EFFECT OF FERTILIZATION ON FOUR SPECIES IN MATURE APPALACHIAN HARDWOOD STANDS

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Abstract.--Four 70-year-old, even-aged Appalachian hardwood stands in north-central West Virginia were studied for their response to fertilization. The red oak site index of the four stands was about 65 feet. Two stands were fertilized with 300 pounds per acre N as ammonium nitrate plus 100 pounds per acre P_2O_5 as triple superphosphate. A total of 249 codominant red oak, black cherry, red maple, and yellow-poplar trees in the four stands were equipped with band dendrometers at breast height; diameter growth was measured annually for 2 years before and 4 years after fertilization. Red oak showed a 17-percent increase in periodic diameter growth during the 4 years after fertilization. Basal area growth increased by about 21 percent during the same period. Maximum response was during the second and third years after treatment. For black cherry, periodic diameter and basal area growth increased by about 40 percent. Increases occurred during the second, third, and fourth years after fertilization. Fertilization did not increase the growth of red maple and yellow-poplar.

Index words: forest fertilization, Appalachian hardwoods

INTRODUCTION

Research has shown that Appalachian hardwoods will respond to nitrogen and phosphorous fertilization. Lamson (1978) and Auchmoody and Smith (1977) reported that in West Virginia on red oak (*Quercus rubra* L.) site index 75 areas, 65-year-old yellow-poplar (*Liriodendron tulipifera* L.) responded better than red oak. In mixed hardwood stands, species composition may be an important consideration in selecting stands for fertilization. If fertilization could increase the growth of species A by 25 percent and that of species B by 5 percent, stands with a larger component of species A would be best to fertilize.

This paper reports differences in growth among four different species in a fertilizer trial in mixed Appalachian hardwood stands. This information will aid in the formulation of forest fertilization guidelines for this region.

METHODS

The study area is in the Fernow Experimental Forest near Parsons, West Virginia. This rugged, mountainous region is characterized by long, steep slopes with elevations ranging from 1,500 to 3,000 feet. The average annual precipitation is 60 inches and the growing season is 145 days.

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Four stands of 6 to 9 acres were selected for study. Two stands have southeastern aspects and two have northwestern aspects. The red oak site index of the south-facing stands is 63 feet; the site index of the north-facing stands is 65 feet. Soils are residual silt loams derived from sandstone and shale. Soil depths range from 18 to 40 inches, and the average elevation is about 2,000 feet.

The well-stocked, even-aged stands developed following heavy cutting around 1910. No cutting had been done in these stands since the early logging. Within each stand, 10 to 22 codominant red oak, yellow-poplar, black cherry (*Prunus serotina* Ehrh.), and red maple (*Acer rubrum* L.) were selected, a total of 249 trees were studied (Table 1). All study trees were seedling origin and 65 to 75 years old. Differences in average tree diameter breast height (dbh) at the time of study were less than 2 inches. For a given species, trees in the north-facing stands were slightly larger than those in the south-facing stands.

Table 1.--Number and average diameter of study trees before treatment

Item	Control		Fertilized	
	South aspect	North aspect	South aspect	North aspect
Red oak				
Ave. dbh (inches)	14.8	14.4	15.5	16.5
Number	20	15	22	15
Black cherry				
Ave. dbh (inches)	13.5	14.2	13.6	17.4
Number	13	12	14	16
Red maple				
Ave. dbh (inches)	12.1	12.5	12.6	12.5
Number	20	15	21	10
Yellow-poplar				
Ave. dbh (inches)	14.4	16.1	14.6	16.4
Number	10	15	15	16

In the spring of 1976, two stands, one each of the south- and north-facing aspects, were fertilized at the rate of 300 pounds per acre N as ammonium nitrate plus 100 pounds per acre P_2O_5 as triple superphosphate. The fertilizer was hand broadcast with cyclone seeders. Even distribution was achieved by gridding each stand into 100- by 100-foot squares, and applying a premeasured amount of fertilizer to each grid. The remaining two stands were untreated and used as controls.

Aluminum band dendrometers were installed on each study tree in March 1974. Measurements of diameter growth to the nearest 0.01 inch were taken each October from 1974 to 1979. These data allow comparisons of growth among the four species for 2 years before and 4 years after fertilization. Differences among treatment means for each year were tested by one-way analysis of variance and the Student-Newman-Keul multiple range test.

RESULTS

Red oak

Red oak trees in the south-fertilized (SF) stand responded to fertilization. Diameter growth of trees in this stand exceeded that of the other stands in all 4 years after treatment (Table 2). Maximum response was during the second and third years after treatment. Diameter growth of red oak trees in the north-fertilized (NF) stand was not increased by fertilization. Diameter growth rate of the SF trees after fertilization was significantly greater than that of trees in the other stands. Average annual diameter growth for the 4 years after fertilization was 0.34 inch compared with about 0.27 inch for trees in other stands. The ratio of annual diameter growth after fertilization to annual diameter growth before fertilization was 1.17 for trees in the SF stand but only 1.00, 0.96, and 0.88, respectively, for those in the NF, south-control (SC), and north-control (NC) stands.

Basal area growth after treatment was generally about the same as diameter growth (Table 3); maximum response was during the second and third years after fertilization. For the 4 years after treatment, the average annual basal area growth of the SF trees was about 21 percent greater than that of trees in the other stands.

Black cherry

Fertilizer significantly increased the growth of black cherry in both the SF and NF stands (Tables 2 and 3). There was no response in either diameter or basal area growth during the first year after treatment. During the years 1974 to 1976, diameter and basal area growth in the NC and NF stands exceeded that in the SC and SF stands, i.e., trees on the higher quality sites grew more. In the years 1977 to 1979, fertilized black cherry trees grew significantly more than control trees.

Average annual diameter growth was not significantly different among the four stands before or after fertilization. Average annual diameter growth after treatment was NF 0.26, SF 0.25, NC 0.21, and SC 0.19. The ratio of diameter and basal area annual growth after fertilization to annual growth before fertilization showed that the NF and SF black cherry trees grew about 1.4 times faster than NC and SC trees. These differences were significant.

Table 2.--Average diameter growth per tree and growth ratios

Year	Control		Fertilized		Statistical significance
	South aspect	North aspect	South aspect	North aspect	
	----------inches----------				
	RED OAK				
Before fertilization					
1974	0.21	0.28	0.24	0.24	NS
1975	0.30	0.35	0.34	0.32	NS
Average	0.26	0.32	0.29	0.28	NS
After fertilization					
1976	0.23a	0.26a	0.29b	0.22a	*
1977	0.25a	0.27a	0.34b	0.29a	*
1978	0.34a	0.34a	0.44b	0.36a	**
1979	0.23	0.23	0.27	0.20	NS
Average	0.26a	0.28a	0.34b	0.27a	*
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.00a	0.88a	1.17b	0.96a	*
	BLACK CHERRY				
Before fertilization					
1974	0.20	0.18	0.15	0.17	NS
1975	0.18	0.22	0.19	0.21	NS
Average	0.19	0.20	0.17	0.19	NS
After fertilization					
1976	0.19	0.18	0.19	0.21	NS
1977	0.18a	0.23a	0.28b	0.31b	*
1978	0.23	0.24	0.29	0.28	NS
1979	0.15	0.19	0.22	0.22	NS
Average	0.19	0.21	0.25	0.26	NS
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.00a	1.05a	1.47b	1.37b	*

Continued

Table 2. (Continued)

Year	Control South aspect	Control North aspect	Fertilized South aspect	Fertilized North aspect	Statistical significance
	----------inches----------				
	RED MAPLE				
Before fertilization					
1974	0.18	0.20	0.17	0.25	NS
1975	0.20	0.22	0.20	0.23	NS
Average	0.19	0.21	0.19	0.24	NS
After fertilization					
1976	0.19	0.18	0.21	0.20	NS
1977	0.22	0.27	0.25	0.27	NS
1978	0.21	0.23	0.26	0.30	NS
1979	0.18	0.18	0.22	0.24	NS
Average	0.20	0.22	0.24	0.25	NS
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.05a	1.05a	1.26b	1.04a	*
	YELLOW-POPLAR				
Before fertilization					
1974	0.25	0.25	0.26	0.22	NS
1975	0.23	0.25	0.27	0.26	NS
Average	0.24	0.25	0.27	0.24	NS
After fertilization					
1976	0.20	0.22	0.25	0.22	NS
1977	0.17	0.24	0.26	0.23	NS
1978	0.28	0.28	0.30	0.26	NS
1979	0.22	0.17	0.23	0.16	NS
Average	0.22	0.23	0.26	0.22	NS
	----------Ratio----------				
Average after fertilization / Average before fertilization	0.92	0.92	0.96	0.92	NS

*$p < 0.05$. **$p < 0.01$.
Values in rows followed by the same letter are not significantly different at the 0.05 level.

Table 3. Average basal area growth per tree and growth ratios

Year	Control South aspect	Control North aspect	Fertilized South aspect	Fertilized North aspect	Statistical significance
	----------in^2----------				
			RED OAK		
Before fertilization					
1974	5.10	6.58	6.06	6.41	NS
1975	7.38	8.56	8.63	8.58	NS
Average	6.24	7.57	7.35	7.50	NS
After fertilization					
1976	5.74	6.51	7.38	6.17	NS
1977	6.35a	6.71a	8.87b	7.85a	*
1978	8.67a	8.89a	11.89b	9.64a	*
1979	6.02	6.10	7.36	5.79	NS
Average	6.70a	7.05a	8.88b	7.36a	*
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.07a	0.93a	1.21b	0.98a	*
			BLACK CHERRY		
Before fertilization					
1974	4.17	4.31	3.30	4.73	NS
1975	3.93a	5.41b	4.06a	6.01b	*
Average	4.05	4.86	3.68	5.37	NS
After fertilization					
1976	4.06	4.37	4.24	6.09	NS
1977	4.09a	5.69a	6.26a	8.76b	**
1978	4.71a	6.00ab	6.76ab	8.61b	*
1979	3.46a	4.65ab	5.24ab	6.75b	*
Average	4.08a	5.18ab	5.63ab	7.55a	*
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.01a	1.07a	1.53b	1.41b	*

Continued

Table 3. (Continued)

Year	Control South aspect	Control North aspect	Fertilized South aspect	Fertilized North aspect	Statistical significance
	----------in^2----------				
			RED MAPLE		
Before fertilization					
1974	3.38	4.10	3.44	4.95	NS
1975	3.87	4.38	3.98	4.57	NS
Average	3.62	4.24	3.71	4.76	NS
After fertilization					
1976	3.71	3.90	4.31	4.22	NS
1977	4.36	5.36	5.24	5.69	NS
1978	4.26	4.98	5.56	6.48	NS
1979	3.82	3.96	4.93	5.35	NS
Average	4.04	4.55	5.01	5.44	NS
	----------Ratio----------				
Average after fertilization / Average before fertilization	1.12a	1.07a	1.35b	1.14a	*
			YELLOW-POPLAR		
Before fertilization					
1974	5.67	6.51	6.00	5.78	NS
1975	5.42	6.67	6.14	6.75	NS
Average	5.55	6.59	6.07	6.27	NS
After fertilization					
1976	4.72	5.85	5.98	5.96	NS
1977	4.02	6.59	6.29	6.27	NS
1978	6.82	7.81	7.39	7.18	NS
1979	5.26	4.60	5.79	4.51	NS
Average	5.20	6.21	6.36	5.98	NS
	----------Ratio----------				
Average after fertilization / Average before fertilization	0.94	0.94	1.05	0.95	NS

*$p < 0.05$. **$p < 0.01$.
Values in rows followed by the same letter are not significantly different at the 0.05 level.

Red maple

Red maple trees responded very little to fertilization. There were no significant differences among treatment means for diameter or basal area growth. During the third and fourth years after treatment, diameter growth in the fertilized stands was greater than that in the control stands. However, for both diameter and basal area growth, the ratio of average annual growth after fertilization to average annual growth before fertilization was significantly greater in the SF stand. The ratios for diameter growth were SF 1.26, SC and NC 1.05, and NF 1.04. Fertilization increased the 4-year annual growth rate by nearly 30 percent.

Yellow-poplar

Yellow-poplar trees did not respond to fertilization. No significant differences due to fertilization were found among the means. In 1979, the percent basal area growth of SC and SF trees was significantly greater than that of NC and NF trees, but these differences are not related to treatment.

DISCUSSION

The response to fertilization can be influenced by stand conditions, site quality, and tree age. Overstocked stands that are stagnated probably would respond less than well-stocked stands where mean annual increment had not begun to slow. Also, understocked stands with large-crowned, widely spaced trees may not respond to fertilization because individual tree diameter growth could be approaching its biological maximum. Although there were small differences in total basal area per acre and diameter distribution among the four stands, each stand was well stocked. Basal areas of stems 5.0 inches or larger in dbh ranged from 94 to 114 ft^2 per acre in the four stands. It appears that stand conditions could not account for differences in response to fertilization.

Red oak site index was determined by the Trimble (1964) equation using slope position, aspect and steepness. Fifteen determinations of site index were made in each stand. Site index did not differ more than 3 feet among the four stands. These differences are probably not large enough to cause differences in response to treatment.

Two site-quality factors could have contributed to the lack of response by yellow-poplar. First, red oak site index 65 is about equal to a yellow-poplar site 65 (Hampt 1965). This is the lower site range for yellow-poplar but midrange for red oak. Thus, moisture may be limiting the growth of yellow-poplar to the extent that fertilization did not increase growth. Second, yellow-poplar growing in northern West Virginia at an elevation of 2,000 feet is approaching the northern limit of the natural range of this species.

Tree age probably had the greatest effect on response to fertilization. Red oak growth continues at a fairly rapid rate beyond 100 years of age while the growth rate of yellow-poplar, black cherry, and red maple begins to decline after age 60 (Hampt 1965). These trees were 65 to 75 years old at the time of fertilization. Thus, response to fertilization could have been masked by naturally declining growth rates.

CONCLUSION

This study was based on a total of 249 trees and was conducted in a region with 60 inches of annual precipitation. Only one fertilizer rate was tested. Regional recommendations about forest fertilization cannot be formulated from this single case study. However, for this region, where even-aged stands about 70 years old are growing on red oak site index 65 areas, it can be concluded that red oak and black cherry probably will respond better to fertilization than yellow-poplar or red maple. Stands with large components of red oak and black cherry probably would be best to fertilize.

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