EFFECTS OF THINNING AND FERTILIZATION ON GROWTH OF UPLAND OAK STANDS IN THE BOSTON MOUNTAINS OF ARKANSAS: 7-YEAR RESULTS[1/]

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Abstract.--A study of thinning and fertilization 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 phosphorous combination were broadcast at two levels to individual oaks that had received thinning or nonthinning treatments. Both levels of fertilization increased diameter growth of all oaks in thinned and nonthinned stands, and thinning further increased this response. Maximum response to fertilization occurred during the first and second years after treatment. Response continued through the fourth year for the lower level of nitrogen and through the fifth year for the higher level. 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.

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 markets for small diameter hardwoods there has been very little intermediate cutting in these stands. But, because demands for hardwood sawtimber are increasing and inventories of large poletimber and immature 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 phosphorous (P) fertilization. Two-year 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, but white oak produced about the same response to medium and higher levels of N (Graney and Pope 1978a, 1978b). This paper summarizes 7-year growth responses of red oaks (northern red and black oaks) and white oak in the Boston Mountains of Arkansas. Objectives were to determine how fertilizer applications affected diameter growth in thinned and nonthinned stands and to determine the effect of thinning on diameter growth response to fertilization.

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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 ft in the valley bottoms to 2,500 ft at the highest point. The plateau is sharply dissected, and most ridges and spurs are flat to gently rolling and 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 sedimentary and predominantly of Pennsylvania age, consisting of alternating horizontal beds of shale and resistant sandstone. Annual precipitation averages 46 to 48 inches, with March, April, and May the wettest months. Extended summer dry periods are common,

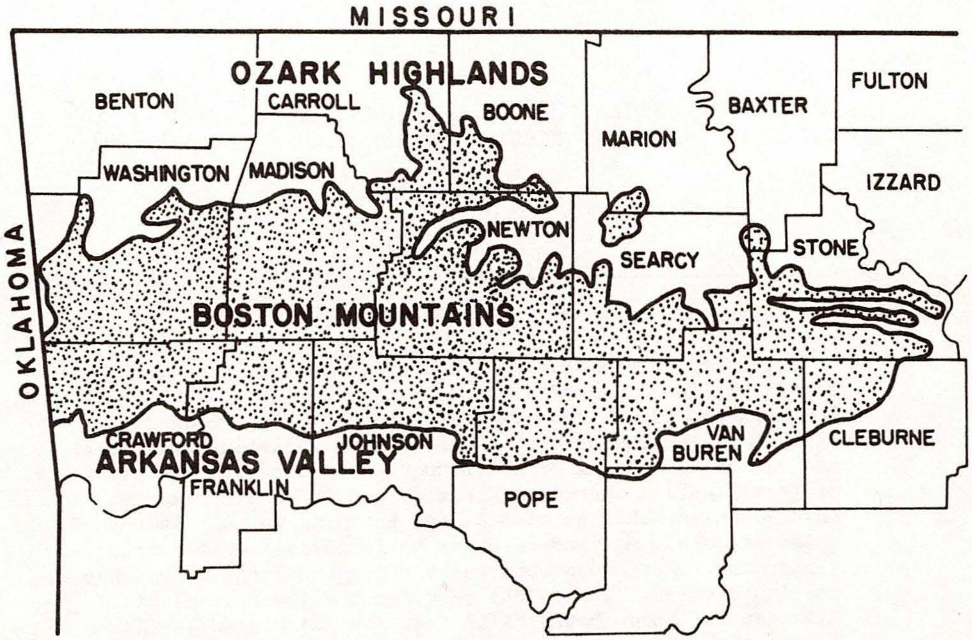

Figure 1.--The Boston Mountains in Arkansas.

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); derived from sandstone and shale colluvium; and rated medium to high in productivity.

Sample Trees

In each area, 48 red oak and 48 white oak 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 3-tree set, and three fertilizer treatments were randomly assigned to trees of the thinned and nonthinned sets. In total, there were 144 red and black oaks and 144 white oaks at three 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 plastic 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. Basal area 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 at this time are shown in Table 1.

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

Treatment	Age	Site Index	Initial Diameter	Basal Area
	years	feet	inches	ft^2/Acre
		RED OAKS		
Thinned	50	62	8.18	68
Nonthinned	50	62	8.48	120
		WHITE OAKS		
Thinned	52	59	8.26	66
Nonthinned	52	59	7.89	123

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 (1970-1974) 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 7-year period of the study (Table 2). Levels of response were greater and more apparent in the fifth through seventh years when fertilizer response declined and growth rates of nonthinned trees slowed to pretreatment levels or less.

Table 2. Mean annual diameter growth response of red and white oaks to thinning[1/].

Year	RED OAKS			WHITE OAK		
	Nonthinned	Thinned		Nonthinned	Thinned	
	Growth	Growth	Response	Growth	Growth	Response
	- - - inches - - -		%	- - - inches - - -		%
1975	0.155	0.179	16	0.162	0.181	12
1976	0.174	0.198	14	0.176	0.198	13*[3/]
1977	0.135	0.173	28**[3/]	0.152	0.169	11
1978	0.126	0.152	21**	0.135	0.145	7
1979	0.127	0.169	33**	0.142	0.161	13*
1981[4/]	0.101	0.162	60**	0.125	0.155	24**
Mean	0.132	0.171	30**	0.145	0.166	15**

1/ Data averaged over all fertilizer rates and adjusted for differences in diameter growth using the 5-year period before thinning.

2/ Percent increase of thinned over nonthinned.

3/ Statistically significant; * =P <.05; ** =P <.01

4/ Mean annual growth for 1980 and 1981.

Diameter growth rates of thinned red oaks were significantly greater than rates of nonthinned trees from the third through the seventh year and averaged a 60 percent increase for the sixth and seventh years. Over the 7-year period, thinning increased red oak diameter growth by about 30 percent.

White oak responded positively to thinning, but the level of response was lower than observed for the red oaks (Table 2). Differences in diameter growth between thinned and nonthinned white oaks were at or near significant levels for 6 of the 7 years, and growth of thinned trees averaged about 24 percent greater than nonthinned trees for the sixth and seventh years. Although initial response of white oak to thinning was small, differences between thinned and nonthinned trees should increase over the next several years. Annual diameter growth of thinned and nonfertilized white oaks were continuing to increase through 1981 while nonthinned and nonfertilized trees were continuing to grow at pretreatment levels (fig. 2). Growth will probably decline as crowding and competition increase in the overstocked stands. The same general pattern of response is also indicated for the red oaks.

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, northern red and black oaks usually average a site index 5 or more feet greater than white oak. The red oaks attain dominant crown positions and develop and maintain relatively large crowns. In overstocked 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 white oak. Apparently, to maintain reasonably acceptable rates of diameter growth, white oak crop trees require release from crown competition earlier than red oaks and certainly before they suffer apprciable loss in crown size.

Response to Fertilization

Fertilization significantly increased diameter growth of both red and white oaks over the 7-year period of the study, but the response varied between species and was influenced by the thinning treatment (Table 3).

Red oaks.--Thinned red oaks produced the greatest overall response to fertilization and were the most responsive to the higher level. Those fertilized at the 400 lb N level were the only trees to produce a significant response the sixth and seventh years after treatment.

For the 7-year period, mean diameter growth of thinned, fertilized red oaks averaged 26 percent more than growth of nonfertilized trees for the 200 lb treatment and 56 percent more for the 400 lb level. Nonthinned red oaks also responded to fertilization with increases of 32 to 36 percent over the nonfertilized trees. Nonthinned trees produced a greater response to the 400 lb treatment the first 2 years following treatment, but the response was about equal to the 200 lb treatment for the remainder of the study.

Maximum response to fertilization occurred during the first 2 years after treatment. Response declined annually, but remained significantly greater than nonfertilized trees through the fifth year. Only the thinned red oaks 400 lb treatment produced a significant response over the sixth and seventh years.

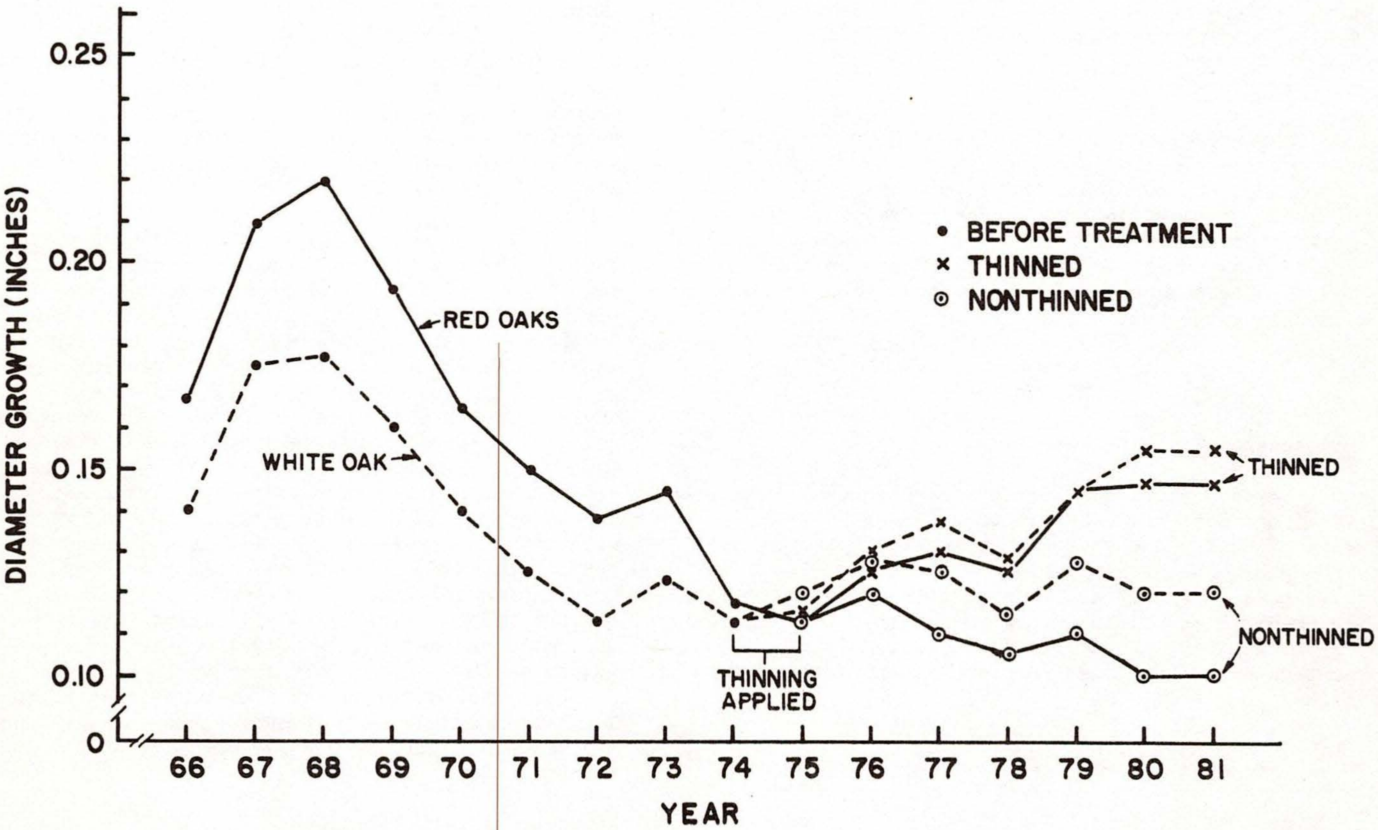

Figure 2.--Mean annual diameter growth of nonfertilized red and white oak crop trees before and after thinning.

Over the 7-year period, growth response to fertilization for thinned red oaks averaged about 40 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 (Watt 1974). Seven-year increases in diameter growth of nonthinned red oaks in the present study averaged 34 percent which was slightly lower than observed for red oaks in the Tennessee Valley (Farmer et al. 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).

White oak.--In contrast to red oaks, thinned white oak was much less sensitive to the two levels of N fertilization. Both produced about the same increase, 30 percent (Table 3). Thinned white oak at the 400 lb level did not produce a significant response over the 200 lb application rate until the fifth year following treatment. Conversely, nonthinned white oak responded significantly more to the 400 lb treatment than to 200 lb, and averaged a 34 percent increase over growth of nonfertilized trees over the entire 7-year period.

White oak also produced a maximum response to fertilization during the first 2 years following treatment. After the second year, response to fertilizer declined annually, but remained significant through the fifth year with thinned and nonthinned trees fertilized at the 400 lb rate producing the greatest response. Mean diameter growth for years 6 and 7 was about the same for all treatments (Table 3).

Mean 7-year response of the thinned and nonthinned trees to the fertilizer treatments was about 29 percent, nearly the same as 5-year responses reported for fertilized white oak in Pennsylvania (Ward and Bowersox 1970) but only about half of the 5-year responses observed for white oak in the Tennessee Valley (Farmer et al. 1970).

DISCUSSION

Overall response of red and white oaks to fertilization was reduced by the general lack of response during a severe drought in 1980 and the inability to recover during the very wet growing season of 1981. Growth of all study trees was affected to some extent, but nonthinned fertilized trees suffered the greatest reductions in growth.

Fertilized nonthinned white oak had greater diameter growth than nonfertilized trees in 1977 and 1978 but decreased to about the same level as the nonfertilized trees during the 1980-81 growing seasons (Table 3). Thinned white oak fertilized at the 400 lb level maintained the same rate of diameter growth, but were overtaken by the

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

Year	Thinned					Nonthinned				
		Fertilizer Treatment					Fertilizer Treatment			
	Nonfertilized	200 lb		400 lb		Nonfertilized	200 lb		400 lb	
	Growth	Growth	Response[2]	Growth	Response	Growth	Growth	Response	Growth	Response
	- - - inches - - - -		%	inches	%	- - - inches - - - -		%	inches	%
					RED OAKS					
1975	0.113a[3]	0.186b	65	0.239c	112	0.114a	0.168b	47	0.185b	62
1976	0.128a	0.202b	58	0.263c	106	0.120a	0.190b	58	0.211b	76
1977	0.131a	0.167b	28	0.220c	53	0.110a	0.142b	29	0.152b	38
1978	0.126a	0.148b	18	0.182c	44	0.105a	0.136b	30	0.136b	30
1979	0.145a	0.163a	12	0.201b	39	0.109a	0.138b	27	0.137b	26
1981[4]	0.148a	0.158a	7	0.177b	20	0.100	0.104	4	0.100	0
Mean	0.134a	0.169b	26	0.209c	56	0.107a	0.141b	32	0.146b	36
					WHITE OAK					
1975	0.115a	0.220b	91	0.205b	78	0.121a	0.169b	40	0.197c	63
1976	0.131a	0.234b	79	0.227b	73	0.127a	0.184b	45	0.218c	72
1977	0.137a	0.189b	38	0.181b	32	0.125a	0.154b	23	0.179c	43
1978	0.127a	0.150b	18	0.160b	26	0.116a	0.135a	16	0.155b	34
1979	0.144a	0.159a	10	0.180b	25	0.128a	0.140a	9	0.159b	24
1981	0.156	0.156	0	0.154	-1	0.120	0.128	7	0.125	4
Mean	0.138a	0.181b	31	0.180b	30	0.123a	0.148b	20	0.165b	34

1/ Data adjusted for differences in diameter growth during the 5-year period before treatment.
2/ Percent increase over nonfertilized treatment.
3/ Values in rows followed by the same letter are not significantly different at the 0.05 level.
4/ Mean annual diameter growth for 1980 and 1981.

nonfertilized trees which actually increased in rate of diameter growth in 1980-81. Diameter growth for nonthinned and nonfertilized white oak trees over the 11-year period 1971-81 indicates the species' ability to survive and grow in dense stands for long periods. 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 11-year period.

Nonthinned red oaks, on the other hand, were much more sensitive to competition and crowding and declined in diameter growth each year following the wetter-than-normal growing seasons of 1967-69. The differences in response for thinned and nonthinned red oak fertilized trees during 1980-81 suggests that effective crown release of fertilized trees may increase the duration of the growth response to fertilization. While diameter growth of nonthinned red oaks fell below the pretreatment level during 1980-81, thinned red oaks remained above this level. Thinned red oaks that had been fertilized showed a 20 percent greater growth than nonfertilized.

The 7-year results of this study indicate that diameter growth of pole-sized red and white oaks can be increased by thinning and/or fertilization. In overstocked stands, where crop trees have been subjected to extended periods of severe crowding, thinned trees will generally produce a positive response within 1 or 2 years after treatment but 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 about 0.20 to 0.25 inch diameter growth per year. To attain these growth rates, thinnings should be initiated before stands become overstocked and crop trees suffer appreciable reductions in crown size. Fertilization with N and P can also increase diameter growth of red and white oak crop trees and the increased growth rate will persist about 5 years. Red oaks will respond to larger applications of N than white oak and their response may continue beyond 7 years when fertilization and thinning treatments are combined.

Although differences in diameter growth between fertilized and nonfertilized treatments were statistically significant it is doubtful that the 7-year cumulative increase in diameter (0.2 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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