QUALITY DYNAMICS IN YOUNG BLACK WALNUT TREES[1]

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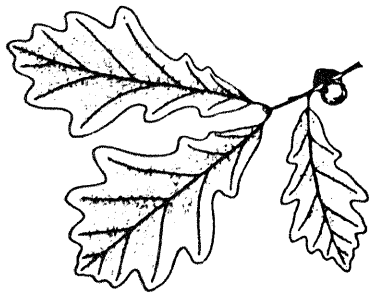

ABSTRACT.--Young black walnut trees were rated for quality each year during the second to the seventh year after planting. There was an initial change to more low quality trees between the second and third years, followed by a gradual increase in the number of higher quality trees through the seventh year. Most of the trees experienced quality changes during the study period. Positive changes in quality occurred more often if the trees were growing vigorously. The observed changes appear to be compatible with current understanding of tree physiology.

High quality black walnut (Juglans nigra L.) trees command higher prices than any other American tree species; therefore, numerous plantings of walnut trees have been made by private, industrial, state, and federal landowners. Since low quality walnut trees have far less value, walnut growers are concerned about maintaining straight, single-stemmed seedlings during the years following planting. In response, the research community has provided corrective pruning techniques for improving seedling form (Beineke 1977, Bey 1972, Krajicek and Bey 1969).

von Althen (1977) determined that corrective pruning could increase the number of excellent and good quality trees severely injured by a late frost. For the usual defects in form, however, the recommendations for correction are usually based more on general observations rather than on designed experiments and controlled observations. Studies of sapling-sized trees have shown that substantial improvement in form and quality can take place naturally for sugar maple (Acer saccharum Marsh.) (Jacobs 1969, Trimble 1968), for red oak (Quercus rubra L.) (Carvell 1967) and for black walnut (Schlesinger and Bey 1978). The objective of this study was to document the quality changes occurring during the second through the seventh year following planting of black walnut seedlings and to examine the patterns of change.

METHODS

One hundred and twenty trees were selected at random, two each from the 60 plots (5 blocks of 12 treatments) of a study designed to test 12 levels of intensive culture, including various combinations of spacing, corrective pruning, interplanting with autumn-olive (Elaeagnus umbellata Thunb.), fertilization, and pest management. Ten trees were lost to flooding early in the study, so this paper is based on the remaining 110 trees.

The intensive culture study was established in 1977 in southern Illinois (Jackson County) on a bottomland site. The silt loam soil is a coarse-silty, mixed, non-acid, mesic Aeric Fluvaquent. Black walnut seedlings (1-0 stock) were planted in the spring. Weed control was applied annually for the first 3 years using 4.5 kg/ha (active ingredient) of simazine[3] in 1.5 m diameter spots around

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[3]Mention of a commercial product does not imply endorsement by the United States Department of Agriculture. This research involves the use of pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered by the appropriate State and/or Federal agencies before they can be recommended. CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticide and pesticide containers.

each tree. The 2 spacings tested were 3.66 m by 3.66 m and 1.83 m by 3.66 m. Corrective pruning consisted of removing or reducing of forks in the spring of the third and the fourth growing seasons.

Autumn-olive was interplanted with the walnut trees, creating an overall spacing of 1.83 m by 3.66 m. In the fertilized plots, 840 kg/ha of 12-12-12 fertilizer (NPK) were broadcast on a 1.5 m diameter spot around each individual tree at the beginning of the third growing season. A general purpose insecticide and fungicide mixture (active ingredients carbaryl and benomyl applied at rates of 0.56 kg/ha and 1.12 kg/ha respectively) was sprayed at least 4 times/year for the first 5 years on the pest management plots.

The trees selected for study were initially photographed after the second growing season. Each tree was photographed from two positions at right angles to one another. Repeat photographs were made after the third, fourth, and fifth growing seasons from the same positions as the originals. The growth of autumn-olive precluded the use of photographs after the fifth year.

Total height was measured annually, and dbh (diameter at 1.37 m) was measured annually after the third year. The trees were inspected periodically and observations of damage recorded. Each tree was also rated annually as to its potential for developing into a high quality tree. The quality of large trees can be evaluated reasonably objectively using published guidelines (King 1957). However, rating systems for small trees generally rely on more subjective classification (e.g. Trimble 1968, von Althen 1977). The system used in this study consisted of the following 6 categories:

1. Excellent. A straight tree with a single, strong leader, no scars or seams on the bole, and a well-shaped crown.

2. Good. A straight tree with a single leader, no scars or seams on the bole.

3. Average. A generally straight tree with a single leader, minor sweep and/or a minor scar or seam allowed.

4. Fair. A tree with two or three leaders, with some sweep, crook, scars, and/or seams on the bole.

5. Poor. A tree with no obvious leader, with major sweep, crook, scars, and/or seams.

6. Impossible. A tree with no obvious leader or with top breakage, extensive sweep, crook, scars, and/or seams, and with apparently no hope of recovery.

The categories were recorded using an even number from 0 (excellent) to 10 (impossible); odd numbers were assigned to trees that did not clearly belong within one of the 6 defined categories.

Changes in tree quality were assessed by comparing the quality ratings from year to year and by comparing the series of photographs for each tree. Quality distributions were obtained by summarizing the data into quality classes. These distributions were analyzed for changes using chi-square tests for significant (5% level) and highly significant (1% level) differences. For some analyses, the data set was subdivided into groups based on the main study treatments. The summarized quality distributions for each year were smoothed with a 3-term running average because tests of the quality rating system showed that ratings by different people, or by the same person at different times, were identical only 40% of the time, but within 1 unit 90% of the time.

RESULTS

Because corrective pruning is an intensive culture treatment intended to correct poor form, its application to some of the trees could affect the quality comparisons. Therefore, the fourth year quality distributions from the plots in which trees were correctively pruned as needed were compared to distributions from the remaining plots (table 1). One might expect the 4-year data, which were collected 1 or 2 years after any actual pruning, to be most different. The calculated chi-square value of 2.64 was not significant at the 5% level, and indeed was of a magnitude that could be expected 85% of the time by chance. Other years showed similar results. Therefore, the data for all 110 trees were pooled for further analysis.

TABLE 1.--Comparison of treatments with and without corrective pruning after four growing seasons.

Quality class	Treatments	
	with	without
	(percent of trees)	
0,1,2[a]	2.70	2.29
3	6.30	6.40
4	13.51	17.36
5	27.03	25.58
6	27.03	26.48
7	18.92	15.52
8,9,10	4.51	6.40

[a]Classes were combined in order that all cells in the table would be equal to or greater than 1, as required for the analysis

The quality dynamics were assessed on both the population level and the individual tree level. On the population level, two periods of change were evident in the distribution of trees within quality classes (table 2). The first occurred between the second and third years, and the second between the fourth and fifth years. After two growing seasons 33 of the trees had good to excellent potential and 79 were at least average or better. However, by the end of the third year, only 3 were potentially high quality (classes 0-2) and only 30 were average or better (classes 0-4). Comparison of the second and

third year distributions, smoothed with a 3-term running average, revealed a highly significant difference between years (table 3). The primary changes occurred in the high quality group (0-2), which decreased from 34.0 trees to 4.7 and in classes 6 and 7, which increased from 10.0 trees to 25.6 and from 5.7 trees to 18.7, respectively.

TABLE 2.--Number of trees by quality class.

Quality class	Year					
	2nd	3rd	4th	5th	6th	7th
0	4	0	0	0	0	0
1	8	0	0	3	5	5
2	21	3	1	8	4	8
3	24	8	6	7	15	7
4	22	19	14	19	16	24
5	13	23	33	9	22	15
6	13	40	39	31	24	25
7	4	14	16	14	10	12
8	0	2	0	19	14	11
9	1	1	0	0	0	3
10	0	0	1	0	0	0

TABLE 3.--Comparisons of smoothed quality distributions using Chi-square.

Quality class	2nd	3rd	4th	5th	6th	7th
	(Number of trees)					
0,1,2[a]	34.0	4.7	2.7	10.7	12.7	12.7
3	22.3	10.0	7.0	11.3	11.7	13.0
4	19.7	16.7	17.7	11.7	17.7	15.3
5	16.0	27.3	28.7	19.7	20.6	21.4
6	10.0	25.6	29.3	18.0	18.6	17.3
7	5.7	18.7	18.3	21.3	16.0	16.0
8,9,10	2.3	7.0	6.3	17.3	12.7	14.3
Chi-square[b]	104.3**[c]	2.5	55.5**	1.3	0.2	

Value of chi-square for alpha of .05 = 14.07

Value of chi-square for alpha of .01 = 18.48

[a]See footnote on table 1

[b]Compares the distribution in year n to that in year n-1 for n = 3...7

[c]"**" indicates a highly significant statistical difference

The distributions did not change significantly between the third and fourth years. The second significant difference was between the fourth and fifth years (table 3). The primary changes occurred at the extremes of the distribution. Both the 0-2 class and the 8-10 class increased, from 2.7 trees to 10.7 and from 6.3 trees to 17.3, respectively. Changes between years 5 and 6 and between 6 and 7 were not significant.

The significant changes can be summarized as changes in the shape of the quality distributions. The distribution in the second year was skewed toward the higher quality classes (fig. 1). The third year distribution showed a higher peak and a shift toward the lower quality classes, as did the fourth year distribution (not shown in the figure). The fifth year distribution had a lower peak and showed an increase in both the higher quality and the lower quality classes. The sixth and seventh year distributions were similar to the fifth year.

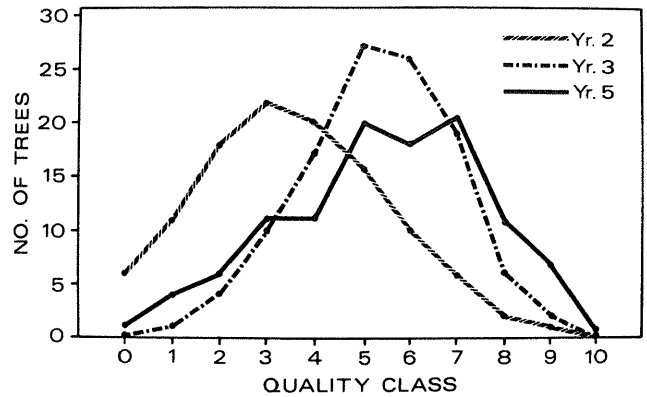

FIGURE 1.--Changes in the shapes of the quality distributions.

When the plantation as a whole is looked at, the percentage of trees of average or better quality is important. In this study, the number of trees of average or better quality was 79 after 2 years, declined to 21 after years, and then increased to 44 at 7 years (table 2).

On the individual tree level, the quality dynamics were examined for year-to-year variation and for variation over the entire 6-year period. From the second to the third year, 66 trees declined in quality and only 4 increased (table 4). These changes correspond with the first change in the shape of the quality distributions (fig. 1). There was little change between the third and fourth years, with 92 of 110 trees remaining essentially the same. From the fourth to the fifth years, 17 declined in quality and 19 increased. These changes correspond to the second change in the shape of the quality distributions. During the last two intervals, more trees improved than declined, although the shape of the overall distributions did not change significantly.

To determine if the gradual improvement in quality during the last two years of the study was related to tree vigor, the data set was divided into three groups based on the parent study treatments. Five treatments (44 trees) with autumn-olive comprised the "fast" growing group, three treatments (30 trees) including pest management but not autumn-olive made up the "medium" growing group, and four treatments (36 trees) without either autumn-olive or pest management made up the "slow" group.

A contingency table analysis of the seventh year quality distributions showed no statistically significant differences among these groups (table 5).

However, between the sixth and seventh years, 10 of the 44 trees in the fast growth group improved in quality but only 1 of 30 and 1 of 36 in the medium and slow growth groups, respectively. The numbers of trees declining in quality were 2, 2, and 5 for the fast, medium, and slow groups. Contingency table analysis of the number of trees improving, remaining the same, and declining within the groups was significant, with the number of trees in the fast, improved group being greater than "expected".

TABLE 4.--Number of individual trees changing in quality from year to year.

Units of change	Year (n) to Year (n+1)				
	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7
	(Number of trees)				
+6[a]	0	0	1	0	0
+5	0	0	0	0	0
+4 (improved)	1	1	3	4	0
+3	0	0	5	4	4
+2	3	8	10	15	8
+1	7	22	16	23	24
0 (same)	15	39	30	34	30
-1	18	31	28	19	35
-2	28	5	14	10	7
-3	22	3	1	0	1
-4 (declined)	11	0	1	0	1
-5	4	1	0	0	0
-6	0	0	1	0	0
-7	1	0	0	0	0

[a]Changes are given by the number of quality classes the trees improved (+) or declined (-). Changes of 1 unit are considered no change because of the aforementioned precision of the quality rating system

TABLE 5.--Characteristics of vigor group.

Item	Slow	Medium	Fast
# of trees	36	30	44
Dbh year 7 (cm)	2.5	4.2	7.8
Dbh growth (mean)	0.2	0.5	1.6
Ht year 7 (m)	2.7	3.4	6.1
Ht growth (mean)	0.2	0.3	0.9
	(Number of trees)		
Quality 1	0	1	4
2	1	2	5
3	2	1	4
4	3	8	13
5	4	4	7
6	10	8	7
7	8	3	1
8	7	2	2
9	1	1	1

Calculated chi-square = 17.40

Chi-square for alpha of .05 = 21.03

Most of the trees experienced quality changes during the 6-year period. Out of 110 trees, 102 changed by at least ± 2 units. Indeed, 57 trees changed by 2 or more quality classes (± 4 units) and 9 changed by ± 6 units. The more desirable trees are those of average (class 4) or better quality, trees of fair (class 6) or less being undesirable, with 5 being a transition rating. Using these classification criteria, 8 trees were desirable for all 6 years and an additional 11 were either desirable or in the transition class for all years (table 6). At the other extreme, 7 were always undesirable and an additional 8 were either undesirable or in the transition class. Thus, 76 trees were desirable in some years and undesirable in other years during the study period.

TABLE 6.--Desirability during the 6-year period.

Not desirable[a] for n years	Desirable for n years						
	0	1	2	3	4	5	6
	(Number of trees)						
0				1	5[b]	5	8
1			2	6	5	2	
2		3	10	5	3		
3	1	8	3	2			
4	3	9	6				
5	4	12					
6	7						

[a]Trees rated 6 through 10 were classified as not desirable and trees rated 0 through 4 as desirable, with class 5 being a transition rating

[b]E.g., 5 trees were rated 5 or better for 4 years, never rated 6 or worse, and thus were in the transition class for the other 2 years

DISCUSSION

This study shows that changes in potential quality are quite common during the early development of black walnut trees. Extreme events, such as the late frost observed by von Althen (1977), can result in an immediate and obvious decline in quality affecting most of the trees in a planting. No such extreme events occurred in this study, yet the majority of the trees underwent quality changes. Although this situation may at first seem surprising, it can readily be explained in light of current understanding of tree physiology.

The growth habit of black walnut generally fits that classified as deliquescent (Brown et al. 1967), in which the lateral branches grow almost as fast as, or sometimes faster than, the terminal shoot. However, branch growth is generally suppressed on the current year's shoot, with the result that young seedlings are usually single, unbranched stems (fig. 2). Thus, most young seedlings initially have high quality potential.

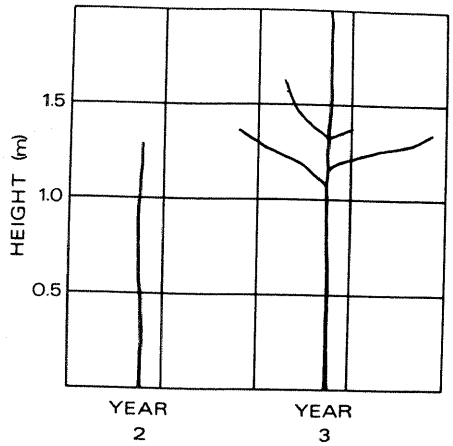

FIGURE 2.--Suppression of branching on current year's shoot. (Tree silhouettes were made by projecting photographic negatives through a photographic enlarger onto a grid and tracing the tree image.)

Several factors can cause single-stemmed seedlings to develop multiple stems and other quality defects. Factors observed during this study included: deer damage to both the terminal shoots and to the lower stem; insect damage to the terminal buds in the spring, including bud borers (Acrobasis demotella Grote) and leaf feeders that destroy the expanding leaves; stem borers (Xylosandrus germanus Blandf.) that kill the aboveground portion of the tree; and death of the terminal buds from unknown causes during the dormant period. Other factors contributing to a decline in quality that have frequently been observed in black walnut plantings, but were not noted in this particular study, include spring frost damage, wind breakage, breakage by birds, and dieback from "transplant shock" (Schlesinger and Funk 1977, von Althen 1977).

In addition to the above negative factors, a reduction in growth rate may result in lower quality. Severe competition has been shown to cause seedlings and saplings of white oak (Quercus alba L.) and sugar maple to develop flat topped crowns when growing in the understory of dense forest stands (Carvell 1967). In the present study, grasses reinvaded the plots following the 3 years of weed control except for the autumn-olive plots, in which the shade from the autumn-olive plants maintained a grass free understory. This competition with the grasses might have been the cause of reduced growth in treatments which did not include autumn-olive.

Factors that operate counter to the above and that can result in quality improvement generally relate to growth processes that allow a tree to compete efficiently (Wilson and Archer 1979). Black walnut saplings appear to overcome lean through a geotropic response (Schlesinger and Bey 1978) and seedlings might be expected to do likewise. Although the mechanism underlying tropic responses has not been satisfactorily defined (Firn and Digby 1980), the phenomenon itself is well established.

The loss of terminal dominance can result in major quality problems (fig. 3). One difference between the excurrent and deliquescent growth habits is the degree of apical control expressed (Brown et al. 1967). Although black walnut is not expected to express strong apical control since it generally fits the deliquescent growth habit, Schlesinger and Bey (1978) observed evidence of apical control in walnut saplings. Several seedlings in this study developed in a manner compatible with strong apical control (fig. 4).

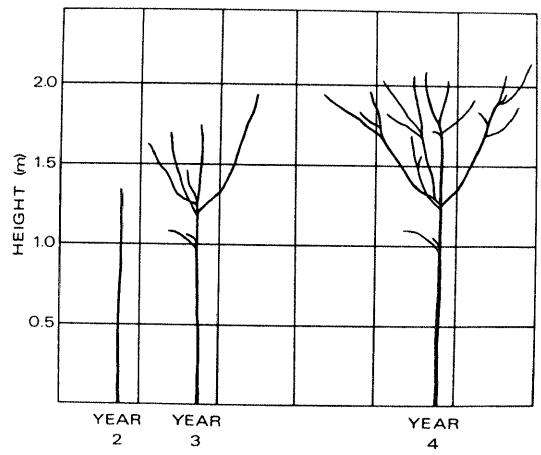

FIGURE 3.--Apparent lack of apical control and loss of single, central stem.

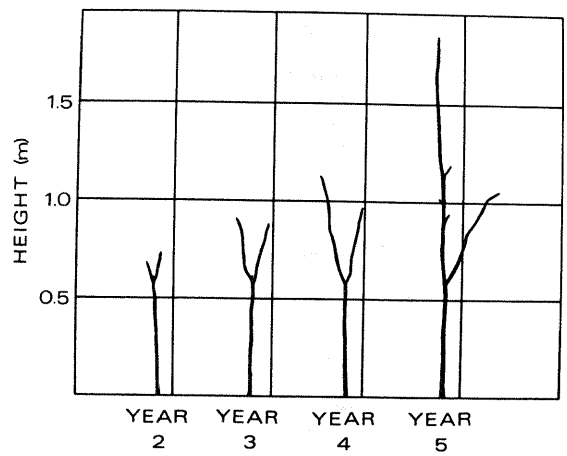

FIGURE 4.--Apparent expression of apical control.

Previously suppressed white and red oak (Carvell 1967) and sugar maple saplings (Trimble 1968) regained a single, dominant stem once they were released from overstory competition. Brown et al. (1967) suggested that vigorous growth is important in both excurrent and deliquescent growth forms for developing and maintaining a single, dominant stem. The quality recovery evident in the fast growing group in this study supports these generalizations and observations with other species.

The change in the quality distribution between years 2 and 3 thus appears to be the cumulative effects of a variety of negative factors acting upon individual trees. Because the seedlings were generally high quality at planting time, there was

little opportunity for improvement but considerable opportunity for decline in quality. The second period of change, between the fourth and fifth years, corresponds to the age found in other mixed plantings of walnut with autumn-olive at which the benefits of the autumn-olive are first apparent (Funk et al. 1979). Improved growing conditions for some of the study trees resulted in gains in quality, while various negative factors were acting upon other trees, with the result that both the high quality and low quality groups increased. Following the abrupt change in the distribution, there was a continued improvement in quality within the fast growing group (i.e., those growing with autumn-olive), and relatively little change in quality within the other groups.

CONCLUSIONS

Quality changes in black walnut trees have been observed following extreme events such as late frosts (von Althen 1977). The present study showed that quality changes can be expected to occur even with normal conditions and that most walnut seedlings will experience changes in quality during the first 7 years after planting.

Since most walnut seedlings are straight, single-stemmed trees when planted, and thus have high quality potential, the initial changes in quality are the result of external factors causing a reduction in quality. Later changes can result in higher quality, lower quality, or one followed by the other. Positive changes in quality are more likely to occur if the trees are growing vigorously.

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