# RESPONSE OF RED OAKS AND WHITE OAK TO THINNING AND FERTILIZATION IN THE BOSTON MOUNTAINS OF ARKANSAS: 7-YEAR RESULTS

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Abstract.--A study of thinning and fertilization in poletimber-size 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 N and P were broadcast at either 224kg N + 50 kg P per ha or 448kg N + 50kg P per ha to individual oaks that had been thinned 0, 1, 2, 3, or 4 years before fertilization.

Oaks receiving the 448 kg/ha fertilizer treatment produced 30 percent increases in periodic diameter growth during the 7 years after fertilization. Periodic diameter growth for the 224 kg/ha treatment increased 17 percent for red oaks and 21 percent for white oak. Maximum response to each fertilizer treatment occurred during the first and second years after treatment. Response continued through the third year after fertilization for trees receiving the 224kg treatment and through the fifth year for the 448kg treatment. The time interval between thinning and fertilizer application (0-4 years) did not significantly affect diameter growth response to fertilization.

Keywords: Forest fertilization, thinning, *Quercus* spp.

## INTRODUCTION

Large areas of northern Arkansas now support even-aged, overstocked, poletimber-size stands of oaks and associated hardwoods. Most stands are from 40 to 70 years old, range from 15 to 30cm in diameter and average about 2.5cm of diameter growth in 10 years. Increasing demand for hardwood sawtimber and small inventories of large poletimber and small sawtimber size classes had encouraged many land managers to begin noncommercial thinning programs to reduce competition and accelerate growth of potential crop trees. Further stimulating growth of crop trees by fertilization may be possible. 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 in this area (Graney and Pope 1978a, 1978b). Two-year diameter growth of fertilized red oaks increased by 45 to 70 percent and growth of white oak increased about 60 percent. Red oaks responded more to higher levels of N, while white oak produced the same response to medium and higher levels of N.

This paper summarizes 7-year growth responses to fertilization of red oaks (northern red oak and black oak) and white oak in the Boston Mountains of Arkansas. Objectives were to determine if fertilizer applications increased

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diameter growth of these oaks in previously thinned stands. Another goal was to determine the importance of time since thinning on diameter growth response to fertilization.

## PROCEDURES

### Study Area

The Boston Mountains are the highest and southernmost member of the Ozark Plateaus physiographic Province (Figure 1). They form a band 50 to 65km wide and 325km long from north central Arkansas westward into eastern Oklahoma. Elevations range from about 275m in the valley bottoms to 790m at the highest point. The plateau is sharply dissected and most ridges and spurs are flat to gently rolling and are less than 1km 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 Pennsylvanian age consisting of alternating horizontal beds of shale and sandstone.

Annual precipitation averages 1170 to 1220mm in the portion within Arkansas an area of 900,000ha. March, April and May are the wettest months. Long, dry summers are common and the autumn is usually dry as well. The frost-free period is normally 180 to 200 days.

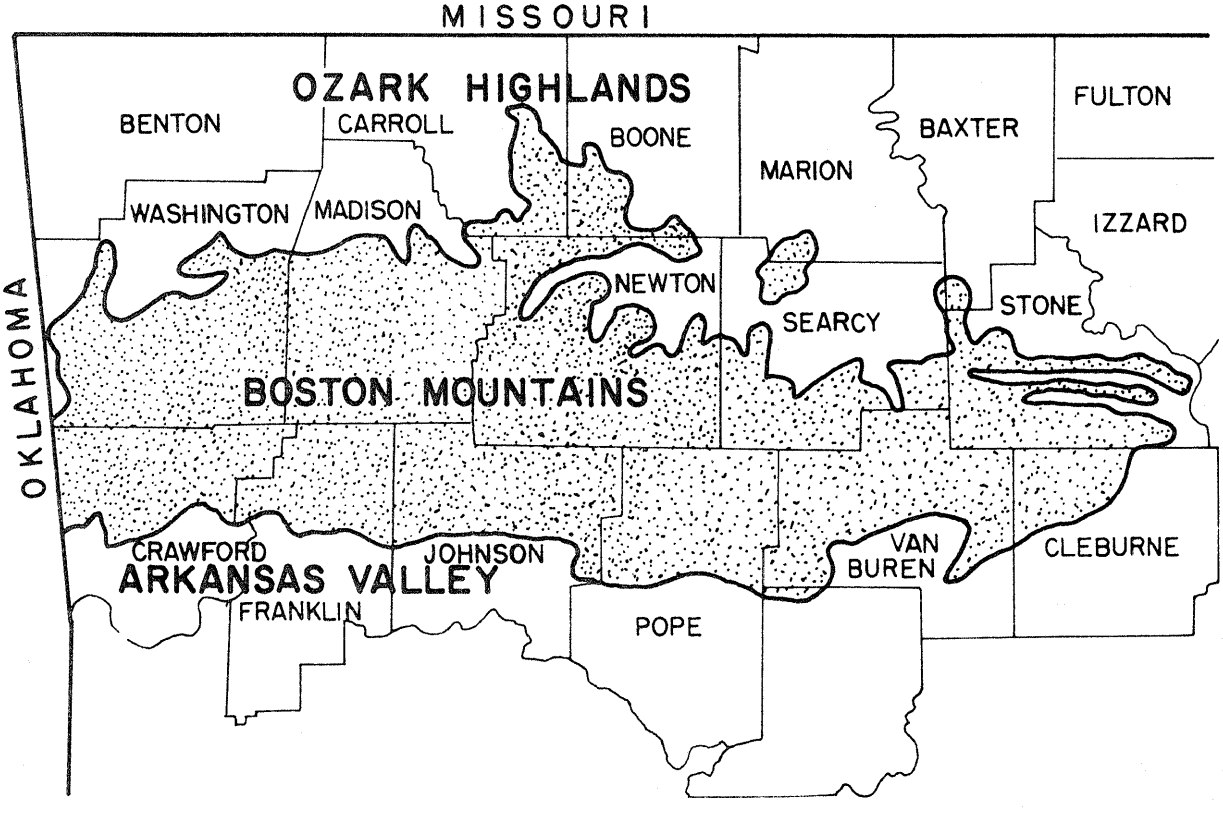


Figure 1.--The Boston Mountains of Arkansas.

## Study Areas

Study areas were located on the Ozark National Forest and consisted of stands that had been thinned by National Forest personnel before the 1971 through 1975 growing seasons. Each thinning date was replicated in three stands for a total of 15 stands. The thinnings were noncommercial, and, in each stand, crop trees were selected at a 6- or 8-m spacing and only those trees directly competing with crowns of the selected crop trees were removed. The degree of competition reduction for selected crop trees varied considerably from stand to stand and from year to year. In general, stands thinned in 1971-73 had less effective competition reduction for selected crop trees than the stands thinned in 1974-75.

Study trees were located on gently sloping mountain benches 40 to 60m wide. The soils (primarily Nella and Leesburg series) were over 150cm deep, medium textured, and well drained. These soils are typical of the more productive upland soils in the mountains. In each stand, 24 red oaks (northern red or black) and 24 white oak trees were selected for fertilizer treatments for a total of 360 red oaks and 360 white oaks in the 15 stands. Each sample tree was either dominant or codominant before thinning and had been partially released from crown competition on two sides (or two competitors had been removed). In each stand, trees representing each species group were arranged in eight sets of three trees each. Trees in each set were located on essentially the same soil and slope condition, and were uniform in height, diameter, crown size, and intensity of thinning.

## Tree Measurements

Diameter at 1.37m (d.b.h.) for each sample tree was measured to the nearest 0.25mm. The diameter measurement point was identified by a painted band to ensure accurate location for remeasurements. Increment cores, extracted from the north, east, west and south sides of each tree, were used to determine tree age and to obtain a measure of past growth. After extraction, increment cores were sealed in plastic soda straws. Annual radial growth of each core was measured to the nearest 0.25mm with a binocular microscope. Total height was also recorded for each tree. An estimate of the residual stand basal area of trees competing with each sample tree was obtained using a prism with the sample tree as plot center. Mean stand and tree values for each year of release indicate that locations were reasonably uniform with respect to age, site index, initial diameter, and basal area (Table 1).

## Fertilizer Treatments

Fertilizers were ammonium nitrate (34-0-0) and diammonium phosphate (18-46-0) Fertilizer treatments were: (a) no fertilizer (nonfertilized), (b) 224kg N + 50kg per ha (224kg treatment), and (c) 448kg N + 50kg P per ha (448kg treatment). Fertilizers were surface broadcast in late April 1975 on a 0.004ha circular plot surrounding each tree.

## Data Analysis

The study design was a split-plot with time since thinning representing the whole plot and fertilizer treatments the subplots. Data were analyzed by analysis of covariance with mean annual growth for the 5-year period before thinning as the covariate. Differences among adjusted treatment means were tested by preselected orthogonal contrasts.

Table 1.--Average stand and tree characteristics for red and white oaks before fertilization in 1975.

| Year thinned | Age [mean (range)] (years) | Site index [mean (range)] ( m) | Initial diameter [mean (range)] ( cm ) | Stand basal area [mean (range)] ( $m^2$/ha) |
|---|---|---|---|---|
| | | Red Oaks | | |
| 1971 | 49 (48-51) | 19.2 (18.6-19.8) | 23.39 (21.82-24.54) | 16.1 (15.6-16.5) |
| 1972 | 61 (55-68) | 18.9 (18.3-19.8) | 28.83 (23.95-32.66) | 17.9 (16.8-18.6) |
| 1973 | 58 (56-65) | 19.2 (18.3-19.8) | 26.31 (24.97-30.86) | 17.9 (16.1-19.3) |
| 1974 | 53 (49-58) | 19.8 (18.9-21.3) | 22.23 (20.47-23.98) | 18.4 (17.2-19.8) |
| 1975 | 50 (47-55) | 18.9 (18.6-19.2) | 20.78 (18.34-23.75) | 16.1 (14.9-17.0) |
| | | White Oak | | |
| 1971 | 53 (51-57) | 17.4 (16.8-18.9) | 21.74 (20.35-22.63) | 16.1 (15.6-16.5) |
| 1972 | 65 (56-72) | 17.1 (16.8-17.4) | 25.55 (22.00-29.13) | 17.9 (16.8-18.6) |
| 1973 | 62 (60-68) | 17.7 (17.4-17.7) | 24.79 (24.00-25.22) | 17.9 (16.1-19.3) |
| 1974 | 56 (52-62) | 18.0 (16.8-18.9) | 20.27 (17.88-23.19) | 18.4 (17.2-19.8) |
| 1975 | 52 (49-54) | 18.0 (17.4-18.6) | 20.98 (18.67-22.58) | 16.1 (14.9-17.0) |

## RESULTS AND DISCUSSION

Fertilization significantly increased diameter growth of dominant and codominant red and white oaks during the 7-year period, but time since thinning had no apparent effect on the degree of response to the fertilizer treatments (Table 2). Mean annual diameter growth of fertilized red and white oaks in previously thinned stands was about the same. Fertilized red oaks averaged 17 and 29 percent increases over nonfertilized trees for the 224 and 448kg treatments while increases for white oaks averaged 21 and 31 percent. Additional diameter growth response to the higher level of N was also significant for each species group.

Although the overall response by red and white oaks was similar, yearly response and response to levels of fertilization varied by species (Table 3, Figures 2 and 3). For each species, maximum diameter growth occurred the first and second years after fertilization. Red oaks averaged about 46 percent increases for the 224kg treatment and 73 percent for the 448kg treatment. For the same period, white oak responded much the same to each level of fertilization with average increases of about 60 and 66 percent for the 224 and 448kg treatments.

Diameter growth of fertilized trees of each species group declined yearly, but remained significantly greater than growth of nonfertilized trees through the fifth year. Red oaks fertilized at the 448kg N level produced the greatest yearly diameter growth response for the 1975-79 period (Figure 2). White oak was less sensitive to fertilizer level the first 2 years, but trees receiving the 448kg rate produced significantly greater response from years three through five (Figure 3). Mean annual diameter growth of fertilized trees of each species during the sixth and seventh years was about the same as for the nonfertilized trees.

Over the 7-year period, mean diameter growth of fertilized red oaks was generally lower than reported for red oaks in New York (Karning 1972) and the Tennessee Valley (Farmer et al. 1970) and slightly greater than observed for red oak in West Virginia (Lamson 1978, 1980) and for black oak in the Missouri Ozarks (Watt 1974). Fertilized white oak in this study grew 26 percent faster than nonfertilized trees which is about the same as response reported for fertilized white oak in Pennsylvania (Ward and Bowersox 1970) but much lower than observed for white oak in the Tennessee Valley (Farmer et al. 1970).

Overall response of fertilized red and white oaks was reduced by the complete lack of response during the severe drought of 1980 and the inability to recover during the wet growing season of 1981. Although diameter growth of all trees was reduced in 1980-81, fertilized trees were apparently more severely affected. Northern red and black oaks were especially hard hit by the 1980 drought. Recent inventories of a Boston Mountain upland oak stocking study, with several fertilized and nonfertilized paired half-acre plots, indicated that mortality of dominants and codominants in both thinned and nonthinned stands was much greater on plots that had been fertilized 3 to 4 years before the 1980 drought than on nonfertilized plots[2/].

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2/ Graney, David L. The effects of intermediate cutting and fertilization on growth of Boston Mountain and Ozark Highland oak poletimber stands (unpublished data on file).

Table 2.--Mean annual periodic (1975-1981) diameter growth of fertilized red and white oak trees by date of thinning. Values were adjusted for differences in diameter growth during the 5-year period before thinning.

| Year thinned | Treatment | | | | |
|---|---|---|---|---|---|
| | Nonfertilized | 224kg | | 448kg | |
| | Growth (cm) | Growth (cm) | Response[1/] (%) | Growth (cm) | Response[1/] (%) |
| | | Red Oaks | | | |
| 1971 | 0.419 | 0.445 | 8 | 0.503 | 20 |
| 1972 | 0.363 | 0.442 | 22 | 0.511 | 41 |
| 1973 | 0.371 | 0.424 | 14 | 0.432 | 16 |
| 1974 | 0.315 | 0.406 | 29 | 0.396 | 26 |
| 1975 | 0.404 | 0.465 | 15 | 0.569 | 41 |
| Mean | 0.373 | 0.437 | 17 | 0.483 | 29 |
| | | White Oak | | | |
| 1971 | 0.422 | 0.503 | 19 | 0.551 | 31 |
| 1972 | 0.366 | 0.427 | 17 | 0.434 | 19 |
| 1973 | 0.358 | 0.404 | 13 | 0.429 | 20 |
| 1974 | 0.297 | 0.356 | 20 | 0.432 | 45 |
| 1975 | 0.330 | 0.452 | 37 | 0.455 | 38 |
| Mean | 0.356 | 0.429 | 21 | 0.465 | 31 |

1/ Percent increase over nonfertilized trees.

Table 3.--Mean annual diameter growth of fertilized red and white oak trees. Data averaged over all thinning dates and adjusted for differences in diameter growth during the 5-year period before thinning.

| Year | Treatment | | | | |
|---|---|---|---|---|---|
| | Nonfertilized | 224kg | | 448kg | |
| | Growth (cm) | Growth (cm) | Response[1/] (%) | Growth (cm) | Response[1/] (%) |
| | | Red Oaks | | | |
| 1975 | 0.312a[2/] | 0.462b | 48 | 0.546c | 75 |
| 1976 | 0.353a | 0.511b | 45 | 0.602c | 71 |
| 1977 | 0.368a | 0.439b | 19 | 0.505c | 37 |
| 1978 | 0.353a | 0.391b | 11 | 0.424c | 20 |
| 1979 | 0.422a | 0.439b | 4 | 0.478c | 13 |
| 1981[3/] | 0.406 | 0.404 | -1 | 0.412 | 1 |
| Mean | 0.373a | 0.437b | 17 | 0.483c | 29 |
| | | White Oak | | | |
| 1975 | 0.300a | 0.493b | 64 | 0.506b | 69 |
| 1976 | 0.343a | 0.536b | 56 | 0.559b | 63 |
| 1977 | 0.361a | 0.437b | 21 | 0.495c | 37 |
| 1978 | 0.328a | 0.368b | 12 | 0.421c | 28 |
| 1979 | 0.396a | 0.422b | 6 | 0.472c | 19 |
| 1981[3/] | 0.381 | 0.376 | -1 | 0.394 | 3 |
| Mean | 0.356a | 0.429b | 21 | 0.465c | 31 |

1/ Percent increase over nonfertilized trees.

2/ Values in rows followed by the same letter are not significantly different at the 0.05 level.

3/ Mean annual growth for 1980 and 1981.

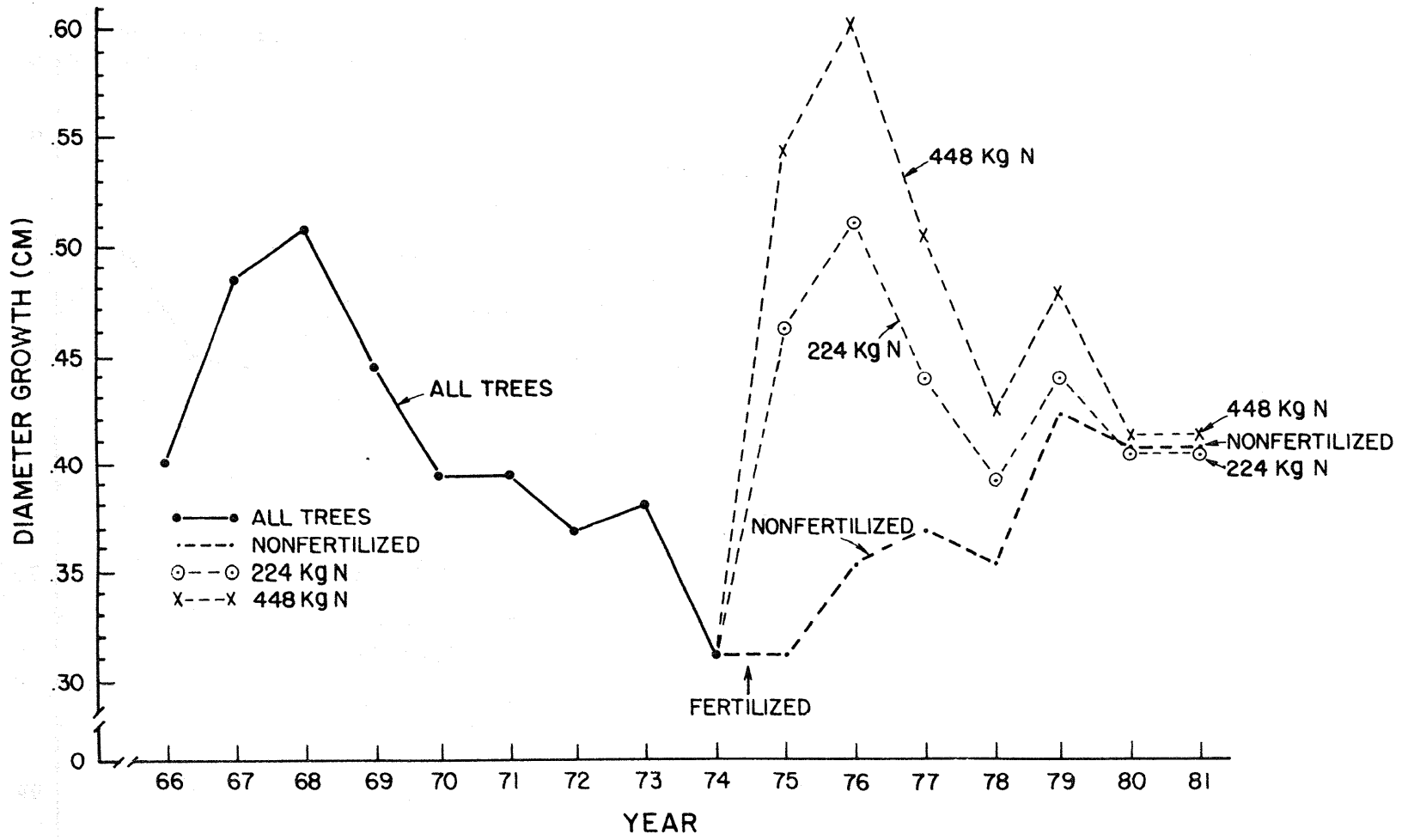


Figure 2.--Adjusted mean annual diameter growth of red oaks before and after fertilization.

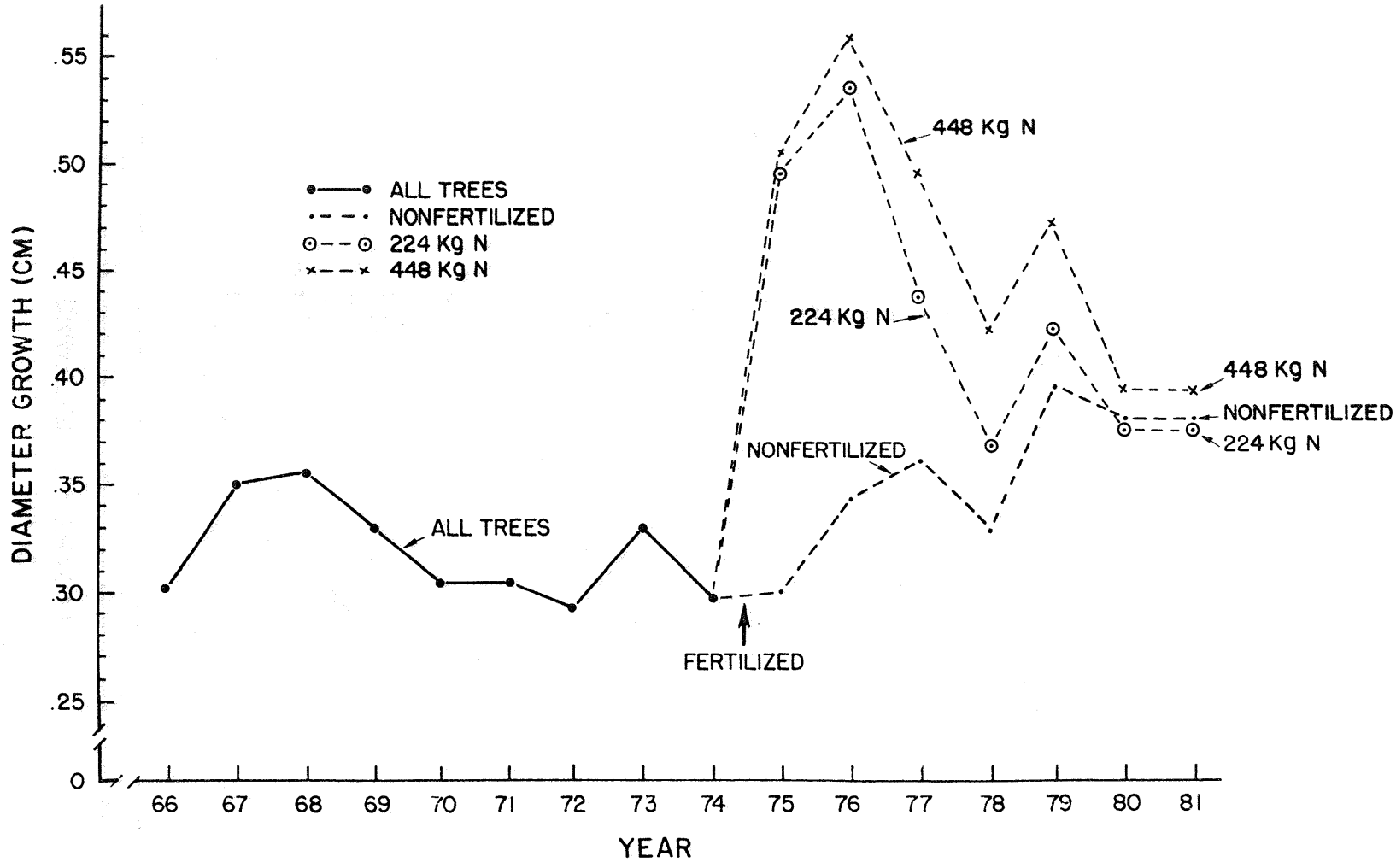


Figure 3.--Adjusted mean annual diameter growth of white oak before and after fertilization.

In reports of the 2-year results of this study and a companion study, Graney and Pope (1978a, 1978b) expressed concern over the observed low level of growth response to thinning and the absence of a measureable effect of thinning on growth response to the fertilizer treatments. Graney[3/], reporting 7-year response of red and white oaks to thinning and fertilization treatments, indicated that significant response to thinning was evident during the third year for red oaks but not until the fifth year for white oaks. Diameter growth of thinned and nonthinned trees was significantly increased by fertilization for 5 years, but the response was greater for thinned trees[3/].

That the 720 red and white oaks receiving thinning treatments between 1971 and 1975 were producing a positive response to thinning is apparent in Table 3. Mean annual diameter growth of red oak nonfertilized trees increased by 30 percent (0.31 to 0.41) between 1975 and 1981 while white oak nonfertilized trees increased by 27 percent (0.30 to 0.38).

The relatively slow growth response to the thinning treatments is illustrated by the 72 red and white oak nonfertilized trees in the 50- and 60-year-old stands thinned in 1971-73 (Figure 4). The diameter growth indicated is affected by alternating wet and dry years, but rate of diameter growth of red oaks did not increase substantially until the 1976 or 1977 growing season, 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.

The effects of high stand density and increasing competition on diameter growth is quite apparent for the nonfertilized trees in the six 50-year-old stands thinned in 1974 and 1975 (Figure 5). Diameter growth rates had declined from highs of about 0.51cm for red oaks and 0.38cm for white oaks during the wet 1967 and 1968 growing seasons to about 0.25cm in 1974. These red and white oaks increased their rate of diameter growth within 2 years after thinning. Response has continued through the 1981 growing season and unlike the fertilized trees in all stands and nonfertilized trees in the stands thinned in 1971-73, did not exhibit a noticeable decline in diameter growth rate in 1980-81.

Although initial response to thinning in this study was much lower than responses reported for white oaks in southern Illinois (Minckler 1967) and south central Tennessee (McGee 1981), the results are not unrealistic when stand conditions and intensity of thinning are considered. All stands sampled in this study had been overstocked for a period of 10 to 20 years before thinning. Most trees, particularly white oaks, 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 those in this study also shows that most trees in partially thinned stands (such as this study) respond very slowly and erratically to thinning[2/].

Another possible cause for the low level of response to thinning in this study could be the degree of the competition reduction treatments. With the exception of the three stands thinned in 1975 and two stands thinned in 1974, most

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3/ Graney, David L. Effects of thinning and fertilization on growth of upland oak stands in the Boston Mountains of Arkansas (unpublished manuscript).

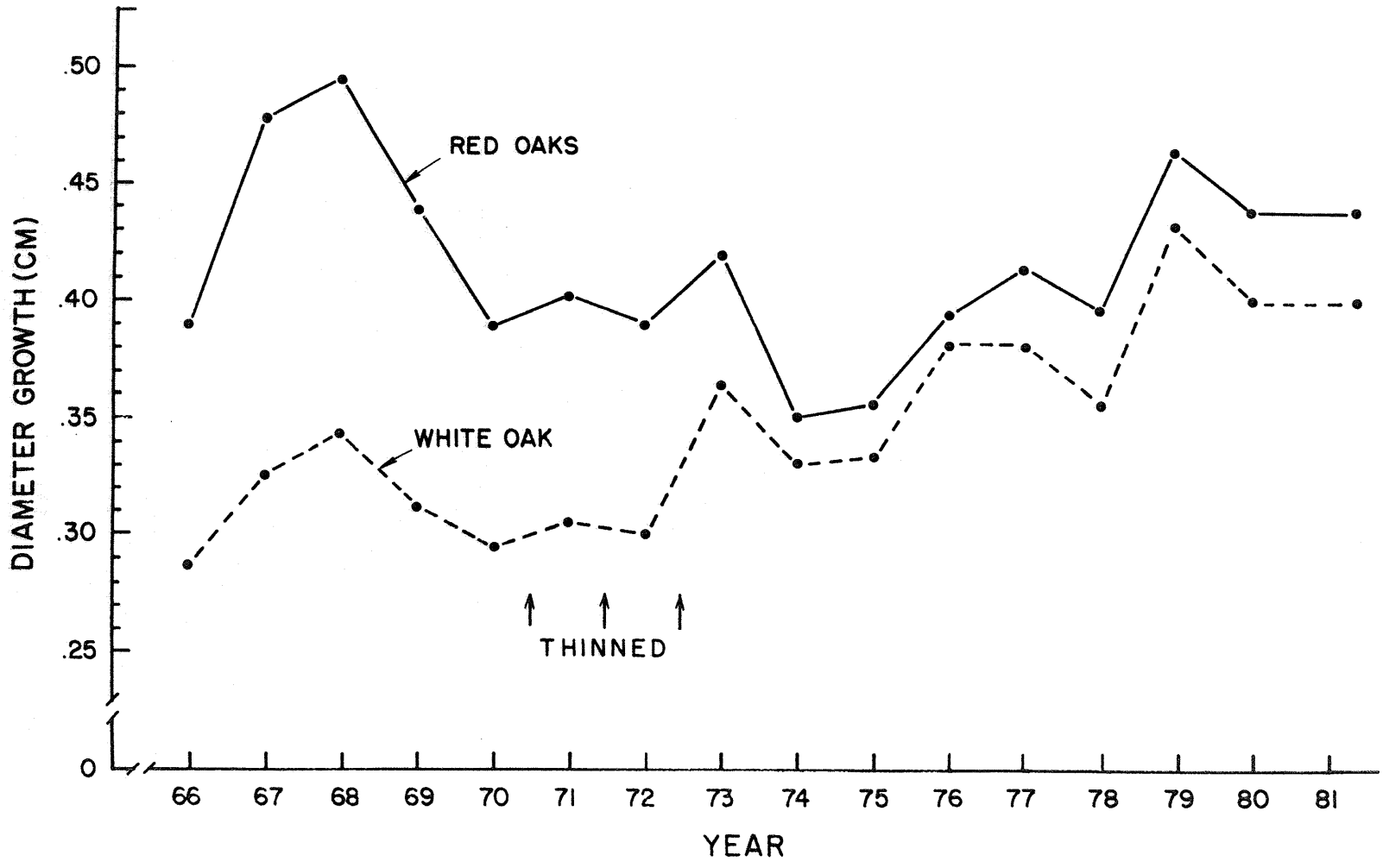


Figure 4.--Adjusted mean annual diameter growth of red and white oak nonfertilized crop trees in stands thinned in 1971, 1972 and 1973.

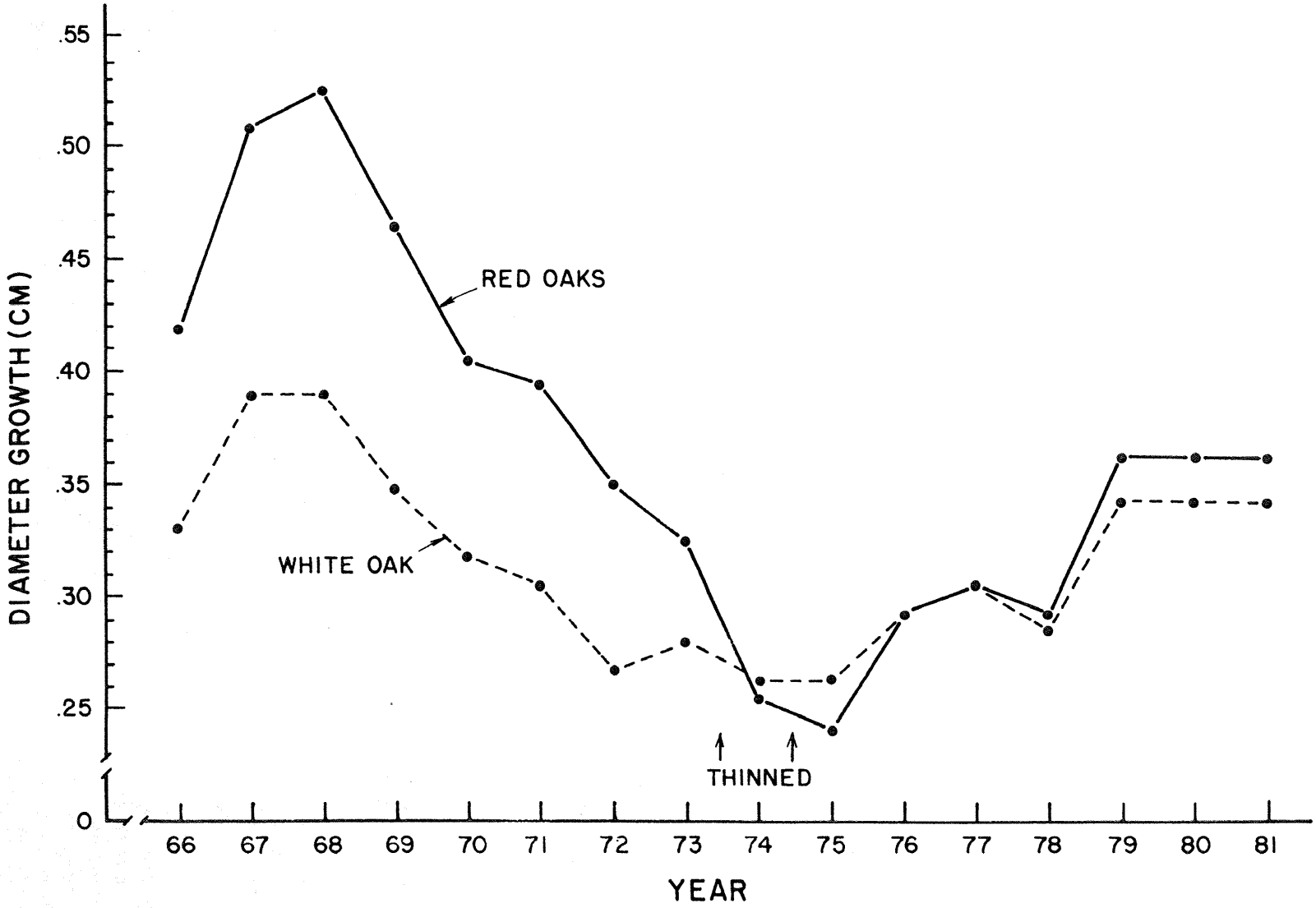


Figure 5.--Adjusted mean annual diameter growth of red and white oak nonfertilized crop trees on stands thinned in 1974 and 1975.

of the thinning treatments were conservative, that is, few major competitors of equal or greater size as the sample trees 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 in that sample trees were crowded to the point that removal of any competing trees would substantially reduce competition. Most white oak sample trees responded immediately to thinning but the level of response was low because of the small crown size. In south central Tennessee, McGee (1981) reported that the greatest 2-year response of intermediate and overtopped white oaks was associated with complete crown release (residual stand basal area of 6.9 $m^2$/ha). Trees receiving partial crown release (residual basal area of 13.8 $m^2$/ha) grew about the same as non-released controls.

Response of Large-Crowned Trees

Most of the trees measured on the 15 sample areas were in the d.b.h. range of 18 to 23cm. However, two of the stands thinned in 1972 and one stand thinned in 1973 were slighly older (ages 65 to 70) than the remaining stands. In the data for these stands, 10 three-tree sets of red oaks and 9 sets of white oak were larger-crowned trees 28 to 33cm d.b.h. that had been effectively released from crown competition. The past growth of these larger crop trees and the indicated response to fertilization and thinning (Figure 6) give some indication of what could occur on these medium sites. Apparently, dominant red oaks will respond to effective thinning treatments. Annual diameter growth of nonfertilized trees increased from about 0.50cm before thinning to 0.66cm in 1979. These larger red oaks also responded to fertilization. Over the 7 year period, the 10 nonfertilized trees averaged 0.56cm per year while those receiving the 448kg treatment averaged 0.69cm, a 23 percent increase. Red oaks fertilized at the 224kg level grew 20 percent faster than nonfertilized trees during 1975 and 1976, but growth slowed to the same rate as nonfertilized trees for the remaining 5 years. The 7-year diameter growth response for these larger fertilized red oaks averaged about 16 percent, nearly the same as the gain reported for N and P fertilized 30 to 41cm diameter northern red oaks in West Virginia (Lamson 1978).

Dominant white oaks were more crowded than the red oaks with mean diameter growth before thinning of about 0.38cm per year but did have sufficient crown to respond to thinning (Figure 6). Annual diameter growth of the nonfertilized white oaks increased by 40 percent (0.38cm to 0.53cm) between 1972 and 1981. Dominant white oaks were less responsive to the fertilization treatment than were the red oaks. Mean annual growth of nonfertilized trees from 1975-81 was about 0.51cm while white oaks receiving the 448kg treatment averaged 0.56cm, an increase of only 10 percent. White oaks fertilized at the 224kg level responded about the same as the 448kg treatment, averaging about a 7 percent increase over the nonfertilized trees.

Results of this study indicate that diameter growth of pole-sized red and white oaks can be increased by combined N and P fertilization and some response to higher levels of N fertilization will persist for about 5 years. Although 7-year differences in diameter growth between fertilized and nonfertilized red and white oak crop trees were statistically significant, it is doubtful that the real cumulative increase in diameter (0.48cm for 224kg N and 0.76cm for 448kg N) could justify the cost of commercial fertilizer applications in these intermediate-aged stands.

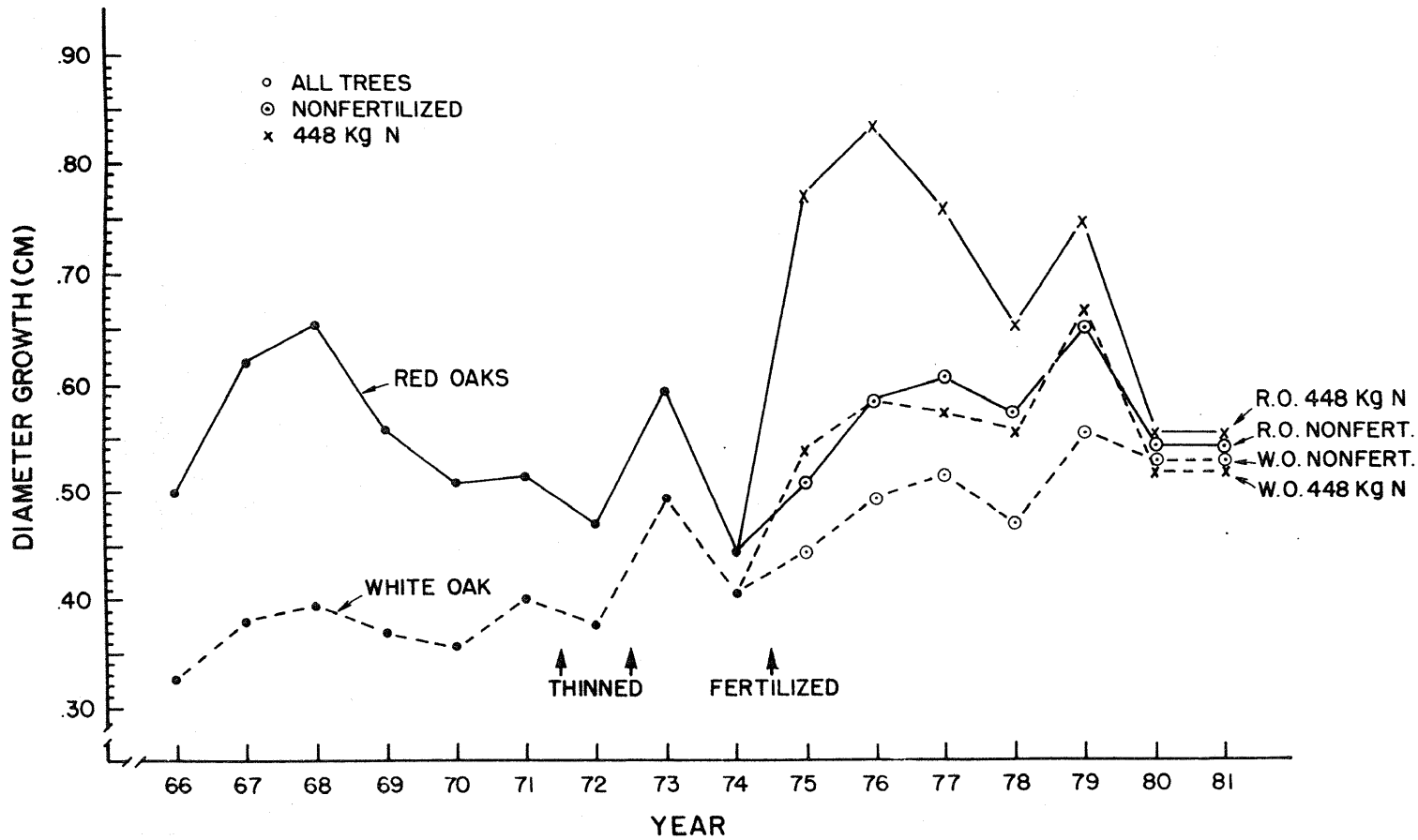


Figure 6.--Adjusted mean annual diameter growth of 28 to 33cm d.b.h. red and white oak crop trees before and after thinning and fertilization.

Diameter growth response of red and white oak crop trees to thinning in these overstocked stands will be slow in developing but can be increased significantly by a more intensive crown release treatment. Graney[3/] reported significant increases in diameter growth rates of red and white oak crop trees whose crowns were released by removal of two major and one or more minor competitors resulting in opening 50 to 75 percent of the crown to a distance of 3 to 4m to the nearest competing crown. Annual diameter measurements for an upland oak growth and yield study in this 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 0.50 to 0.60cm 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.

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