PLANTING STOCK TYPE X GENOTYPE INTERACTIONS AFFECT EARLY OUTPLANTING PERFORMANCE OF BLACK WALNUT SEEDLINGS

J. W. Van Sambeek, James W. Hanover, and Robert D. Williams[1]

Abstract: A provenance/progeny test was established in south central Indiana with seedlings from 72 open-pollinated families from across the commercial range of black walnut (*Juglans nigra* L.). The seedlings were grown in a conventional hardwood nursery and in containers in a greenhouse. Seedlings were outplanted in 1981 on an old-field site in Johnson County using a split plot design with families randomly assigned within planting stock type. Survival after three growing seasons averaged 95% across all families and planting stock type. A planting stock type x genotype interaction existed for height growth for the first 2 years after establishment. Both nursery-grown and container-grown seedlings showed varying amounts of dieback during the first growing season. After the second growing season, the container-grown stock has initiated positive height growth while the nursery-grown seedlings continued to die back. Three years after establishment, effects of genotype and planting stock type had dissipated and effects of seed collection zone (provenance) were still not present. Results with container-grown seedlings are consistent with other studies using nursery-grown seedlings and show that effects of genotype and site account for increasingly more of the tree growth variation as the planting gets older.

INTRODUCTION

Nursery-grown seedlings of black walnut (*Juglans nigra* L.) characteristically have a long taproot with few lateral roots to serve as future sites for new root initiation. In addition, the taproot on nursery-grown seedlings is frequently cut during lifting or planting, thus altering the shoot-to-root balance which may also contribute to transplant shock. Because container-grown seedlings usually have a well-developed fibrous root system, they have many more sites for initiating new roots following outplanting. Past research has shown that

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[1]Supervisory Research Plant Physiologist, USDA Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, Carbondale, IL 62901; Professor, Department of Forestry, Michigan State University, East Lansing, MI 48824; and Research Forester (Retired), USDA Forest Service, North Central Forest Experiment Station, Bedford, IN 47421.

The authors wish to acknowledge the cooperation of the Indiana Department of Natural Resources staffs at the Vallonia Tree Nursery and at the Atterbury State Fish and Wildlife Area.

seedlings grown in containers initiate height growth sooner than bare-root seedlings from nursery beds (Van Sambeek et al. 1987, von Althen 1986).

The effects of genotype and/or provenance (geographical source) on early field performance of nursery-grown seedlings are well documented (Bey 1979; Rink 1984, Rink and Van Sambeek 1987); however, similar studies with container-grown seedlings have not been done. The extent to which planting stock type and genotype may interact with seedling growth following outplanting is unknown for black walnut seedlings. Therefore, we established a study in 1980 to determine the extent to which growth interactions occur among nursery-grown and container-grown seedling from the same open-pollinated families from across the commercial range of black walnut.

MATERIALS AND METHODS

In the fall of 1979, seed from 250 single-tree or stand collections from 14 provenances (seed collection zones) were collected, assigned accession or family numbers, and cleaned. Collections were limited essentially to the commercial range of black walnut (Funk 1978). Half of the seed from each collection with more than 300 sound seed were sown by seedlot in single plots at the Vallonia Tree Nursery near Brownstown, Indiana, in December of 1979. Seedlings were lifted in November and December of 1980. A random sample of 32 seedlings from each seedlot was measured for basal diameter (3 cm above the root collar), root and shoot length, and an index (0 to 2) of root fibrosity (0 = less than three lateral roots per cm of taproot, 1 = three to five lateral roots per cm of taproot, 2 = six or more lateral roots per cm of taproot). For each seedlot, seedlings were randomly divided into bundles of four seedlings each with one seedling labelled with the seedlot number. Four bundles of four seedlings for each seedlot were packaged in kraft paper for overwinter storage at 4° C for each planting to be established.

In June 1980, germinating seed from each seedlot were sown in 6- x 6- x 30-cm polyethylene-coated paperboard plant bands in a Michigan State University greenhouse and grown according to the techniques described by Wood and Hanover (1981). Briefly, seedlings were grown in RediEarth, a commercial peat-vermiculite soil mix, under continuous fluorescent light and carbon dioxide enrichment for approximately 4 months. Seedlings were hardened-off for approximately 3 months before being removed from the containers for packaging and overwinter storage. For each collection, 16 seedlings were randomly divided into four bundles of four seedlings each with one seedling from each bundle labelled with seedlot number. Labelled bundles were packaged in kraft paper for cold storage and shipping to the Indiana planting site in late March.

Container-grown and nursery-grown seedlings were both slit-planted using the MICHOTIP hardwood tree planter on March 25, 1981. Nursery-grown seedlings with excessive lateral roots or taproots over 25 cm long were root pruned before planting. Seedlings were planted on an open, grass-covered old field in the Atterbury State Fish and Wildlife Area located in Johnson County, Indiana. Soils are primarily poorly- to moderately-well drained Crosby (fine, mixed, mesic, Aeric Ochraqualfs) and Miami (fine-loamy, mixed, mesic, Typic Hapludalfs) silt loams. Seedlings were planted in 4-tree row plots at a nominal spacing of 2.0 m within rows and 3.0 m between rows using a split plot design for planting stock type with individual seedlots randomly arranged within each planting stock type.

The planting site was sprayed in the fall of 1980 with glyphosate (2.5 l ai per ha) using 1-m wide bands at 3-m intervals. Immediately after seedlings were outplanted, all rows were strip-sprayed with simazine (4.5 kg ai per ha). There was no additional weed control in subsequent years to control competition from the grass sod. Climatological data for 1980 to 1983 for central Indiana were obtained from records published by the National Oceanic and Atmospheric Administration.

Survival, live height, and basal diameter (3 cm above soil line) were recorded at outplanting and annually after each growing season for 3 years. Means for height, basal diameter, and net growth for all live trees were determined for each four tree plot. For this report, only data from 72 open-pollinated families (single-tree collections) that had both nursery-grown and container-grown seedlings and were replicated across all four blocks were analyzed. Families were assigned to provenances according to the preliminary seed collection zones identified for black walnut in 1980 (Deneke et al. 1987). Variation was analyzed as a split-plot experiment using plot means to determine if differences ($p < 0.05$) existed among planting stock type and/or genotype or if an interaction was present. Pearson correlation analyses were used to generate correlation matrices on a family mean basis.

RESULTS

Analysis by Family Means

Survival for both the nursery-grown and the container-grown seedlings has been excellent on this questionable site for black walnut. After the first growing season, survival for the nursery-grown seedlings averaged 98.9% with the container-grown seedlings averaging 97.4%. After three growing seasons, survival for the nursery-grown seedlings averaged 95.7% compared to 96.2% for the container-grown seedlings (Table 1). Survival among the families after three growing seasons ranged from 81% for family 189 from Bell County, Kentucky, to 100% for 21 of the 72 families. Overall, there were no statistically significant differences for survival among families or planting stock type.

A highly significant interaction for height growth existed among planting stock types x genotype during the first two years after outplanting which disappeared after the third growing season (Table 2). Many of the walnut seedlings showed substantial dieback after the first growing season; however, because of the interaction there was no consistent genotypic response among families outplanted as nursery- and container-grown planting stock. For example, dieback on nursery-grown seedlings for family 295 from Alexander County, Illinois, averaged 30.9 cm compared to 15.2 cm for the container-grown seedlings. Conversely,

Table 1.--Third year survival, annual net height growth, and root fibrosity index for nursery-grown and container-grown black walnut seedlings by family and seed collection zone.

Seed Coll. Zone[1]	Family number[2]	Location State	Location County	Third Year Survival Nurs.	Third Year Survival Cont.	Net annual height growth First year Nurs.	First year Cont.	Second year Nurs.	Second year Cont.	Root Fibr. Index[3]
				- - - % - - -		- - - - - - - - - - - - cm	- - - - - - - - - -			
2	328	IA	Cedar	94	100	- 8.5	- 4.6	- 4.7	1.5	0.50
	329	IA	Clayton	100	4	- 2.1	-10.1	- 0.7	6.3	0.47
	330	IA	Taylor	100	100	0.9	- 7.9	- 6.4	7.1	0.22
	333	IA	Marshall	100	81	- 0.8	-10.9	-17.1	5.2	0.16
	336	IA	Jefferson	100	94	- 3.9	- 7.0	- 3.8	8.0	0.28
	339	IA	Taylor	100	94	- 2.3	-13.0	- 8.9	- 3.9	0.16
	340	IA	Marshall	94	94	- 5.6	-14.5	- 0.1	4.8	0.13
Seed Collection Zone Means				98	94	- 3.3	- 9.7	- 6.0	4.1	0.27
3	297	IL	Fulton	94	94	7.3	- 9.6	-12.3	- 6.1	NA
	298	IL	Warren	100	100	- 1.0	- 1.2	4.0	7.9	0.44
	299	IL	Henry	100	100	6.3	- 1.4	- 5.9	7.4	0.88
	300	IL	Carroll	100	100	0.5	- 4.2	-14.6	8.5	0.66
Seed Collection Zone Means				98	98	3.3	- 4.1	- 7.2	4.4	0.66
4	127	MI	Allegan	100	100	- 7.2	5.9	- 1.0	1.2	0.88
	131	MI	Berrien	100	92	- 5.8	- 6.0	- 8.7	1.1	0.00
	134*	MI	St. Joseph	94	88	- 1.6	- 4.4	- 4.0	3.4	0.13
	139	MI	Branch	94	94	-10.4	-16.6	- 1.4	0.1	0.28
	143*	MI	Eaton	100	81	- 2.4	- 5.2	2.1	8.9	0.50
	146*	MI	Jackson	88	100	-12.0	- 6.2	0.7	1.8	0.00
	147	*MI	Jackson	100	100	- 7.2	-13.0	-15.9	0.8	0.13
	212	ON	Middlesex	100	100	1.8	- 6.3	0.6	6.4	0.84
	215	ON	Brantford	94	94	- 2.9	- 8.1	- 3.8	1.5	0.56
	218	NY	Chautauqua	100	94	-15.4	- 4.7	- 8.0	1.7	0.56
	222	OH	Huron	94	100	3.4	0.6	4.3	2.2	0.25
	247	MI	Igham	100	100	- 8.8	- 1.0	- 7.3	3.5	0.16
Seed Collection Zone Means				97	95	- 5.7	- 6.4	- 3.5	2.7	0.36
6	345	MO	Adair	100	100	- 9.0	- 1.4	- 4.9	8.2	0.13
	354	MO	Pike	94	100	- 6.7	- 9.0	-13.1	- 0.1	0.13
	384	IL	Macon	100	88	- 6.4	-10.5	-15.1	6.5	0.25
	386	IL	Macon	100	100	- 1.9	- 1.8	-16.5	13.9	0.31
Seed Collection Zone Means				97	97	- 6.0	- 5.7	-14.9	7.2	0.20

7	261	IN	Owen	100	100	- 5.6	- 0.1	- 3.1	-11.2	0.09
	264	IN	Putnam	100	100	- 0.1	- 7.0	-11.2	0.6	1.19
	266	IN	Bartholomew	94	100	- 4.4	-16.1	-21.6	4.6	1.00
	274	IN	Lawrence	100	100	- 5.9	-20.7	-27.9	5.3	0.97
	277	IN	Lawrence	94	94	-13.9	- 1.9	- 8.3	1.8	0.72
	286	IN	Lawrence	94	100	7.0	- 3.6	2.9	12.0	1.22
Seed Collection Zone Means				97	99	- 3.1	- 9.2	-13.0	3.5	0.86
10	174	KY	Hancock	100	100	- 4.9	- 5.2	-16.5	5.2	0.19
	202	KY	Ohio	100	94	- 7.1	-14.4	- 2.1	- 4.2	0.66
	295	IL	Alexandria	69	100	-30.9	- 7.7	-15.2	6.9	0.00
	296	IL	Hardin	94	94	- 3.8	- 4.0	-17.5	6.0	1.00
	341	MO	Texas	100	94	-18.7	- 3.4	- 7.6	3.7	0.50
	348	MO	Perry	88	88	-17.1	-15.3	- 8.7	3.4	0.38
	380	IL	Jackson	94	100	-21.6	- 6.6	- 2.7	6.1	0.19
	381	IL	Randolph	100	88	- 3.3	- 1.3	-11.4	10.4	0.88
	382	IL	Williamson	88	100	-15.8	- 5.5	-24.8	8.9	0.19
Seed Collection Zone Means				92	95	-13.7	- 7.0	-11.8	5.2	0.44
11	158	KY	Hardin	100	100	- 0.9	-14.1	-11.9	8.3	0.50
	172	KY	Boyd	94	94	- 4.9	- 5.2	- 3.0	9.2	0.50
	194	KY	Barrier	100	100	- 2.7	-14.4	-11.9	- 0.1	1.19
	203	KY	Wolfe	94	100	- 5.2	-11.9	-16.6	6.4	0.66
	207	KY	Washington	100	100	- 2.2	- 5.9	- 6.1	2.3	0.75
	233	WV	Tucker	100	100	3.4	-13.1	0.1	3.2	0.75
	242	WV	Tyler	94	94	2.5	- 4.8	- 5.1	3.4	0.47
	244	WV	Mason	94	94	4.7	- 1.7	1.9	4.3	0.41
	320	WV	Harrison	100	100	4.2	- 7.1	- 4.4	0.8	0.22
Seed Collection Zone Means				97	98	- 0.1	- 8.7	- 6.3	4.2	0.60
13	342	MO	Ripley	94	100	-11.8	-22.6	-25.8	8.0	0.53
	356	MO	Pulaski	100	81	0.3	- 7.4	-13.3	2.6	0.56
	357	MO	Oregon	100	94	-10.6	-13.5	-22.5	3.1	0.28
Seed Collection Zone Means				98	92	- 7.4	-14.5	-20.5	4.6	0.46
14	253	TN	Macon	88	100	0.2	- 3.2	- 0.6	7.6	0.31
	254	TN	Macon	100	94	- 1.6	- 4.7	- 6.2	7.2	0.34
	369	TN	Smith	94	100	- 6.1	- 8.8	-17.4	- 1.4	0.28
Seed Collection Zone Means				94	98	- 2.5	- 5.6	- 8.1	4.5	0.31
15	180	KY	McCreary	94	94	- 6.6	- 4.1	-15.0	3.8	0.06
	189	KY	Bell	69	94	-10.7	- 7.5	- 1.4	1.7	0.09
	192	KY	Clay	94	94	- 5.4	-11.5	- 9.9	3.6	0.50
	225	WV	Greenbriar	100	94	3.6	-10.2	0.9	12.5	0.53
	228	WV	Rock Bridge	94	94	- 7.0	-16.0	- 2.3	8.5	1.19
	229	WV	Rogne	88	100	-14.1	- 9.1	-10.8	3.1	0.38

	236	WV	Mercer	88	94	1.4	- 4.9	- 0.5	5.5	0.69
	246	WV	Wyoming	81	100	- 4.6	-14.6	- 9.9	3.7	0.59
Seed Collection Zone Means				88	96	- 5.4	- 9.7	- 6.1	5.3	0.50
16	149	TN	Anderson	94	100	- 4.5	-19.7	- 7.9	10.2	0.84
	360	TN	Lincoln	100	100	- 1.6	- 9.6	- 9.2	0.9	0.50
	363	TN	Washington	94	94	- 1.0	-11.0	-35.9	1.6	0.69
	366	TN	Warren	94	100	- 5.2	-10.8	-18.1	7.9	0.22
	372	TN	Overton	100	94	2.6	-16.6	- 1.4	- 1.8	0.97
	374	TN	White	100	100	1.9	- 3.6	-16.6	3.4	1.03
	376	TN	Knox	100	100	- 2.0	- 3.1	- 6.1	2.4	1.19
Seed Collection Zone Means				98	97	- 1.4	-10.6	-13.6	3.5	0.78

[1]Provenance is based on the preliminary seed collection zones for black walnut identified by Deneke et al. (1987).
[2]Family number can be converted to the North Central Forest Experiment Station Accession Number or the MICHOTIP Accession Number by adding 10,200 or 47,350,000, respectively. An * indicates seed was collected from an above average tree in a small black walnut planting.
[3]Root Fibrosity Index ranges from 0 for seedlings with less than 3 lateral roots per cm of taproot to 2.00 for seedlings with 6 or more lateral roots per cm of taproot.

Table 2.--Analyses of variance for seedling height and basal diameter growth from 72 families grown as both nursery- or container-grown planting stock.

Source of variation	Degrees of freedom	Height growth			Basal diameter growth		
		Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
		mean sum of squares[1]					
Stock type	1	1,953	25,120	834	22.41	10.43	37.38*
Blocks	3	443	1,245	38	18.77	0.33	7.96
Error A	3	649	1,190	1,122	9.53	2.84	4.23
Families	71	166**	176**	77	0.61	0.98	1.10
S x F	71	128**	165**	61	0.73	0.82	1.20
Error B	426	65	100	62	0.61	0.82	1.43

[1]Mean sum of squares followed by an * or ** are statistically significant at the alpha = 0.05 and 0.01 levels, respectively.

dieback on container-grown seedlings for family 386 from Lawrence County, Indiana, averaged 3.6 cm while nursery-grown seedlings of the same family averaged 7.0 cm of net height growth.

Overall, nearly all families showed some first-year dieback for both the nursery-grown and the container-grown seedlings. Nursery-grown seedlings after outplanting were on the average 50.6 cm tall compared to only 46.0 cm after the first growing season. Conversely, container-grown seedlings showed a significantly greater percentage of dieback after the first growing season having averaged 31.3 cm at outplanting and only 23.1 cm after the first growing season. Only family 222 from Huron County, Ohio, outgrew the initial stem dieback for both the nursery-grown and container-grown seedlings and were taller after one growing season than when outplanted.

The variable growth of the nursery-grown seedlings was primarily responsible for the planting stock type x genotype interaction found after the second growing season (Table 2). The second-year growth of both the nursery- and container-grown seedlings for many families was similar. While for approximately one-third of the families, the nursery-grown seedlings showed extensive dieback with little or no dieback on the container-grown seedlings (Table 1). For example, family 146 from Jackson County, Michigan, and family 244 from Mason County, West Virginia, averaged 2 to 4 cm of net height growth for both the nursery-grown and container-grown seedlings, while family 274 from Lawrence County, Indiana, and family 363 from Washington County, Tennessee,continued to show substantial dieback of the nursery-grown seedlings (27.9 and 35.9 cm, respectively) with net height growth for the container-grown seedlings (5.3 and 1.6 cm, respectively).

After the second growing season, many of the nursery-grown seedlings showed additional dieback and were 8.9 cm shorter than after the first growing season. Conversely, the container-grown seedlings were 4.3 cm taller than after the first growing season and had recovered approximately half of the initial dieback. After the second growing season, seedlings from 9 of the 72 families for both the nursery-grown and container-grown planting stock were taller than after the first growing season. Conversely, seedlings from only 8 families showed net dieback for both types of planting stock during the second growing season.

After the third growing season, the interaction between planting stock type and genotype for height growth was no longer present and no differences among families were present (Table 2). Nearly all families showed 4 to 7 cm of net height growth for both types of planting stock. Differences in diameter growth were found only for the planting stock type after the third growing season. Diameter growth for the container-grown seedlings averaged 0.1 mm compared to -0.4 mm for the nursery-grown seedlings. Over two-thirds of the families outplanted as nursery-grown stock showed net negative diameter growth. The negative values occur because of stem dieback on one or more seedlings within these families and subsequent resprouting from the root collar.

Analysis By Seed Collection Zones

Analyses of height growth by seed collection zone and planting stock type again showed a highly significant interaction after the first and second growing seasons. Height growth during the first growing season within each collection zone was extremely variable for planting stock types with no apparent pattern (Table 1). For example, in seed collection zone 6, container-grown and nursery-grown seedlings showed approximately 6 cm of dieback. In contrast, container-grown seedlings from seed collection zone 13 showed extensive dieback (14.5 cm) while nursery-grown seedings from seed collection zone 3 were 3.3 cm taller than when outplanted. The amount of dieback did not appear to follow any geographical pattern related to seed collection zone.

After the second growing season, container-grown seedlings from all seed collection zones consistently showed height growth of 3 to 7 cm (Table 1). In contrast, the amount of dieback on nursery-grown seedlings ranged from 4 to 20 cm across the eleven seed collection zones. Seedlings from the northernmost seed collection zones tended to show the least dieback; however, they also tended to be the shortest when outplanted. A seed collection zone x planting stock type interaction was not found after the third growing season when seedlings from all collection zones averaged 2 to 9 cm of height growth without any apparent geographical pattern.

Results of family mean correlation coefficients showed that increased root fibrosity of nursery-grown seedlings was positively correlated with outplanting basal diameter, first-year height growth, and third-year survival (Table 3). Root fibrosity of container-grown seedlings was not determined and the lack of any correlation between nursery-grown seedling fibrosity and container-grown seedling characteristics of the same family suggests that small changes in root fibrosity on container-grown seedlings are not as important as the well-developed fibrous root system itself.

The lack of any correlation between root fibrosity of nursery-grown seedlings and container-grown seedling growth may also mean that the growth patterns and morphology of seedlings from the same family can be quite different when grown under forcing conditions in a greenhouse. The latter conclusion is supported by the fact that basal diameter of the container-grown seedlings was not correlated with the basal diameter of the nursery-grown seedlings ($r = 0.066$). The outplanting height of the nursery-grown seedlings was correlated with that of the container-grown seedlings; however, the correlation coefficient was relatively low ($r = 0.401$).

DISCUSSION

Survival after three growing seasons in this provenance/progeny test has been exceptional and is substantially better than in an adjacent planting methods study using nursery-grown and container-grown seedlings (Van Sambeek et al. 1987). Survival rates for the nursery-grown planting stock in the adjacent planting after three growing seasons was less than 70% compared to 96% in the present study. We attribute the lower survival in the adjacent planting to the somewhat poorer internal drainage. Survival of container-grown stock after three growing seasons averaged around 95% in both the provenance/progeny and the adjacent planting.

Table 3.--Correlation matrix for initial seedling characteristics and outplanting performance of nursery-grown and container-grown seedlings of 72 black walnut families.

Variables	Root fibr. index	Outplanting Basal diameter	Outplanting Stem height	Annual height growth First year	Annual height growth Second year	Annual height growth Third year	Third year survival
	- - - - - - - - - - - - r[1] - - - - - - - - - - - -						
xxxxxxx			FOR NURSERY-GROWN FAMILIES				
Root fibrosity	xxxxxx	0.367**	-0.104	0.350**	0.015	-0.046	0.238*
Basal diameter	-0.087	xxxxxxx	0.273*	0.497**	-0.128	-0.125	0.183
Stem height	0.129	0.454**	xxxxxxx	-0.386**	-0.778**	-0.123	-0.101
First year growth	-0.144	0.053	-0.700**	xxxxxxx	0.221	-0.176	0.443**
Second year growth	0.094	-0.035	-0.332**	0.154	xxxxxxx	-0.056	0.001
Third year growth	0.144	-0.203	-0.123	0.002	0.437**	xxxxxxx	-0.126
Third year survival	0.167	0.193	0.184	-0.005	0.020	0.285*	xxxxxxx
			FOR CONTAINER-GROWN FAMILIES				

[1]Correlation coefficients followed by an * and ** are statistically significant at the alpha = 0.05 and 0.01 levels, respectively.

The outplanting height for the nursery-grown seedlings was not well correlated with their basal diameter (Table 3). This may be a reflection of the wide variation in seedling density present in the nursery beds due to low germination in some families. Likewise, the outplanting height of the container-grown seedlings was not highly correlated with their basal diameter suggesting that the position of the containers on the greenhouse bench may have affected seedling growth rates.

The overall poor height growth of both the nursery-grown and container-grown seedlings was probably in response to inadequate weed control, moisture stress, and competition from the invading grasses. During the first growing season, many of the nursery-grown seedlings, especially the larger seedlings, showed some dieback with 2 to 5 cm of new shoot growth from lateral buds. Over the winter, the stems on many of these seedlings died. Most seedlings resprouted from the root collar which resulted in large net negative height growth for the second growing season. During the latter part of the second growing season and again during January through March of 1983, rainfall was substantially below normal. This was followed by excess moisture on a somewhat poorly drained site during April and May of the 1983 growing season.

The first- and second-year height growths were negatively correlated with the outplanting height for both the nursery-grown and container-grown seedlings (Table 3). Potentially, the taller seedlings were unable to obtain adequate soil moisture and showed repeated dieback until the root-to-shoot ratios become balanced under stressful conditions. First-year height growth of nursery-grown, but not container-grown seedlings, was positively correlated with outplanting basal diameter. Since taproot volume is highly correlated with basal diameter and is not substantially reduced by root pruning, seedlings with large basal diameters may have had more stored reserves available for root and shoot growth during the first year.

Overall, the container-grown seedlings initiated positive height growth sooner than the nursery-grown seedlings. Similar results have also been found for container-grown planting stock by von Althen and Prince (1986) on a good walnut site and Anderson et al. (1983) on a reclaimed minespoil. Earlier height growth results in our provenance/progeny test are consistent with those from the adjacent planting methods study reported earlier (Van Sambeek et al. 1987). As in the planting methods study, container-grown seedlings in this provenance/progeny test overcame dieback during the second growing season, while nursery-grown seedlings did not show net height growth until the third growing season. Repeated annual dieback for 1 to 3 years in response to site or competition is not uncommon and has been reported for several other provenance/progeny tests (Williams et al. 1985). Heritabilities for height growth were not calculated because previous research has shown them to be highly variable until after the fourth growing season (Rink 1984).

The dissipation of the genotype x environment interaction in Atterbury provenance/progeny test for early height growth is not uncommon in black walnut provenance/progeny tests. In two separate studies, Rink et al. (1982) and Williams et al. (1985) found that the interaction between where the nursery seedlings were grown and genotype also dissipated several years after outplanting. Although seed collection zone (provenance) effects were not found, we expect these effects to be evident in later measurements based on results from other black walnut provenance/progeny tests.

The highly significant planting stock type x genotype interaction during the first two growing seasons reinforces the conclusion from other studies that early height growth cannot be used as a predictor of future height growth, at least for nursery-grown seedlings (Clausen 1984, Rink 1984). Whether early height growth can be used as a reliable predictor for future height growth of black walnut established with container-grown planting stock remains to be determined. The poor initial growth of the container-grown stock in this provenance/progeny, however, makes it unlikely that our study will satisfactorily answer the question. The study has shown that planting stock type x genotype interactions can significantly affect the early field performance of black walnut plantings.

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