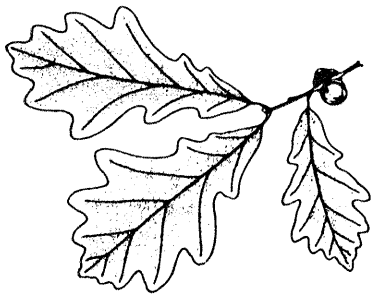
RELEASE AND FERTILIZATION OF BLACK WALNUT IN NATURAL STANDS[1]

J.W. Stringer and R.F. Wittwer[2]



ABSTRACT.--A single release of pole-size black walnut (Juglans nigra L.) provided a significant 12-yr growth response in trees 12.6-22.5 cm dbh as compared with unreleased trees ($P \leq 0.01$). The mean post-treatment basal area increase was 80% above the pretreatment for released trees compared with 28% for unreleased trees. The use of 2,4-D injections in the release treatment produced "flashback" damage to 15% of the potential crop trees. Individual tree fertilization with 4.5 kg/tree ammonium nitrate yielded a 31% increase in the average basal area of the fertilized trees compared with unfertilized trees over a 3-yr period ($P \leq 0.05$). Application of 2.25 kg/tree ammonium nitrate did not significantly affect diameter growth. Foliar analysis near the end of the second season, suggested additional nitrogen could produce a further growth response.

INTRODUCTION

Intensive culture of black walnut (Juglans nigra L.) is more likely to be economically justified than any other commercial timber species. The most popular form of intensive culture is the establishment and management of plantations. As a result the majority of walnut research has focused on the various aspects of this type of culture for timber as well as nut production. However, a preponderance of naturally regenerated stands containing black walnut exists throughout the range of the species. The relative importance of walnut in these stands ranges widely from a near monoculture, to stands with scattered individuals representing an insignificant portion of the total stand basal area. However, the culture of these individual trees may have merit based on their current and/or potential log quality. The expectation of a high rate of return on the investment has spurred the interest of many timber owners into considering the application of treatments to enhance the development of these individual stems.

This paper presents the results of two studies directed at determining the effect of single-tree release, and release and fertilization on the diameter growth of young black walnut trees growing in mixed natural stands. All of the stands utilized in these studies were located in Grant County, within the Outer Bluegrass Physiographic Region of central Kentucky.

LITERATURE REVIEW

Intermediate treatments such as release and improvement cuttings are normally the first cultural treatments considered when attempting to improve the growth of individual trees in previously unmanaged stands (Schlesinger and Funk 1977; Phares 1973). However, the widespread use of these treatments without accounting for the age and condition of each stem may lead to a high degree of variability in growth response of the trees in question (Fischer 1982).

Hilt and Dale (1982) found that intermediate cuts in hardwood stands less than 20 years of age proved ineffective in substantially increasing diameter growth. However, pole-sized trees over 20-years-old have exhibited diameter growth increases upon release. Thinnings in 24- to 80-year-old oak (Quercus spp.) stands produced relative diameter growth responses negatively correlated with stand age (Hilt 1979). Release of Quercus spp. and Carya spp. in Missouri tended to prolong the continual declining growth rate (Clark and Liming (1957). Phares and Williams (1971) reported a positive relationship between the degree of release and diameter growth rates of pole-size black walnut. Fully and partially released trees maintained over 2 and 1.5 times the growth rate of unreleased trees.

---

[1]A paper presented at the Fifth Central Hardwood Forest Conference held at Urbana, Illinois on April 15-17, 1985.

[2]Research Specialist, Department of Forestry, University of Kentucky, Lexington, KY 40546-0073, and Associate Professor, Department of Forestry, University of Kentucky, presently at Department of Forestry, Oklahoma State University, Stillwater, OK.

In 1967, Clark investigated the relation between crown class and response to release of black walnut. Four years after release dominant, codominant and 'strong' intermediates were growing at twice the rate of the unreleased controls. Intermediate and overtopped trees did not respond to release.

Studies in the fertilization of black walnut have been restricted primarily to potted seedlings and young plantations (Dickson 1971; Ponder 1980; and Braun and Byrnes 1982). Results from these studies have been mixed. In some studies fertilization did significantly alter growth. Von Althen (1976) observed growth increases after fertilizing a 27-year-old black walnut plantation on former agricultural land in Ontario. Diameter growth of the largest 250 trees/ha was increased 27% by an application of 504 kg/ha ammonia nitrate, 244 kg/ha of triple superphosphate and 244 kg/ha of potassium sulfate. However, results from other field studies have shown that fertilization alone may not promote increased diameter growth. Pope et al. (1982) found fertilization with 112 kg/ha elemental N in combination with weed control increased volume 121% in a 12-year-old (treatment age) plantation in Indiana. Fifty-six kg N/a alone did not result in a statistically significant growth increase, however the addition of competition control to the fertilizer treatment produced a significant growth response. Geyer and Naughton (1979) found that both release and fertilization increased the annual growth rate of 38-year-old black walnut growing on surface mine spoil. Fertilization treatments of 373 and 746 kg/ha elemental N yielded a higher average annual growth rate compared with controls throughout the 5-yr study period.

Limited study on the effect of fertilization of naturally occurring walnut has been undertaken. However, a study of pole and sawtimber size walnut trees in Wisconsin showed that trees growing on 'medium'-fertility sites were most responsive to fertilization while trees on fertile, bottomland sites showed little or no response (Anon. 1968).

STUDY AREAS AND METHODS

Study I - Release of Pole-size Black Walnut Using 2,4-D Injections

In 1970, 100 black walnut trees were selected for study from a mixed hardwood stand approximately 0.8 hectares in size. Predominant overstory species in addition to black walnut included: Ulmus spp., and Celtis occidentalis L. Species of minor importance included Robinia pseudoacacia L., Prunus serotina Ehrh., and Sassafras albidum. Average diameter of the study trees was 15.9 cm dbh (1.3 m above ground line) ranging in age from 18 to 25 years. Diameters of the 100 study trees ranged from 8.9-22.4 cm, and were selected from the dominant, codominant and 'strong' intermediate crown classes. Eighty-four of these trees were selected for release (crop trees), the remainder acting as a control. Crop tree selection was based on stem form, potential log quality, and canopy position. Diameters (determined at 1.3 m) were determined prior to release.

Release was performed by injecting 2,4-D concentrate with a tree injector into the main stem of competing trees. Injections were spaced 5.0-7.5 cm apart near the ground line. Competing trees were considered those individuals whose canopies touched crop tree canopies. In some instances crop tree canopies were in contact; however, all trees were fully released on at least 3 sides. A few of the injected trees which did not defoliate over the course of the next growing season were injected a second time resulting in 100% mortality by the end of the second post-treatment growing season.

Diameter measurements were obtained at 6-yr intervals in 1976 and 1982. For analysis trees were grouped into 5 cm diameter classes; 7.5-12.5 (dbh class 1), 12.6-17.5 (dbh class 2), and 17.6-22.5 cm (dbh class 3).

Study II - Fertilization of Individual Trees in Natural Stands

Forty-four naturally regenerated, pole-sized black walnut trees were selected for study. The walnut trees were distributed in small groups or as individual trees in association with Ulmus spp., Celtis occidentalis L., Acer negundo L. and various upland oaks. The stands utilized in this study originated after the area was abandoned from use as pasture. To minimize growth differentials due to competition the study trees, residing as dominants or codominants were released twice (7 and 2 years) prior to fertilization. Release was implemented by using a chainsaw girdle on the competing trees to obtain full release of the study trees.

Twelve trees were growing on an alluvial stream bottom and the remainder were located on 2 adjacent side slopes. Since topographic differences suggested variability in productivity among sites, each site was treated as a block. Twelve trees were located on the alluvial bottom site, a fine, silty, mixed, mesic Dystric Fluventic Eutrochrept lying 2-3 m above an easily accessible water table. Twenty-one trees were located on the lower slope site (slope I) and 11 trees on the lower to mid-slope site (slope II). Soils on the slope sites were characterized as a fine, mixed, mesic Typic Hapludalf with a high degree of stoniness and clay content compared with the alluvial bottom. Single soil samples derived from compositing collections at 5 locations for the 0-15 and 15-30 cm depths within each block were analyzed by the University of Kentucky College of Agriculture Soil Testing Laboratory. Total N was determined by the macro Kjeldahl procedure. Phosphorus was extracted by the Bray No. 1 method and K, Ca, and Mg with 1N NH_4OAc adjusted to pH 7.0. Aliquots of these solutions were analyzed for P colorimetrically, for K and Mg by atomic absorption spectroscopy and for Ca by flame photometer. With the exception of extractable P all the nutrient levels were consistent between sites. Total N (0-30 cm depth) ranged from 0.17% (slope II) to 0.13% (slope I). Soils were slightly acidic ranging in pH from 6.8 to 5.7 for the alluvial bottom and slope I, respectively. Extractable P ranged from

76 ppm on the alluvial bottom to 4 ppm for slope II. The high degree of variation in extractable P was due to the deposition of sediment derived from the highly phosphoric Inner Bluegrass Region of Kentucky onto the alluvial bottom.

Within each block, tree diameter at 1.3 m was measured and trees assigned to groups of three with similar diameters. One of three fertilizer treatments was randomly assigned to each tree within a group. Diameters of the 44 study trees ranged from 17.8 to 26.7 cm with a mean of 21.6 cm. Treatments were: no fertilizer, and 2.25 kg/tree or 4.50 kg/tree of ammonium nitrate (33% elemental N). Before treatment, average diameter of the unfertilized trees was 21.3 cm, and for the trees to be fertilized, 22.0 cm and 21.7 cm, for the 2.25 and 4.50 kg/tree treatments, respectively. Fertilizers were applied by placement in holes punched to a depth of 30 cm with a metal bar (2.5 cm diameter) within an area defined by the crown spread of each tree. Treatments were applied in early May 1981.

Diameter measurements were made at the end of the growing season for three years. During late July of the second growing season foliage samples from near the mid-crown position at three equally spaced locations around the crown circumferences of each tree were collected, composited and analyzed for total N by the Kjeldahl method after drying and grinding in the Wiley mill.

RESULTS AND DISCUSSION

Study I. Release

GROWTH RESPONSE.--Release resulted in significant diameter and basal area growth responses of the selected crop trees (Tables 1 and 2). Annual diameter increment of released trees over the entire study period was positively related to diameter class ranging from 0.34 cm/yr (class 1 to 0.57 cm/yr (class 3). The overall mean annual diameter increment for the unreleased trees was 0.26 cm/yr. Trees comprising the 2 larger diameter classes (classes 2 and 3) exhibited a significant diameter and basal area growth response compared with non-released controls. Growth responses for diameter class 2 and 3 continued throughout the 12-yr study period although slight decreases in diameter growth were exhibited during the second 6-yr period. Mean diameter increases over the 12-yr study period was 2.4 to 5.7 cm for control and released trees, respectively. Basal area growth calculated as a percentage of the initial basal area was higher for class 3, 87.2% versus 72.9% for diameter class 2. The mean basal area percentage increase for all released trees was 79.7% compared with 27.9% for control trees. Given the average tree age of 21 years, current growth rates, and the median diameter (class 3) of released and unreleased trees a merchantable size of 45.7 cm (18 in.) could be obtained with rotation lengths of 65 years and 150 years, respectively, for released and unreleased trees.

TABLE 1.--Mean annual diameter response to release.

Time Period (yrs)	Diameter Size Class (cm) 7.5-12.5 C[1]	7.5-12.5 R	12.6-17.5 C	12.6-17.5 R	17.6-22.5 C	17.6-22.5 R
	cm					
0-6	n.d.	0.34	0.25	0.41**	0.29	0.59**
6-12	n.d.	0.34	0.24	0.38*	0.26	0.55**

[1]C = control, R = released

**Statistically greater than control at $P \leq 0.01$ using ANOVA and Duncan's Multiple Range Test.

*Statistically greater than control at $P \leq 0.05$ using ANOVA and Duncan's Multiple Range Test.

TABLE 2.--Mean annual basal area response to release.

Time Period (yrs)	Diameter Size Class (cm) 7.5-12.5 C[1]	7.5-12.5 R	12.6-17.5 C	12.6-17.5 R	17.6-22.5 C	17.6-22.5 R
	cm^2					
0-6	n.d.	6.23	6.73	10.32**	7.22	19.80**
6-12	n.d.	7.51	7.14	10.25*	9.11	21.70**

[1]C = control, R = released

**Statistically greater than control at $P \leq 0.01$ using ANOVA and Duncan's Multiple Range Test.

*Statistically greater than control at $P \leq 0.05$ using ANOVA and Duncan's Multiple Range Test.

'FLASHBACK' DAMAGE.--While the release was responsible for doubling the relative growth rate the most significant finding of this study may have come from the observed 'flashback' damage incurred by the crop trees. Necrosis of basal tissues on 12 of the crop trees was observed during the 3rd post treatment growing season. The damage was confined to a small portion of the circumference of the trees facing an adjacent injected black walnut. After 6 years these trees were exhibiting substantial degrade. All but 2 of these damaged trees were surviving after 12 years, however the 'flashback' had rendered the trees unmerchantable (fig. 1). Transmission of herbicides via root grafts has been observed and reported by various researchers (Bormann and Graham 1960; and Eis 1972). However, no accounts of herbicide transmission via root grafting in black wlanut could be found in the literature. In Kansas, Geyer and Chandler (1979) witnessed no 'flashback' damage when utilizing chemical injections of Tordon 101R (active ingredients 2,4-D and picloram)

FIGURE 1.--Flashback damage of black walnut crop tree 12 years after 2,4-D injection of a competing black walnut tree.

in black walnut stands. Normally herbicides containing picloram are known for their greater basal movement compared with herbicides containing only 2,4-D, such as was used in this study. However factors such as relatively high transporational fluxes of healthy crop trees compared with adjacent treated trees may provide for increased basal movement and transmission of this herbicide. Stands with a high percentage of their basal area occupied by a single species may contain a larger number of intra-specific root grafts and are normally considered poor candidates for herbicide treatments (Fischer 1982). This study supports this recommendation.

Study II. Release and Fertilization

DIAMETER GROWTH.--While the soil properties evaluated did not show striking differences between sites the degree of topographic variability would suggest highly variable moisture regimes. From this one might expect variation in the uptake of the fertilizer by the trees growing on different sites. However, when diameter growth data were subjected to analysis of variance no significant block-treatment interactions were indicated and data from all blocks were pooled to analyze for effects of N treatment levels (Table 3). No significant growth increases were found during the first two growing seasons. During the third year after treatment the high N-treatment level (4.5 kg/tree) resulted in a significant diameter growth increment. The total diameter increment for the 3-yr study period was also significantly increased by this treatment; the increase represented a 28% gain over the unfertilized trees.

Decreased diameter growth was observed for the third year following treatment and the mean for all fertilizer treatments was 0.13 cm less than the previous year. This may be due to precipitation trends during each of the growing seasons; June to July monthly means for the third season after treatment were 4.0 and 6.3 cm less, respectively, than the 30-yr monthly mean for these months.

BASAL AREA GROWTH.--Diameter growth of individual trees does not provide a direct measure of bolewood production; small trees would be expected to make larger diameter increments and a relatively small diameter increase on a large tree may represent more bolewood volume growth. Basal area increment provides a better measure of bolewood production since tree size is incorporated into this variable. In this study, the range of tree sizes was relatively narrow and an attempt was made to allocate the various tree size classes uniformly among the various treatment. Thus, basal area growth trends are very similar to diameter growth trends (Table 4). A significant response to the high N treatment (4.5 kg/tree) was found for the third growing season (30%) and the total 3-yr increment (31%).

TABLE 3.--Diameter growth response of black walnut to N fertilization.

Fertilizer Rate	Diameter Increment[1]			
	Year 1	Year 2	Year 3	Total
kg/tree	cm			
0	0.64a[2]	0.64a	0.56a	1.84a
2.25	0.58a	0.74a	0.48a	1.80a
4.50	0.79a	0.81a	0.76b	2.36b

[1]Mean value of 15 trees for treatments 0 and 2.25 kg/tree and 14 trees for 4.50 kg/tree treatment.

[2]Treatment means within a column followed by the same letter are not significantly different at the $P \leq 0.05$ level by Duncan's Multiple Range Test.

TABLE 4.--Basal area growth response of black walnut trees to N fertilization rates.

Fertilizer	Basal Area Increment[1]			
	Year 1	Year 2	Year 3	Total
kg/tree	cm^2			
0	22.3a[2]	22.8a	21.0a	66.1a
2.25	20.7a	26.9a	18.0a	65.6a
4.50	27.9a	29.6a	28.9b	86.4b

[1]Mean of 15 trees for treatments, 0 and 2.25 kg/tree and 14 trees for 4.5 kg/tree treatment.

[2]Means within a column followed by the same letter are not significantly different at the $P \leq 0.05$ level by Duncan's Multiple Range Test.

FOLIAR N CONCENTRATIONS.--Foliar N concentrations based on samples collected during July of the second season did not indicate significant differences due to N-fertilization rates. Treatment means were: no fertilizer - 2.05% N; 2.25 kg/tree - 2.05% N; and 4.5 kg/tree - 2.14% N. These levels appear to be consistent with guidelines suggested by Schlesinger and Funk (1977) as follows: < 2% foliar N-deficient (will probably respond to fertilization); 2.0 to 2.6% -intermediate (may or may not respond); > 2.6% -adequate (probably will not respond). In this study, foliar N levels for both fertilized and unfertilized treatments are in the intermediate range and a response was observed for the 4.5 kg/tree treatment. The observed foliar N values are based on sampling near the end of the second year after treatment when one might expect near maximum values to be found since responses to N fertilizers are often short-lived and disappear after approximately five years. The comparatively low foliar N levels associated with the N treatment producing a response in this study suggest that higher N application rates may produce an additional response. Fertilizer placement as well as competing vegetation interaction may well have negated the effect of the lower 2.25 kg/tree treatment.

CONCLUSIONS

Full release of pole-size black walnut provided for a doubling of the growth rate of the released trees compared with the controls in this study. The trees have maintained this accelerated growth over a 12-yr period. However, a subsequent intermediate cut may be necessary as canopy competition may eventually alter the current diameter growth rate. Utilization of herbicide injections to control competition from adjacent black walnut trees should be approached with caution. Alternative methods such as girdling or felling may be more appropriate for intra-specific control.

Application of 4.5 kg/tree of ammonium nitrate placed in 30 cm deep holes beneath the crown of pole-sized black walnut produced an average basal area increase of 31%, compared with unfertilized trees, during the 3-yr period following treatment. Foliar N concentrations measured for unfertilized trees indicated trees on the study site ranked 'intermediate' in nutrient status based on recommended guidelines; thus, the trees might or might not respond to added N. The comparatively low foliar N concentrations (2.14%) found for trees responding to added N in this study suggests that higher N application rates or another method of placement could produce a furhter growth response.

While the effect of fertilization was not as prominent as that of release the significant diameter growth response of released and fertilized trees indicates that fertilization may have merit. Since there were no site-fertilizer interactions noted, nitrogen fertilization may be effective on areas normally considered as 'good' black walnut sites where available nitrogen has conventionally not been considered a limiting factor. However, further investigation is needed to determine the most effective method of single-tree fertilization as well as the cost effectiveness of this type of treatment.

ACKNOWLEDGEMENTS

The authors would like to thank the Kentucky Department of Fish and Wildlife Resources and Reb Stacey for the study sites and Jim Newman (Willamette Industries, Inc.) and Jim Hurst (Kentucky Division of Forestry) for their assistance. The investigation reported in this paper (85-8-9) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director. This research was supported by the McIntire-Stennis Cooperative Forest Research Program.

LITERATURE CITED

ANONYMOUS. 1968. Walnut responds well to treatment in FPL research. For. Ind. 95(2):34-35.

BORMANN, F.H., and B.F. GRAHAM. 1960. Translocation of silvicides through root grafts. J. For. 58:402-403.

BRAUN, J.M., and W.R. BYRNES. 1982. Growth of black walnut in a fertilized plantation. pp. 79-104. IN: Proceedings, Black Walnut for the Future. USDA For. Serv. Gen. Tech. Rep. NC-74.

CLARK, F.B. 1967. Pole-size black walnut responds quickly to crown release. J. For. 65: 406-408.

CLARK, F.B., and F.G. LIMING. 1957. Low-grade hardwood stands in the Missouri Ozarks respond to stand improvement. J. For. 55:354-358.

DICKSON, R.E. 1971. The effects of soil moisture, texture, and nutrient levels on the growth of black walnut. USDA For. Serv. Res. Pap., NC-66.

EIS, S. 1972. Root grafts and their silvicultural implications. Can. J. For. Res. 2:111-120.

FISCHER, B.C. 1982. Principles of managing black walnut in natural stands. pp. 92-96. IN: Proceedings, Black Walnut for the Future. USDA For. Serv. Gen. Tech. Rep. NC-74.

GEYER, W.A., and P. CHANDLER. 1979. Tree control with injection of Garlon and Tordon brand herbicides. Down To Earth 35(3):9-13.

GEYER, W.A., and G.C. Naughton. 1979. Black walnut (Juglans nigra Linnaeus) response to release and fertilization on strip-mined lands in southeastern Kansas. Transactions of the Kansas Academy of Science 82(3):178-187.

HILT, D.E. 1979. Diameter growth of upland oaks after thinning. USDA For. Serv. Res. Pap. NE-437. 12p.

HILT, D.E., and M.E. DALE. 1982. Effects of repeated precommercial thinnings in central hardwood sapling stands. South. J. of Appl. For. 6:53-58.

PHARES, R.E. 1973. Managing immature trees for more high quality logs and related products. pp. 49-54. IN: Black Walnut as a Crop. USDA For. Serv. Gen. Tech. Rep. NC-4.

PHARES, R.E., and R.D. WILLIAMS. 1971. Crown release promotes faster diameter growth of pole-size black walnut. USDA For. Serv. Res. Note NC-124. 4p.

PONDER, F., JR. 1980. Fertilization improves black walnut growth on a poorly drained site. Tree Planters' Notes 31(4):17-19.

POPE, P.E., H.A. HOLT and W.R. CHANEY. 1982. Interaction of nitrogen fertilization and chemical weed control on a four-year volume growth of a black walnut plantation. pp.105-109. IN: Proceedings, Black Walnut for the Future. USDA For. Serv. Gen. Tech. Rep. NC-74.

SCHLESINGER, R.C., and D.T. FUNK. 1977. Manager's handbook for black walnut. USDA For. Serv. Gen. Tech. Rep. NC-38.

VON ALTHEN, F.W. 1976. Ten-year results of thinning and fertilization of a pole-sized black walnut plantation. Can. For. Serv., Sault Ste Marie, Ont. Report O-X-245. 17p.