clone bank	1	Tippecanoe	—

* Grafted trees from ortets selected for excellent quality.

Data Collection and Analysis

Trees on each site were measured for height, diameter at breast height (DBH), and two timber quality traits 3, 5, 8, and 10 years after planting. Trees were rated as “1” having a single leader or “0” for those not having a clear single central leader. Timber form was rated on a 5-point subjective scale based upon a composite of straightness, apical dominance, self-pruning, lateral branch numbers, angles, and sizes, depressed knots, and crooks in the stem. Each value represents the following subjective quality rating: 1 = poor, 2 = below average, 3 = average, 4 = above average and 5 = excellent.

Improvement values were calculated by dividing population mean values for each trait, at each site, by the overall planting mean for the trait at that site, and then a total improvement value for each population was calculated by adding the values for height, DBH, single-leader, and stem-form quality, and dividing by four. Means for each trait were analyzed by one-way ANOVA using Microsoft Excel 2010. When ANOVAs were significant ($P \leq 0.05$), means were compared by least significant difference (Steel and Torrie 1980).

Results

Three years after planting, survival, height, and presence or absence of a single-leader differed significantly (data not shown). At Martinsville, survival averaged 84 percent overall with individual populations ranging from 72 to 91 percent. Survival averaged 98 percent

at Fishers, with populations ranging from 94 to 100 percent. The SEPAC population had the lowest survival at both sites. Tip-dieback and stem cankers affected 57 percent of seedlings across all populations at Martinsville compared to just 6 percent at Fishers. These diseases were primarily due to a large infestation of ambrosia beetles, particularly at Martinsville, in 2004. The stem cankers appeared to be a result of either *Fusarium* or *Phomopsis* fungi, both of which cause annual cankers on walnut, but no known pathogen was confirmed. By the fifth year, survival remained unchanged at either site but growth varied significantly between sites (data not shown). Trees were larger and more uniform at Fishers. Trees that had been affected by stem cankers at Martinsville had mostly recovered or re-sprouted from disease/insect problems encountered in years two and three. At Martinsville however, blocks planted on the Ava silt loam soil failed to thrive. Most of the half-sib family planted on this soil began to show signs of stress by five years.

By the tenth year, quality differences remained significantly different among populations (table 2) while height and DBH differences still present were no longer statistically significant. The half-sib family performed very well at Fishers and had remarkable consistency in growth indicated by the low standard deviations for height and DBH. However, at Martinsville, on the Ava soil, the same family grew far below average. Under these poor growing conditions, the half-sib family still had good stem form although the percentage of trees with single leaders was greatly reduced. Figure 1 illustrates the range and variation in height distribution among the three most distinctly different populations and how the median height value shifts above or below the mean.

Table 2. Performance of 10-year old seedlings from eight different black walnut seed sources grown at two central Indiana sites.

Population	Site	Growth				Quality				Total Improvement ³ (%)
		Height (cm)	SD	DBH (mm)	SD	Single Leader ¹ (%)	SD	Stem Form ² (1-5)	SD	
Vallonia Subline ¹	Fishers	514	69	65	9	48 ^A	14	3.4 ^A	0.3	113
	Martinsville	478	138	47	15	42 ^a	13	3.1 ^a	0.4	121
Martell Clone Bank ¹	Fishers	502	41	66	4	47 ^A	13	3.5 ^A	0.2	113
	Martinsville	443	84	44	8	33 ^b	8	2.8 ^b	0.4	106
State School	Fishers	500	91	61	11	35 ^B	13	2.9 ^B	0.4	99
	Martinsville	488	110	49	12	25 ^{bc}	7	2.8 ^b	0.1	105
Seymour Home	Fishers	470	71	58	10	34 ^B	14	2.8 ^B	0.1	97
	Martinsville	404	30	42	4	20 ^c	10	2.4 ^{cd}	0.2	106
Seymour Woods	Fishers	462	104	56	12	41 ^{AB}	11	2.9 ^B	0.5	94
	Martinsville	455	72	45	9	35 ^{ab}	7	2.5 ^c	0.1	94
IN DoF Check	Fishers	450	47	56	6	33 ^B	9	2.9 ^B	0.3	92
	Martinsville	410	50	41	6	17 ^c	5	2.5 ^c	0.2	86
SEPAC Plantation	Fishers	442	101	57	14	33 ^B	4	2.7 ^B	0.3	91
	Martinsville	350	110	33	3	33 ^b	10	2.1 ^d	0.2	88
#226 Half-Sib Family ⁴	Fishers	572	26	70	5	47 ^A	3	3.6 ^A	0.1	119
	Martinsville ⁵	362	39	37	6	14 ^c	9	3.0 ^a	0.2	—

¹ Proportion of trees with a single leader at 10-years. Means followed by different letter are significantly different $P \leq 0.05$.

² Average quality rating: 1 = poor, 2 = below average, 3 = average, 4 = above average, 5 = excellent. Means followed by different letter are significantly different $P \leq 0.05$.

³ Sum of the mean for each growth and quality character, divided by four, weighing each character equally, to generate relative improvement value.

⁴ The half-sib family was planted adjacent to the seven 1-0 bare root seedling populations as five blocks of 80 trees.

⁵ At Martinsville, this family was planted on the Ava silt loam and not the Wilbur silt loam like the other 7 bulked populations.

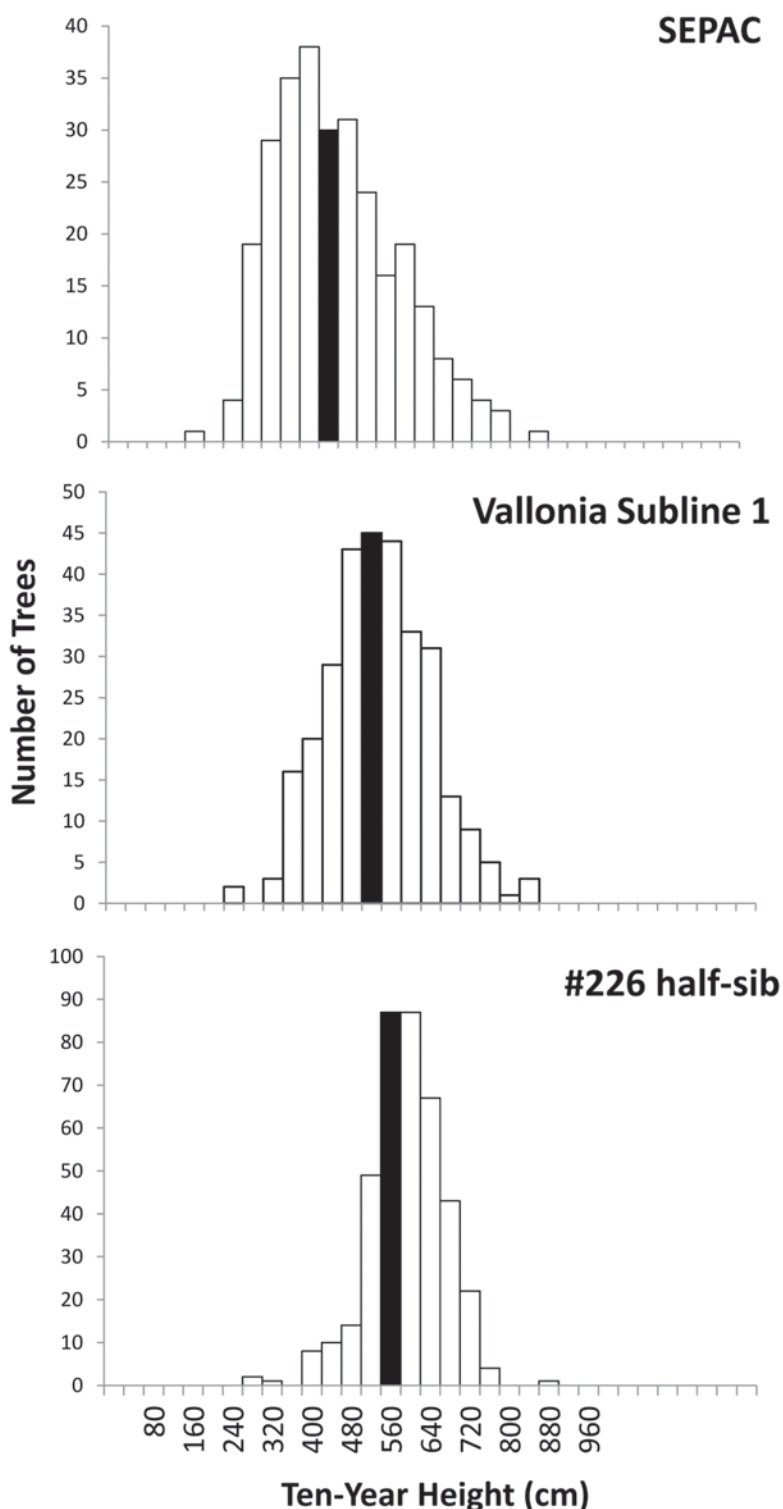


Figure 1. Height distribution of the three most distinctly different populations. (SEPAC) with a mean height of 439 cm (173 in) and a median value of 419 cm (165 in); (Vallonia Subline 1) with a mean height of 514 cm (202 in) and a median value of 511 cm (201 in); and the half-sib (#226) with a mean height of 572 cm (225 in) and a median value of 576 cm (227 in). Dark bars indicate each population mean. Data from the Fishers site only.

SEPAC

Trees rated as poor or below average in quality are candidates for early thinning, while trees rated as average or better can be retained as potential crop trees. Combining trees rated as poor and below average (quality ratings 1 and 2 out of 5) together into a “below average quality” class and comparing that value with the remaining trees rated as average, above average, or excellent (quality ratings 3, 4, and 5 out of 5) into an “average to above average quality” class, shows over 80-percent of the select Vallonia seedlings and half-sib seedlings rating as average or better compared to the poorest performing SEPAC population (figure 2). The other populations had more even distributions with values ranging between 45 to 55 percent below average and 55 to 45 percent average or better, compared to the three sources in figure 2.

Discussion

Both growth and quality traits of the walnut trees in this study varied greatly in the early years after planting. Age-to-age correlations studies in other species suggest that 8-16 years is necessary before meaningful early data can be obtained (Squillace and Gansel 1974; Lambeth 1980; Riemenschneider 1988). Rink and Kung (1995) found that eight year growth data was strongly correlated with 20-year growth data for black walnut. Indeed, in the present study, significant differences among populations in early growth disappeared by ten years. However, quality differences remained significant throughout the decade. Seedlings from the Purdue University clone bank, the Vallonia Subline 1 seed orchard, and from the half-sib family, all had significantly better stem quality than did the other five bulked populations throughout the study. Increasing the single leader percentage should minimize the need for pruning co-dominant leaders and increase the length of merchantable logs. Raising the stem quality rating should reduce the need and volume of corrective pruning along with elevating the timber-grade of trees, which ultimately will increase the timber value.

Beineke (1989) reported a 2% to 12% improvement in height and diameter from several previous walnut progeny tests, but does not indicate if the differences were statistically significant. Both the Vallonia orchard and Martell clone bank material showed height growth trending above the plantation mean, but the ANOVA was not significant ($P = 0.28$). We found a similar trend with stem diameter (DBH), consistent with Beineke’s values but again, by ten years, the differences were statistically insignificant suggesting that non-genetic factors have a large effect on walnut growth rates. It is not uncommon to find more genetic variation within populations than among them (Paul Bloese, personal communication 2013).

Walnut trees are not naturally apically dominant as they commonly grow with crooks and sweep, particularly when they grow vigorously. Selecting for improvement in both growth rate and stem quality simultaneously in walnut has proven difficult. While the general goal of walnut forest tree improvement is to develop bigger and better trees, there are biological constraints for breeding both simultaneously.

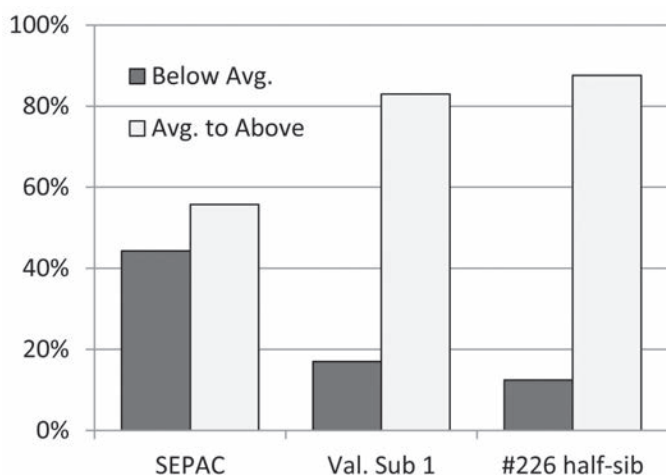


Figure 2. Proportion of 10-year-old trees rated below average or average to above average in quality of the three populations from figure 1. Below average trees scored a 1 or 2 stem-form rating at ten years and are candidates for early thinning. Average, above average, and excellent trees have a stem-form rating of 3, 4, or 5, respectively, and represent potential crop trees. Data from the Fishers site only.

For walnut, the two traits tend to oppose one another as a large vigorous walnut will often have bad form while smaller, slower growing walnut can have excellent form. Typical non-genetic factors that affect walnut growth include soil, hydraulic conditions (too wet or too dry), and neighboring competition (both above and below ground). Only by first growing walnut well on a good site, then analyzing numerous replicated genetic tests across many sites, can one accurately evaluate the genetic component of vigor in walnut selections.

The performance of the half-sib family between the two different sites in the current study is very dramatic and highlights this difficulty. While the half-sib had the highest overall improvement value at Fishers (+19 percent), it performed far below average at Martinsville. It was, however, inadvertently planted on a very poor soil at Martinsville, and as such is not directly comparable to the bulk populations grown there on the better soil. Clearly, utilizing too few test sites, and not controlling or accounting for soil differences within a given test site, can lead to erroneous conclusions on the genetic growth potential of walnut. This result underscores the extreme site sensitivity of walnut, and furthermore, the fact that genetically improved walnut will not show any gain when grown on an unsuitable walnut site. As we begin to make a second cycle selections from a broad series of progeny tests, we expect to be better able to select for vigor by selecting larger individuals grown in even-aged plantations that already have an improved level of genetic quality for timber form.

For the grower, a reduction in the number of slower growing and poorly formed trees, like the Vallonia Subline 1 and half-sib trees offer (figure 2), functionally improves the plantation. While improvement can be made culturally through pruning, staking, and fertilizing trees, such cultural management is costly and uncommon in forestry. Thus, having planting stock with genetic qualities for good timber form and uniform growth are very desirable. As better hardwood nursery stock and plantation management strategies have developed, today's landowners can achieve higher survival rates in new plantings. By utilizing select genetic stock that produces a higher percentage of acceptable trees, and grows more uniformly overall, pruning can be simplified and reduced, thinning decisions can become more systematic, and fewer walnut trees

need to be planted which can make mixed hardwood plantings more successful (McKenna and Farlee 2013).

Through progeny testing, tree improvement provides a means of weeding out poor performing seed sources as well as developing sources that will be bigger and better. Thus, source-identified and progeny-tested seed, given good site selection and management, provides a grower confidence that trees have the genetic capacity to grow well. The practical reality is that walnut seed for reforestation will only rarely ever come from forest stands. By creating grafted walnut seed orchards from wild plus-trees we are able to capture genotypes from the forest, and by planting them together in an orchard, seed production and harvesting can be more economically managed. As replicated progeny test data becomes available, poorer performing clones can be eliminated from the Vallonia orchard, thereby converting it into an improved walnut seed orchard.

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