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THINNING IN A 28-YEAR-OLD WATER OAK PLANTATION IN NORTH LOUISIANA: SEVEN-YEAR RESULTS'

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Abstract-A 21-acre, 28-year-old water oak (*Quercus nigra* L.) plantation on an old-field loessial site near Winnsboro, LA. was subjected to three thinning treatments during the winter of 1987-88: (1) no thinning, (2) light thinning to 180 dominant and codominant trees per acre, and (3) heavy thinning to 90 dominant and codominant trees per acre. Prior to thinning, the plantation averaged 356 trees and 86 ft^2 of basal area per acre, with a quadratic mean diameter of 6.7 in. Thinning reduced stand basal areas to 52 and 34 ft^2 per acre for the light and heavy thinning treatments, respectively. After 7 years, thinning did not significantly increase stand-level basal area growth, but both thinning treatments produced shifts in stand structure. Diameter distributions of thinned stands were skewed to the larger diameter classes and crown class distributions of thinned stands were skewed to the upper crown classes. Both thinning treatments increased diameter growth of residual trees, but there were no significant differences between the two levels of thinning. Diameter growth of residual trees in the lightly thinned stand averaged 1.63 in. after 7 years, whereas those in the heavily thinned stand averaged 2.02 in. on this relatively poor site. Trees in the unthinned stand grew an average of only 1.04 in.

INTRODUCTION

Information on growth and development of southern oak plantations greater than 20 years of age is lacking. Most past research on oak plantations emphasized the development of suitable techniques for successful plantation establishment (Allen and Kennedy 1989, Kennedy 1993). but subsequent growth was generally followed for only a few years.

Through the Conservation Reserve Program and the Wetland Reserve Program, many thousands of acres of marginal cropland in the South have been reforested, primarily to various oak species (Kennedy 1990). As these oak plantations develop and mature, the demand for information on how to manage them will increase. Land managers will need practical guidelines on thinning and other intermediate silvicultural operations. However, information on growth and yield, pattern of stand development, and the response of older oak plantations to silvicultural operations is sparse. Consequently, few guidelines currently exist for successful management of these older plantations.

For these reasons, a thinning study was established in the winter of 1987-88 in two 28-year-old water oak plantations in north Louisiana. The study was designed to determine the diameter growth and stand structure responses of water oak to three levels of thinning. Stand parameters of the plantations prior to thinning were previously described by Krinard and Johnson (1988). Meadows and Goelz (1993) reported fourth-year responses to thinning.

METHODS

Study Area

The plantations were established in 1960 on old agricultural fields of loessial soil on the Macon Ridge landform in Franklin Parish east of Winnsboro, LA. The fields were under continuous cultivation for several decades prior to the establishment of the oak plantations. The two plantations encompass 21 acres (a 14.5acre tract and a nearby 6.5-acre tract). Both tracts are privately owned.

Both fields were planted at the rate of aporoximatelv 950 water oak seedlings per acre. Initial spading was variable, but appears to have been about 5 x 9 ft. No cultivation or other means of weed control was conducted after planting at either site.

The plantations are located on the Calhoun-Calloway-Loring soil association (Krinard and Johnson 1988) that developed from wind-blown silt, or loess. Within these terrace sites, Calhoun soils occur on the flats and depressional areas, Calloway soils are found on low ridges, and Loring soils occur on slightly higher ridges. Well over half of the study area consists of Calhoun soils, with lesser proportions of Loring and Calloway soils. The soils are generally poorly to somewhat poorly drained, but some of the higher ridges are moderately well-drained. Permeability is slow across most of the area. These soils have low-to-medium natural fertility that has been reduced through many years of use for crop production. Texture in the upper soil horizon at both sites is silt loam. Soil pH is very strongly to medium acid and ranges from 4.5 to 6.0 across both sites. Calloway and Loring soils both contain fragipans at depths of 20 to 30 in. that limit effective rooting depth and hinder tree growth.

The loessial soils of the Macon Ridge are somewhat unproductive for the growth of hardwood species, when compared to well-drained alluvial soils or the loessial hills on the east side of the Mississippi River. Broadfoot (1976) reported an average site index of 83 ft at 50 years for water oak on Calloway soils, but did not provide similar information for Calhoun or Loring soils. Based on the method described by Baker and Broadfoot (1979), we estimated that site index for water oak averaged 86 ft at 50 years across the entire study area, but ranged as high as 90 ft on the higher ridges.

Treatments

In the fall of 1986, the plantations were divided into 12 treatment plots, nine on the larger tract and three on the smaller tract. Each treatment plot was 150 ft by about 400-450 ft (45 rows) and covered an area of about 1.4 to 1.5 acres. Three O.l-acre square measurement subplots were systematically established within each of the 12 treatment

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plots; data were pooled across the three subplots within each treatment plot. Diameter-at-breast-height (d.b.h.) and crown class were assessed on all trees within each subplot. Stocking percent was estimated from trees per acre and quadratic mean diameter, according to the stocking equation developed by Goelz (1995).

Thinning treatments were originally scheduled for the winter of 1988-87, but wet soil conditions prevehted harvesting activities. The plantations were not measured again prior to thinning. Consequently, pre-treatment measurements were actually taken 1 year prior to thinning.

Four replications of three levels of thinning were applied in a randomized block design to the 12 treatment plots (experimental units) during the winter of 1987-88 at age 28 years: (1) no thinning, (2) light thinning to 180 dominant and codominant trees per acre, and (3) heavy thinning to 90 dominant and codominant trees per acre. Low thinning was used to remove trees primarily from the lower crown classes. Logs were removed from the stand and utilized as fuelwood.

RESULTS AND DISCUSSION

Residual Stand Conditions

One year prior to thinning, the plantation as a whole averaged 356 trees and 86 ft^2 of basal area per acre, with a quadratic mean diameter of 6.7 in. (Krinard and Johnson 1988). Stocking averaged 87 percent across the entire study area. No statistical differences were detected among the three treatments in any of the stand parameters 1 year prior to thinning.

Light thinning reduced stand density to 188 trees and 52 ft^2 of basal area per acre; heavy thinning reduced stand density to 103 trees and 34 ft^2 of basal area per acre. These residual densities were slightly greater than the target densities of 180 and 90 dominant and codominant trees per acre for the light and heavy thinning treatments, respectively. Expressed as percentages, light thinning removed 47 percent of the trees and 40 percent of the basal area from the plantation, whereas heavy thinning removed 71 percent of the trees and 60 percent of the basal area. Light thinning reduced stocking to 52 percent; heavy thinning reduced stocking to 33 percent. The intensity of both thinning treatments turned out to be quite severe.

Although low thinning was used to remove the smaller, less-vigorous trees, primarily from the lower crown classes, no significant differences in quadratic mean diameter could be detected among the three treatments immediately following thinning. Quadratic mean diameter ranged from 7.1 in. in the lightly thinned stand to 7.8 in. in the heavily thinned stand. Quadratic mean diameter in the unthinned stand was 7.3 in.

Stand Development Following Thinning

Prior to thinning, the plantation was a dense stand composed of small-diameter trees with short boles. The presence of many dead trees scattered throughout the stand and the presence of numerous epicormic branches along the boles of many of the living trees were indicators that the stand was not healthy and was approaching stagnation. Bottomland red oaks, when grown in even-aged mixtures with sweetgum (*Liquidambar styraciflua* L.), are generally able to eventually gain a competitive advantage over the sweetgum, dominate the stand, and develop into large trees with long, clear boles (Clatterbuck 1987, Clatterbuck and Hodges 1988, Johnson and Krinard 1988). However, oaks do not generally compete well with other oaks when grown in pure stands (Aust and others 1985), such as these two water oak plantations. Under these circumstances, it is difficult for individual oaks to gain a competitive advantage over neighboring oaks. Consequently, pure oak stands have a tendency to stagnate quickly after several years of intense competition among individual trees.

Stand development over the 7-year period following thinning was characterized by high mortality in the unthinned stand and by steady recovery in the thinned stands. The number of trees per acre in the unthinned stand steadily declined from 319 at the time of study installation to 280 in 7 years (table 1). This decrease is equivalent to 18 percent mortality over the 7-year period. In contrast, mortality in the thinned stands was substantially less, about 7 percent and 5 percent 7 years after light and heavy thinning, respectively. Mortality in the unthinned stand occurred primarily in the smaller, less-vigorous, lower-crown-class trees. As expected, we found significant differences among treatments in the number of trees per acre 7 years after thinning.

Table l-Stand conditions 7 yr after thinning in a 28-yr-old water oak plantation. Means followed by the same letter are not significantly different at the 0.05 level of probability

Treatment	Trees	Basal area	Stocking
	No./acre	*Sq ft/acre*	*Percent*
Unthinned	280 a	109 a	102a
Light thinning	175b	75 b	69 b
Heavy thinning	98 c	52 c	47 c

Light and heavy thinning greatly reduced stand basal areas to-52 and 34 ft^2 per acre, respectively, immediately following thinning. However, basal area increased steadily to 75 and 52 ft^2 per acre during the 7 years following thinning in the lightly and heavily thinned stands, respectively (table 1). Basal area in the unthinned stand increased from 92 to 109 ft^2 per acre over the same period. Neither thinning treatment significantly affected stand-level basal area growth rates, which averaged 3.3, 2.6, and 2.4 ft^2 per acre per year in the lightly thinned, heavily thinned, and unthinned stands, respectively. Although the thinned stands are recovering, their rates of basal area growth are insufficient to produce densities that approach that of the unthinned stand. Consequently, large significant differences in stand basal area across treatments still exist 7 years after thinning (table 1).

We observed a similar trend for changes in stocking among the three treatments 7 years after thinning (table 1). Light thinning originally reduced stocking to 52 percent, a value consistent with the recommended residual stocking level after thinning, as proposed by Putnam and others (1960), in stands of similar size and density. On the other hand, heavy thinning originally reduced stocking to 33 percent, a value well below recommended residual density following thinning (Goelz 1995, Putnam and others 1980). Seven years after thinning, stocking in the lightly thinned stand rose to 69 percent, a level approaching adequate stocking to promote satisfactory stand-level growth and recovery from thinning disturbance. However, stocking in the heavily thinned stand increased to only 47 percent, a level still below recommended stand density (Goelz 1995, Putnam and others 1960). Even 7 years after thinning, the heavily thinned stand is still severely understocked. Stocking in the unthinned stand increased from 91 percent at the time of study installation to 102 percent over the 7-year period.

Stand Structure

Prior to thinning, the diameter distribution pooled across the water oak plantation resembled a bell-shaped curve in which the most abundant diameter class was 6 in. (fig. 1). Seven years after study installation, the diameter distributions of the unthinned stand and the lightly thinned stand were very similar: both peaked in the 8-in. class. In contrast, heavy thinning removed most of the trees in the lower diameter classes and caused a shift in peak abundance to the 10-in. class. Because the shape of the diameter-distribution curve of a pure, even-aged stand generally flattens and peak abundance shifts to the right as the stand develops and matures, heavy thinning effectively increased the rate of stand development in this water oak plantation.

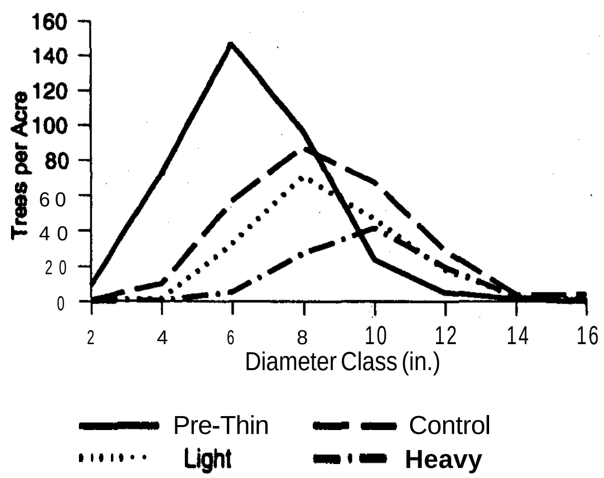

Figure l-Pooled diameter distribution 1 year prior to thinning and the diameter distributions produced by each treatment 7 years after thinning in a 28-year-old water oak plantation.

Prior to thinning, 74 percent of the trees in the water oak plantation were classed as either dominant or codominant (fig. 2), a proportion indicative of a young stand in the early phases of the canopy stratification stage of stand development. However, in addition to a large reduction in the total number of trees due to mortality in the unthinned stand over the last 7 years, we also observed a significant shift in the crown class distribution of the unthinned stand as many trees moved down one or more classes. Many of the dominant trees became codominant; many of the codominant trees became intermediate or suppressed. Seven years after study installation, the proportion of upper-crown-class trees in the unthinned stand dropped dramatically from 74 percent to only 47 percent, indicative of a stressed stand experiencing severe competition and intense canopy stratification. Crowns of individual trees in the unthinned stand are deteriorating, losing dominance, and suffering diminished photosynthetic capacity, a situation leading to reduced tree growth, increased mortality, and reduced stand productivity. In contrast, both thinning treatments removed trees primarily from the lower crown classes and produced stands that have been able to maintain high proportions of upper-crown-class trees: 65 percent in the lightly thinned stand and 79 percent in the heavily thinned stand (fig. 2). Crown subordination of some trees has occurred in the lightly thinned stand, but was not widespread. The proportion of upper-crown-class trees in the heavily thinned stand 7 years after thinning is still higher than in the pre-treatment stand. Both thinning treatments maintained or enhanced the vigor of most residual trees, as evidenced by these high proportions of upper-crown-class trees.

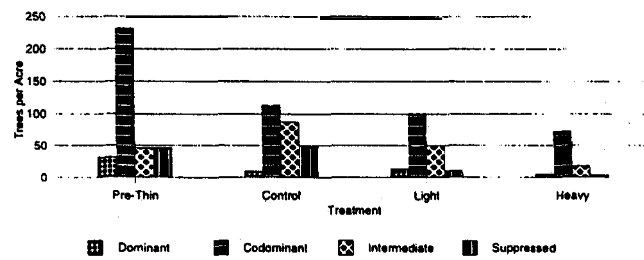

Figure 2-Pooled crown class distribution 1 year prior to thinning and the crown class distributions produced by each treatment 7 years after thinning in a 28-year-old water oak plantation.

Diameter Growth

Heavy thinning produced a significant increase in quadratic mean diameter, but quadratic mean diameters in the lightly thinned and unthinned stands were nearly equal 7 years after thinning (fig. 3). Prior to this most recent measurement, we were unable to detect significant differences among treatments in quadratic mean diameter, even though it was generally greater in the heavily thinned stand. As is apparent in figure 3, quadratic mean diameter of the heavily thinned stand has been increasing at a more rapid rate than in either the lightly thinned or unthinned stands since the second or third year after thinning, and averaged 9.9 in. at the end of the seventh year. We expect this difference to continue to increase in the future.

Cumulative diameter growth of individual trees may provide the most accurate assessment of the effects of the thinning treatments (fig. 4). Neither thinning treatment significantly affected cumulative diameter growth during the first 2 years after thinning, with growth averaging 0.44 in. across all treatments. However, a response to thinning was detected after the third year, when cumulative diameter growth of residual trees in the heavily thinned stand (1 .OO in.) was significantly greater than in the unthinned stand (0.58 in.).

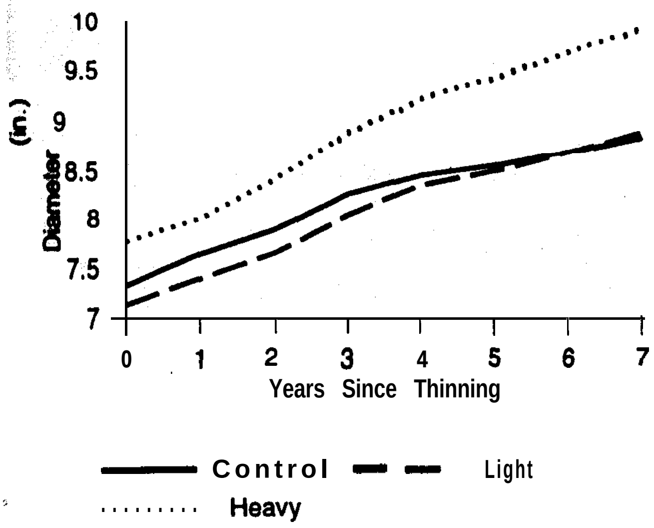

Figure 3—Changes in quadratic mean diameter, by treatment, following thinning in a 28-year-old water oak plantation.

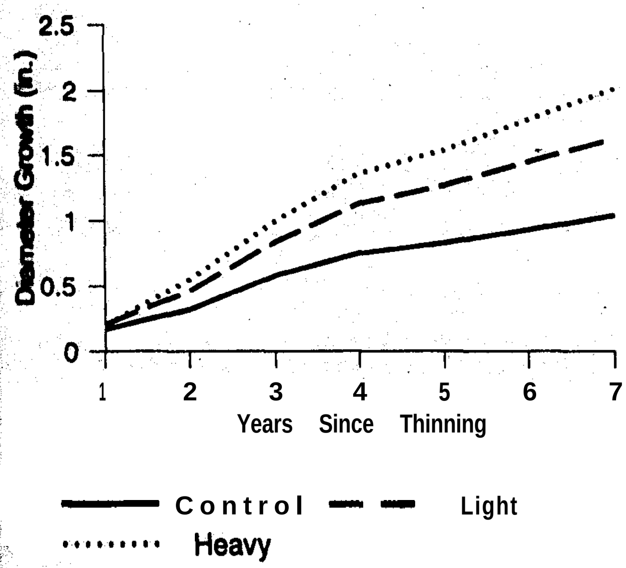

Figure 4—Cumulative diameter growth of residual trees, by treatment, following thinning in a P&year-old water oak plantation.

This trend has continued since then, with ever-widening differences between the thinned and unthinned treatments.

By the end of the seventh year after thinning, surviving trees in the unthinned stand had grown an average of only 1.04 in. in diameter. This poor growth is indicative of a low-vigor stand in which additional mortality of small trees is expected in the near future. In contrast, residual trees in the lightly thinned stand grew an average of 1.63 in. in 7 years; those in the heavily thinned stand grew an average of 2.02 in., growth rates classified as "medium" for water oak by Putnam and others (1960). Seven-year cumulative diameter growth did not differ significantly between the two levels of thinning, but both produced cumulative diameter growth significantly greater than that observed in the unthinned stand. We anticipate that these differences in diameter growth rate will continue to widen over the next several years.

Both levels of thinning increased diameter growth of trees in all crown classes. The effect was most pronounced in the codominant and intermediate classes, but even dominant trees responded well to thinning. In fact, light thinning increased diameter growth of dominants by 32 percent and codominants by 51 percent. Heavy thinning increased diameter growth of dominants by 42 percent and codominants by 86 percent.

CONCLUSIONS

Trees in the unthinned stand are not currently growing in diameter at an acceptable rate for water oak. Expressed on a 10-year basis, these trees are growing at the rate of 1.5 in. per decade. More than half of the trees are in subordinate crown classes and will likely continue to decline in growth, vigor, and quality if left unmanaged. Mortality will continue to be high over the next several years. Stand density is simply too high to promote the development of vigorous, high-quality trees.

Light thinning increased the average diameter growth rate of residual trees to an acceptable level of 2.3 in. per decade. Stand-level basal area growth appears to be sufficient to promote recovery of the stand to a fully stocked condition in a reasonable period of time. At its present rate of development, this stand will achieve 100 percent stocking when quadratic mean diameter reaches about 11 to 12 in., in approximately 9 to 10 years. Another low thinning will be necessary at that time. Among the treatments evaluated in this study, light thinning promoted the most desirable combination of individual-tree diameter growth and stand-level basal area growth.

Heavy thinning increased the average diameter growth rate of residual trees to 2.9 in. per decade, a value nearly double that of trees in the unthinned stand. However, heavy thinning reduced stocking to the point that stand-level basal area growth is inadequate to allow full recovery of the stand in the near future. It will not achieve 100 percent stocking until quadratic mean diameter averages 15 to 16 in., in approximately 20 years. Although this level of thinning greatly increased diameter growth of residual trees, it created a severely understocked stand that cannot fully occupy the site for many years to come.

Without conducting a much earlier precommercial thinning in these two water oak plantations, average initial spacing (5 x 9 ft) was too narrow to allow satisfactory development of individual trees for sawtimber management. The narrow spacing led to the onset of intense competition among neighboring trees at an early age. Trees severely competed with one another for soil moisture, nutrients, light, and growing space for many years prior to thinning. As a result, surviving trees in the stand at the time of thinning were small, low-vigor trees with deteriorating crowns, poor bole quality, and less-than-satisfactory diameter growth rates. We believe that the diameter-growth response to thinning observed in this study was diminished largely as a consequence of this narrow initial spacing that led to the long period of intense competition prior to thinning. To alleviate these problems, we currently recommend that initial spacing in bottomland red oak plantations range from 8 x 9 ft to 12 x 12 ft, depending on anticipated survival of planted trees and expected availability of markets for small-diameter trees.

The relatively poor site also impaired the ability of residual trees to respond adequately to thinning. Poor drainage, low-to-medium fertility, past land use, and the presence of fragipans on portions of the study site combined to restrict growth of trees in these plantations. A fragipan greatly hinders tree growth because it results in a perched high water table during winter and spring, but limits the effective rooting depth and leads to severe water deficits during summer. This situation, coupled with the poor drainage and slow permeability of the soil above the fragipan, creates a harsh site that is very wet in the winter and spring months and very dry in the summer and fall months. Even though thinning alleviates some of the competitive factors previously mentioned, the inherent low productivity of the site itself limits the ability of residual trees to respond to the thinning.

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