BLACK WALNUT TREE GROWTH IN A MIXED SPECIES, UPLAND HARDWOOD STAND IN SOUTHERN INDIANA

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Abstract: A study was initiated in 1971 on Purdue University woodlands in southern Indiana to monitor the growth of black walnut trees in a natural, unmanaged evenaged stand. Objectives included documentation of walnut growth rates and survival in the absence of management, as well as establishing stand and tree development data baselines prior to initiation of management activities. Individual-tree periodic diameter growth rates were determined and analyzed in relation to tree crown class, stem diameter, and both overstory and understory stocking levels. Growth and survival data suggest that walnuts of intermediate or suppressed crown classes are of doubtful suitability as potential crop trees. Basal area measurements on .05-acre plots surrounding study trees were segregated into overstory and understory components. Results suggested the importance of concentrating timber stand improvement efforts on releasing crowns of walnut crop trees rather than controlling understory vegetation.

INTRODUCTION

The occurrence of black walnut (*Juglans nigra* L.) as a component of mixed-species upland hardwood forests has historically been an important aspect of forestry and a key factor in the wood products industry in the Central States Region. An unwavering demand for the wood of black walnut has kept it at the top of the hardwood market. Intensive procurement of walnut has resulted in a dwindling supply of naturally occurring trees of high quality. As a consequence, the number of acres of agricultural land being converted to black walnut plantations continues to increase. There is also a high degree of interest in managing natural hardwood stands to produce an improved supply of walnut timber.

A remarkable shortage of information exists concerning the growth of individual black walnut trees in natural stands and their subsequent response to silvicultural practices. This paper lends some insight into the growth characteristics of black walnut trees in unmanaged mixed stands based on observations of a population of walnut trees made over the past 19 years in southern Indiana. The intent is to provide foresters and landowners with information that will

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assist in making rational decisions relating to improving walnut growth in the mixed hardwood type.

METHODS AND ANALYSIS

In 1971, 92 black walnut trees were located and chosen for study in a mixed-species hardwood stand on the Southern Indiana Purdue Agricultural Center (SIPAC) in Dubois County, Indiana. These trees are situated on a moist, generally north-facing site, on middle to lower slope positions. Soils are of the Gilpin-Berks complex, have silt loam surface textures, are moderately deep to sandstone and shale parent material (20-36 inches), and are well drained (Wingard 1980). Slopes range from 20 to 50 percent. In 1989, the stand was fully stocked (Gingrich 1967), averaging 119 sq. ft. per acre basal area. Common associated overstory trees are hickories (*Carya* spp. Nutt.), yellow-poplar (*Liriodendron tulipifera* L.), sugar maple (*Acer saccharum* Marsh.), white ash (*Fraxinus americana* L.), red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), and chinkapin oak (*Q. muehlenbergii* Engelm). The stand is evenaged, as indicated by observed stand structure. Site index for red oak is 80-85. Increment borings of 7 codominant trees from different parts of the stand gave ages ranging from 76 to 85 years in 1989. A strong component of sapling and pole-sized sugar maple is currently present in the understory.

In 1971, all black walnut study trees were assigned a permanent identification number and were measured for diameter at breast height (DBH) to the nearest 0.1 inch. Initial tree diameters for the 92 walnuts ranged from 6.8 to 19.5 inches. In 1982, DBH of surviving walnuts was remeasured, providing diameter growth information over twelve growing seasons. Diameter was the only tree characteristic recorded in both the initial and second measurements.

Following the 1989 growing season, another remeasurement was made of surviving study trees, providing a second, seven-year period of known growth rates. In this recent survey, a variety of tree characteristics and stand parameters were recorded. These included walnut DBH, individual tree crown class (dominant, codominant, intermediate, suppressed), basal area of all stems 3.0 inches or larger DBH on a .05-acre circular plot surrounding each walnut, basal area of overstory trees only (trees competing with walnuts for crown space) on the same .05-acre plots, a 10 BAF prism sample of basal area surrounding each walnut, and number of epicormic branches on merchantable stems of each study tree. Diameter growth rates of trees during this 19-year study period were analyzed using analysis of variance and regression techniques.

RESULTS AND DISCUSSION

Survival

After 19 years, 83 of the original study trees have survived. Original (1971) average DBH of the nine walnuts that died was only 8.7 inches, compared with 11.7 inches original average DBH for the 83 trees that currently remain. Since individual tree crown position was not described at study initiation, it is not possible to correlate initial crown class with 19-year survival or growth rates. However, it is reasonable to assume that in evenaged stands, intolerant tree species (such as black walnut) with relatively small stem diameters generally have small crowns, and are most likely to be individuals that are in the process of being overtopped. Such suppressed or weak-intermediate trees, in this case black walnuts, are most certainly the individuals that have died over the past 19 years. None of the surviving walnuts in 1989 had suppressed crowns, and only about one-fourth of the 83 survivors were intermediate in crown class. Considering the intolerance of black walnut to shading, it is to be expected that in this maturing and fully-stocked mixed species stand, small diameter/small crowned walnut trees are being crowded out. It is probable that additional weak-intermediate trees will die in this stand in the future.

Diameter Growth

The average annual DBH growth of the 83 surviving trees was 0.13 inches for the 19-year period. This rate compares favorably with results from regional growth summaries for black walnut for Indiana-Illinois, 0.13 (Smith and Shifley 1984), for Indiana, 0.12 (Kershaw and Fischer 1985) and Missouri, 0.11 (Shifley and Smith 1982).

Not surprisingly, black walnut trees with the larger stem diameters and the largest crowns in 1989 were those making the most rapid current diameter growth. Dominant trees grew at an average rate of 0.18 inch/year over the 19-year study period, compared to 0.13 and 0.08 inch/year, respectively, for codominant and intermediate trees (Table 1). Intermediate class walnut trees consistently had the smallest stem diameters and the slowest current (1983-89) growth rates. Phares and Williams (1971) found that unreleased, pole-sized walnuts with intermediate to codominant crown positions averaged only 0.06 inches annual DBH growth.

As shown in Table 2, walnuts with small initial diameters (8 to 10 inch DBH classes) in 1971 had much slower growth rates than did larger diameter trees (16 and 18 inches DBH classes). This trend held true for both measurement periods. Presently (1989) the smallest diameter trees are growing at only about half the annual increment (.08 inch/year) as are the largest study trees (0.16 inch/year). Such findings, in combination with the higher rate of mortality for small diameter trees as noted previously, illustrate why intermediate class and smaller-than-average-diameter walnut trees are usually poor candidates for selection as crop trees.

Table 1.--Black walnut diameter growth by crown class.

1989 Crown Class	Number trees per class	19-year average annual growth	Period 1 (1971-82) Annual Increment	Period 1 (1971-82) Range	Period 2 (1983-89) Annual Increment	Period 2 (1983-89) Range
		(in.)	(in.)	(in.)	(in.)	(in.)
Dominant	13	.18	.20 a[1]	.12-.29	.15 a	.10-.21
Codominant	48	.13	.14 b	.05-.28	.11 b	.01-.24
Intermediate	22	.08	.09 c	.03-.19	.07 c	.01-.18

[1] Column values followed by the same letter are not significantly different (p < .05), based on Duncan's New Multiple Range Test.

Table 2.--Black walnut diameter growth by DBH class for 2 measurement periods.

Initial DBH Class (1971)	Number trees per class	Period 1 (1971-82) Avg. Annual Growth	Period 1 (1971-82) Range	Period 2 (1983-89) Avg. Annual Growth	Period 2 (1983-89) Range
(in.) (in.)		(in.)	(in.)	(in.)	
8	15	0.11 a[1]	.05-.21	0.08 a	.01-.18
10	30	0.13 a	.03-.29	0.10 ab	.03-.18
12	14	0.15 ab	.05-.26	0.12 ab	.01-.24
14	15	0.14 a	.05-.22	0.11 ab	.01-.20
16	5	0.16 ab	.07-.24	0.14 b	.06-.21
18	4	0.21 b	.08-.28	0.16 b	.09-.21

[1] Column values followed by the same letter are not significantly different (p < .05), based on Duncan's New Multiple Range Test.

Diameter growth rates are decreasing for walnut trees in all crown classes (Table 1). For dominant trees, diameter increment averaged 0.20 inch per year for 1971-1982, but dropped to 0.15 inch per year during the 1983-1989 growing seasons. Codominant and intermediate DBH growth averaged 0.14 and 0.09 inches per year, respectively, during 1971-1982, but was down to 0.11 and 0.07 inches per year for 1983-1989. Increases in stem circumference, increasing stand density, and drier-than-normal growing conditions during the latter growth period are likely contributing causes of this decline in DBH increment. It is apparent that some type of partial harvest or timber stand improvement (TSI) treatment would be appropriate in the near future if a management goal is to improve the growth of walnut trees in this stand.

Diameter of trees 3.0 inches DBH and greater was measured on .05-acre plots and on 10 BAF prism points around each walnut tree, and basal area was compared with tree diameter increment. It was hypothesized that total plot or point basal area (including both overstory and understory trees) might provide an easily obtainable competition index for predicting current diameter growth. However, correlation analysis showed no evidence of a relationship between walnut DBH growth and either total plot or point basal area. An attempt was also made in this study to identify some combination of observable factors in a mixed stand that may be used to predict walnut growth and survival. A multiple regression analysis showed that crown class, in combination with current DBH (relative to average stand diameter) was the most consistent predictor of diameter increment ($r^2 = 0.3516$, $F = 21.7$; $df = 82$), and was somewhat better than using crown class alone ($r^2 = 0.3096$). Although the relationship is not strong, this evidence does indicate that a refinement of a multi-variable growth prediction model for naturally-occurring walnut trees should certainly include some measure of crown competition. However, non-subjective methods for evaluating crown competition in natural, mixed species hardwood stands have yet to be developed.

Interestingly, the largest and fastest growing walnut trees (dominants) in this study also had the heaviest understory competition, as measured by basal area of suppressed and intermediate trees in the .05-acre plot around each walnut (Table 3). Such results strongly support the idea that the growth of black walnut and other intolerant species on good sites is influenced more by availability of light (crown space) than by any other factor. At any rate, faster diameter growth rates in this stand are clearly not associated with lower levels of understory competition.

Table 3.--Average basal area around walnut trees in three crown classes, as measured on 0.05-acre plots with individual trees as plot center.

1989 Crown Position	Total Basal Area 0.05-acre Plot	Per Acre	Understory Basal Area 0.05-acre Plot	Per Acre
	(ft^2)	(ft^2)	(ft^2)	(ft^2)
Dominant	4.80 a[1]	96.0	2.76 a	55.2
Codominant	5.20 a	104.0	1.77 b	35.4
Intermediate	5.29 a	105.8	1.45 b	28.9

[1] Column values followed by the same letter are not significantly different ($p < .05$), based on Duncan's New Multiple Range Test.

Correlation analysis (Figure 1) showed that diameter growth for the second measurement period is strongly dependent on diameter growth rate in the first period ($r^2 = 0.5570$). In other words, past growth predicts future growth in unmanaged/undisturbed stands. The implication is that periodic measurements may provide especially useful information for the management of woodlands containing high value trees. However, foresters rarely have such information available and are understandably hesitant to obtain growth rate information by the increment coring of potentially high value trees.

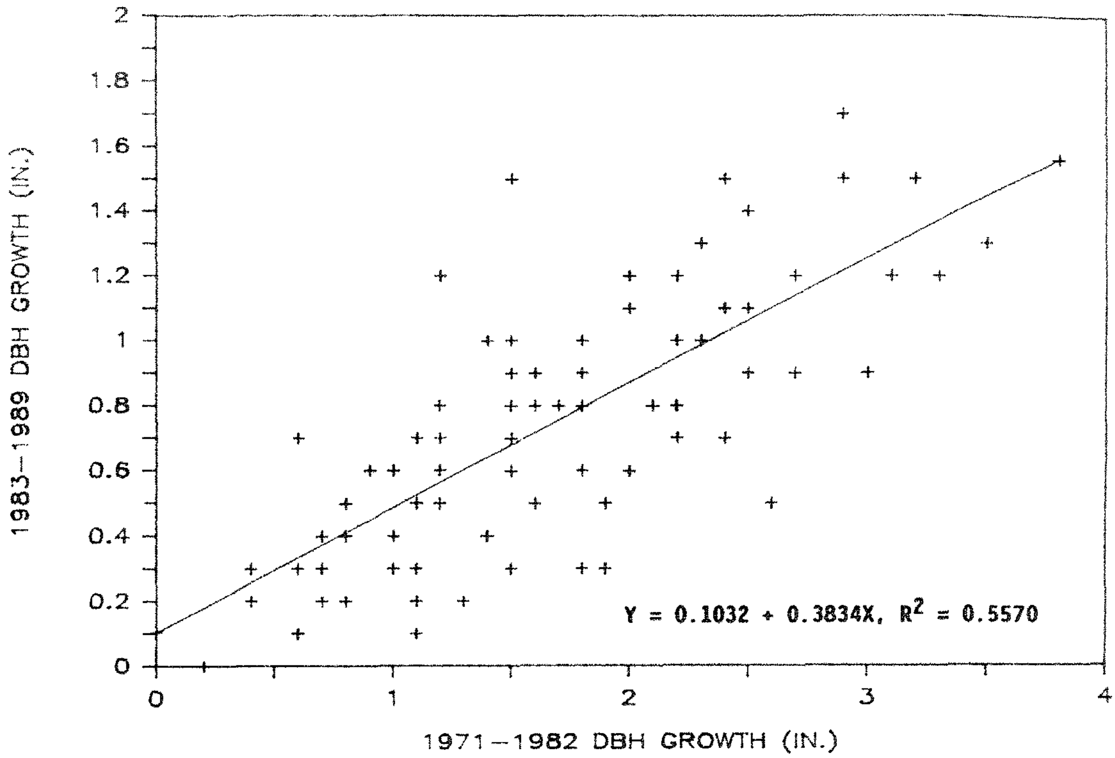

Figure 1. Diameter growth for 83 black walnut trees showing relationship of the first period rate (1971-82) to the second period (1983-89).

What then, is the best method for obtaining information concerning individual tree growth rates? One approach would be to implement continuous forest inventory (CFI) systems involving permanent re-measurement plots or mapped individual trees. Though intensive and time-consuming, systematic approaches for quantifying growth and yield should be considered as potentially useful management tools, especially for high-value hardwood stands with a substantial black walnut component.

SUMMARY

A goal of this investigation was to identify single factors or a combination of tree and stand attributes that can be used to give a consistent prediction of current individual walnut diameter growth rates. Such a system should aid in crop tree identification, assist in avoiding unnecessary TSI work, and improve timber marking decisions. Crown class, in combination with tree diameter relative to the stand average, was found to be the best indicator of current DBH increment.

One of the measurements in this study included a separate tally of understory tree basal area. Such a description of stocking density can be used as an indirect expression of root competition, since understory trees in this study stand were in no way competing with walnuts for crown space. Since higher levels of understory stocking were not correlated with lower rates of walnut diameter increment, it may be inferred that walnut growth is not influenced nearly as strongly by competition for root space as it is for crown space. Therefore, TSI efforts should be concentrated on releasing black walnut crowns from low-value trees and grapevines, and not on removing understory trees. Research by Phares and Williams (1971) resulted in a similar conclusion.

Black walnut has been shown to be capable of responding to release, if trees have sufficiently full crowns and vigorous root systems (Phares and Williams 1971). However, the size and duration of the growth response must be large enough to offset the cost of the release in order to be considered a sound management decision. The ability to make such decisions depends on further study of walnut response to release in a combination of stand conditions, soil types, geographic locations, and economic situations.

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