INTERMEDIATE OAK STAND MANAGEMENT IN THE BOSTON MOUNTAINS

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Several hundred thousand acres of forest land in the Boston Mountains support overstocked, even-aged 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 of crop trees averages only about 1 inch in 10 years. Limited outlets for small diameter hardwoods in this area have discouraged intermediate cutting in these stands at younger ages. But, because demands for hardwood sawtimber are increasing and inventories of large poletimber and immature sawtimber are small, some land managers are considering initiation of noncommercial thinning and fertilization programs to accelerate growth of potential crop trees.

In 1974, we began installation of a series of research studies in upland oak stands to evaluate the short- and long-term effects of overstory thinning and fertilization on overstory growth and yield, wildlife forage production, and development of oak advance reproduction. This paper summarizes 5- and 7-year growth responses of upland oak stands and individual crop trees in the Boston Mountains in Arkansas.

The Boston Mountains

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 generally less than one-half mile wide. Mountain slopes consist of an alternating series of steep simple slopes and gently sloping benches.

Soils common to mountain tops and slopes are shallow to medium in depth, medium-textured members of the Hartsells, Linker, and Enders series (Typic Hapludults); derived from sandstone or shale residuum; and rated medium to low in productivity. Soils common to mountain benches 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.

Rocks in the area are sedimentary and predominantly of Pennsylvanian age, consisting of alternating horizontal beds of shales and resistant sandstones.

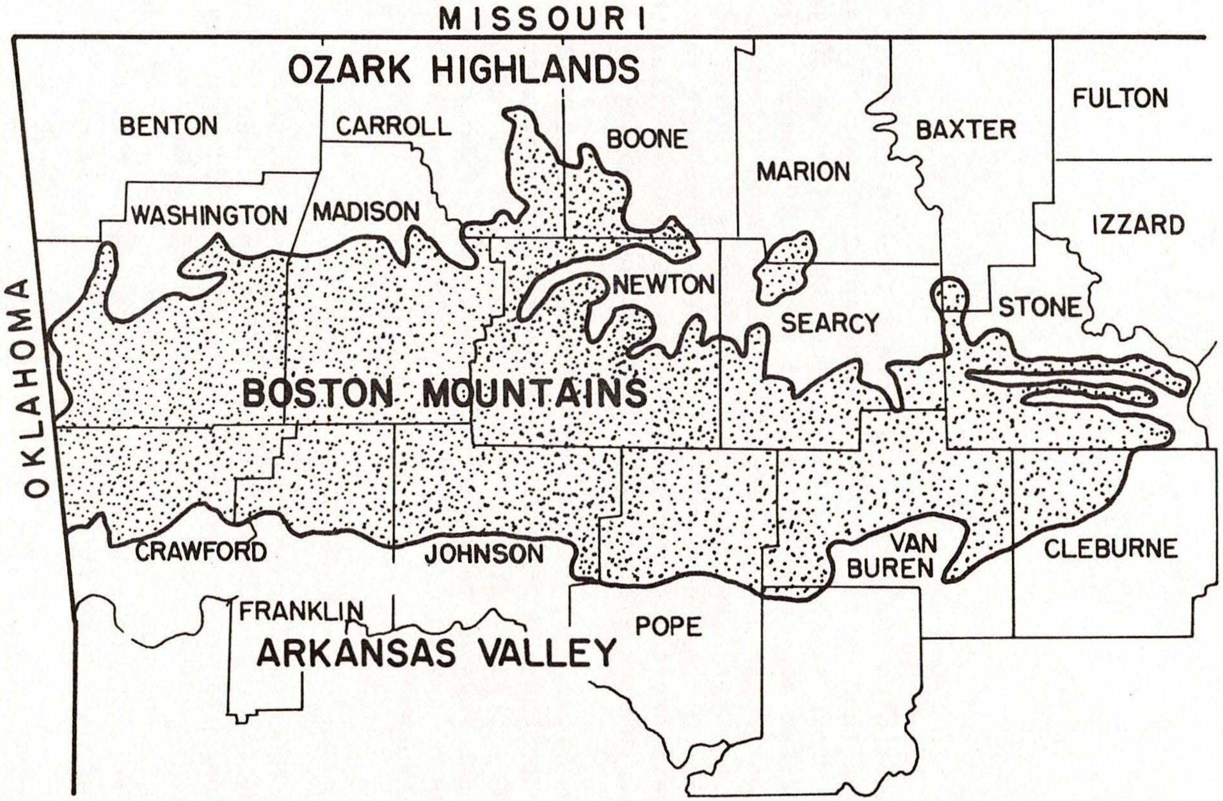

Figure 1. -- The Boston Mountains in Arkansas.

Annual precipitation averages 46 to 48 inches, with March, April, and May 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.

Stand Characteristics

The oak overstory in most Boston Mountain stands is essentially even-aged with the 60- to 70-year age classes predominating, but many stands are irregular (Graney 1980). In most upland stands, black, northern red, and white oaks account for nearly 80 percent of the total basal area and more than 90 percent of the overstory basal area. White oak is the dominant species in site 50 and 60 stands; a mixture of white, red, and black oaks is common in the stands on site 70. Northern red and black oaks dominate the stands on the best Boston Mountain sites. Most stands originated from stump and seedling sprouts, which developed into a dominant oak understory with the advent of effective fire control in the early 1900's. Periodic removal of the overstory in shelterwood-type cuts allowed development of the overstocked, poletimber stands that now occupy the area. Most stands contain several older trees that were left, for various reasons, at the time of the last overstory cut. These trees, which are primarily culls or of poor quality, now constitute an older age group of 5 to 10 trees per acre that are generally of larger diameter than the main stand.

Intermediate-aged upland oak stands in the Boston Mountains typically have many stems per acre and, from stand age 36 to 75, have many more stems than reported for upland oak stands in older areas (Schnur 1937; Gingrich 1971). Also, the number of stems per acre is increasing with stand age. The major contributors to the many total stems in Boston Mountain stands are the 1- and 2-inch diameter classes dominated by blackgum, hickory, red and sugar maples, dogwood, hophornbeam, and pawpaw. Numbers of 1- and 2-inch trees often average over 1,000 per acre in the older site 70 to 80 stands. In most older stands, oak advance reproduction is sparse or absent, so regenerating these stands to oak will require some type of understory treatment.

Structure of Boston Mountain upland oak stands is more irregular than typical even-aged stands. Boston Mountain stands typically have many more stems in the small diameter classes and a few more stems in the larger diameter classes than the even-aged stands described by Schnur (1937) and Gingrich (1971). Diameter distribution for all trees in the Boston Mountain stands is typical of an all-aged stand over all ages and sites, but the distribution of oaks closely resembles the even-aged situation (fig. 2).

Intermediate cutting in most Boston Mountain stands has been severely restricted by the lack of outlets for small diameter hardwoods. As stands became older, stocking increased to the point where most stands, wholly or in part, became badly overstocked and average annual diameter growth of potential crop trees declined to about 0.1 inch per year. Starting in 1970 the Ozark National Forest began a noncommercial thinning program to reduce competition and stimulate diameter growth of selected crop trees on medium to good sites. In 1974 our research project at Fayetteville installed a series of studies to evaluate responses to crown release and fertilization in the Boston Mountain area.

Response to Thinning and Fertilization

Diameter growth responses of individual red oaks (black and northern red) and white oaks were evaluated in two studies. One study evaluated responses to

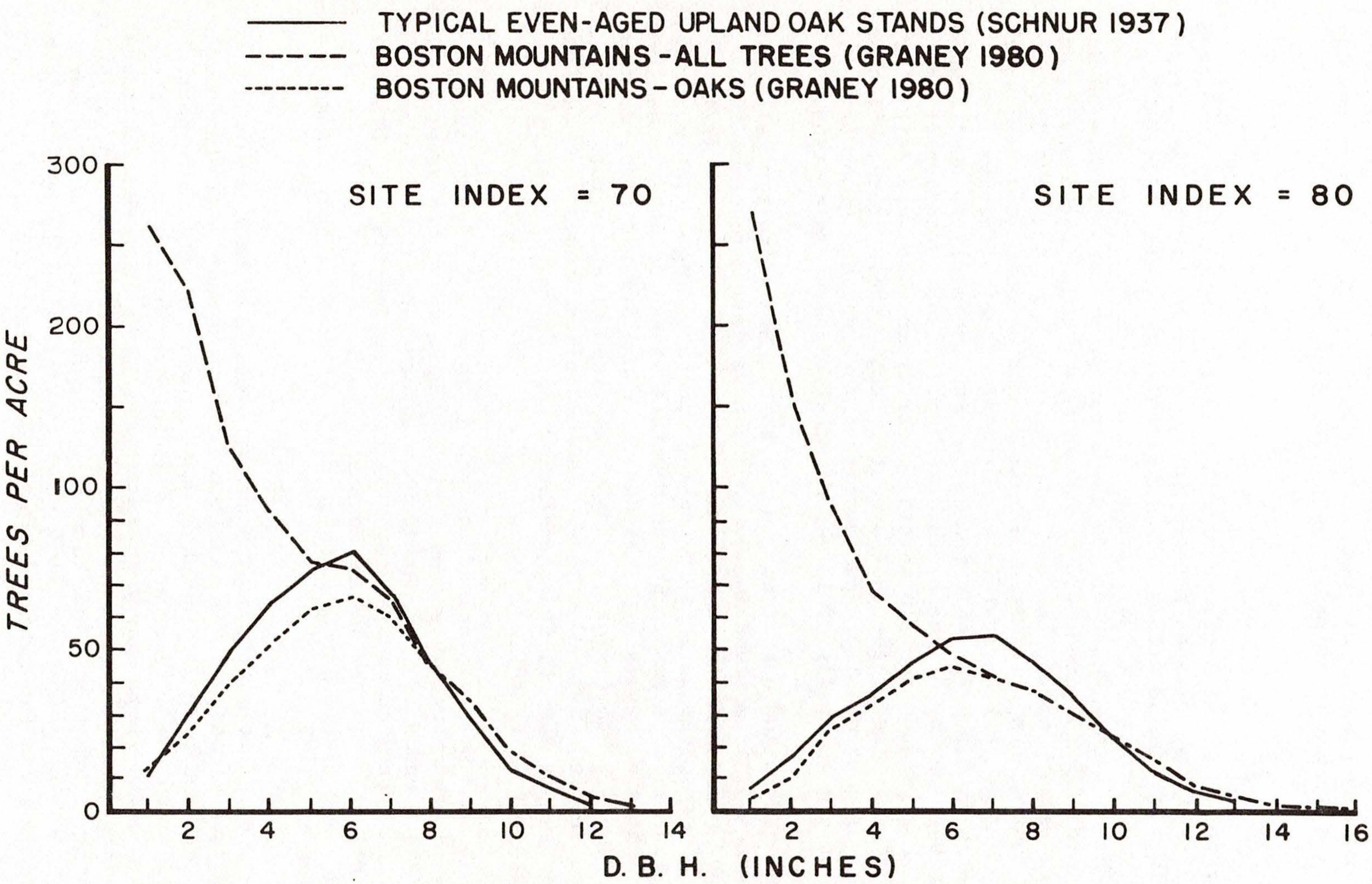

Figure 2. -- Distribution of all stems and oaks for 40-year-old, nonthinned Boston Mountain stands and stands in the eastern United States.

crown release and fertilization for 720 individual trees in 15 stands thinned between 1971 and 1975. The second study included thin, nonthin, and fertilizer treatments for 288 trees in 3 stands treated prior to the 1975 growing season. Methods, and 2-year and 7-year results for each study, have been reported elsewhere (Graney and Pope 1978a, 1978b; Graney 1982, 1983).

Response to Thinning

Diameter growth response of individual red and white oak crop trees following partial crown release treatments has been disappointingly slow, as illustrated by the nonfertilized trees in the 9 stands thinned in 1971-73 (fig. 3). Diameter growth of red oaks did not increase substantially until the 1976 or 1977 growing seasons, or 3 to 5 years after thinning. White oak produced a positive response within 1 to 2 years after thinning, and the rate of diameter growth has continued to increase through 1981. Actually, differences in red and white oak response were probably due to differences in the degree of release for each species. In general, the thinning treatments in each stand were conservative; that is, few major competitors of equal or greater size as the selected crop tree were cut. This was especially true for the red oaks, which were generally in the upper crown positions and had maintained somewhat larger crowns. Most competing trees removed were intermediate or suppressed white oaks, hickories, and gums, along with an occasional dominant or codominant tree. For white oak, thinning was somewhat more effective because selected crop trees were crowded to the point that removal of any competing trees would substantially reduce competition. Most white oaks responded immediately to release, but the level of response was low because of small crown size.

Another study was installed in three badly overstocked 50-year-old stands in an attempt to overcome the problem of differential release between species. Basal area of trees competing with each selected crop tree was reduced to 60 or 70 square feet by removing at least two major competitors and several smaller trees until the basal area goal was reached. The thinning approximated a relative stocking density of 60 percent, and at least 75 percent of the crown of each sample tree was opened to a distance of at least 5 feet to the nearest competing crown.

Although all red and white oak crop trees receiving the thinning treatment were in a free-to-grow situation with no direct crown competition and crowding, diameter growth response of released trees was again very slow to develop (fig. 4). Diameter growth rates of thinned red oaks were significantly greater than rates of nonthinned trees from the third through 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 red oaks (fig. 4). Diameter growth difference between thinned and nonthinned trees was 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 white oaks continued to increase through 1981, while nonthinned trees were continuing to grow at pretreatment levels. Growth of nonthinned trees 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.

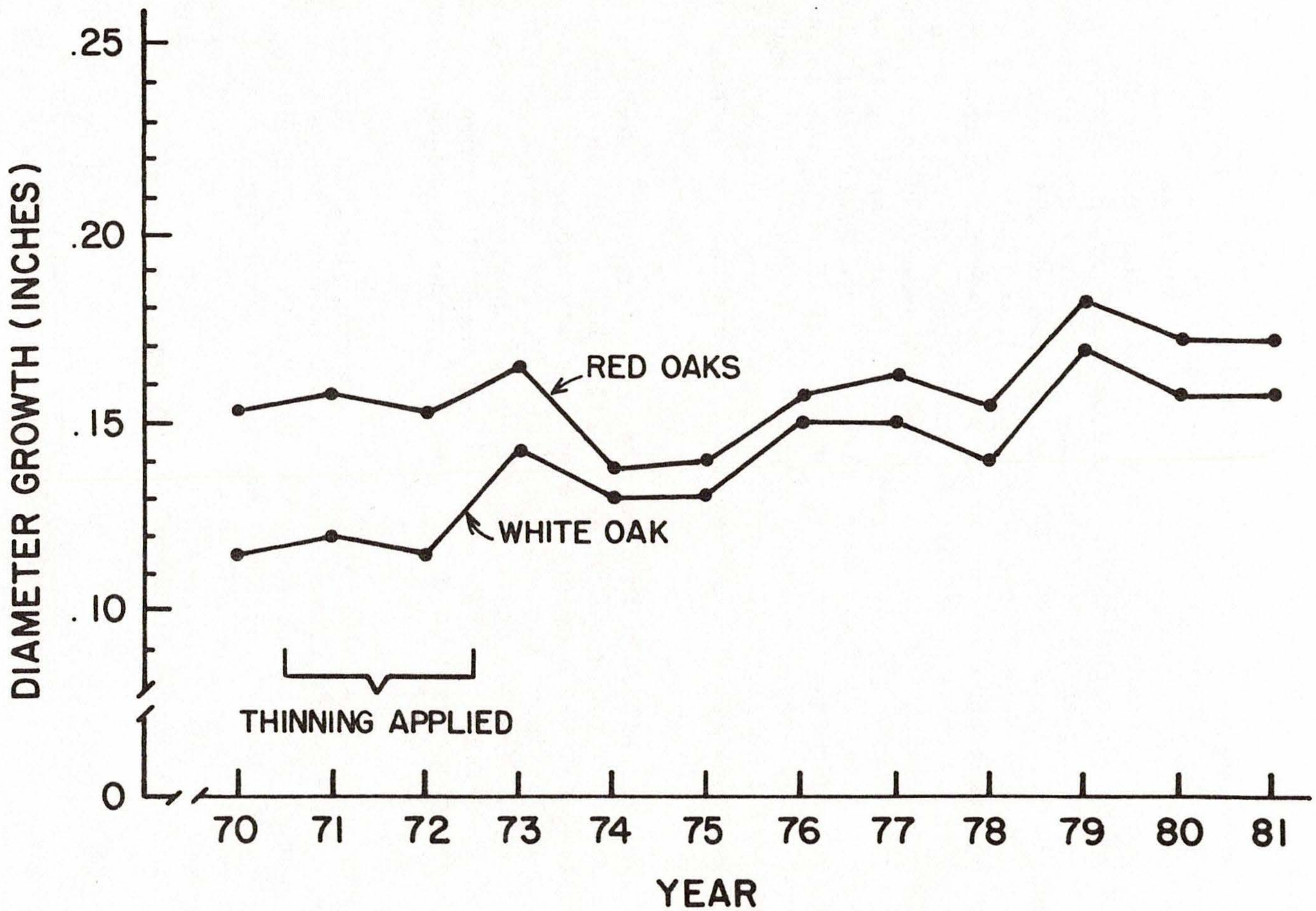

Figure 3. -- Mean annual d.b.h. growth of red oaks (black and northern red) and white oak nonfertilized crop trees thinned in 1971 - 1973.

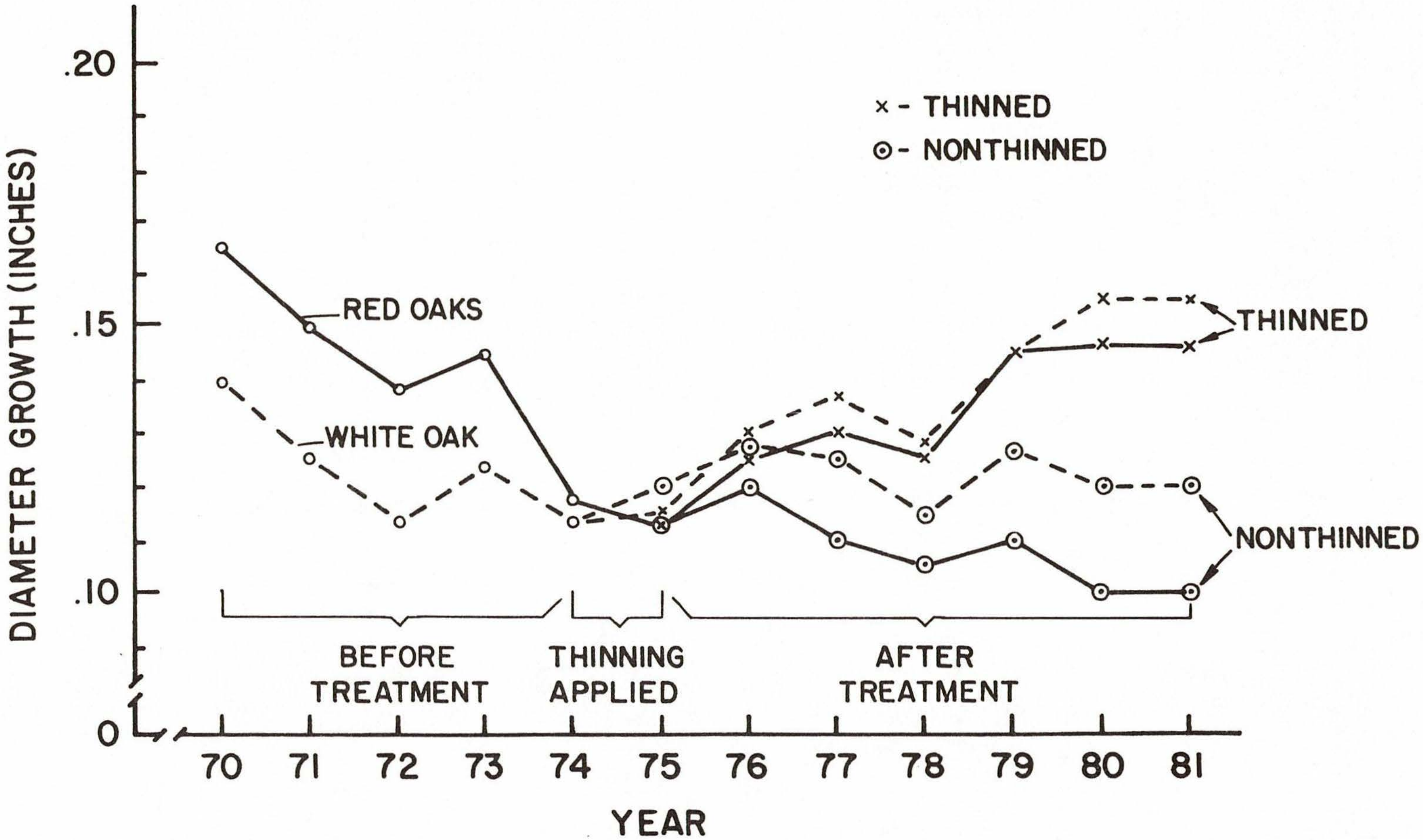

Figure 4.--Mean annual d.b.h. growth of nonfertilized red oaks (black and northern red) and white oak crop trees before and after thinning.

Although diameter growth response to thinning in these studies was much lower than for white oaks in southern Illinois (Minckler 1967) and south central Tennessee (McGee 1981), the results are not unrealistic when stand and sample tree conditions are considered. All stands sampled in these studies had been overstocked for a period of 10 to 20 or more years before thinning. Most selected crop trees had been subjected to a long period of crowding, had relatively small crowns, and were unable to respond immediately to the thinning treatment. Annual diameter growth measurements for a Boston Mountain upland oak stocking study in overstocked stands similar to stands sampled for the present studies also shows that most crop trees in partially thinned stands respond slowly and erratically to thinning. Apparently, to maintain reasonably acceptable rates of diameter growth, red and white oak crop trees are going to require release at much younger ages than 50 to 60 years and certainly before they become severely crowded and suffer appreciable loss in crown size.

Response to Fertilization: Individual Tree Growth

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 lb. N + 45 lb. P per acre (200-lb. treatment), and (3) 400 lb. N + 45 lb. P per acre (400-lb. treatment). Fertilizers were surface broadcast in late April of 1975 on a 0.01 acre circular plot surrounding each tree.

Fertilization significantly increased diameter growth of both red and white oaks over the 7-year period, but the response varied between species and was influenced by the thinning treatment (Table 1).

Thinned red oaks produced the greatest overall response to fertilization and were 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.

Maximum response to fertilization occurred during the first 2 years after treatment. Response declined annually but remained significantly greater than nonfertilized through the fifth year. 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.

In contrast to red oaks, thinned white oak was much less sensitive to the two levels of N fertilization. Both levels produced about the same increase, 30 percent, over the 7-year period (Table 1). Thinned white oak fertilized 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 7-year period.

White oak also produced the 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.

Table 1. 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.

Although differences in diameter growth between fertilized and nonfertilized treatments were statistically significant, it is doubtful that the cumulative 7-year increase in diameter (0.2 to 0.5 inch) would justify the cost of a commercial fertilizer application in these intermediate-aged stands.

Response to Fertilization: Per Acre Growth

As part of our upland oak stand density growth and yield study, a series of fertilized-nonfertilized paired 0.5 acre plots were installed to evaluate stand response to fertilization over a wide range in site quality, stand age, and residual stand density. Individuals of each plot-pair were usually contiguous (or located in the same stand) and received the same residual stocking treatment. One plot in each pair received a single fertilizer application of 300 lb. N per acre applied as ammonium nitrate one year after the thinning treatment. We now have 5-year basal area and preliminary cubic-foot volume growth estimates for 20 of the 35 plot pairs. Although these are only preliminary average estimates of stand response to fertilization in the Boston Mountain area, they do illustrate a potential disadvantage in operational fertilization of upland oak stands in this area.

Figure 5 indicates 5-year gross and net basal area and cubic-foot volume (outside bark to a 0-inch top) growth for all stems greater than 2.5 inches dbh on plot pairs thinned to residual stocking densities of 40 or 60 percent plus nonthinned control plots with stocking densities of greater than 100 percent.

Across all stand densities, the greatest total basal area and cubic-foot volume growth occurred on the fertilized plots. However, only fertilized plots at 40 percent stocking (understocked stands) produced any appreciable net increase in growth over nonfertilized plots. Mortality offset nearly 40 and 70 percent of the growth in the 60 percent stocking and nonthinned plots. Net growth for fertilized plots at 60 percent stocking was actually less than that of the nonfertilized plots. Most of the mortality on all plots occurred during the severe drought of 1980. The plots indicated in figure 5 were fertilized before the 1977 or 1978 growing seasons and were still responding to the fertilizer treatment. The last group of plots fertilized in conjunction with this study (in 1979) also indicated fairly heavy mortality, but the 5-year growth information is not available at this time.

Although the physiological basis for the high mortality rate on fertilized plots is unknown, it is probably related to the timing of the fertilizer application relative to the drought. Mortality on plots fertilized 1, 2, or 3 growing seasons prior to 1980 was greater than observed on the nonfertilized plots. However, of the nearly 600 red and white oak crop trees fertilized in 1975 as part of the individual tree studies described above, no mortality occurred in 1980.

Severe droughts, such as occurred in the Boston Mountains in 1980, cannot be predicted but do occur with greater frequency in the western part of the oak range. When drought-caused mortality could reduce or eliminate expected gains from operational fertilization programs, it is doubtful that significant investments in oak stand fertilization would be justified for the Boston Mountain area.

Conclusions

The individual tree diameter growth responses described represent the "worst case" situation for most Boston Mountain upland oak stands. Crop trees selected

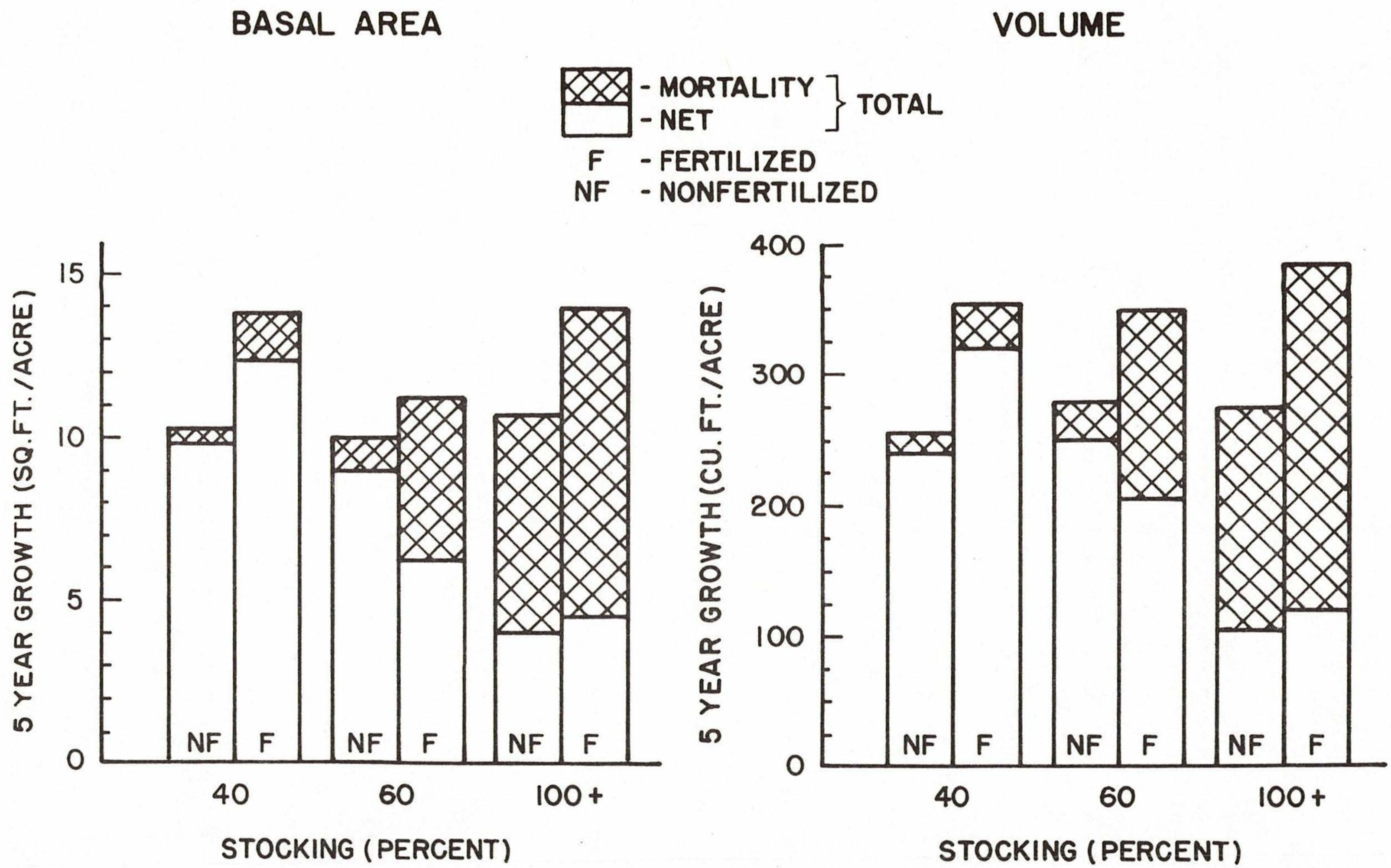

Figure 5.-- 5-year basal area and cubic foot volume (o.b. to 0-inch top) growth for all trees greater than 2.5 inches d.b.h. on fertilized-nonfertilized plot pairs.

to receive the thinning and fertilizer treatments were tightly-grown, small-crowned, lower-vigor codominants that would have to be selected as crop trees to maintain a fully stocked stand after thinning. Most overstocked stands have about 30 to 40 percent relative stocking density in higher vigor dominant and codominant red and white oak crop trees that have maintained competitive crown positions and size. These larger crowned trees will respond to both thinning and fertilizer applications.

Annual diameter measurements taken in conjunction with our oak stand density study indicate that free-to-grow red and white oak crop trees in 40- to 70-year-old stands on medium to good sites should average about 0.20 to 0.30 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 relative crown size. In considering silvicultural investments in this area, regulation of stand density in younger stands should have first priority.

The problem of what to do with the thousands of acres of overstocked stands in the 60-year plus age classes still remains. These stands are within 30 to 40 years of the 100-year rotation age; and, although some benefit in additional crop tree growth could be obtained, it is doubtful that a noncommercial thinning could be justified. However, most stands on sites 70 to 80 have enough removable volume in sawtimber size classes so that stands can be thinned commercially through small sawlog sales.

Many of the overstocked stands on sites 60 through 80 have little or no advance oak regeneration. These stands are going to require overstory and, in most cases, understory density treatments to promote establishment and development of advance oak reproduction. In most stands the overstory density treatments will involve both commercial sales of the small sawtimber size classes and noncommercial removal of the nonmerchantable trees required to reach the overstory stocking goal. Such treatments, justified on the basis of promoting advance oak reproduction, will also release crop trees for increased growth during the remainder of the rotation.

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