SIXTH-YEAR RESULTS OF A BLACK WALNUT PROVENANCE TEST IN MAINE[1]

by David J. Schmitt, Graduate Assistant, and
Katherine K. Carter, Associate Professor, Univ. of Maine, Orono 04469

Abstract.--Twenty-nine provenances of black walnut were planted as 1-0 stock in May, 1980 near Newport, Maine. The provenances were evaluated for height growth, dates of bud burst and bud set, length of dominant shoot, and amount of winter damage after six years. Significant variation between the provenances was found for height growth, date of bud set, and length of dominant shoot. These variables were negatively correlated with elevation and/or latitude of the seed source. It is concluded that some provenances can be recommended for planting in Maine.

This study is part of a larger provenance test initiated by Dr. D.H. DeHayes of the University of Vermont in response to many inquiries from the public as to the selection of proper seed sources of black walnut, J. nigra L. for use in New England. The plantation in Newport, Maine is one of six in the larger project, which includes other plantations in Vermont, New Hampshire and Pennsylvania.

The primary interest in black walnut in Maine currently is by the individual small landowner. Because of the potential value of mature trees, people may plant them early in life in anticipation that the money made 30-40 years hence can be used in their retirement. Other attractions include the value of the edible nuts and the fact that many people favor the black walnut as an ornamental. Since Maine is to the north of the natural range of the species, the importance of selecting the seed source best adapted to Maine conditions is clear.

Height growth, winter damage, date of bud burst, date of bud set, and rate of shoot elongation have been examined in the Newport plantation, as well as the relationship of the elevation, latitude, and longitude of the original seed source to the above variables.

METHODS

Plantation Establishment

The study site is located in Newport, Maine, (Latitude 44° 55'N, Longitude 69° 20'W), on land owned by the Maine chapter of the Nature Conservancy. It is an old field site with a slight north facing slope and a well drained sandy loam soil. The area is bordered by a woodlot on the west and pasture on the north, east and south.

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The seedlings were grown from seed collected by Dr. Don DeHayes and cooperators, sown in the fall of 1978 and spring 1979. Trees were lifted in the fall of 1979, and kept in cold storage over the winter. The Newport planting consists of 29 provenances from 13 states and two Canadian provinces arranged in a randomized complete block design with four replications (Table 1). Each provenance is represented by a four tree row plot in each replication.

Table 1.--Location of black walnut provenances, with 1985 height and phenology data at Newport, Maine

Provenance Number	Degrees North Latitude	Degrees West Longtitude	Elevation (ft.)	1985 Mean Height (ft.)	Bud Burst (J.D.)	Bud Set (J.D.)
VT-654	44°23'	73°17'	100	34.9	145	210
MN-658	45°96'	94°35'	1111	22.8	146	202
WV-665	39°20'	78°45'	1600	27.9	153	204
IN-666	38°30'	86°28'	620	37.8	143	212
NY-672	43°11'	74°06'	820	30.4	144	213
NY-675	42°35'	74°20'	640	30.9	140	207
IA-684	42°27'	96°24'	900	25.8	142	211
WI-685	43°30'	90°48'	736	34.7	146	209
WV-692	38°24'	79°57'	1475	26.1	142	202
PA-695	40°47'	77°40'	1200	35.4	147	212
PA-697	39°57'	75°22'	200	34.2	147	220
NJ-699	39°48'	74°46'	20	36.3	148	213
MI-702	42°24'	85°24'	875	38.8	144	201
MI-705	42°02'	85°58'	600	28.6	148	211
NY-707	42°26'	78°55'	1110	28.4	144	204
QUE-719	46°40'	71°50'	10	28.0	145	201
KY-725	37°27'	84°01'	1020	39.5	146	219
OH-727	40°22'	83°04'	940	24.4	148	215
ONT-731	42°40'	80°22'	400	25.3	147	206
ONT-734	44°02'	79°27'	750	33.3	142	200
IA-741	42°75'	95°55'	650	37.0	146	212
IN-745	40°24'	86°51'	650	25.5	144	216
IN-747	40°48'	86°24'	700	27.6	146	216
MI-748	41°57'	86°51'	650	26.1	148	203
ONT-813	45°50'	76°54'	330	24.9	143	201
IL-814	37°40'	89°16'	520	26.8	144	215
IL-815	37°90'	89°81'	550	37.4	144	211
KY-817	37°00'	89°00'	500	35.7	--	223
WV-836	39°38'	79°56'	1200	22.0	145	205

The seedlings were planted May 14 and 15, 1980, using a gas-powered augur to create holes at an 8X8 ft. spacing. The area around the base of the seedlings was treated with Simazine in order to control the heavy herbaceous competition on the site. In the spring of 1981, the site was mowed. In October 1984, April 1985, and October 1985 the seedlings were treated with deer repellent in an attempt to reduce damage from deer browse and rubbing.

In June 1986, soil samples were taken from each replication and analyzed for pH and exchangeable Ca, Mg, K, and P by the Maine Soil Testing Service, Orono, Maine.

Total Height

Total height was recorded in the fall of 1980, 1982, 1984, and 1985 to the nearest tenth of an inch.

Date of Bud Burst

In late April, 1985, well before black walnut breaks bud, cuttings were made from several lateral branches. These were placed in a greenhouse where the date of bud burst could be advanced and the characteristics recorded. On the basis of these observations, a 0-3 scale was used to quantify bud burst, with Stage 3 indicating the emergence of the leaves through the bud scales. Stage of bud burst was recorded every 4 to 5 days over the period May 8-June 11, 1985. For the purposes of the analysis, the Julian date upon which the tree was first rated as Stage 3 was used as the date of bud burst. Bud break was examined only on terminal buds.

In anticipation of measurement of the rate of shoot elongation, slim (#0) insect pins were inserted 5 mm below the resting bud in order to have a stable position from which to measure. This method has been used successfully on southern pines. Nearly 57% of the terminal buds in this study, however, never reached Stage 3. Whether this was due to cambium disruption by the pins themselves, or that the holes made by the pins served as an entry for bacteria or other pathogens is unknown. As a result, analysis of date of bud burst was based only on those trees on which the terminal buds survived.

Length of Dominant Shoot

As previously mentioned, the majority of terminal buds failed to elongate during the 1985 growing season. As an alternative estimate of one-year growth potential, length of the dominant shoot (whether terminal or lateral) was measured after the end of the 1985 growing season. Shoot elongation of surviving terminals was also recorded biweekly from the date of bud burst through bud set in 1985.

Bud Set

Beginning in the second week of July, the trees were examined every 5 days to determine approximate date of bud set. As with bud burst, the Julian value of the date on which bud set was first seen was recorded. For the purposes of this study bud set was defined as "the conspicuous presence of a well-formec bud on the terminal leader visible after the period of rapid shoot expansion" (Bihun, 1982). At this point, the mound of tissue associated with the cessation of growth has differentiated into a distinctive bud structure. The new resting bud is fairly large, 12-15 mm, and light green in color. The bud scales are densely packed. Determination of bud set consisted solely of ocular examinations.

Winter Damage

In the spring of 1984 the damage suffered during the 1983-1984 winter was estimated. Two separate observations were recorded: First, the number of winter killed trees/plot, and second the percent damage to the terminal leader in increments of ten percent. Winter damaged black walnut twigs are a dark and shiny black as compared to the rich dark brown of a healthy stem. Identical measurements were taken in April of 1986 to determine damage from the 1985-86 winter. For the purposes of analysis, the average result per four tree row plot was used.

Statistical Analysis

The statistical analyses were based upon individual tree values, save for the analysis of winter damage. Computer analysis of variance (ANOVA) and Duncan's Multiple Range Test was conducted separately for each variable measured. All of the variables were examined for correlation with the elevation, latitude, and longitude of the original seed source. Elevation and latitude were combined using the formula 400' of elevation = 1 degree of latitude (Hopp, 1974).

As mentioned before, the winter damage analyses were based upon the mean values of the four tree row plots. Due to the large number of zeros, this data did not lend itself to analysis by standard ANOVA proceedures. Instead, Friedman's Test, a non-parametric statistical method was used. This method first assigns ranks to the various values within a replication, and then uses ANOVA procedures upon these ranks.

RESULTS AND DISCUSSION

Survival

Survival in the plantation was excellent. The overall survival rate was 95.7%, and there were no significant differences between provenances. This is in keeping with the results of Williams et al. (1985) who found survival rates on their sites ranging from 88-96%. It is somewhat above the overall average of 70% found by Bey (1979). The tallest 20% of the trees in Bey's study had a survival rate of 81%, well above the 70% overall plantation average. In Maine, the tallest 20% actually had a slightly less than average survival rate of 93.8%.

The survival rates at Newport are at variance with the findings of Clausen (1983) who returned to the same plantations established by Bey to report the fifteen year results. Survival rates ranged from 85% in the Missouri planting to only 34% on the Minnesota site, the most northerly of the seven sites measured. The Minnesota planting was at 44.2 N latitude, very similar to the 44.6 N latitude of this study's plantation. Further, Clausen found that trees from seed sources more than 200 miles south of the Minnesota plantation had only a 22% survival rate. This is greatly in variance with the findings of this study in which virtually every seed source is from more than 200 miles south of the planting. The large difference in overall survival between these two studies may be explained by the fact that Clausen's survival rates are based on fifteen year results while ours are based only on six-year findings. Many trees at the Newport plantation have suffered winter dieback and it may well be that ten years hence they will have suffered mortality. Furthermore, the "southern" sources in the Bey/Clausen plantations are from much further south than those classified as southern in our study.

Height Growth

Total mean height in 1985 ranged from 39.5" for KY-725 to 22.0" for WV-836 (Table 1). Table 2 shows the results of the ANOVA on height growth data for the years 1980, 1982, 1984, and 1985. There were significant differences at the .0001 level between the provenances in each of these years. Significant variation was also found between the four replications in each year, as well as in the replication x provenance interaction in 1982, 1984, 1985. Table 3 shows the rankings of each provenance in each year.

Table 2.--Summary of significance levels (prob. >F) and R^2 values as calculated by analysis of variance

Dependent Variable	Independent Variable	Prob. >F	R^2
Height 1980	Prov.	0.0001	
	Rep.	0.0001	0.47
	Rep.xProv.	0.4937	
Height 1982	Prov.	0.0001	
	Rep.	0.0009	0.45
	Rep.xProv.	0.0001	
Height 1984	Prov.	0.0001	
	Rep.	0.0001	0.52
	Rep.xProv.	0.0001	
Height 1985	Prov.	0.0001	
	Rep.	0.0001	0.52
	Rep.xProv.	0.0001	
Bud burst	Prov.	0.2193	
	Rep.	0.0128	0.56
	Rep.xProv.	0.3233	
Bud set	Prov.	0.0001	
	Rep.	0.1254	0.79
	Rep.xProv.	0.0001	
Length of dominant shoot	Prov.	0.0001	
	Rep.	0.4151	0.58
	Rep.xProv.	0.0001	

Table 3.--Height rankings of 29 black walnut provenances growing near Newport, Maine (1 = greatest mean height)

Source #	Year 1980	1982	1984	1985
VT-654	21	20	9	9
MN-658	29	28	29	28
WV-665	16	26	20	18
IN-666	5	8	7	3
NY-672	11	12	13	14
NY-675	25	13	17	13
IA-684	24	18	24	23
WI-685	7	1	5	10
WV-692	28	24	21	22
PA-695	19	10	10	8
PA-697	23	11	2	11
NJ-699	10	4	6	6
MI-702	6	6	3	2
MI-705	13	15	15	15
NY-707	9	17	18	16
QU-719	20	19	16	17
KY-725	4	7	1	1
OH-727	8	27	25	27
ON-731	27	21	26	25
ON-734	26	14	12	12
IA-741	3	2	4	5
IN-745	18	29	27	24
IN-747	17	16	14	19
MI-748	22	23	22	21
ON-813	15	22	23	26
IL-814	1	3	19	20
IL-815	2	5	8	4
KY-817	12	9	11	7
WV-836	14	25	28	29

Source KY-725 was the tallest in each of the last two years. In 1985, seven of the ten tallest sources were among the more southern of the provenances tested here. Seven provenances were among the top ten in height in each of the measuring periods.

Table 4 shows the correlation coefficients resulting from the correlation of height with elevation, latitude, and longitude. As noted previously, elevation and latitude can be combined. The results for this adjusted latitude are also presented.

Table 4.--Pearson corrrelation coefficients (r) of variables related to growth and provenance location

Growth Variables	Location Variables			
	Elevation	Latitude	Adjusted Latitude	Longitude
Height 1980	-0.06	-0.23*	-0.26*	0.17
Height 1982	-0.11*	-0.09*	-0.14*	0.05
Height 1984	-0.11*	-0.08	-0.13*	-0.02
Height 1985	-0.09*	-0.10*	-0.14*	-0.00
Bud burst	-0.02	-0.07	-0.07	0.02
Bud set	-0.14*	-0.37*	-0.43*	0.13*
Shoot length	-0.02	-0.91*	-0.21*	0.02
Terminal damage 1983	-0.21*	-0.07	-0.15	0.10
Terminal damage 1985	0.03	-0.10	-0.09	0.11
Dead/plot 1983	-0.11	-0.12	-0.17	-0.14
Dead/plot 1985	-0.01	-0.06	-0.07	-0.01

* = significant at the .01 level.

In 1980, latitude and adjusted latitude showed negative correlations with provenance mean height while longitude was positively correlated with height. Height was significantly correlated with longitude only in 1980. Height in 1982 showed significant negative correlation with elevation, latitude,and adjusted latitude. In 1984, the significant results were only with elevation and adjusted latitude, again with negative correlations. Finally, in 1985, height was once again negatively correlated with elevation, latitude, and adjusted latitude. It is interesting to note that even when only elevation of latitude shows significant results, that adjusted latitude is also significant.

These trends agree with Wright's (1954) observation that southern seed sources grew taller than those from central or north-west regions, and with those of Bey and Phares (1968) who found that seedlings from southern sources were taller and had larger dry weights than northern sources. These differences occurred early in the growing season and became greater as the growing season progressed. Bey and Phares concluded that, "Growth plotted over latitude shows a straight line relationship. This supports the conclusion that the geographic variation pattern for black walnut is continuous over latitude," and also that latitude of seed source had an effect that increased with time (Bey and Phares, 1968).

The findings from the Newport planting are, however, somewhat at variance with the Clausen (1983) study. Of the seven plantations measured by Clausen, three (MS, KS, and MI) showed no correlation between latitude of origin of the seed source and fifteen-year height. The Illinois plantation showed a negative correlation similar to the Newport site, but Clausen's Ohio, Iowa, and Minnesota plantations showed significant positive correlation, i.e., northern seed sources tended to be taller than their southern counterparts. Part of this difference may be explained by the extremely low survival rates of southern sources at the Minnesota planting and to a lesser extent at the Iowa planting.

Elevation was found to have a significant negative correlation with height in each of the last three measuring periods at Newport, indicating that the trees from higher altitude seed sources tended to be shorter. This may be due in part to the shorter growing season at higher elevations. Elevation was negatively correlated with date of bud set (i.e., higher elevation sources set bud earlier), although not with date of bud burst.

Two additional provenances in the Newport plantation should be noted because of their marked improvement over the study period. VT-654 improved from a ranking of 21st in 1980 to 9th in 1985, and PA-695 increased from 19th to 8th over the same period. It will be interesting to see if they continue to show the same steady climb in the rankings.

Table 5 shows the year to year correlations for rank in height growth. Height ranking in 1980 was not well correlated (r = 0.49) with height in 1985, the final measurement, even though the correlation was significant. Height in 1982, however, showed a strong correlation (r = 0.80) with height in 1985. Correlation between heights in 1984 and 1985 was very high.

Table 5.--Year to year correlations for height growth rankings of black walnut provenances near Newport, Maine

	Correlation Coefficients		
	Rank 1982	Rank 1984	Rank 1985
Rank 1980	0.62*	0.47*	0.49*
Rank 1982		0.82*	0.80*
Rank 1984			0.94*

* = signficant at the .01 level.

The correlation coefficient for 1980-1985 height is nearly doubled by the 1982-1985 coefficient. Clearly, some major changes occurred between planting in 1980 at one year of age, and 1982. One obvious component of this change is the fact that the seedlings had survived two winters. Whatever the reason, by 1982 those provenances which rank highly in 1985 were beginning to assert themselves.

Bud Burst

There were no significant differences in date of bud burst between provenances (Table 2). This is a bit surprising since several other hardwood species which share much of the range of black walnut show geographic variation in this respect. There were also no significant correlations between date of bud burst and elevation, latitude, or longitude of seed source (Table 4). McGee (1974) found that for red oak elevation of seed source had a definite effect on bud burst. A look at Table 1 helps explain why no significant results were found. From the date on which the first source (NY-675) broke bud on May 20 to the day on which the 28th source (MI-748) broke bud is little more than a week. The final source to open, WV-665, was on June 2. It should also be noted that among the five earliest sources to break bud there is a wide range of elevations, from 620 ft. to 1475 ft. It seems clear that no significant differences in date of bud burst exist at the Newport plantation.

Bud Set

The differences between provenances for date of bud set were highly significant (Table 2). Date of bud set was also negatively correlated with both latitude and elevation of original seed source. In other words, sources from higher elevations and more northerly latitudes tended to set bud earlier. The five seed sources which set bud latest, including KY-725 (the tallest provenance in 1985), were all from the southern range in this test.

Table 1 illustrates the contrast between the results for bud set and those for date of bud burst. First, the range of dates is wider, with over 3 weeks between the first and last bud sets. The two sources which set bud earliest, ONT-734 and QUE-719, are among the most northerly sources in the test, while the five sources setting bud latest are uniformly from the more southerly range.

The plantation average for bud burst was May 25th, while the average for bud set was July 27th. This gives an average growing season of 9 weeks, a finding similar to that of Bey and Phares (1968) who found that 90% of height growth took place in 8-10 weeks, ending in mid-July. The length of growing season ranged from 54.58 days for QUE-719 to 72.94 days for PA-697.

Length of the Dominant Shoot

There was highly significant variation between provenances in the length of the dominant shoot, as shown by Table 2. Although the replication x provenance interaction also proved to be significant, there was no significant difference between the replications. Table 4 shows the results of the correlation of the length of the dominant shoot with elevation, latitude, adjusted latitude, and longitude. Correlation with adjusted latitude produced a highly significant negative result, while the correlation with longitude produced a non-significant result.

The close relationship between the length of the dominant shoot and height growth is illustrated by Table 6. Of the ten sources with the longest average dominant shoots, five have consistently been in the top ten for growth, and three were in the top ten at least two out of the four years. The former five includes KY-725 and MI-702, the two top-ranked sources for total height in

1985. The latter three includes VT-654 and PA-695, two sources noted earlier for their swift rise in the height rankings.

Table 6.--Ten black walnut provenances with greatest mean length of dominant shoot in 1985

Source	Mean Length (cm)
KY-817*	31.036
MI-702**	28.787
PA-695*	28.021
NJ-699**	25.875
KY-725**	25.600
IL-815**	24.221
IL-814	23.864
NY-675	23.838
IA-741**	23.800
VT-654*	23.464

* = inconsistently in top ten for height.
** = consistently in top ten for height.

Winter Damage

Two aspects of winter damage, percent of the terminal damaged and the number of dead trees/plot, were examined in 1983 and 1985. Neither of these variables produced significant variation between the provenances in either of the two years. A similar lack of effects was found in the correlation of winter damage with elevation, latitude, adjusted latitude, and longitude. The only significant correlation was negative, between percent of terminal damaged and elevation of seed source for damage suffered in the winter of 1982-83. All other correlations were non-significant (Table 4).

A simple examination of the raw data, however, does show some interesting trends. First, looking at Table 7 showing the number of trees suffering mortality listed by provenance, it is seen that as far as the sources are concerned, similar amounts of damage were recorded in each winter. It is also evident that some of the better growing sources are among those most heavily damaged. Despite excellent height growth, therefore, these sources should not be recommended.

Table 8 shows the number of plots/provenance suffering an average of at least 20% dieback on the terminal leader in either of the two winters. An interesting trend here is that the list for the winter of 1982-83 contains quite a few of the better growing sources, while the list for the winter of 1984-85 contains only two, neither of which were consistently in the top ten for growth. It is important to point out that KY-725, the top grower in each of the last two measurements, appears on neither of these tables, indicating that it is well able to cope with the winter conditions in Maine.

Table 7.--Number of trees suffering mortality

Source	Winter of 1982-83	Winter of 1984-85
IN-666**	1	3
NY-675	1	1
PA-695*	1	1
PA-697	2	2
NJ-699**	2	2
NY-707	1	1
ON-731	1	1
ON-734	1	1
IN-745	0	1
IN-747	3	2
IL-814	0	1
IL-815**	0	1
KY-817*	1	2
WV-836	2	2

* = inconsistently in top ten for height.
** = consistently in top ten for height.

Table 8.--Plots averaging over 20% damage to the terminal leader

Source	Winter of 1982-83	Winter of 1984-85
VT-654*	1	1
MN-658	0	1
WV-665	0	1
IN-666**	1	0
IA-684	0	1
WI-685**	1	0
PA-695*	1	0
NJ-699**	1	0
MI-702**	1	0
MI-705	1	0
QU-719	0	1
IA-741**	1	0
IN-747	0	1
MI-748	1	0
ON-813	1	0
IL-814	2	2
IL-815**	1	0
KY-817*	1	2

* = inconsistently in top ten for height.
** = consistently in top ten for height.

Soil Sampling

Soil analysis found no significant differences between replications in soil pH, or in amounts of exchangeable phosphorus (P), potassium (K), calcium (C), and magnesium (Mg). Average soil pH was 5.0. The nutrients K, Ca, and Mg were uniformly low, while P was ranked as medium on a scale with high as the ideal.

Before sampling, it was thought that micro-site nutrient differences might have been responsible for the differences between replications, especially in regards to height growth. This, apparently, is not the case. The results of the soil analysis indicating a low pH and low levels of exchangeable nutrients may, in part, explain the slower than average growth of black walnut on this site. According to Fowells (1965), walnut is sensitive to soil conditions, and grows best on fertile, nearly neutral soils.

CONCLUSIONS

Geographic variation was found in black walnut for height growth, date of bud set, and length of dominant shoot. In all of these cases, there was significant negative correlation with elevation and/or latitude of the seed source. Length of the dominant shoot in 1985 indicates that many of the tallest sources put on more growth in this year than their shorter counterparts, suggesting that the differences between the sources in height growth which are evident now will continue to increase in the future.

The survival and winter damage results confirm Bey's (1979) conclusion that there is a great deal of inherent cold hardiness in black walnut when planting in Maine. There is often little choice but to exceed the 200 mile south of the plantation limit suggested by Bey and by Clausen (1983). On the basis of these early results, however, it is clear that some sources are able to survive to grow well under the conditions experienced in 1980-85 in central Maine.

Among the provenances tested here, provenance KY-725 appears to be the best suited to Maine conditions. This source was ranked first in height growth in both 1984 and 1985, and although it was one of the sources to set bud latest, it suffered no appreciable winter damage. Another good choice would be provenance MI-702, ranked second in height growth in 1985. Source 702 suffered no mortality due to winter conditions, and though one plot had an average of over 20% damage to the terminal leader in 1983, this was not repeated in the winter of 1984-1985. Based on results in older provenance tests, recommendations at age six should be viewed as provisional. Over the next five to ten years, continued observations should lead to reliable seed source recommendations which will include evaluation of tree form as well as updated measurements of growth and survival.

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