TEN-YEAR GROWTH OF RED AND WHITE OAK CROP TREES FOLLOWING

THINNING AND FERTILIZATION IN THE BOSTON

MOUNTAINS OF ARKANSAS[1/]

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Abstract.--A thinning and fertilization study of 50-year-old northern red oak (Quercus rubra L.), black oak (Q. velutina Lam.), and white oak (Q. alba L.) was initiated in the Boston Mountains of Arkansas in the spring of 1975. Fertilizer applications of a nitrogen and phosphorus combination were broadcast at two levels to individual oaks that had received thinning or nonthinning treatments. Both levels of fertilization increased diameter growth of oaks in thinned and nonthinned stands. Maximum response to fertilization occurred during the first and second years after treatment. Response continued through the sixth year for white oak and through the eighth year for red oaks. A significant diameter growth response to thinning occurred during the third growing season after treatment for red and black oaks and the fifth growing season for white oak. From this point, the rate of annual diameter growth for all oaks in thinned stands increased annually through the tenth year.

INTRODUCTION

Several hundred thousand acres of forest land in northern Arkansas support overstocked, even-aged, pole-sized stands of oaks and associated species. Although many stands are on medium-to-good sites (site index of 60 to 70 feet at 50 years), diameter growth averages only about 1 inch in 10 years. Since there are very few outlets for small diameter hardwoods, there has been very little intermediate cutting in these stands. However, because demands for hardwood sawtimber are increasing and inventories of mature sawtimber are small, some land managers have begun noncommercial thinning programs to accelerate growth of potential crop trees. Fertilization may further stimulate growth of crop trees. Research has shown that northern red (Quercus rubra L.), black (Q. velutina Lam.), and white (Q. alba L.) oaks will respond to nitrogen (N) and phosphorus (P) fertilization. Diameter growth of fertilized red oaks has been shown to increase by 45 to 70 percent and white oak about 60 percent. Red oaks responded more to higher levels of N, while white oak produced about the same response to medium and higher levels of N (Graney and Pope 1978a, 1978b; Graney 1983). In this paper, 10-year growth responses of red oaks (northern red and black oaks) and white oak in the Boston Mountains of Arkansas are summarized. Objectives were to determine how fertilizer applications affected diameter growth in thinned and nonthinned stands and to determine the effect of thinning on the diameter growth response to fertilization.

METHODS

Study Area

The Boston Mountains are the highest and southernmost member of the Ozark Plateaus physiographic province (fig. 1). They form a band 30 to 40 miles wide and 200 miles long from north central Arkansas westward into eastern Oklahoma. Elevations range from about 900 feet in the valley bottoms to 2,500 feet at the highest point. The plateau is sharply dissected, and most ridges and spurs are flat to gently rolling and are generally less than one-half mile wide. Mountain slopes consist of an alternating series of steep simple slopes and gently sloping benches.

Rocks in the area are sedementary and are of Pennsylvanian and Mississippian age, consisting of alternating horizontal beds of sandstones and shales. Annual precipitation averages 48 inches, with March, April, and May being the wettest months. Extended summer dry periods are common, and autumn is usually dry. The frost-free period is normally 180 to 200 days long.

Three study areas were selected in overstocked stands on mountain benches that range from 2 to 3 chains wide. Soils are deep, well-drained, medium-textured members of the Nella and Leesburg series (Typic Paleudults). They are derived from sandstone and shale colluvium and rated medium to high in productivity.

[1/]Paper presented at Southern Silvicultural Research Conference, Atlanta, Georgia, November 4-6, 1986.

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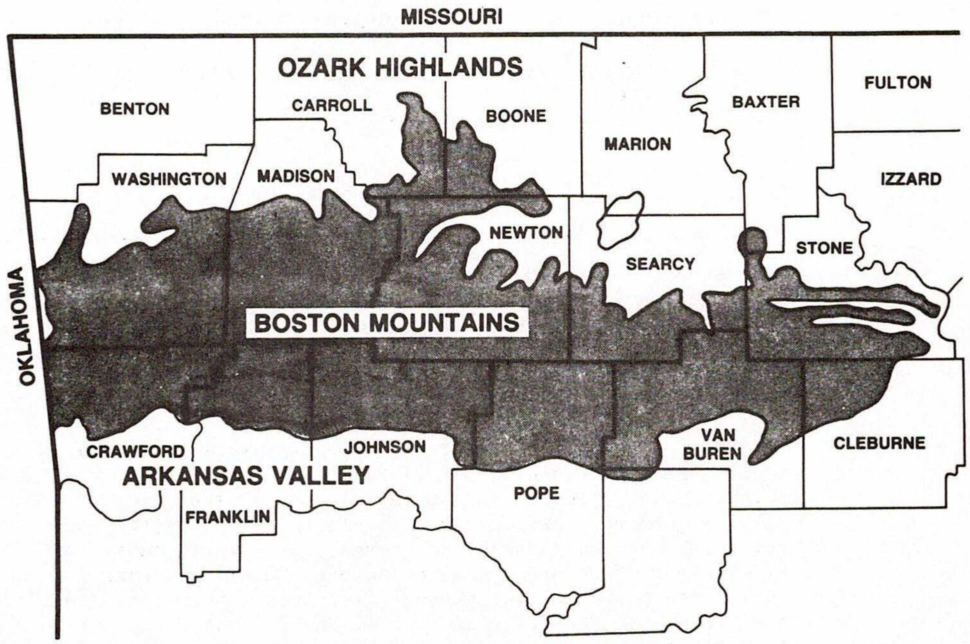

Figure 1.--The Boston Mountains of Arkansas.

Sample Trees

In each stand, 48 red oak and 48 white oak crop trees were selected for the thinning and fertilizer treatments. Trees from each species group were arranged into 16 sets of 3 trees each. Members of each 3-tree set were uniform in diameter, crown size, and height and were located on essentially the same site conditions. Thin or nonthin treatments were randomly assigned to each three-tree set, and three fertilizer treatments were randomly assigned to trees within each set. In total, there were 144 red and black oaks and 144 white oaks at 3 locations.

Tree Measurements

Diameter at breast height (d.b.h.) of each sample tree was measured to the nearest 0.01 inch. The diameter measurement point was identified by a painted band on each tree. Increment cores, extracted from the north, east, south, and west sides of each tree, were sealed in soda straws. These were used to determine tree age and to obtain a measure of past growth. Past annual radial growth was measured to the nearest 0.01 inch using a binocular microscope. Total height was also recorded for each tree.

Thinning Treatment

Basal area around each sample tree was determined with a prism and was reduced to about 70 ft^2 by removing two major competitors and several smaller trees. Thinning was completed in March 1975. Average tree and stand characteristics following thinning in 1975, along with 10-year diameter and basal area values, are shown in table 1.

Table 1.--Mean stand and tree characteristics for red and white oak thinned and nonthinned treatments at the beginning and ending of the study

Treatment	Age	Site Index	After Treatment D.b.h.	After Treatment Basal Area	10-year Change D.b.h.	10-year Change Basal Area
	years	feet	inches	ft^2/acre	inches	ft^2/acre
			Red Oak			
Thinned	50	62	8.18	68	9.93	82
Nonthinned	50	62	8.48	120	9.73	115
			White Oak			
Thinned	52	59	8.26	66	9.98	82
Nonthinned	52	59	7.89	123	9.24	118

Fertilizer Treatments

A combination of two fertilizers, ammonium nitrate (34-0-0) and diammonium phosphate (18-46-0) was used. Fertilizer treatments were: (1) No fertilizer (nonfertilized), (2) 200 lbs N + 45 lbs P per acre (200 lb treatment), and (3) 400 lbs N + 45 lbs P per acre (400 lb treatment). Fertilizers were surface broadcast in late April 1975 on a 0.01 acre circular plot surrounding each tree.

Data Analysis

The study design was a split-plot with thinning representing the whole plots and fertilizer treatments the subplots. Data were analyzed by analysis of covariance with mean annual diameter growth for the 5-year period prior to treatment (1970-74) as the covariate. Differences among adjusted treatment means were tested using Duncan's multiple range test.

RESULTS

Response to Thinning

Red and white oak sample trees produced an immediate positive response to thinning, and the rate of annual diameter growth generally increased throughout the 10-year period of the study (table 2). Levels of response to thinning were greater and more apparent in the fifth through tenth years when fertilizer response declined and growth rates of nonthinned trees slowed to pretreatment levels or less.

Diameter growth rates of thinned red oaks were significantly greater than rates of nonthinned trees from the third through the tenth year and averaged more than a 75-percent increase over the last 5 years of the study. Over the 10-year period, thinning increased red oak diameter growth by about 40 percent.

White oak responded positively to thinning, but the level of response was lower than that observed for the red oaks (table 2). While differences in diameter growth between thinned and nonthinned white oaks were at or near significant levels through the fourth year following thinning, growth differences between nonfertilized trees receiving thin or nonthin treatments were not apparent until the fifth year. White oak produced the greatest response from years 6 through 10 where thinned trees averaged about 50 percent greater diameter growth than nonthinned trees.

Response to Fertilization

Fertilization significantly increased diameter growth of red and white oaks over the 10-year period of the study, but the response varied between species and was influenced by the thinning treatment.

Table 2.--Mean annual diameter growth response of red and white oaks to thinning[a]

Year	RED OAK Nonthinned	RED OAK Thinned	WHITE OAK Nonthinned	WHITE OAK Thinned
	------inches-------		------inches-------	
1975	0.155	0.179	0.162	0.181
1976	0.174	0.198	0.176	0.198*[b]
1977	0.135	0.173*[b]	0.152	0.169
1978	0.126	0.152*	0.135	0.145
1979	0.127	0.169*	0.142	0.161*
1980	0.089	0.135*	0.108	0.128*
1981	0.114	0.183*	0.135	0.179*
1982	0.107	0.190*	0.122	0.183*
1983	0.107	0.196*	0.114	0.189*
1984	0.103	0.199*	0.110	0.195*
Mean	0.125	0.175*	0.135	0.172*

a/ Data averaged over all fertilizer rates and adjusted for differences in diameter growth using the 5-year period before thinning.
b/ * indicates statistically significant at $P<0.05$.

Red Oak

Thinned red oaks produced the greatest overall response to fertilization and were the most responsive to the higher level of N (table 3). For the 10-year period, mean diameter growth of thinned, fertilized red oaks averaged 28 percent more than growth of thinned, nonfertilized red oaks for the 200 lb treatment and 42 percent more for the 400 lb level. Nonthinned red oaks produced about the same response to the 200 and 400 lb levels and averaged a 38-percent increase in diameter growth for each level of N.

Maximum response to fertilization occurred during the first 2 years after treatment. Response declined annually but was generally greater than nonfertilized trees through the ninth and tenth years. After the fifth growing season, thinned red oaks indicated no difference in response to the 200 or 400 lb treatments.

Over the 10-year period, growth response to fertilization for thinned red oaks averaged about 35 percent, slightly lower than the response reported for northern red oak in thinned stands in New York (Karning 1972) and higher than reported for thinned black oaks in the Missouri Ozarks (McQuilkin 1982). Ten-year increases in diameter growth of nonthinned Boston Mountain red oaks averaged 38 percent, which was slightly lower than observed for red oaks in the Tennessee Valley (Farmer and others 1970) and slightly higher than increases for northern red oak in West Virginia (Lamson 1978, 1980) and scarlet oak in Pennsylvania (Ward and Bowersox 1970).

Table 3.--Mean annual diameter growth response to fertilization for thinned and nonthinned red oaks[1/]

Year	Nonthinned Fertilizer Treatment			Thinned Fertilizer Treatment		
	Nonfertilized	200 lb	400 lb	Nonfertilized	200 lb	400 lb
	--------------inches--------------			--------------inches--------------		
1975	0.114a	0.168b	0.185b[2/]	0.113a	0.186b	0.239c[2/]
1976	0.120a	0.190b	0.211b	0.128a	0.202b	0.263c
1977	0.110a	0.142b	0.152b	0.131a	0.167b	0.220c
1978	0.105a	0.136b	0.136b	0.126a	0.148b	0.182c
1979	0.109a	0.138b	0.137b	0.145a	0.163a	0.201b
1980	0.095a	0.090a	0.081a	0.125a	0.138b	0.141b
1981	0.105a	0.118b	0.120b	0.170a	0.188b	0.192b
1982	0.100a	0.115b	0.105a	0.178a	0.195b	0.197b
1983	0.095a	0.115b	0.110b	0.185a	0.200b	0.202b
1984	0.092a	0.112b	0.105b	0.192a	0.202a	0.204a
Mean	0.100a	0.138b	0.138b	0.142a	0.181b	0.202c

1/Data adjusted for differences in diameter growth during the 5-year period before treatment.
2/Values in rows follwed by the same letter are not significantly different at the 0.05 level.

White Oak

In contrast to the red oaks, thinned white oak was much less sensitive to the two levels of N fertilization. Both levels produced about the same 10-year increase, 30 percent (table 4). Nonthinned white oaks produced the greatest response to the 400 lb treatment, averaging a 40-percent increase over the 10-year period.

White oak produced the maximum response to fertilization during the first 2 years after treatment. Fertilizer response declined annually, but remained significant through the fifth year.

Table 4.--Mean annual diameter growth response to fertilization for thinned and nonthinned white oaks[1/]

Year	Nonthinned Fertilizer Treatment			Thinned Fertilizer Treatment		
	Nonfertilized	200 lb	400 lb	Nonfertilized	200 lb	400 lb
	--------------inches--------------			--------------inches--------------		
1975	0.121a	0.169b	0.197c[2/]	0.115a	0.220b	0.205b[2/]
1976	0.127a	0.184b	0.218c	0.131a	0.234b	0.227b
1977	0.125a	0.154b	0.179c	0.137a	0.189b	0.181b
1978	0.116a	0.135a	0.155b	0.127a	0.150b	0.160b
1979	0.128a	0.140a	0.159b	0.144a	0.159a	0.180b
1980	0.105a	0.112a	0.108a	0.135a	0.125a	0.125a
1981	0.125a	0.140a	0.141a	0.175a	0.183a	0.178a
1982	0.115a	0.127a	0.123a	0.180a	0.187a	0.183a
1983	0.110a	0.118a	0.113a	0.184a	0.196a	0.188a
1984	0.105a	0.112a	0.112a	0.190a	0.199a	0.195a
Mean	0.109a	0.144b	0.153b	0.144a	0.188b	0.184b

1/Data adjusted for differences in diameter growth during the 5-year period before treatment.
2/Values in rows followed by the same letter are not significantly different at the 0.05 level.

Mean 10-year response of the thinned and nonthinned white oaks to the fertilizer treatments was about 33 percent, nearly the same as responses for fertilized white oak in Pennsylvania (Ward and Bowersox 1970) but only about one-half the response observed for white oak in the Tennessee Valley (Farmer and others 1970).

DISCUSSION

Overall response of red and white oaks to fertilization was reduced by the general lack of response during the severe drought of 1980. Growth of all study trees was affected to some extent, but fertilized trees suffered the greatest reductions in growth (tables 3 and 4).

Thinned and nonthinned red oaks continued a significant growth response to fertilization through the ninth and tenth growing seasons after treatment, although actual growth rates for the nonthinned fertilized red oaks were relatively low. While annual diameter growth for thinned and nonthinned fertilized white oaks were slightly higher than nonfertilized trees over the 4-year period following 1980, levels of response were not statistically significant (table 4). In that fertilized red oaks maintained a fertilizer response following the 1980 drought, it is probable that the 5-year response will be the maximum white oak response for the 200- and 400-lb levels of N applied in this study.

Initial response of red and white oaks to thinning was relatively small, but differences between thinned and nonthinned trees increased rapidly after the third to fifth year. Annual diameter growth of thinned and nonfertilized red and white oaks continued to increase through 1984, while growth of nonthinned and nonfertilized trees declined to below pretreatment levels (fig. 2).

Differences in early levels of response to thinning by red and white oaks are probably due to differences in initial crown size and competitive position in these overstocked stands. On the same site, site index values for northern red and black oaks usually average 5 or more feet greater than white oak. The red oaks attain dominant crown positions and develop and maintain relatively large crowns. In mixed stands, most white oaks occupy lower crown positions and will suffer continuous reduction in crown size due to crowding but will persist for many years with very low rates of growth. As indicated by the consistent decline in diameter growth prior to thinning (fig. 2), all trees needed release, but the red oaks were generally in better condition to respond than were the white oaks.

Diameter growth for nonthinned and nonfertilized white oak trees over the period 1970-84 indicates the species' ability to survive and grow in these dense stands for long periods of time (fig. 2). Though generally in a less competitive crown position, subjected to intense crowding and competition, and possessing very small crowns, white oak maintained a fairly consistent rate of diameter growth over the 15-year period.

Nonthinned red oaks, on the other hand, were much more sensitive to competition and crowding and declined in diameter growth throughout the 1970-84 period (fig. 2). To maintain reasonably acceptable rates of diameter growth in these upland stands, red and white oak crop trees will require release from crown competition, and release should occur before crop trees suffer appreciable reduction in crown size.

The 10-year results of this study indicate that diameter growth of pole-sized red and white oaks can be significantly increased by thinning and/or fertilization. In overstocked stands where crop

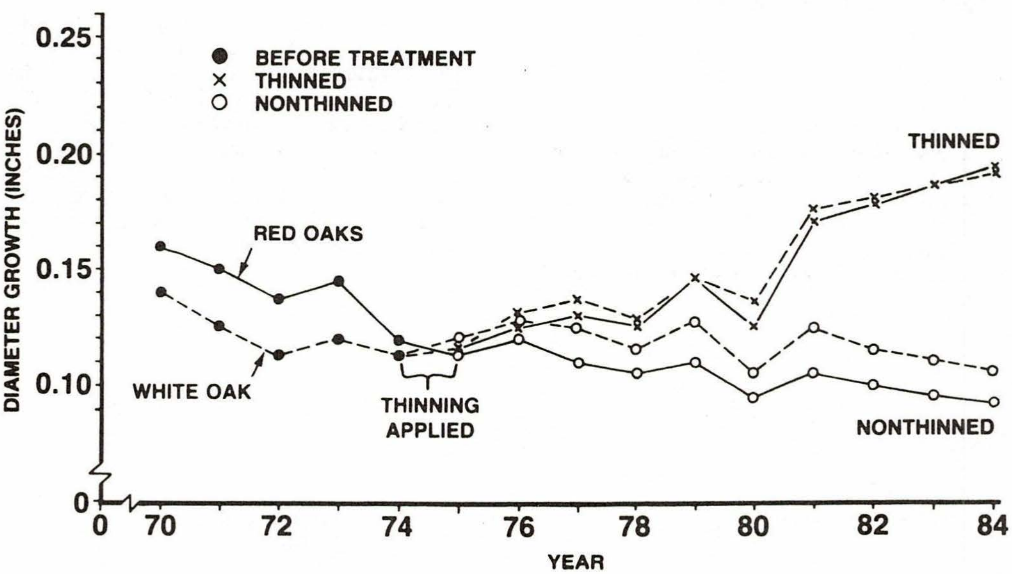

Figure 2.--Mean annual diameter growth of nonfertilized red and white oak crop trees before and after thinning.

trees have been subjected to extended periods of severe crowding, released trees will generally produce a positive response within 1 or 2 years after treatment, but a significant response to thinning may be delayed several years. Annual diameter measurements taken in conjunction with an oak growth and yield study in the Boston Mountain area indicate that free-to-grow red and white oak crop trees in 40- to 70-year-old stands on medium sites should average diameter growth of about 0.25 inch per year. To attain these growth rates, thinnings should be initiated before stands become overstocked and crop trees suffer appreciable reduction in crown size.

Fertilization with N and P can also increase diameter growth of oak crop trees and the increased growth rate will persist about 5 years for white oak and up to 10 years for red oaks. However, while differences in diameter growth between fertilized treatments were statistically significant, it is doubtful that the 10-year cummulative increase in diameter (0.3 to 0.5 inch) would justify the cost of a single commercial fertilizer application in these intermediate-aged stands. In considering silvicultural investments on these sites, regulation of stand density in younger stands should have first priority.

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