RESPONSE OF A YOUNG BLACK WALNUT PLANTATION TO CHEMICAL WEED CONTROL AND NITROGEN FERTILIZATION

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Abstract.--Height, diameter, and volume growth of 12-year-old plantation grown black walnut (*Juglans nigra* L.) trees in response to nitrogen fertilization and chemical weed control were investigated for three years after treatment. The trees had been planted at 11 x 11 foot spacing on a Martinsville silt loam soil in Morgan County, Indiana. Nitrogen as urea was broadcast at rates of 0, 50, or 100 lbs. elemental nitrogen per acre equivalent. Herbicide treatment consisted of a combination of glyphosate and simazine, each at 4 lbs. active ingredient per acre. Trees averaged 20 ft. in height and 3.5 in. in diameter at 4.5 ft. above the ground at the initiation of the study. Untreated trees grew 5 ft. in height and 0.75 in. in diameter after three growing seasons. Only trees that received weed control and elemental nitrogen at 100 lbs. per acre were significantly taller than untreated trees. Weed control alone produced a 40% increase in height growth and a 45% increase in diameter growth over the untreated trees. Fertilization without weed control did not significantly influence height growth and increased diameter growth only when 100 lbs. nitrogen per acre was applied. The greatest three year cumulative diameter increment (1.36 in.) and total volume growth (357 cu. ft.) occurred on trees fertilized with 100 lbs. nitrogen per acre in combination with weed control. Weed control alone resulted in a 47% increase in volume growth above untreated trees after three years whereas weed control in conjunction with 100 lbs. nitrogen per acre produced a 100% increase in volume growth. Changes in foliar nitrogen levels corresponded closely with changes in volume growth.

Additional keywords: *Juglans nigra*, nitrogen, herbicides, fertilizer.

Both private and industrial woodland owners have shown increasing interest in planting and growing black walnut (*Juglans nigra* L.). Expectations of high return on investment are certainly a stimulus for this activity. Cultural techniques to hasten growth and shorten rotation are of potential value. Considerable research has been done on genetic improvement, spacing and planting methods, weed control, pruning, and fertilization, but many questions still remain (Bey and Williams, 1976; Dickson, 1971; Holt and Voeller, 1975; Krajicek, 1971, 1975; Krajicek and Williams, 1971; Schlesinger and Funk, 1977; and Williams, 1974). This paper reports a study of the

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effect of nitrogen and chemical weed control on growth of 12-year-old black walnut trees for three years after treatment. Most studies on fertilization have dealt with the response of trees to nutrients applied at the time of planting. The intent of this research was to ascertain the growth response to nitrogen fertilization and weed control of established, plantation grown black walnut trees.

METHODS

The study was established in a 12-year-old black walnut plantation planted in Morgan County, Indiana in the spring of 1965. The trees were planted at 11 x 11 ft. spacing on a Martinsville silt loam soil (Typic Hapludalfs, fine-loamy, mixed, mesic). A combination of nitrogen fertilization and/or chemical weed control was applied to a section of the plantation on May 20 and 21, 1977. The experimental design was a split plot with three replications of each treatment and unequal observations per replication. Data were analyzed by analysis of variance (ANOVA) and Duncan's new multiple range test. Nitrogen treatments constituted the whole plot (0.20 acres) and chemical weed control was applied in 4 ft. bands down either side of the planted rows to one-half of each fertilized plot (0.04 acres). Nitrogen as urea was broadcast by hand at rates equivalent to 0, 50, or 100 lbs. of elemental nitrogen/acre. Weed control treatments were none and a combination of glyphosate [N-(phosphonomethyl)glycine] and simazine [2-chloro-4,6-bis(ethylamino)-S-triazine], each at 4 lb ai/A in water. To allow for border trees, 18 trees were measured in each replication of no weed control treatments whereas 12 trees were measured in each replication of weed control treatments.

On May 1, 1977, prior to treatment application, trees averaged 20 ft. height and 3.5 in. diameter at 4.5 ft. above the ground. Total height and diameter measurements were taken after the growing season for each of three years following treatment. These parameters were used to compute volume in cubic feet and expressed on a per acre basis with 360 trees per acre. Volume computation utilized an equation developed for seedling and sapling black walnut; $V = -2.86094 + 0.14366 \sqrt{D^2H+400}$, where V = total stem volume in cubic feet, D = diameter at 4.5 ft. in inches, and H = height in feet (Todhunter, et al., 1979).

Foliage samples were collected and analyzed for nitrogen by micro-kjeldahl distillation (Wilde, et al., 1972) prior to treatment and in mid-September for two years following treatment.

RESULTS

Average annual diameter increments and total diameter increment over 3 years are shown in Table 1. Weed control alone, without nitrogen fertilization, did not affect diameter growth the first two growing seasons. Likewise, the total increase in diameter for the three-year measurement period was not significantly greater than no weed control; although weed control did increase diameter growth in 1979. Weed control in conjunction with nitrogen application, however, did result in greater diameter growth over the three-year measurement period. Trees that received nitrogen and weed control grew more than those that received the same rate of nitrogen application but no weed control, although statistically significant differences at P = .05 were evident in only two of the treatment combinations. The greatest increase

Table 1.--Effect of weed control and fertilization on diameter increment

Fertilizer Rate (lbs N/A)	Weed Control	Diameter Increment (in.) Year '77	'78	'79	Total
0	No	0.21a[a/]	0.20a	0.34a	0.75a
	Yes	0.21a	0.33ab	0.55b	1.09ab
50	No	0.25a	0.18a	0.51ab	0.94a
	Yes	0.34b	0.38b	0.48ab	1.20b
100	No	0.32ab	0.30ab	0.61b	1.23bc
	Yes	0.36b	0.37b	0.63b	1.36c

[a/] Column values not followed by the same letter are significantly different (Duncan's New Multiple Range Test, $P < .05$)

in diameter growth occurred on trees that were fertilized with 100 lbs. nitrogen/acre with weed control. These trees increased in diameter 0.61 in. more than unfertilized trees with no weed control. Fertilization with urea at 100 lbs/acre in the absence of weed control produced more diameter growth than occurred on unfertilized trees or those receiving 50 lbs. nitrogen/acre This difference was greatest for the total 3-year growth accumulation. Approximately 40 to 50 percent of the radial growth in all treatments, including the control, occurred in 1979, three years after treatment; thus suggesting good environmental conditions for growth and no lag in response to weed control and/or nitrogen application.

Weed control alone did not affect height growth of 12-year-old black walnut trees (Table 2). Also, nitrogen application did not influence height growth in the absence of weed control. Trees that received 100 lbs. nitrogen/acre and weed control were significantly taller in the first year following treatment and in the cumulative growth for the three-year period than trees in plots with no fertilizer or weed control.

Volume increase of black walnut per acre during the three-year study period, like height and diameter growth, was unaffected by weed control alone (Table 3). Generally, per acre volume increment increased with increasing levels of nitrogen fertilization and weed control. Fertilization at 100 lbs. nitrogen/acre with no weed control significantly increased volume growth over that of untreated trees. The largest volume increment during the three year study period occurred on trees that received weed control and 100 lbs. nitrogen/acre. These trees added about 178 $ft.^3$ more wood/acre than untreated trees. Increased growth response to the high nitrogen-weed control treatment relative to high nitrogen and no weed control was limited to the first growing season following treatment. Both increased height and diameter growth accounted for the increased volume of wood produced.

No differences in percent foliar nitrogen were evident in leaves collected on May 20, 1977, prior to treatment application (Table 4). At the end of

Table 2.--Effect of weed control and fertilization on height growth

Fertilizer Rate (lbs N/A)	Weed Control	Height Increment (ft.) Year '77	'78	'79	Total
0	No	2.2a[a/]	0.8a	2.0a	5.0a
	Yes	2.8a	0.8a	3.4ab	7.0ab
50	No	3.0a	1.3a	1.4a	5.7a
	Yes	2.9a	2.0a	2.6ab	7.5ab
100	No	3.2ab	1.4a	4.3b	8.9ab
	Yes	4.5b	2.1a	3.8ab	10.4b

[a/] Column values not followed by the same letter are significantly different (Duncan's New Multiple Range Test, $P < .05$).

Table 3.--Effect of weed control and nitrogen fertilization on volume growth of 12-year-old black walnut

Fertilizer Rate (lbs N/A)	Weed Control	Per Acre Volume Increment (ft^3) Year '77	'78	'79	Total
0	No	60.28a[a/]	39.87a	78.50a	178.65a
	Yes	68.30a	59.85ab	134.46b	262.60ab
50	No	77.57ab	43.52a	97.31ab	218.40ab
	Yes	91.20b	85.02b	110.41ab	286.63ab
100	No	92.02b	63.64ab	158.88c	314.54b
	Yes	117.01c	84.82b	154.76c	356.59c

[a/] Column values not followed by the same letter are significantly different (Duncan's New Multiple Range Test, $P < .05$).

the first growing season, September 1977, increased foliar nitrogen was found in response to both weed control and nitrogen application. Weed control alone resulted in increased foliar nitrogen in both the first and second years after treatment. When 50 lbs. nitrogen/acre were added in conjunction with weed control, the levels of foliar nitrogen were greater than that of leaves of control trees at the end of the first season. Weed control applied along with 50 lbs. nitrogen/acre did not influence foliar nitrogen levels in September, 1977, or September, 1978. At the end of the first growing season, 100 lbs. nitrogen/acre with weed control resulted in levels of foliar nitrogen that were much higher than control trees and this difference existed for two years after application.

Table 4.--Percent foliar nitrogen in black walnut in relation to nitrogen fertilization and weed control

Fertilizer Rate (lbs N/A)	Weed Control	Nitrogen (% dry weight) Date May '77	Sept. '77	Sept. '78
0	No	2.36a[a/]	2.26a	2.48a
	Yes	2.51a	2.59b	2.85b
50	No	2.63a	2.66bc	2.91b
	Yes	2.58a	2.95c	3.42bc
100	No	2.41a	2.49b	3.46bc
	Yes	2.53a	2.84c	3.61c

[a/] Column values not followed by the same letter are significantly different (Duncan's New Multiple Range Test, $P < .05$).

DISCUSSION

Black walnut growth response to nitrogen application was anticipated based on results of Phares and Finn (1971). They predicted no probable growth response of black walnut trees from adding nitrogen when foliar level is above 2.6 percent, some response at foliar levels of 2.0 to 2.6 percent, and a likely response at levels below 2.0 percent foliar nitrogen. Foliar nitrogen levels for trees in this study were in the high side of the medium range, about 2.4 to 2.6% (Table 4). The first growing season after nitrogen fertilization, nitrogen levels increased to a point where no additional response was expected except in those trees that did not receive weed control. This study clearly shows that weeds are very competitive sinks for available nitrogen. Weed control treatments alone resulted in significant increases in tree foliar nitrogen levels. Nitrogen application increased foliar nitrogen levels above that of unfertilized trees around which weeds were controlled only when done in conjunction with weed control. Fertilization without weed control was no more effective than weed control alone at the end of the first growing season. The benefits of 50 lbs. nitrogen/acre and weed control were lost in the second year after treatment. This was due to the reestablishment of competing weeds on the weed control plots in the second year. On the plots that received 100 lbs. nitrogen/acre, luxuriant amounts of nitrogen were apparently still available for both weeds and trees during the second growing season.

The increased levels of foliar nitrogen in response to treatments relate closely to the volume growth increments that were found. These results support the suggestion by Russell (1961) that nitrogen generally affects leaf area of plants and that over a considerable range of nitrogen supply the amount of leaf area available for photosynthesis is proportional to the nitrogen applied. Ellis and von Althen (1973) who worked with 30 to 85-year-old natural stands of several hardwood trees in southern Ontario also concluded

that nitrogenous fertilizer increased diameter growth through increased leaf area.

Nitrogen fertilization of established trees does not always produce increased growth. A 40-year-old stand of black walnut in southern Wisconsin on an upland site did not show a significant increase in diameter growth when fertilized with 500 lbs/acre of elemental nitrogen as ammonium nitrate. The same rate of nitrogen application on a fertile bottomland site reduced the rate of diameter growth below that of unfertilized trees (Maeglin, et al. 1977). Phares[2/] (unpublished data) found a similar retardation of black walnut growth in Indiana. Trees of a 60 to 80-year-old stand growing on a fertile bottomland site grew less when fertilized with nitrogen than trees not fertilized. Nevertheless, Schlesinger and Funk (1977) stated that fertilization of pole-size trees is likely to provide the best economic returns and that nitrogen is the most promising nutrient to apply. They suggested that it may be necessary to refertilize approximately every 5 years to maintain growth stimulation. They also emphasize that fertilization should be considered a supplement to other cultural practices, and cannot be expected to compensate for other limiting factors such as light and moisture. The results of the present study reinforce these observations since nitrogen was found to significantly increase diameter, height, and volume growth of pole-size trees and was most effective when done in combination with weed control.

CONCLUSIONS

For the specific conditions of this study, significant increases in volume growth of a young black walnut plantation can be achieved by fertilizing with 100 lbs/acre nitrogen. The largest volume increase was recorded for plantations fertilized with 100 lb/acre N, plus weed control. While fertilization with 50 lb/acre N and/or weed control improve volume growth over the unfertilized control these growth differences were not significantly different.

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