12-1995

Crop Tree Management of Upland Hardwoods in West Tennessee

David O'Neal
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To the Graduate Council:

I am submitting herewith a thesis written by David O'Neal entitled "Crop Tree Management of Upland Hardwoods in West Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Edward R. Buckner, Major Professor

We have read this thesis and recommend its acceptance:

John C. Rennie, Allan E. Houston, Fred L. Allen

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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and recommend its acceptance:

J.M. Rennie

Fred J. Allen

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

CROP TREE MANAGEMENT OF UPLAND HARDWOODS IN WEST TENNESSEE

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

Dwight David O'Neal

December 1995

ACKNOWLEDGMENTS

First and foremost I would like to thank Dr. Edward R. Buckner, for graciously serving as my Major Professor and for providing insight and guidance throughout my graduate studies. Special appreciation goes out to Dr. Allan E. Houston for his constant support and hard work. Appreciation is also expressed to Drs. John C. Rennie and Fred L. Allen for their expertise and guidance as committee members throughout the course of this study.

Many thanks go to the personnel of Ames Plantation and the Trustees of the Hobart Ames Foundation for providing constant support and an exceptional facility on which to conduct research. Special thanks are expressed to Dr. James M. Anderson, Superintendent, and Dr. Ricky J. Carlisle, Assistant Superintendent, Ames Plantation. Special thanks go to Mr. James Morrow at Ames Plantation for his hard work during the implementation of this research.

Sincere appreciation is expressed to the U.S. Forest Service, Southern Forest Experiment Station for their interest in and financial support of this research. Special thanks go to Dr. Steve Meadows for his guidance and support throughout the course of this study.

I would also like to thank Dr. Don O. Richardson, Dean, Agricultural Experiment Station, for his support of this study.

Sincere appreciation also goes out to The Tennessee, Agricultural Experiment Station.

Sincere appreciation is expressed to Dr. Arnold Saxton for his statistical expertise and willingness to aid in the analysis of this study. Many thanks go to Mr. John A. Mullins for being a constant source of technical support and advice. I would also like to thank Mr. Brien Ostby for his "legwork", especially in the final stages of the study.

This thesis is dedicated to three people, my wife, Brenda R. O'Neal, my father, Frank S. O'Neal and my mother, Patsy R. O'Neal. A huge debt is owed to my wife and best friend Brenda, for her unending patience, advice and love. I thank my parents for giving me the opportunity to achieve my goals and for providing sound advice and constant love.

ABSTRACT

A 40-year-old upland hardwood stand in west Tennessee was selected to test the effectiveness of crop tree management techniques. The stand consisted of 20 acres with each acre having the potential to contain 36 crop trees. Treatments consisted of: 1) a crown release, 2) fertilization (150 lbs. N and 35 lbs. P_2O_5 per acre) and 3) a combined release and fertilizer treatment.

A severe ice storm struck west Tennessee the winter following the study's initiation. Results indicated that release greatly increased a crop tree's susceptibility to severe ice damage and that black cherry (Prunus serotina Ehrh.) was particularly susceptible with only 6 of the original 28 trees surviving the storm.

Covariate analyses were conducted to account for the differences in initial volume among the treatments due to the ice storm. These results showed that cumulative 2 year growth per acre in the combined treatment (46.28 cu. ft.) was significantly greater than growth in all other treatments. Cumulative 2 year growth in the release treatment (39.03 cu. ft.) was significantly greater than growth in the control (29.97 cu. ft.) but not the fertilizer treatment (35.09 cu. ft.). There was no significant difference in cumulative 2 year volume growth per acre between the fertilizer and the control treatments.

Cumulative 2 year diameter growth of white oak (Quercus alba L.) in the combined treatment was 0.679 inches followed by the

release treatment (0.568 in.), the fertilizer treatment (0.468 in.) and the control (0.3955 in.). All means were statistically different. Basal area growth followed a similar pattern: combined treatment 0.0801 sq. ft., release treatment 0.0664 sq. ft., fertilizer treatment 0.0532 sq. ft., and the control 0.0440 sq. ft.

Cumulative 2 year diameter growth of southern red oak (Quercus falcata Michx.) in the combined treatment (0.787 in.) was significantly greater than growth in all other treatments: release (0.560 in.), fertilizer (0.550 in.), and control (0.433 in.) Basal area growth in the combined treatment (0.0960 cu. ft) was also greater than growth in the other treatments: release (0.0648 sq. ft.), fertilizer (0.0650 sq. ft.), and control (0.0458 sq. ft.).

Crop tree management concepts, as developed in this study seem to have far ranging practicality for non-industrial forest landowners. These concepts can be easily conveyed to the landowner and tailored to meet his/her management objectives.

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CHAPTER I

INTRODUCTION

Non-industrial private forests (NIPF) make up approximately 66% of the commercial forest land in the South (Webb 1990). Historically the majority of these lands were part of farming based ownerships. In many instances, biologically sound forest management was not practiced on these lands because: 1) owners had little knowledge of forest management, 2) forest management was secondary to farming, 3) sound silvicultural practices did not offer sufficient economic incentives, and 4) the sound practices did not suit landowner desires (McGee 1982). Nowhere have the negative effects of a lack of sound management been more apparent than on southern hardwood forests belonging to the NIPF owner (McGee 1987). Workable silvicultural alternatives should emphasize maintaining multiple forest benefits without sacrificing the productive capacity of a hardwood stand. Crop tree management is one alternative that may effectively meet these needs.

Crop tree management can be easily understood by landowners and tailored to fit their needs. As defined in this study it involved 2 phases: 1) stand assessment and 2) crop tree enhancement. The assessment phase entails dividing a forested acre into 36 square cells. Each cell is evaluated for a potential crop tree based on a list of objectives developed specifically by/for the landowner. These objectives may emphasize any combination of wildlife, aesthetics or timber.

Four treatments were examined: 1) release, 2) fertilizer, 3)combined release and fertilizer and 4) a control. Treatment responses were analyzed using cubic foot volume growth per acre, and diameter and basal area growth on an individual tree basis by crop tree species. In addition to evaluating growth response, several crop tree variables were measured to determine tree characteristics having some relationship with growth.

The objectives of the study were:

1. To determine cubic foot volume growth response per acre of hardwood trees occurring naturally on an upland hardwood site in west Tennessee to release and fertilizer treatments applied singularly and in combination.
2. To determine diameter at breast height (dbh) and basal area response of individual upland hardwood species to release and fertilizer treatments applied singularly and in combination.
3. To evaluate species characteristics that are indicators of response to release and fertilizer applied singularly and in combination.
4. To implement and evaluate the initial phases of the crop tree management system proposed in this study.

CHAPTER II

LITERATURE REVIEW

Crop tree management is a silvicultural technique developed primarily for non-industrial private forest (NIPF) ownerships. The technique can be easily communicated to a landowner and tailored to meet multiple goals (Perkey et al. 1993). These merits when contrasted with a history of failures in managing the NIPF resource increase the pertinence of this management technique. Crop tree management places emphasis on culturing selected individual crop trees. The most common cultural practices used to enhance the survival and growth of forest trees have been release/thinning and fertilization.

Non-industrial Private Forest Management

Non-industrial private forests make up approximately 66% of the commercial forest land in the South (Webb 1990). The lack of sound management of this resource has greatly eroded timber production in this region. Dubois et al. (1991) noted that timber growth on NIPF lands in Mississippi averaged approximately one half of its potential. Nowhere is this lost potential more apparent than on southern hardwood forests (McGee 1987).

In many cases sound silvicultural practices have not been implemented due to inadequate economic incentives or because they violated landowner desires (McGee 1982). NIPF owners generally desire an income from their timber but they also want to maintain a stand of trees for future income, wildlife and/or aesthetic values (McGee 1982). In many instances NIPF owners have opted for "selection" harvests to meet these goals. To be economically feasible, selection harvests often became "high-grading." High-grading is a harvesting practice in where the best trees are removed leaving a less valuable forest cover to restock the area. Repeated application of this practice progressively degrades a forest stand.

A majority of the South's NIPF lands were once a part of farm ownerships. The interests and economics of this livelihood generally caused farm owners to reject available timber management opportunities (Marlin 1978, Jones and Thompson 1981, and Hickman and Gehlhausen 1981). When a timber income was desired it was generally done in the form of a boundary sale in which all the merchantable timber within a prescribed area was removed at the discretion of the buyer. Little consideration was given for the residual or future stand.

Changes in NIPF ownership patterns have increased opportunities for improved management of this forest resource (Waddell et al. 1989). According to a USDA report (1987), the amount of non-industrial forest land in the South owned by farmers decreased from 99,259,000 acres in 1952 to 48,709,000 acres in 1987, while the amount owned by other private individuals increased from 55,808,000 acres in 1952 to 88,761,000 acres in 1987 (Waddell et al. 1989). Non-farming owners have generally shown higher interest in forest management than have farming-based owners (Marlin 1978, Jones and Thompson 1981, and Hickman and Gehlhausen 1981).

Along with changing ownership patterns, the increasing value of forest products makes forest management more attractive. A marked reduction in timber harvesting on public lands will require that the NIPF resource to play a larger role in supplying wood and fiber (Perkey and Wilkins 1993). Silvicultural techniques that are biologically sound and address the desires of NIPF owners are necessary if professional forestry is to help this community take full advantage of their forested resource (Webb 1990).

Crop Tree Management

Several studies have identified individual stems in a forest stand as "crop trees" (Heitzman and Nyland 1991). Generally defined a crop tree is any tree a landowner would like to favor in his forest (Kidd and Smith 1989, Perkey 1993). The basis for selection depends on landowner objectives (e.g., wildlife, aesthics or timber). This approach to stand management leads to the relatively new silvicultural technique termed "crop tree management" (Kidd and Smith 1990, Perkey 1993, and Perkey et al. 1993).

Crop tree management focuses on stand management by placing emphasis on crop trees selected based on landowner objectives. Management objectives are generally accomplished by enhancing growth of selected crop trees thereby reducing rotation length and improving overall stand quality (Smith and Lamson 1983). To date most studies have been designed using timber value as the main criterion for crop tree selection (Stringer et al. 1988, Kidd et al. 1989, Voorhis 1990, and Lamson et al. 1990).

Perkey et al. (1993) provided the following criteria for crop tree selection where timber production is the primary goal:

* Dominant/codominant trees (at least 25 feet tall)
  - Healthy crown; large in relation to dbh
  - No dead branches in upper crown
  - Either low-origin stump sprouts (less than six inches above groundline) or seedling-origin stems are acceptable
  - U-shaped stem forks are acceptable; avoid V-shaped forks

* High-quality trees
  - Butt-log potential of Grade 1 or 2
  - No epicormic branches (living or dead) on butt log
  - No high-risk trees (leaners, splitting forks, etc.)

* High-value commercial species

* Expected longevity of 20+ years

* Species well-adapted to the site

These criteria are similar to those used in other crop tree studies (Stringer et al. 1988, Kidd et al. 1989, Voorhis 1990, Lamson et al. 1990, Lamson and Smith 1989, Conover and Ralston 1959, Smith and Lamson 1983, Trimble 1971, and Lamson and Smith 1978).

A basic question that arises when implementing crop tree management is how many crop trees should be selected per unit area. A definitive answer cannot be given because the decision will vary by landowner objectives and existing stand conditions (Perkey et al 1993). For example Perkey (1993) suggested "managing as few a 5 high value red oak pole or sawtimber crop trees on as few as 10 acres makes good financial sense." Lamson et al. (1990) suggested selecting as many as 50 to 75 crop trees per acre.

He also states "never release more than 100 crop trees per acre in precommercial stands." In general, suggested crop tree spacing has been 20 to 25 feet (Lamson et al. 1990, Voorhis 1990, and Trimble 1971).

Crop Tree Enhancement

The most common treatments applied to enhance tree performance in forested stands are thinning\release and fertilization. Other treatments, such as irrigation and pruning, may also provide benefits to crop trees but are generally not feasible.

Release

The most widely accepted cultural treatment known to increase growth of individual trees is thinning, also sometimes termed release (Smith 1986). In past publications these terms have been defined in ways that give them technically different meanings. As defined by the Society of American Foresters D-2 Silviculutral Working Group release is "a treatment designed to free young trees from undesirable, usually overtopping, competing vegetation" and thinning is defined as "a cutting made to reduce stand density of trees primarily to improve growth, enhance forest health, or to recover potential mortality" (Society of American Foresters 1993). However in this study the treatment that frees a crop tree from competition is termed "release" even though this reflects a variance from the Society of American Forester definition.

Individual trees are "released" when neighboring stems competing for the same growing space are removed. The released tree responds initially with increased growth primarily from an increase in root uptake of water and nutrients (Smith 1986). Following there is usually an increase in leaf (crown) area and root mass. The increase in photosynthetic area and root mass will maintain accelerated wood production. Increased wood production is expressed in larger stem size (diameter and/or height). In addition release will help maintain growth rates of selected trees that may be losing crown position and becoming suppressed.

Thinning in hardwood stands has generally focused on reducing stand density (area wide) to a prescribed residual basal area or stocking level (Brenneman 1986). In some cases, this approach has resulted in sacrificing higher quality trees to maintain spacing and may result in inadequate release of the remaining stems (Stringer et al. 1988 and Lamson et al. 1990). Crop tree release differs from area-wide thinning in that no consideration is given to overall residual stand density. The emphasis is on releasing only selected crop trees and leaving non-competing trees as a 'matrix' that maintains stand character. This approach to thinning may have particular merit for timber management in hardwood forests since a large portion of the value in these stands is due to the value of a few high quality stems (Kidd et al. 1989, Perkey 1993, and Perkey et al. 1993).

Most studies have used one or a combination of two different methods of crop tree release. These are: 1) removing all trees having crowns that touch or appear to be interfere with the crown of the crop tree, and 2) removing all trees within a prescribed radius of the crop tree (Mitchell et al. 1988 and Lamson and Smith 1989).

In general, crop tree release studies involving younger (sapling-stage) hardwood stands have concluded that more release (up to a point) results in more diameter growth (Heitzman and Nyland 1991). Height growth is generally not affected in younger stands unless release is extremely severe, in which case height growth rates may decrease over that of non-released crop trees.

Trimble (1971) suggested that crop trees cannot be selected in young Appalachian hardwood stands until the canopy has closed and crown dominance is expressed, generally between 7-9 years. Lamson and Smith (1978, 1989) and Lamson et al. (1990) recommended that crop trees should not be selected until total height was at least 25 feet.

Though not as well documented, research on crop tree release in older stands (pole and sawtimber-stage) also showed that relatively more release results in more diameter growth, although response varied among sites and the size and vigor of the tree crown before release (Lamson et al. 1990) Lamson et al. (1990) concluded that crown release on at least 3-sides (preferably all 4-sides) was needed to show significant increases in diameter growth for 54-year-old chestnut oak, red oak, and yellow-poplar crop trees. Crop tree research in older stands has either not addressed height growth response to release or it has shown that there is a reduction in the amount of height growth (Allen and Marquis 1970, and Lamson and Smith 1978, 1989.

Some species once they reach an older age, failed to respond even to a full crown release. Smith and Miller (1991) found that, red maple, black cherry, sugar maple, chestnut oak, and white ash showed no significant increase in diameter growth to full crown release in a 75 to 80-year-old sawtimber sized Appalachian hardwood stand. However, yellow-poplar, red oak, beech, basswood, white oak and hickory in the same study had significant responses in diameter growth. Stringer et al. (1988) noted significant diameter growth increases for older (73 years) white oak when release was applied.

A concern when thinning/releasing hardwood stems is the effect on stem quality, especially limb-related defects (Sonderman and Rast 1988). Thinning tends to decrease the number of live limbs while increasing the size of remaining limbs (e.g., some small branches persist and develop into larger limbs while some die and fall off).

Also release treatments may stimulate epicormic branching. While there are several factors that affect epicormic branching, the best way to avoid it is to select crop trees that have full vigorous crowns with no evidence of epicormic branching prior to release (Smith 1986, Perkey et. al. 1993).

Hardwoods are more prone to epicormic branching than are conifers. For example white oak tends to develop epicormic branches when released (Perkey et al. 1993). Although the effect of crop tree release on epicormic branching of white oak is uncertain, heavy area-wide thinnings involving this species have shown an increase in epicormic branching (Stringer et al. 1988). Where epicormic branches are present on white and red oak, with release, they should be expected to persist and possibly develop into larger limbs, potentially resulting in a significant reduction in log value (Sonderman 1984).

Fertilization

"Few forest soils provide an optimum supply of the nutrient elements essential nutrient elements for the growth of trees" (Smith 1986). In attempts to supplement nutrient levels of forest soils and increase tree growth, numerous forest fertilization studies have been conducted over the past 60 years.

Two of the more recent reviews dealing with research on hardwood fertilization in the eastern U.S. are Auchmoody and Filip (1973) and Auchmoody (1986). An important research finding is that on a variety of sites, the growth of many hardwood species can be increased with nitrogen (N) applied singularly or in combination with other nutrient(s), usually phosphorous (P). Fertilization can increase leaf size and number per tree. This increase in photosynthetic area can translate into extra growth. Photosynthetic efficiency may also be increased with fertilization. Exceptions have been shown when fertilization studies were conducted on high quality sites presumably not nutrient deficient or when tree species were fertilized near biological maturity.

Stone et al. (1982) found that fertilization did not increase diameter growth of sawlog-sized sugar maple in the upper Peninsula of Michigan on a good site having deep silt loam soil and a temporarily perched water table. Francis (1984) noted no response to fertilization in natural bottomland stands of oak and sweetgum in the Mississippi Delta. Lamson (1980) found that 70-year-old red maple and yellow-poplar did not respond to N/P fertilization, while red oak and black cherry in the same stands did. The lack of response of red maple and yellow-poplar was attributed to their older age and/or because of the high site quality. Because most forest stands are nutrient deficient (particularly for N), fertilization has been shown to stimulate growth responses for a variety of species under a wide range of site conditions. Some examples are: Farmer et al (1970) with yellow-poplar, various hickory species and red and white oak in the Tennessee Valley; Lamson (1978) and Auchmoody and Smith (1977) with yellow-poplar and red oak in West Virginia; Stone (1980) with red and sugar maple in Wisconsin; McQuilkin (1982) with scarlet, black and white oak in the Missouri Ozarks; Auchmoody (1982) with young black cherry in Pennsylvania; Ward and Bowersox (1970) with white and scarlet oak and red maple in Pennsylvania; Karnig (1972) with northern red oak in New York; and Graney (1982, 1986), Graney and Pope (1978), and Graney and Murphy (1992) with northern red, black and white oak in Arkansas.

Nitrogen additions alone seem to produce the most consistent responses in hardwoods, but in some cases the addition of other elements has produced an additive effect. Lime, calcium, potassium and phosphorous are some of the nutrients frequently applied in addition to N. In general, P is the most widely used additive to N. Auchmoody (1982) and Stone (1980), found that phosphorous produced small increases in growth of young black cherry and maple. Lamson (1978) found that added P increased the growth of red oak as much as N.

Results from other studies have been less positive relative to P additions. Farmer et al. (1970) obtained inconsistent responses to additive P on a variety of sites with yellow-poplar, and various hickory and oak species.. Other studies have failed to obtain growth responses with P additions for various oak species and yellow-poplar (Ward and Bowersox 1970, McQuilkin 1982, Auchmoody and Smith 1977). Auchmoody and Filip (1973) concluded that "N is by far the primary growth-limiting nutrient in hardwood forests, but response to P additions may frequently be forthcoming after the N deficiency is overcome."

Responses to fertilization can vary considerably among species. Except in younger stands where height response has been documented (Auchmoody 1982), response is usually evaluated using diameter or basal area. Among the hardwoods native to Eastern North American, yellow-poplar has generally shown the greatest growth increases from fertilization (Lamson 1978, Auchmoody and Smith 1977). Farmer et al. (1970) found yellow-poplar to be the most responsive species followed by white oak, red oak and various hickory species. respectively. Except for yellow-poplar, this ranking may vary among sites (McQuilkin 1982).

Urea (46% nitrogen) and ammonium nitrate (33% nitrogen) are the most readily available and commonly used sources of N (Auchmoody 1986 and Auchmoody and Filip 1973). Ammonium sulfate and urea formaldehyde have also been used as N sources in forest fertilization studies. Ellis and Von Althen (1973) used perfusion tests to examine the net rate of nitrate formation in the A1 horizon of a hardwood forest soil in Ontario following fertilization with ammonium sulfate, urea and urea formaldehyde. They found that "90% of the N in ammonium sulfate and urea had been converted to nitrate after 10 days, as opposed to only 23 percent of that from urea formaldehyde." This slower conversion to nitrate reduces leaching loss compared to the other N-sources. Less leaching will insure that more of the applied N will be available for uptake over a longer period than where conversion is rapid, prolonging the response to a single application of N (Auchmoody and Filip 1973).

The longevity of response to a single N application is not well documented (Auchmoody 1986). Response can generally be expected for up to 5 plus years although most occurs during the first 2 to 3 years. In years where rainfall is low, response will be lower. Auchmoody and Smith (1977) and Lamson (1978) noted basal area response to N and P, applied singularly and in combination, lasted at least 7 years for upland red oaks and yellow-poplar. However response was not statistically significant after year 3. McQuilkin (1982) found that elevated soil P levels were maintained longer than N levels following the application of triple-super-phosphate and urea to an upland hardwood stand in Missouri.

Fertilizer application rates in research studies have varied considerably. Current literature suggests between 150 to 300 lbs/acre of available N and 44 to 87 lbs/acre of available P (Auchmoody and Filip 1973). McQuilken (1982) found that diameter growth of black and scarlet oak increased linearly as the rate of N increased from 0, 105, 210, and 315 lbs/acre of available N (0, 228, 455, and 684 lbs/acre of urea). Ward and Bowersox (1970) also found that increasing levels of applied N (0, 60, 180 lbs. of available N per acre) resulted in increasing diameter response for scarlet and white oak. In another study white oak showed no response to N/P fertilization while red oak and scarlet oak responded with increased diameter growth (Graney 1982, 1986).

Release and Fertilization

Only a few studies have compared the effects of release and fertilization, singularly and in combination, on growth of overstory hardwoods. The best documentation is provided by Graney and Pope (1978), and Graney (1982, 1986) with northern red, black and white oak in the Arkansas, and Stone (1973, 1977, 1986) with sugar and red maple and yellow birch in Michigan and Wisconsin.

Graney and Pope (1986) found that thinning significantly increased diameter growth response to fertilization from year 3 to 10 for red oak and in year 2 and 5 through 10 for white oak. Fertilization significantly increased diameter growth in both thinned and unthinned treatments for red oak in years 1-10 and white oak in years 1-5.

Stone (1977) reported that thinning significantly increased diameter growth of sugar and red maple, while fertilization did not significantly increase diameter growth 3 years after application. Similar results for sugar maple were obtained by Ellis (1978). Ellis also noted that black cherry responded well to fertilization but not to release. Auchmoody (1985) concluded that only when applied in combination would fertilization and thinning have a significant long term effect on the growth of 12-year-old black cherry.

Bollig (1992) concluded that crop-tree-release was more effective at increasing yellow-poplar growth than fertilization on highly productive sites. On less productive sites, fertilization was more effective.

CHAPTER III

STUDY AREA

Location

The study was conducted at Ames Plantation in southwestern Tennessee (Figure 1). Ames Plantation is approximately 60 miles east of Memphis Tennessee and 10 miles north of the Tennessee-Mississippi border near the town of Grand Junction, Tennessee (35.03° North and 89.10° West). Ames Plantation is comprised of 18,548 acres (7,509 ha), with approximately three-fourths of the acreage in Fayette County and the remaining one-fourth in Hardeman County. The Plantation is administered by the Hobart Ames Foundation for the benefit of The University of Tennessee and is a branch Agricultural Experiment Station. The study stand was located in Hardeman County on the 370 acre Demonstration Farm. The Demonstration Farm was established in 1955 as a model for converting "run-down" cotton farmland into a modern farm featuring cotton, hog, beef, and forestry as the primary commodities (Whatley 1994).

Climate

The climate of the area is characterized by hot summers and relatively mild winters. Mean annual temperature is 61.3° F (16.3° C). Average temperatures range from 42.6° F (5.9° C) in January to 80.2° F (26.8° C) in July. The mean annual precipitation is 61.0 in (155 cm) with 24.1 in (61 cm) occurring in the growing season. The growing season lasts approximately 210 days. The average

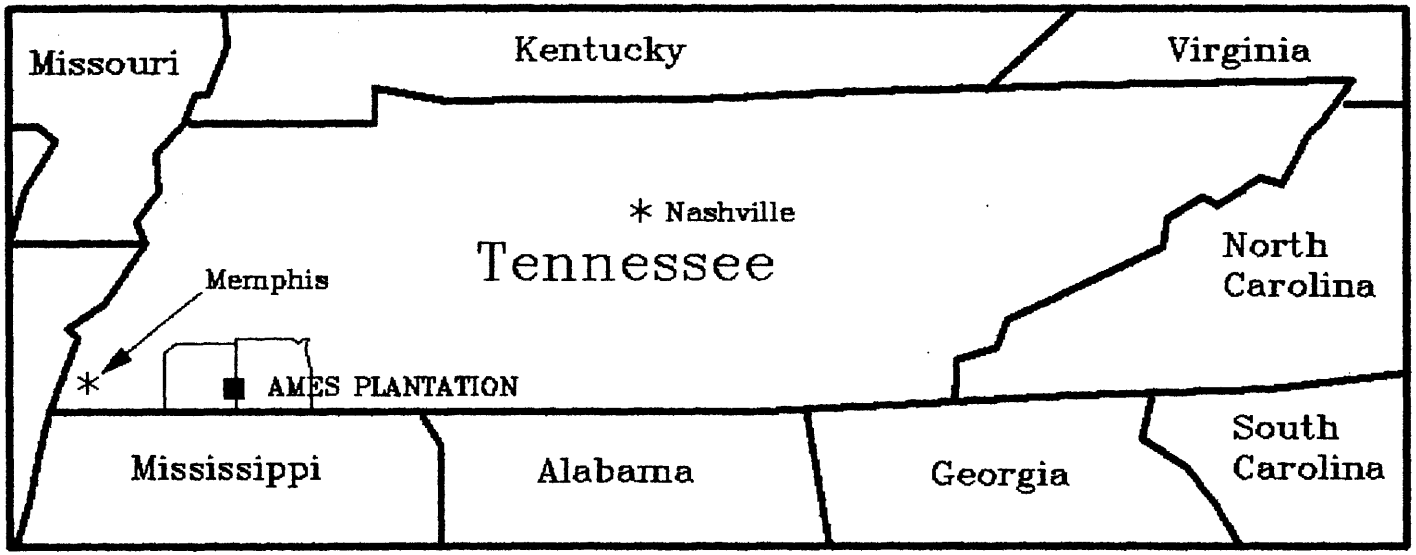

Figure 1. Study area location, Ames Plantation, Hardeman County, Tennessee.

date of the first and last killing frost is October 24 and April 2 respectively (Flowers 1964).

Topography and Soils

The soils in West Tennessee are derived from wind-blown loess deposits that comprise the Holly Springs formation. In some areas erosion has removed these loess soils and exposed the older Coastal Plain deposits (Flowers et al. 1964).

The study was on gently rolling ground with slopes up to 20 percent. Average elevation for the area is 575 ft (175 m). Two intermittent streams drain the area from southeast to northwest. Soils are in the Lexington and Smithdale series. Lexington soils on the study area are silt loam with slopes of 5 to 8 percent and silty clay loam with slopes of 5 to 8 percent. The Smithdale soil is a sandy clay loam commonly found on 12 to 25 percent slopes. Both soils are well drained with deep rooting zones and moderate to high available water capacity (USDA 1991, unpublished notes). They are well suited for upland oaks. Average site index (base age 50 years) for oaks is 75 to 85 feet (Flowers et al. 1964).

Vegetation

Between 1903 and 1945 no timber was harvested on Ames Plantation although tenant farmers cut fuelwood and grazed livestock in the study stand until 1955. A series of partial harvests in 1945-1946 and again in 1955-1956 established advanced regeneration that comprises the present stand (Ewing 1956 and Salmon 1989). A commercial clearcut in 1967 removed all merchantable trees (d.b.h. > 11.0 in). This harvest acted as a liberation cut releasing the advanced regeneration established from the two previous harvests.

A survey of advanced regeneration completed prior to the 1967 harvest reported that 65 percent of the stand "showed potential" for merchantable sawtimber (Countess 1971). Oak and hickory comprised 73 percent of the advanced regeneration (27 percent white oak, 27 percent red oak, and 20 percent hickory). Flowering dogwood and eastern redbud accounted for the remaining 26 percent. There were some scattered, large trees left following the previous harvests. The pole-sized stand was even-aged, approximately 40 years old (Allan E. Houston, 1994: personal communication).

In 1992-1993, the primary overstory species in the stand were white oak, red oak species, black cherry and hickory species. Other overstory species included:

red maple
winged elm
blackgum
yellow-poplar
black locust
white ash
American sycamore
river birch
royal paulownia

The primary understory species were:

flowering dogwood
sassafras
eastern redbud
common persimmion
eastern redcedar
American hornbeam.

CHAPTER IV

METHODS

Crop Tree Criteria

In this study the primary objective was to produce high value timber. Requirements for all crop trees were: 1) must score 10 or better in a Crown Class Point System (discussed in **Pretreatment Crop Tree Data** section page 26), 2) must have the potential to produce a 16-foot merchantable log based on the existing stem, and 3) not a 'super dominant/wolf tree' or judged to be in an older age class.

The preferred crop tree species in order of preference were: white oak, black oak and southern red oak. These species were the most valuable in the stand. If a suitable white, black or southern red oak was not available then other species were selected.

Additional considerations in crop tree selection were stem form and crown vigor. Attempts were made to avoid stems with excessive crook, bow, sway, forks and\or large or excessively numerous epicormic branches. In cases where there was relative equality in stem form, the tree with the largest crown containing the most live branches and having the most favorable relative crown position (as determined by the Crown Class Point System) was selected.

Stand Assessment

The first step in the stand assessment phase of the study was to determine if stocking of acceptable crop trees was adequate. This was done by subdividing the stand into 1.01 acre plots with each plot containing 36, 35 by 35 foot square cells. The 36-cell-per-acre design was used because it accommodated 2 major landowner considerations: 1) locating and inspecting 36 crop trees per acre does not require an unreasonable investment of time and effort, and 2) where sawtimber production is a primary goal, approximately 36 crop trees per acre provide a reasonable economic base at maturity [e.g., assume an 18", 2-log, Girard form class 78 tree yields 233 board feet (Doyle log rule) times 36 trees giving 8,388 board feet per acre. A stumpage value of $200 per thousand board feet yields a value of approximately $1,678 per acre].

Cell centers were located using a 300-foot fiberglass utility tape marked at 35-foot-intervals. After a buffer of at least 100-feet was established along stand boundaries, 35-foot-intervals were marked with wire pin flags to establish cell centers. The entire stand was marked in this manner giving 20-1.01 acre treatment plots with a 35-foot-wide buffer zone surrounding each plot.

Trees in each cell were evaluated and a crop tree was selected where criteria were meet. If two potential crop trees were relatively equal in both stem quality and crown vigor the tree closest to the center of the cell was selected. If 26 out of every 36 cells (72 percent) contained a potential crop tree the acre was considered to be adequately stocked (i.e., suitable to implement crop tree enhancement).

Crop trees were marked with an orange paint band approximately 4 feet above the groundline and a numbered aluminum tag nailed into the west side of each tree 6 inches above the groundline. In cells where no crop tree was selected, the numbered tag was placed on the wire pin flag marking the cell center.

Experimental Design and Treatments

The study was conducted using a randomized complete block design (Figure 2). There were 5 blocks each containing 4 treatment plots. Blocks were based on similarities in topographic characteristics. Each treatment plot contained 36 cells. Treatments were: 1) control (no treatment), 2) release, 3) fertilization and 4) release and fertilization.

Control

Crop trees were selected, marked and measured, but no treatment was applied.

Release

The crown of each crop tree was released on at least 3 and preferably 4 sides. Any tree that appeared to be impeding the crown expansion of the crop tree (except adjacent crop trees) was felled using a chain saw. Trees not directly competing with a crop tree were left standing. There was no attempt to reduce basal area by a prescribed amount, so the residual basal area was somewhat random. If the cutting of a tree posed a substantial threat to a crop tree (i.e., a competing tree was extremely large), the tree was "girdled" using a chain saw and left

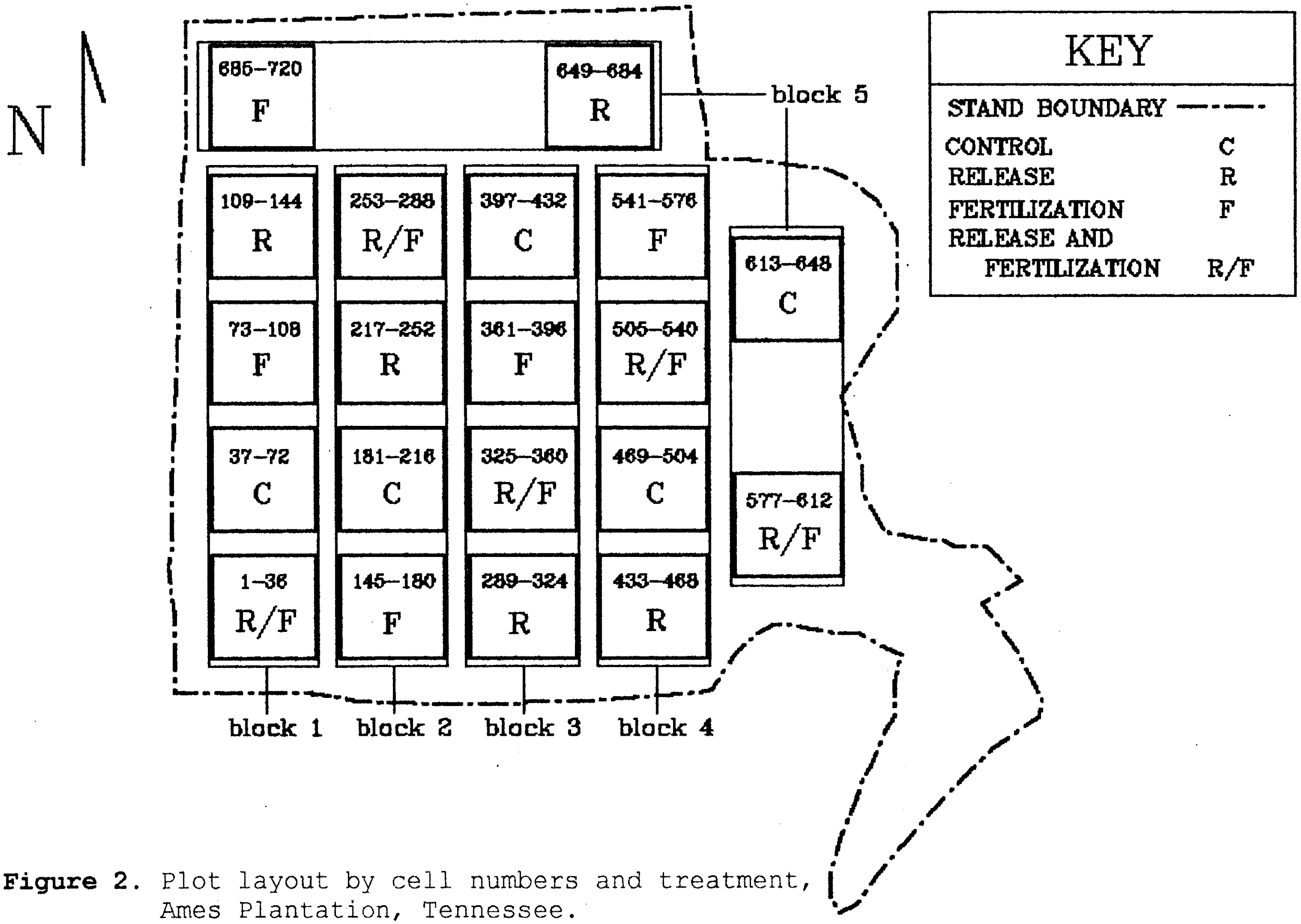

Figure 2. Plot layout by cell numbers and treatment, Ames Plantation, Tennessee.

standing. Release treatments were accomplished prior to April 15, 1993. Downed wood was carefully removed by a firewood crew in the summer of 1993. Ten plots received release treatments; 5 release plots and 5 release and fertilized plots.

Fertilization

In the fertilization treatments nitrogen was applied as urea at the rate of 150 pounds of available N per 1.01 acres. Phosphorus was applied as triple-super-phosphate (P_2O_5) at a rate of 30 pounds per 1.01 acre. Triple-super-phosphate was used due to availability in bulk packaging. The fertilizer was broadcast by hand over the entire treatment plot. Fertilization was accomplished during mid-March. Several days of cool wet weather followed application. Ten plots received fertilization; 5 fertilization plots and 5 release and fertilization plots.

Initial recommendations for fertilization were to apply fertilizer around the "drip-line" of individual crop trees, the amount to be based on the diameter of the crop tree. This type of application was not conducted because of time limitations.

Release and Fertilization

Release and fertilization treatments were applied as a combination of each of the two individual treatments. There were 5 plots receiving both release and fertilization.

Data Collection

Pretreatment data were collected between January 1993 and March 1993 and separated in two categories 1) crop tree data, and 2) "in" tree data (trees selected using a BAF 10 (sq. ft./acre) prism point 2 feet west of the crop tree). No data were recorded for unfilled cells.

Pretreatment Crop Tree Data

Data recorded for each crop tree were:

1. crop tree number "cell number",

2. species,

3. diameter at breast height - (4.5 feet. above groundline) to the nearest 0.1 inch using a diameter tape, breast height was determined by placing a 4 foot. pole on the nail supporting the cell number tag which was 6 inches above groundline on the west side of the crop tree,

4. total height - to the nearest 1-foot using either a Haga altimeter or Sunto clinometer,

5. height to green (live) crown - to the nearest 1-foot using either a Haga altimeter or Sunto clinometer,

6. basal area - using a BAF 10 prism taken at a point 2 feet west of each crop tree, distances to borderline trees were measured to the nearest 0.1-foot to determine status,

7. mean crown diameter - to the nearest 1-foot measured with a 100-foot fiberglass utility tape in each of the cardinal directions,

8. tree quality - using a U.S. Department of Agriculture Forest Service Tree Classification (modified from Putnam 1960) - recorded as either a) preferred b) reserve or c) cutting,

9. number of epicormic branches per 16-foot log - the topmost log could include lengths from 16-feet to 8-feet, on 2-foot intervals,

10. Point System Hardwood Crown Classes (Meadows et al. unpublished manuscript) - point values ranging 1-10 for a) direct sunlight from above and b) direct sunlight from the side, and point values ranging 1-4 for c) crown balance and d) crown size with a total point value ranging 0-28 points.

Pretreatment "In" Tree Data

A point sample was taken 2 feet west of each crop tree to gather information on the "competition cluster" around the tree. Trees found "in" with the BAF 10 prism were considered the crop trees' competitors (e.g., those trees that are directly competing with the crop tree for growing space). The following data were recorded on all "in" trees:

1. "in" tree number,
2. azimuth from prism point to "in" tree - to the nearest 5 degrees,
3. diameter at breast height - to the nearest 1-inch using calipers,
4. total height - to the nearest 1-foot using a Christen hypsometer,
5. height to green (live) crown - to the nearest 1-foot using a Christen hypsometer,
6. distance to "in" tree from crop tree - to the nearest 1-foot, using a 100-foot fiberglass tape measured at breast height,
7. crown projection toward the crop tree - to the nearest 1-foot, using a 100-foot fiberglass utility tape measured from the stem at breast height.

Posttreatment Data Collection

Crop tree d.b.h. was remeasured at the end of the first and second growing seasons, January 1994 and October 1994, respectively. D.b.h. measurements were used to calculate annual and two year diameter growth. In January 1994 total height of all crop trees was remeasured. Heights for all crop trees were measured with the same instrument, a Haga altimeter, to establish more consistent baseline data.

The Point System for determining hardwood crown class and epicormic branching was also remeasured in October 1994 to monitor changes in crown class and condition and stem quality, particularly of released crop trees.

In February 1994 there was a major ice storm throughout much of the Southeast including southwestern Tennessee. The temperature at Ames Plantation went from a high of 72 degrees F (22 degrees C) on February 9 to a high of 33 degrees F (0.5 degrees C) on February 11 with lows in the 20's F (-5 C) on the 10th and 11th (NOAA 1994). The drastic drop in temperature coupled with 2.31 inches (5.8 cm)of freezing rain on February 9-11, resulted in over an 1 inch (2.54 cm) of ice on the ground and vegetation including crop trees. An ice storm of this magnitude can be expected about once every 20 years in west Tennessee with previous storms in 1952 and 1973 (Allan E. Houston; personal communication 1994). Damage to crop trees was evaluated using five severity classes: 1) no damage, 2) crown damage not affecting total height, 3) crown damage affecting total height, 4) damage that caused a tree to lean and affected total height, and 5) broken bole below the live "green" crown.

Statistical Analysis

All data were entered into permanent files and analyses were conducted using various programs in the Statistical Analysis System (SAS 1985). Variables generated from the pre- and posttreatment data included year one diameter growth (d.b.h. 1993

- d.b.h. 1992), year two diameter growth (d.b.h. 1994 - d.b.h. 1993) and cumulative two year diameter growth (d.b.h. 1994 - d.b.h. 1992). Individual tree basal area (0.005454 d.b.h.^{2}) and basal area growth (year one, year two and cumulative two year) were also calculated. Cubic foot volume was calculated using the formula:

volume = (1/3) * total height * basal area.

Treatments were compared by grouping all crop trees within each one acre treatment plot and calculating volume growth per acre. Treatment comparisons by species were examined using diameter and basal area growth on an individual tree basis. Basal area perhaps gives a better reflection of individual tree growth but diameter is more easily understood by the landowner so both were examined. Data were checked for normality and equal variance using SAS Univariate Procedures. Both per acre and individual tree growth were examined with covariate analysis. Initial volume proved to be a significant covariate for volume growth. Both adjusted and unadjusted values were reported. Neither the linear nor the quadratic interactions of initial d.b.h. and basal area were significant covariates for individual tree growth analysis.

Due to unequal and small sample sizes the General Linear Models Procedure of SAS was unable to calculate least square means for all species-treatment groups. A Mixed Models Procedure had to be executed to calculate least square means and was used for parameter testing.

Growth was analyzed using Mixed Models estimate statements to compare treatment differences. Volume growth comparisons were made among treatments on a per acre basis over all species. Individual tree growth was compared: 1) within species and year, 2) between years within species and treatment 3) among species within treatment and year. Statistical significance was reported at the 5 percent level of probability ($P < 0.05$).

Initial tree condition (size and canopy position) and amount of release have been shown to affect crop tree growth (Perkey et al. 1993, Lamson and Smith 1978, Lamson et al. 1990). These factors are best evaluated by a measure of their correlation to tree growth response (Knowe 1991). Correlation analysis was used to identify the variables that had the strongest relationships with crop tree growth. Cumulative 2 year basal area growth was used for the correlations and significance was reported at the $P < 0.05$ level.

Variables used in the correlation analysis were:

A. Pretreatment variables
 1) crown length
 2) total height
 4) direct sunlight from above
 5) direct sunlight from the side
 6) crown balance
 7) relative crown size
 8) total crown point value
 9) basal area

B. Posttreatment variables
 10) basal area removed
 11) residual basal area
 12) direct sunlight from above
 13) direct sunlight from the side
 14) crown balance
 14) relative crown size
 15) total crown point value.

CHAPTER V

RESULTS AND DISCUSSION

Crop Tree Selection

There were 653 crop trees selected out of a possible total of 720 (90.7% filled cells) (Table 1). Species sufficiently represented to warrant statistical testing were white oak (445), southern red oak (101), black oak (38), scarlet oak (33) and black cherry (27). Other species selected as crop trees but in insufficient numbers to allow statistical testing were, willow oak (1), yellow-poplar (1), American sycamore (1), and mockernut hickory (6).

Ice Storm Damage

The ice storm of February 1994 had a major impact on the sample size of the primary crop tree species (Table 2). Of the 5 primary species, 100 crop trees had to be dropped from growth analysis because of severe ice damage (damage that reduced total height; i.e., broken top, broken bole or leaning tree). Forty-seven crop trees had minor ice damage (damage not affecting total height) which consisted mainly of a few broken branches, primarily in the lower crown. Crop trees with minor damage were not dropped from the statistical analysis. Five hundred and six crop trees "weathered" the ice storm with no visible damage.

The ice storm had the least effect on crop trees in control treatment plots with only 7 percent having severe damage. Slightly higher damage was recorded for crop trees in fertilized plots, with 8 percent having severe damage. There was

Table 1. Number of crop trees by species and treatment selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment				
Species	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/ FERT**[4]	**Total**
white oak	104	117	122	102	445
southern red oak	26	28	21	26	101
black oak	9	8	3	18	38
scarlet oak	7	5	15	6	33
willow oak	-	-	-	1	1
black cherry	7	5	6	9	27
yellow-poplar	-	-	-	1	1
American sycamore	-	-	-	1	1
mockernut hickory	3	-	1	2	6
Total	156	163	168	166	653

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment

Table 2. Number and percent (**in bold**) of crop trees by ice damage severity class, species and treatment in a 20 acre upland hardwood stand in west Tennessee.

	Treatments											
	Control			Release			Fertilization			Release and Fertilization		
Species	NO[1]	MIN[2]	SEV[3]	NO	MIN	SEV	NO	MIN	SEV	NO	MIN	SEV
white oak	100[4]	1	3	93	11	13	111	5	6	65	15	22
	96[5]	**1**	**3**	**79**	**9**	**11**	**91**	**4**	**5**	**64**	**15**	**21**
s. red oak	21	2	3	20	2	6	14	3	4	15	2	9
	81	**8**	**11**	**71**	**7**	**21**	**67**	**14**	**19**	**57**	**8**	**35**
black oak	9	-	-	5	2	1	3	-	-	17	-	1
	100			**62**	**25**	**13**	**100**			**94**		**6**
scarlet oak	7	-	-	4	-	1	13	1	1	6	-	-
	100			**80**		**20**	**86**	**7**	**7**	**100**		
black cherry	2	-	5	-	-	5	1	3	2	-	-	9
	29		**71**			**100**	**17**	**50**	**33**			**100**
Total	139	3	11	122	15	26	142	12	13	103	17	50
	91	**2**	**7**	**75**	**9**	**16**	**85**	**7**	**8**	**61**	**10**	**29**

1/ No damage
2/ Minor damage not affecting total height
3/ Severe damage that affected total height (broken top, bole or leaning trees)
4/ Number of crop trees
5/ Percent of crop trees in the damage-treatment group

a larger percentage of minor ice damage in the fertilizer plots (9 percent) versus the control (2 percent). Release, and release and fertilizer plots had the most damage with severe damage at 16 and 29 percent, respectively, and minor damage at 9 and 10 percent, respectively.

Black cherry was the most susceptible species to ice storm damage. One hundred percent of the black cherry crop trees had severe ice damage in the release, and the release and fertilizer plots, while 71 and 33 percent had severe damage in the control and fertilization plots, respectively. Only 6 of the 27 black cherry crop trees selected had minor or no ice damage. Black cherry was dropped from further statistical analysis. Of the remaining four species (white, southern red, black, and scarlet oak), all exhibited relatively equal tolerance/susceptibility to ice damage.

Volume Per Acre

There was an average of 417.73 cubic feet of volume per acre in crop trees prior to the ice storm. The average volume per acre lost was 66.69 cubic feet, leaving an average residual volume of 351.04 cubic feet. There were some large differences in the amount of initial cubic foot volume per acre among treatments although the differences were not statistically significant. Initial volume (before treatment application) per acre in crop trees prior to the ice storm was highest in the combined treatment (478.98 cu. ft.), followed by the release treatment (425.94 cu. ft.), the fertilizer treatment (412.63 cu. ft.) and control

(353.38 cu. ft.). The differences were due primarily to differences in average tree size.

The fertilizer treatment had the highest number of crop trees (168) but the second lowest initial volume. Volume per acre in crops tree after the ice storm was highest in the fertilized plots (378.25 cu. ft.), followed by the release (358.00 cu. ft.), the combined treatment (346.25 cu. ft.) and the control (321.67 cu. ft.). Another good example of how tree size varied among treatment plots is in the after-damage volumes; the control treatment had the second highest number of trees but still had the lowest average volume per acre.

The differences in tree size could have been controlled for by grouping plots (i.e., creating blocks before treatment application) based on the diameter distribution or the volume of the crop trees.

Diameter and Total Height

Mean d.b.h. of the remaining 547 crop trees was 9.9 inches, ranging from 3.6 to 18.5 inches (Table 3). Per acre basal area surrounding each crop tree ranged from 50 to 210 square feet per acre with an average of 113 square feet per acre. Mean d.b.h. of competing trees selected with the prism was 8.7 inches, ranging from 2.0 to 28.0 inches. Total heights of crop trees ranged from 35 to 88 feet with an average of 64 feet (Table 4). The average height of "in" trees was 57 feet ranging from 10 to 112 feet.

Table 3. Pretreatment mean diameter and range (in parenthesis) by species and treatment of crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Species	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	----------inches----------			
white oak	9.6 (3.9-15.8)	10.1 (4.3-17.9)	9.6 (3.6-18.5)	10.4 (6.1-16.9)
s. red oak	9.0 (5.8-14.5)	10.1 (6.1-14.3)	10.4 (6.6-17.5)	10.7 (5.0-15.2)
black oak	10.5 (7.4-13.3)	10.3 (6.6-13.8)	11.7 (10.5-12.5)	10.6 (6.5-14.6)
scarlet oak	8.4 (4.8-13.9)	9.4 (7.6-11.5)	10.1 (7.3-14.1)	9.7 (6.5-14.3)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment

Table 4. Pretreatment mean total height and range (in parenthesis) by species and treatment for crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Species	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	--------------------feet--------------------			
white oak	61 (35 - 82)	62 (42 - 80)	64 (35 - 87)	66 (42 - 88)
s. red oak	63 (47 - 85)	66 (53 - 76)	66 (47 - 81)	66 (47 - 79)
black oak	69 (55 - 77)	64 (57 - 72)	64 (63 - 65)	65 (51 - 73)
scarlet oak	63 (48 - 75)	65 (60 -70)	68 (40 - 86)	65 (49 - 81)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment

Tree and Crown Class

According to The Hardwood Tree Classification System, (Putnam et al. 1960) of the 547 crop trees remaining for analysis after the ice storm 189 were preferred, 326 were reserve, and 32 cutting stock. Average total score for crop trees (pretreatment) using the Point System for Hardwood Crown Classes (PSHCC) was 20.8 which is classified as a "high codominant crown position" (Meadows et al. unpublished manuscript). The breakdown of this average score was: 1) direct sunlight from above = 9.4; 2) direct sunlight from the side = 4.7; 3) crown balance = 3.2; and 4) crown size = 3.4). Total scores ranged from 11 to 27. Crown position of the average crop tree was classified as intermediate to dominant.

Epicormic Branching

Over the 2 year period of the study there was no significant increase in epicormic branching for any of the crop tree species. In some cases there was a reduction in the number of epicormic branches. This may have been partially contributed to the ice storm (e.g., the weight of the ice broke off some of the small, possibly dead epicormic branches).

Crop Tree Release

A total of 868 trees were cut to release the 257 crop trees in the release and combined treatment plots averaging 3.4 'cut trees' per crop tree. There were 469 trees cut in the release plots (average 3.4 per crop tree) and 399 cut trees in the combined treatment plots (average 3.3 per crop tree).

Many harvested trees were tallied with the prism for more than 1 crop tree so the basal area reduction per crop tree averaged slightly higher (40 square feet per acre) than what the average 3.4 cut trees per crop tree would indicate. Basal area reduction ranged from 10 square feet per acre to 80 square feet per acre. Average residual basal area was 72 square feet per acre with a range of 20 to 160 square feet per acre. The difference between the average cut and residual basal area in the release and the combined plots was less than 2 square feet.

The PSHCC score for crop trees in released and combined treatments was increased approximately 4 points to an average of 24.8. Most noticeably direct sunlight from the side increased an average of 3.2 points (4.7 to 7.9). Of the remaining 0.6 increase in the point system values, 0.5 points was due to the increase in direct sunlight from above (9.4 to 9.9). Had the PSHCC been measured immediately following release the values would have been only slightly lower than the ones reported.

Per Acre Volume Growth

Year 1 volume growth per acre (values unadjusted for initial volume) was greatest in the combined treatment (19.14 cu. ft.), followed by the release (16.63 cu. ft.), the fertilizer (16.40 cu. ft.) and the control (12.79 cu. ft.) treatments (Table 5). Treatment differences were nonsignificant.

Year 2 volume growth per acre was also greatest in the combined treatment (25.07 cu. ft.) followed by the release (22.49 cu. ft.), the fertilizer (20.63 cu. ft.) and the control (14.02 cu. ft.). Growth in the combined treatment and the release

Table 5. Volume growth per acre and percent increase in growth over the control (in parenthesis) by treatment and year for crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	---------------cubic feet/acre---------------			
Year 1[5]	13.25[a]	16.63[a] (25.5)	16.78[a] (26.6)	20.00[a] (50.9)
Year 2	14.17[a]	22.49[b] (58.7)	20.99[ab] (48.1)	26.07[b] (84.0)
Cumulative 2 year	27.42[a]	39.12[ab] (42.7)	37.77[ab] (37.8)	46.06[b] (68.0)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$), SAS, Mixed Model Procedure.

treatment were significantly greater than growth in the control. Growth in the fertilizer treatment was not significantly different from growth in any other treatment.

Cumulative 2 year volume growth per acre in the combined treatment was 44.21 cubic feet, followed by the release (39.12 cu. ft.), the fertilizer (37.02 cu. ft.) and the control treatment (26.81 cu. ft.). There were no significant differences among the treatments.

Because initial volume per acre varied among the treatments a covariate analysis was conducted to remove these differences (Table 6). This analysis presents results that would have most likely occurred had initial volume been the same within all treatment plots.

There were no significant differences in volume growth per acre among any of the treatments after adjustment for initial volume with the covariate analysis. The apparent gains in crop tree growth per acre associated with the treatments (primarily the combined and the release treatment) were offset by the differences in ice damage among the treatments.

There appeared to be a direct relationship between the amount of growth in each treatment to the number of trees severely damaged by the ice storm (Figure 3). Growth was greatest in the combined treatment but ice damage was also the most severe (29% severe damage). Growth was second highest in the release (16% severe damage), followed by the fertilizer (8% severe damage) and the control (7% severe damage).

Table 6. Volume growth per acre (adjusted for differences in intital plot volume) and percent increase in growth over the control (in parenthesis) by treatment and year for crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	----------------cubic feet/acre----------------			
Year 1[5]	15.15[a]	16.88[a] (11.4)	16.37[a] (8.1)	18.26[a] (20.5)
Year 2	17.31[a]	22.90[a] (32.3)	20.31[a] (17.3)	23.20[a] (34.0)
Cumulative 2 year	32.47[a]	39.77[a] (22.5)	36.68[a] (13.0)	41.45[a] (27.7)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Models Procedure

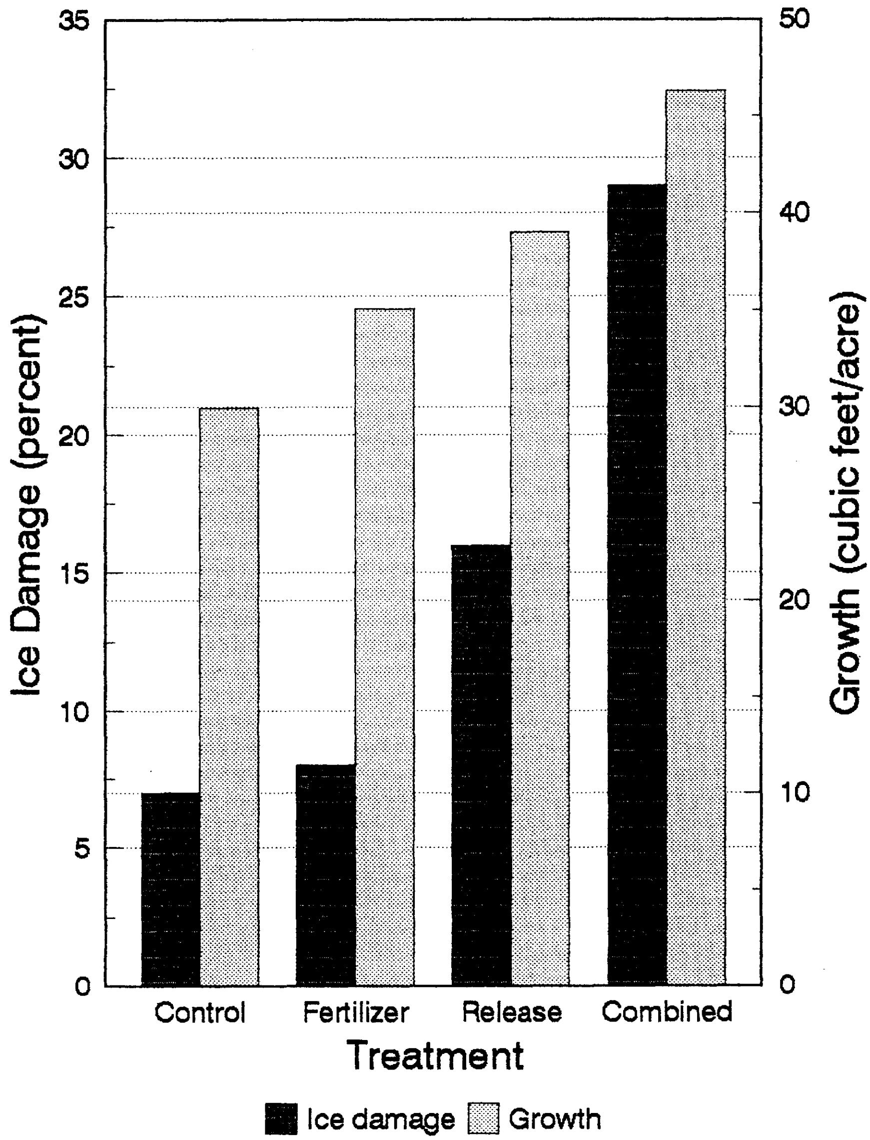

Figure 3. Percent severe ice damage and cumulative 2 year volume growth of crop trees by treatment.

Even though differences in volume growth per acre when adjusted for initial volume differences were nonsignificant release and fertilizer applied singularly and in combination have the potential to increase per acre volume growth of crop trees. Increases in volume growth in these treatments were large enough to offset the losses due to ice damage enough that growth was still essentially the same for all treatments.

Volume growth per acre was also examined by adjusting for differences in initial volume due to initial treatment plot differences and differences in volume due to the loss of volume due to the ice storm (Table 7). This covariate analysis presents values as if the ice storm had not occurred.

Significant differences in per acre volume growth occurred each year. Year 1 volume growth was greatest in the combined treatment (20.08 cu. ft.) followed by the release (16.59 cu. ft.) the fertilizer (15.73 cu. ft.) and the control (14.26 cu. ft.). Growth in the combined treatment was significantly greater than growth in the fertilized and control treatments, but not the release treatment. There was no difference in growth for the control, release and fertilizer treatment.

Year 2 volume growth per acre in the combined treatment (26.19 cu. ft.) was significantly greater than growth in any other treatment. Volume growth per acre in the release treatment (22.44 cu. ft.) and the fertilizer treatment (19.46 cu. ft.) was significantly greater than growth in the control (15.55 cu. ft.).

Cumulative 2 year volume growth per acre in the combined

Table 7. Volume growth per acre (adjusted for differences in intial volume and volume loss due to ice damage) and percent increase in growth over the control (in parenthesis) by treatment and year, for crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	----------------cubic feet/acre---------------			
Year 1[5]	14.26[a]	16.59[ab] (16.3)	15.73[a] (10.3)	20.08[b] (40.8)
Year 2	15.63[a]	22.44[b] (43.6)	19.46[b] (24.5)	26.19[c] (67.6)
Cumulative 2 year	29.97[a]	39.03[b] (30.2)	35.09[ab] (17.1)	46.28[c] (54.4)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Models Procedure

treatment (46.28 cu. ft.) was significantly greater than growth in any other treatment. There was no significant difference between the release (39.03 cu. ft.) and the fertilizer (35.09 cu. ft.) treatments. Growth in the control (29.97 cu. ft.) was significantly less than growth in release treatment but not the fertilizer treatment.

When adjusted for the initial differences in plot volume and ice damage, cumulative 2 year growth was 54% greater in the combined treatment than in the control, followed by the release (30%) and the fertilizer (17%) treatments. Even though response was lower than the unadjusted values, statistical significance was greater because variation was reduced.

There was greater growth in year 2 than in year 1, perhaps partially attributed to a relatively high rainfall in the second growing season. The effect of the unusually wet 1994 growing season was reflected by 12.2% more volume growth in the control treatment in 1994 than in 1993. Total rainfall from April through October 1993 was 26.8 inches and 35.6 inches during 1994 (National Oceanic and Atmospheric Administration 1993, 1994). For the months of June, July and August there were 9.6 inches more rainfall in 1994 than in 1993. Total precipitation for these 3 months for 1993 was about 3.9 inches below normal while the 1994 total was about 5.7 inches above normal. Based on the average evapotranspiration rate for this region of west Tennessee (Flowers 1964), evaporation far exceeded precipitation in June, July and August of 1993 significantly reducing available water. Unusually high rainfall in 1994 during June, July and August, created above average growing conditions.

A tree's first response to release and/or fertilization is to increase overall crown size and/or number of leaves (Smith 1986). Increases in photosynthetic area creates an increase in volume growth, although, it takes time for the process to occur. Energy must first be allocated to produce these increases in crown/leaf area before significant increases in stem size can occur or at least be measurable. It has also been reported that fertilizer may increase photosynthetic efficiency in tree leaves resulting in increased growth (Auchmoody 1986). Though not quantified in this study, there was a noticeable difference in leaf color and abundance for crop trees that received fertilizer (Allan E. Houston, 1994: personal communication). The difference represents an increase in chlorophyll (seen as "greener" leaves) suggesting an increase in photosynthetic efficiency.

The increases in growth over the control are expected to become more substantial over time particularly in the release and the combined treatment. Increased growth of released trees has been shown to last up to 20 years (Schlesinger 1978), while response to fertilizer is expected to last about 5 years (Auchmoody 1986).

Individual Tree Growth by Species

White Oak

Diameter Growth

There were significant differences between treatments for both annual and cumulative 2-year growth for white oak (Appendix B-1). Annual and cumulative 2 year diameter growth of white oak was highest for the combination treatment, followed by the release, the fertilization and the control (Table 8). At the end of the first growing season following treatment diameter growth of released and fertilized white oak (0.280 inches) was significantly higher than both the control (0.181 inches) and the fertilizer treatment (0.197 inches). While not statistically significant, growth in the combination treatment was somewhat greater than growth in the release treatment (0.239 inches). There were no statistically significant differences in year 1 growth among the control, release and fertilizer treatments.

Year 2 diameter growth was greater for the combined treatment (0.400 inches) followed by release (0.329 inches), fertilizer (0.270 inches) and control (0.214 inches). All treatment means were statistically different.

Cumulative 2 year diameter growth for the combined treatment was 0.679 inches, followed by release (0.568 inches), fertilizer (0.468 inches) and control (0.395 inches). All treatment means for 2 year diameter growth were statistically different.

Table 8. Diameter growth and percent increase in growth over the control (in parenthesis) by year and treatment for white oak crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	-------------------inches-------------------			
Year 1[6]	0.181[a]	0.239[ab] (32.0)	0.197[a] (8.8)	0.280[b] (54.7)
Year 2	0.214[a]	0.329[b] (53.7)	0.270[c] (26.2)	0.400[d] (86.9)
Cumulative 2 year	0.395[a]	0.568[b] (43.8)	0.468[c] (18.5)	0.679[d] (71.8)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Model Procedure

Basal Area Growth

Basal area growth of white oak crop trees was significantly different among treatments (Appendix C-1). Basal area growth followed the same trend as diameter growth but there were some differences in statistical significance among the treatment comparisons (Table 9). Both annual and cumulative basal area growth was greatest for the combination treatment followed by release treatment, fertilizer treatment and control.

Year 1 basal area growth of the combination treatment (0.0334 sq. ft.) was significantly greater than the control (0.0205 sq. ft.) and the fertilization treatment (0.0226 sq. ft.) but not the release treatment (0.0283 sq. ft.).

Year 2 basal area growth of the combined treatment (0.0468 sq. ft.) was significantly greater than all other treatments. The release treatment (0.0382 sq. ft.) was significantly greater than the control (0.0235 sq. ft.) but not the fertilization treatment (0.0382 sq. ft.).

Cumulative 2 year basal area growth of the combined treatment (0.0801 sq. ft.) was significantly greater than the release treatment (0.0664 sq. ft.), and both were significantly greater than the control (0.0440 sq. ft.) and fertilizer treatments (0.0532 sq. ft.). There was no significant difference in basal area growth between the control and the fertilization treatments.

Table 9. Basal area growth and percent increase in growth over the control (in parenthesis) by year and treatment for white oak crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	----------------square feet----------------			
Year 1[5]	0.0205[a]	0.0283[ab] (38.0)	0.0226[a] (10.2)	0.0334[b] (62.9)
Year 2	0.0235[a]	0.0382[b] (62.6)	0.0306[ab] (30.2)	0.0468[c] (99.1)
Cumulative 2 year	0.0440[a]	0.0664[b] (50.9)	0.0532[a] (20.9)	0.0801[c] (82.0)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Model Procedure

Discussion

The growth response of released, and released and fertilized white oak crop trees in this study was comparable to earlier research. In this study average annual diameter growth of released crop trees increased 43% over the control. Stringer et al. (1988) reported a 23% increase in annual diameter growth over 3 years for 73-year-old white oak crop trees released using a crown-touching technique. Dierauf (1987) reported a 46 percent increase in annual diameter growth of 27- to 53-year-old white oak crop trees over 15 to 20 years after 2 heavy thinnings.

Graney (1987) found that reducing basal area to 70 square feet around 52-year-old white oak crop tree significantly increased diameter growth over untreated crop trees. Thinning plus fertilization increased growth over fertilization alone by 43% while thinning alone did not increase growth over fertilization.

In Graney's study, white oak diameter growth in released and fertilized treatments was increased 91% over untreated white oak. In the 2 year period of the crop tree study at Ames Plantation, white oak growth in the combined treatment averaged 71% more than growth in the control.

Over the 2 year period diameter and basal area growth in the fertilizer treatment was 17% and 20% greater than growth in the control, respectively, a response lower than that reported by Graney (1978) and Farmer et al. (1970). Graney reported increased white oak diameter growth of 48% over 2 years from the application of 200 lbs. of N per acre. Farmer et al. (1970) reported a 5 year increase in basal area growth of white oak of 63% using 300 lbs. of N and 66 lbs. of P per acre.

Response to the fertilizer treatment in the study at Ames was lower than that reported in these earlier studies, likely due to differences in site and crop tree position in relation to the method of fertilization. The upland hardwood stand used in this study had a higher site index than those used in the Graney (1978) and Farmer et al. (1970) studies. Growth responses of trees to fertilization is usually less on higher quality sites because soil nutrients are less limiting (Auchmoody 1986).

In our attempts to focus on white oak, some white oak crop trees were selected that were not always the "best tree." Some white oak crop trees even though they were in a codominant position, were subordinate to surrounding trees of a different species, usually faster growing red oaks. By the second growing season some white oak crop trees in both the fertilizer and control plots began to lose crown position to surrounding red oaks.

By fertilizing the entire acre applications likely benefited surrounded trees as much as the crop tree. This is especially true where a white oak crop tree was in close competition with one or more red oaks because southern red oak responded more than white oak to fertilizer treatments (discussed in **Species Comparisons** section, page 63).

In the future it may be more beneficial to fertilize only the crop trees. The efficiency of fertilization could be increased by selecting a constant rate of fertilization per crop tree rather than basing the amount of fertilization on the size of the tree. A general guideline would be to take the average number of crop trees per acre (28) and divide that into the amount of fertilizer recommended (150 lbs. available N and 30 lbs. of P_2O_5 per acre) to get a constant rate of about 5 lbs. of N and 1 lb. of P_2O_5 per crop tree.

Graney (1987), Ward and Bowersox (1970), and Farmer et al. (1970), noted that significant diameter growth responses of white oak to N fertilization can be expected only through about year 5, with peak response expected in years 2 or 3. Response of released white oak has been shown to last up to 20 years (Schlesinger 1978). The benefits of a release and fertilizer treatment over release treatment may subside after the first 5 years, but have remained apparent at least through year 10 (Graney 1987). In the upland study at Ames, if crop trees are going to be re-fertilized the application should occur sometime between the third and sixth growing season.

Year 2 d.b.h. and basal area growth were greater than year 1 growth for all treatments. The differences were significant for all treatments except the control (Appendix B-1). Diameter growth in the combined treatment was 54.7% and 86.9% higher than growth in the control in years 1 and 2 respectively. Basal area growth in the combined treatment was 62.9 percent higher than the control at year 1 and 99.1 percent higher at year 2. The increase in diameter growth over the control for the fertilizer treatment and the release treatment was 8.8% and 32.0% for year 1 and 26.2% and 53.7% for year 2, respectively. The increase in basal area growth over the control for the fertilizer treatment and the release treatment was 10.2% and 38.0% for year 1 and 30.2% and 62.6% for year 2 respectively.

The above average moisture availability in the second growing season may have contributed partially to increased growth during the second growing season. However, significant growth increases in the second year for white oak in fertilizer, release and combined treatments were also due to the responses of trees to these treatments (e.g., increase in photosynthetic area stimulates increase diameter and basal area growth) (Smith 1986).

Using white oak data, estimates of crop tree stumpage volume (Doyle log rule, Girard form class 78) among the treatments can be calculated. Estimates were based on an average merchantable height of 2-logs and an average pretreatment d.b.h. of 10.0 inches. Ten year growth was calculated by multiplying cumulative 2 year growth by 5.

Assuming 36 crop trees per acre, volume for the 4 treatments in 10 years would be: 1) combined treatment = 2.124 bd. ft. per acre 2) release treatment = 2,124 bd. ft. per acre,3) fertilizer treatment = 1,548 bd. ft. per acre, and 4) control treatment = 1,548 bd. ft. per acre. Allowing for ice storm damage among the treatments, white oak volumes would be: 1) combined treatment = 1,678 bd. ft. per acre, 2) release treatment = 1,890 bd. ft. per acre, 3) fertilizer treatment = 1,471 bd. ft. per acre, and 4) control treatment = 1,502 bd. ft. per acre. Even though the release and the combined treatment had a higher percentage of ice damage the board foot volume would still be slightly greater than the control except for the fertilizer only treatment. The estimates for ten year growth of the combined and the release treatments were considered conservative since crop trees probably did not have time to fully respond to release. Peak response of white oak crop trees to release has occurred as late as 10 years after treatment (Graney 1987).

Southern Red Oak

Diameter Growth

There were significant differences between treatments for both year 2 and cumulative diameter growth of southern red oak crop trees (Appendix A-2). For these year groups, the combined treatment exhibited the highest diameter growth followed by the release treatment, the fertilizer treatment and the control (Table 10).

For year 1 the diameter growth was highest in the combined treatment (0.352 inches) followed by the fertilizer treatment (0.245 inches), the release treatment (0.238 inches) and the control (0.187 inches). There were however, no statistically significant differences among the treatment means.

Year 2 diameter growth in combined treatment (0.416 inches) was significantly greater than growth of crop trees in both the control (0.244 inches) and the fertilizer treatment (0.301 inches)

Table 10. Diameter growth and percent increase in growth over the control (in parenthesis) by year and treatment for southern red oak crop trees selected in a 20 acre upland hardwood stand in west Tennessee.

Year	Treatment			
	CONT[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	------------------inches-------------------			
Year 1[5]	0.187[a]	0.238[a] (27.3)	0.245[a] (31.0)	0.352[a] (88.2)
Year 2	0.244[a]	0.327[ab] (34.0)	0.301[a] (23.4)	0.416[b] (70.5)
Cumulative 2 year	0.433[a]	0.561[a] (29.6)	0.550[a] (27.0)	0.787[b] (81.7)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Model Procedure

but it was not greater than the release treatment (0.327 inches). There were no significant differences among control, fertilizer and release treatments.

Cumulative 2 year diameter growth was greatest in the combined treatment (0.787 inches), which was significantly different from all other treatment means. There were no significant differences among the control (0.433 inches), the release (0.561 inches) and the fertilizer treatments (0.550 inches).

Basal Area Growth

There were statistically significant differences in basal area growth among treatments within each year group (Appendix B-2). The combined treatment had the greatest growth during both years.

Year 1 basal area growth in the combined treatment was 0.0437 square feet (Table 11). This was significantly greater than growth in the release (0.0274 sq. ft.) and the control (0.0205 sq. ft.) treatments but it was not greater than the fertilizer treatment (0.0285 sq. ft.). There were no significant differences among release, fertilizer and control treatments.

Year 2 basal area growth was greatest in the combined treatment (0.0510 sq. ft.), followed by the release (0.0368 sq. ft.), the fertilizer (0.0357 sq. ft.), and the control (0.0263 sq. ft.) treatments. Basal area growth in the combined treatment was significantly greater than the control, but was not significantly different from release or fertilizer treatments. There were no

Table 11. Basal area growth and percent increase in growth over the control (in parenthesis) by year and treatment for southern red oak crop trees selected in a 20 acre upland hardwood stand in west Tennnessee.

	Treatment			
Year	**CONT**[1]	**REL**[2]	**FERT**[3]	**REL/FERT**[4]
	----------------square feet----------------			
Year 1[5]	0.0205[a]	0.0274[a] (33.7)	0.0285[ab] (39.0)	0.0437[b] (113.2)
Year 2	0.0263[a]	0.0368[ab] (40.0)	0.0357[ab] (35.7)	0.0510[b] (93.9)
Cumulative 2 year	0.0458[a]	0.0648[a] (41.5)	0.0650[a] (41.9)	0.0960[b] (109.6)

1/ Control treatment
2/ Release treatment
3/ Fertilizer treatment
4/ Combined release and fertilizer treatment
5/ Least square means with different letters are different ($P < 0.05$) SAS, Mixed Model Procedure

significant differences among release, fertilizer and control treatments.

Two-year basal area growth in the combined treatment was (0.0960 sq. ft.), which was significantly greater than that of all other treatments. Basal area growth in the other treatments was; release (0.0650 sq. ft.), fertilizer (0.0648 sq. ft.) and control (0.0458 sq. ft.). There were no significant differences among these 3 treatments.

Discussion

Annual diameter growth of southern red oak in the combined treatment was 79% greater than the control, 49% greater than the release and 52% greater than the fertilizer treatment. Annual basal area growth in the combined treatment was 104% greater than in the control, 67% greater than in the release, and 66% greater than in the fertilizer treatment.

Cumulative 2 year diameter growth in the combined treatment was 82% greater than in the control, 52% greater than in the release and 55% greater than in fertilizer treatment. Basal area growth in the combined treatment was 110% greater than the control and 68% greater than the release treatment and the fertilizer treatment.

Growth in year 2 was significantly greater than growth in year 1 (Appendix C-1). However, growth increases over the control varied between the 2 years. There was a slightly higher response to fertilizer than to release during the first year. Diameter and basal area growth in the release treatment were 27% and 34%

greater than in the control, respectively. Diameter and basal area growth in the fertilizer treatment were 31% and 39% greater than the control, respectively.

For year 2 growth in the release treatment was greater than in the fertilizer treatment. The increase in diameter growth over the control for the year 2 and cumulative growth was 34% and 30% for the release and 23% and 27% for the fertilizer treatment, respectively. The increase in basal area growth over the control in year 2 was 40% and 36% for the release and fertilizer treatment, respectively.

The increase in cumulative basal area growth was 41% and 42% for the release and the fertilizer treatment, respectively. The differences indicate that if release is not a desirable option then fertilization may produce the same short term benefits for southern red oak.

The increases in growth over the control for the combined treatment were lower for year 2 than year 1. Diameter growth was 88% greater than the control in year 1 and 71% greater than the control in year 2. Basal area growth was 113% greater than the control in year 1 and 94% greater than the control in year 2. This may be in part due to better growing conditions in 1994 as evidenced by a 31% increase in diameter growth and a 28% increase in basal area growth in the control. The lower increases in growth over the control the second year may also be attributed to the higher response of southern red oak to fertilization in the first growing season.

Even though growth differences among treatments were not significant in all cases (mainly due to a relatively small sample size), if these growth rates could be maintained up to 10 years they would represent some significant differences in tree value. Ten year diameter growth in the combined treatment for southern red oak would be about 1.1 inches greater than both the release treatment and the fertilizer treatment (3.9 inches versus 2.8 inches) and about 1.7 inches greater than the control (3.9 inches versus 2.2 inches). Based on 2 year data the 10 year difference in growth over the control would be about 0.6 inches for both the release and the fertilizer treatments. Based on earlier studies (Graney 1987) the 10 year values calculated for the release and the combined treatment will probably be lower than the actual 10 year growth. Peak response of red oak has been shown to occur as late as the tenth growing season after release. Two growing seasons after release most crop trees had not yet fully occupied the increased crown area afforded them by the release treatments.

No information on southern red oak could be found to make comparisons of the results of this study. Most research with similar treatments has either grouped red oak species or has dealt primarily with northern red oak.

Black and Scarlet Oak

There were no statistically significant differences in growth among the treatments for either black or scarlet oak (Appendices A-3, A-4, B-3, and B-4). The primary reason differences were not statistically significance was due to the small number of observations (36 black and 31 scarlet oak crop trees over all treatments). However, black and scarlet oak have shown significant increases in growth with release (Mitchell et al. 1988) and fertilization (McQuilkin 1982) applied singularly.

Although sample sizes of these 2 species were small, the trends in the growth were similar to those found with white and southern red oak and suggest that had sample size been larger significant differences might have occurred. Variations from the growth trends observed with white and southern red oak were; 1) first year growth of black oak in released plots was lower than growth in any of the other treatments but this did not occur in the second year and 2) growth of scarlet oak in the release treatment was about the same as growth in the combined treatment.

Species Comparisons

There were no statistically significant differences in diameter or basal area growth among species within any treatment (Appendix C). However, there were some differences in response trends that appear to be important. Because sample size for black and scarlet oak was small, the following discussion was limited to white and southern red oak.

White oak growth in the release treatment was greater than growth in the fertilizer treatment, but southern red oak growth was the same in both these treatments. In general white oak crop trees were beginning to lose crown position or were in heavy competition for light. On this site and under these conditions, light was more of a limiting factor to growth of white oak than N and P. Southern red oak tended to have a higher crown position and was under less initial competition for light than white oak. Apparently under these conditions light and N/P levels were equally limiting for southern red oak.

Farmer et al. (1970) reported that white oak responded more to fertilization than red oak. Although the differences in the study at Ames were nonsignificant, white oak grew less than southern red oak in the combined and the fertilizer only treatment. However, in the release treatment the percent increase in growth over the control was slighter greater for white oak than for southern red oak. This may have been due to the lower crown position of many white oak crop trees which were not able to take full advantage of the increased N and P levels. Graney (1987) found that white oak and red oak responded about the same to a combined and a release only treatment.

A release treatment is needed to maintain the growth of white oak in the fertilized and the control treatments. White oak is less competitive than most red oaks and will begin to show reduced crown size and growth as competition intensifies. However, white oak has the ability to persist in an intermediate or suppressed position for many years. This may occur to many unreleased white oak crop trees that have red oaks competing for the same canopy position. Once white oaks become suppressed response to release will be less likely (Clatterbuck 1992 and McGee and Bivens 1984).

Correlation Analysis

Due to the small sample size and the lack of statistically significant differences in growth between treatments no correlation analysis was conducted for black and scarlet oak.

White oak

For white oak, all variables included in the analysis except 1) total height, 2) initial basal area and 3) direct sunlight from the side 1994 had a significant positive correlation with cumulative basal area growth in the control treatment (Table 12). Correlation coefficients ranged from r = 0.652 for total crown points in 1993 to r = 0.017 for direct sunlight from above 1994. The variables that express crown size (total height, crown length, mean crown diameter and crown size 1993 and 1994) and the variables that reflect crown position (direct sunlight from above, direct sunlight from the side and total crown points 1993 and 1994) seem to have an equally important influence on white oak growth in the control treatment. It would be expected that initial basal area would show a fairly good correlation with basal area growth of individual trees (Opie 1968). Because selected trees in the study at Ames partially on the basis of being above average in size and form that relationship proved to be weak.

All variables except crown balance had a significant correlation with white oak basal area growth in the fertilizer treatment. All variables had a positive r-values except for initial basal area (r = -0.239). Correlation coefficients ranged from r = 0.734 for mean crown diameter to r = 0.187 for crown

Table 12. Correlation coefficients (r) for tree variables with cumulative 2 year basal area growth of white oak crop trees selected in the control and the fertilizer treatments in a 20 acre upland hardwood stand in west Tennessee.

	Treatments	
Variable	**Control**	**Fertilization**
	-----correlation coefficients------	
DBH[1]	**0.621**[2]	**0.753**
total height	0.048	**0.532**
crown length	**0.223**	**0.521**
mean crown diameter	**0.506**	**0.734**
DSA[3] **1993**	**0.512**	**0.304**
DSS[4] **1993**	**0.540**	**0.445**
crown balance 1993	**0.359**	0.187
crown size 1993	**0.511**	**0.546**
total crown points[5] **1993**	**0.652**	**0.538**
initial basal area	0.045	**-0.239**
DSA 1994	0.017	**0.342**
DSS 1994	**0.616**	**0.464**
crown balance 1994	**0.458**	**0.210**
crown size 1994	**0.553**	**0.536**
total crown points 1994	**0.260**	**0.544**

1/ diameter at breast height (4.5 feet above ground line)
2/ values in **bold** are significant ($P < 0.05$)
3/ direct sunlight from above
4/ direct sunlight from the side
5/ total value of the crown point system

balance 1993.

Initial crown size had a stronger relationship with white oak growth in the fertilizer treatment than crown position. Although crown position, particularly direct sunlight from the side, did have a relatively strong relationship with growth. In general correlation coefficients for variables reflecting crown size are larger than the variables that reflect crown position. This is probably due to the ability of trees with larger crowns and assumed large root systems to assimilate and utilize more N and P than trees with smaller crowns.

The r-values for total height, crown length, mean crown diameter, and crown size 1993 were all higher in the fertilizer treatment than in the control. These higher r-values may be a product of the accelerated growth in the fertilizer treatment (e.g., crop trees have a better relationship with growth because more growth has occurred and the importance of these factors is more apparent; similar to comparing 3 year growth to 2 year growth).

Only 6 of 17 variables had a significant correlation with basal area growth of released white oak (Table 13). All variables had positive r-values except residual basal area ($r = -0.023$). Correlation coefficients ranged from $r = 0.401$ for crown size 1994 to $r = 0.003$ for crown balance 1993. Growth of released white oak had a slightly stronger relationship to crown size than to crown position. Trees with larger crowns were able to accumulate more basal area growth since they were able to produce

Table 13. Correlation coefficients (r) for tree variables with cumulative 2 year basal area growth of white oak crop trees selected in the release and the combnined release and fertilizer treatments in a 20 acre upland hardwood stand in west Tennessee.

Variable	**Treatment**	
	Release	**Release and Fertilization**
	------correlation coefficients-----	
DBH[1]	**0.260**[2]	**0.621**
total height	0.153	**0.318**
crown length	**0.233**	**0.386**
mean crown diameter	0.179	**0.587**
DSA[3] **1993**	**0.194**	0.075
DSS[4] **1993**	0.086	**0.446**
crown balance 1993	0.003	0.173
crown size 1993	**0.293**	**0.573**
total crown points[5] **1993**	0.193	**0.456**
initial basal area	0.057	-0.208
basal area removed	0.146	-0.089
residual basal area	-0.023	-0.170
DSA 1994	0.106	0.020
DSS 1994	0.189	**0.425**
crown balance 1994	0.024	**0.300**
crown size 1994	**0.401**	**0.559**
total crown points 1994	**0.268**	**0.606**

1/ diameter at breast height (4.5 feet above ground line)
2/ values in **bold** are significant ($P < 0.05$)
3/ direct sunlight from above
4/ direct sunlight from the side
5/ total value of the crown point system

more photosynthate than trees with smaller crowns.

For released white oak most variables will probably show a stronger relationship with growth as the trees grow older This can be seen indirectly by noting the larger r-values calculated in the combined treatment. Apparently, fertilizer accelerates the response of white oak to release.

In the combined treatment, eleven variables showed a significant relationship with white oak growth. Correlation coefficients were positive for all variables except initial basal area ($r = -0.208$), basal area removed ($r = -0.089$), and residual basal area ($r = -0.170$). The highest r-value was 0.621 for d.b.h. and the lowest was 0.020 for direct sunlight from above 1994. The PSHCC value of direct sunlight from above should have been 9 or 10 for all crop trees in the release and combined treatments because release provided the crop trees with almost 100% full sunlight. Therefore, there is not a good relationship between this variable and growth. The importance of both initial crown size and crown position was more apparent for crop trees in the combined treatment than for crop trees in the release only treatment.

For all treatments d.b.h. had a significant relationship with basal area growth. One reason is because in even-aged stands larger trees represent trees that are either genetically superior and/or are growing on a better microsite than smaller stems (Perry 1985). Another reason is because trees with a larger d.b.h. have a larger basal area and a tenth of an inch in growth on a larger diameter tree represents more basal area growth than a tenth of an inch on a smaller tree.

Southern red oak

Nine of the 15 variables had a significant correlation with basal area growth of southern red oak in the control (Table 14). All variables except initial basal area had positive r-values. Correlation coefficients ranged from r = 0.717 for crown length to r = 0.024 for crown balance 1993. As with white oak in the control neither variables that reflected crown size nor variables that reflected crown position appeared more important in explaining growth. For red oak crown length was the crown dimension having the strongest relationship with growth whereas with white oak it was mean crown diameter. This may be due to differences in tolerance between white and southern red oak. Southern red oak is less shade tolerant than white oak (Fowells 1965). Species with less shade tolerance tend to have smaller crown diameters relative to their d.b.h than more tolerant species (Carvell et al. 1987). This may mean that growth of less tolerant trees in a codominant or dominant position depends more upon crown length than crown diameter.

Only 6 variables had a significant correlation with basal area growth of fertilized southern red oak. All r-values were positive and ranged from r = 0.706 for d.b.h. to r = 0.138 for crown balance 1994. For fertilized southern red oak, crown position variables, particularly direct sunlight from the side and the total crown point value, had a stronger relationship to growth than did the actual crown dimensions. However, the relationship

Table 14. Correlation coefficients (r) for tree variables with cumulative 2 year basal area growth of southern red oak crop trees selected in the control and fertilizer treatments in a 20 acre upland hardwood stand in west Tennessee.

	Treatments	
Variable	**Control**	**Fertilization**
	-----correlation coefficients------	
DBH[1]	**0.694**[2]	**0.706**
total height	0.627	0.335
crown length	**0.717**	0.142
mean crown diameter	0.391	0.339
DSA[3] **1993**	0.332	0.378
DSS[4] **1993**	**0.653**	**0.665**
crown balance 1993	0.024	0.147
crown size 1993	**0.448**	**0.562**
total crown points[5] **1993**	**0.549**	**0.618**
initial basal area	-0.241	0.242
DSA 1994	**0.457**	0.429
DSS 1994	**0.517**	**0.679**
crown balance 1994	0.186	0.138
crown size 1994	**0.616**	0.344
total crown points 1994	**0.551**	**0.620**

1/ diameter at breast height (4.5 feet above ground line)
2/ values in **bold** are significant ($P < 0.05$)
3/ direct sunlight from above
4/ direct sunlight from the side
5/ total value of the crown point system

with crown size 1993 was strong (r = 0.562).

In the study at Ames southern red oak had a relatively small crown compared to white oak, but in most cases the red oak had a larger bole and better canopy position. Apparently southern red oak is very efficient photosyntheticlly and when fertilized, (nutrient demands met) crown position is more important than actual crown size. This may also be related to the tolerance of southern red oak; since it is more intolerant than white oak (Fowells 1965), it is photosynthetically efficient in full sunlight.

Nine of the 17 variables were significantly correlated with basal area growth of released southern red oak (Table 15). All r-values were positive except for crown balance 1993. Correlation coefficients ranged r = 0.670 for mean crown diameter to r = -0.023 for crown balance 1993.

For the combined treatment seven variables showed a significant correlation with basal area growth. All r-values were positive except for initial basal area (r = -0.645), basal area removed (r = -0.595), residual basal area (r = -0.378) and crown balance 1994 (-0.101). Correlation coefficients ranged from r = 0.749 for crown length to r = 0.004 for direct sunlight from the side 1994.

Initial crown size showed a stronger relationship with basal area growth in both the released and the combined treatments than did initial crown position. Crown size was a more important indicator of basal area growth in these treatments because these

Table 15. Correlation coefficients (r) for tree varibales with cumulative 2 year basal area growth of southern red oak crop trees selected in the release and the combined release and fertilizer treatments in a 20 acre upland hardwood stand in west Tennessee.

Variable	**Treatments**	
	Release	**Release and Fertilization**
	------correlation coefficients-----	
DBH[1]	**0.563**[2]	**0.748**
total height	0.299	0.425
crown length	**0.541**	**0.749**
mean crown diameter	**0.670**	**0.661**
DSA[3] **1993**	0.154	0.165
DSS[4] **1993**	**0.456**	0.328
crown balance 1993	-0.023	0.083
crown size 1993	**0.592**	**0.752**
total crown points[5] **1993**	**0.474**	0.504
initial basal area	**0.450**	**-0.645**
basal area removed	0.224	**-0.595**
residual basal area	0.281	-0.378
DSA 1994	0.301	0.404
DSS 1994	0.382	0.004
crown balance 1994	0.114	-0.101
crown size 1994	**0.470**	**0.678**
total crown points 1994	**0.443**	0.303

1/ diameter at breast height (4.5 feet above ground line)
2/ values in **bold** are significant ($P < 0.05$)
3/ direct sunlight from above
4/ direct sunlight from the side
5/ total value of the crown point system

trees had more initial photosynthetic area and were able to respond faster to the increase in sunlight. In the fertilizer treatment crown position was more important than crown size because light was still a major limiting factor (e.g. fertilizing a suppressed tree of a species that is relatively intolerant would do it little good).

Initial basal area was significantly correlated (r = 0.450) with basal area growth in the release treatment but showed a significant negative relationship (r = -0.645) in the combined treatment. These results seem contradictory and there is little information on release versus release and fertilization of southern red oak to indicate a clear explanation.

Within an even-aged, fully stocked stand, basal area is a fairly good indication of micro-site quality (Smith 1986). Where initial basal area was low, site quality was low and release without fertilization produced a response but it was less than the response on areas where initial basal area was higher (e.g. site quality was higher). When release was combined with fertilization the temporary productivity of the lower quality site (lower initial basal area) was increased and growth was increased. On the more productive site (higher basal area) fertilization was not as effective because nutrition was not as limiting. Fertilization on the more productive areas possibly had a negative effect since fertilizer was applied over the entire acre benefiting crop trees competitors as much as the crop tree.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Growth analysis

Release and fertilization treatments were applied singularly and in combination to crop trees in an upland hardwood stand in west Tennessee. White and southern red oak were selected in sufficient numbers to detect statistical differences in individual tree growth among treatments. The following conclusions were made based on the growth of 2 species:

1. When adjusted for differences in initial volume due to plot variation, release and fertilizer applied singularly and in combination produced no significant increases in per acre volume growth of crop trees due to disproportionately higher ice damage in the release and the combined treatment. However, annual and cumulative 2 year volume growth in these treatments was slightly higher than growth in the control and significant differences may become more apparent in the future.
2. When adjusted for differences in initial volume due to plot variation and ice damage, per acre volume growth among the treatments was significantly different. Per acre volume growth in the combined treatment was significantly greater than all other treatments. Growth in the release treatment was

significantly greater than in the control. Growth in the fertilizer treatment was consistently greater than in the control but differences were not significant.

3. Release and fertilization applied in combination significantly increased cumulative 2 year diameter and basal area growth of white and southern red oak crop trees over release and fertilization applied singularly and over the control.

4. White oak had a significantly greater response to release than to fertilization. Southern red oak had essentially the same response for both treatments.

5. Diameter growth of fertilized white oak was significantly greater than growth of the control. Basal area growth of fertilized white oak was slightly greater than growth of the control but the difference was not significant.

6. Release and fertilizer applied singularly to southern red oak crop trees appeared to produce substantial growth increases over the control although the differences were not significant.

Correlation analysis

Extensive measurement of each crop was done to gain information on tree characteristics that appeared to have greatest influence on treatment effects. Identification of these characteristics should aid in developing guidelines for crop tree selection. The following conclusions are based on the correlation analysis used to examine these variables:

1. Crown size and crown position had equally important positive relationships with growth of crop trees in the control treatment.
2. Crown size of white oak in the fertilizer and release treatments had a stronger relationship with growth than did initial crown position.
3. Fertilizer appeared to accelerate the response of white oak to release.
4. Initial crown size and crown position were equally important for white oak when these treatments were combined.
5. For southern red oak (which is more intolerant than white oak) crown position was highly correlated with growth when fertilized.
6. Crown size had the strongest relationship with the growth of southern red oak in the release and the combined treatments, because: 1) shading was no longer a limiting factor and 2) trees that had more initial photosynthetic area were able to respond faster to increased sunlight.

Recommendations

After observing the crop tree management study for 2 years, the following recommendations should be considered for management of upland hardwood stands similar to the one examined in this study. These guidelines also apply for future crop tree management research:

1. SAS Univariate Procedures showed that blocking (as done in this study) did not increase statistical sensitivity. The best way to control variation would have been to select and measure all crop trees within each 1.01 acre plot previous to selecting an experimental design. If there is considerable variation in diameter distributions of treatment plots, then blocking should be done based on these distributions. If there is little variation in diameter distributions among treatment plots then a completely randomized design should be considered.
2. Additional fertilizer will be needed probably within the next 2 to 3 (4 to 5 years after initial application) years to maintain the current growth rates. However, there may be some valuable information gained by looking at the longevity of the response to fertilizer. Understanding the longevity of response will aid in developing the most efficient fertilization scheme to maximize a landowner's returns.
3. Make future applications of fertilizer around the dripline of the crop tree. Since determining

fertilization rate based on diameter is time consuming, select a constant rate for all crop trees. This type of application puts emphasis entirely on the crop tree which is the key in facilitating crop tree management to a landowner

4. Some white oak crop trees in both the control and the fertilizer treatments appeared to be losing crown position to more competitive red oaks. This change in stand structure should be monitored closely with the Point System for Hardwood Crown Classes. Release is probably the only option available to maintain white oak growth rates. It is extremely important that this information be relayed to a landowner.

5. Do not select black cherry as a crop tree in regions where ice storms are likely to occur. Black cherry appears to be very susceptible to ice damage, especially when released.

6. Although the treatments appeared to yield potential increases in tree value, a rigorous economic analysis is suggested. To make crop tree enhancement acceptable to a landowner it must be economically feasible.

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APPENDICES

APPENDIX A

Appendix A. Tree species occuring on the study site by common and scientific name.

white oak (<u>Quercu</u> <u>alba</u> L.)
black oak (<u>Quercus</u> <u>velutina</u> Lam.)
southern red oak (<u>Quercus</u> <u>falcata</u> Michx.)
scarlet oak (<u>Quercus</u> <u>coccinea</u> Muenchh.)
willow oak(<u>Quercus</u> <u>phellos</u> L.)
black cherry (<u>Prunus</u> <u>serotina</u> Ehrh.)
red maple (<u>Acer</u> <u>rubrum</u> L.)
winged elm (<u>Ulmus</u> <u>alata</u> Michx.)
blackgum (<u>Nyssa</u> <u>sylvatica</u> Marsh.)
yellow-poplar (<u>Liriodendron</u> <u>tulipifera</u> L.)
black locust (<u>Robinia</u> <u>pseudoacacia</u> L.)
white ash (<u>Fraxinus</u> <u>americana</u> L.)
American sycamore (<u>Platanus</u> <u>occidentalis</u> L.)
river birch (<u>Betula</u> <u>nigra</u> L.)
royal paulownia (<u>Paulownia</u> <u>tomentosa</u> Thunb).
mockernut hickory (<u>Carya</u> <u>tomentosa</u> Nutt.)
flowering dogwood (<u>Cornus</u> <u>florida</u> L.)
Sassafras (<u>Sassafras</u> <u>albidum</u> Nutt.)
eastern redbud (<u>Cercis</u> <u>canadensis</u> L.)
common persimmion (<u>Diospyros</u> <u>virginiana</u> L.)
eastern redcedar (<u>Juniperus</u> <u>virginiana</u> L.)
American hornbeam (<u>Carpinus</u> <u>caroliniana</u> Walt.).

APPENDIX B

Appenix B-1. Cubic foot volume growth per acre comparisons using Mixed Model Least Square Means, values unadjusted for differences in initial volume and ice damage.

YEAR 1 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	2.05	0.1613

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	13.24742000	1.92739140	12	6.87	0.0000
rel	16.62994000	1.92739140	12	8.63	0.0000
fer	16.78458000	1.92739140	12	8.71	0.0000
r/f	19.99614000	1.92739140	12	10.37	0.0000
con v rel	-3.38252000	2.72574306	12	-1.24	0.2383
con v fer	-3.53716000	2.72574306	12	-1.30	0.2188
con v r/f	-6.74872000	2.72574306	12	-2.48	0.0292
rel v fer	-0.15464000	2.72574306	12	-0.06	0.9557
rel v r/f	-3.36620000	2.72574306	12	-1.23	0.2405
fer v r/f	-3.21156000	2.72574306	12	-1.18	0.2615

YEAR 2 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	4.58	0.0233

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	14.17070000	2.64446426	12	5.36	0.0002
rel	22.49082000	2.64446426	12	8.50	0.0000
fer	20.98712000	2.64446426	12	7.94	0.0000
r/f	26.06726000	2.64446426	12	9.86	0.0000
con v rel	-8.32012000	3.29357208	12	-2.53	0.0266
con v fer	-6.81642000	3.29357208	12	-2.07	0.0607
con v r/f	-11.89656000	3.29357208	12	-3.61	0.0036
rel v fer	1.50370000	3.29357208	12	0.46	0.6561
rel v r/f	-3.57644000	3.29357208	12	-1.09	0.2989
fer v r/f	-5.08014000	3.29357208	12	-1.54	0.1489

CUMULATIVE 2 YEAR VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	3.73	0.0419

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	27.41812000	4.23283038	12	6.48	0.0000
rel	39.12074000	4.23283038	12	9.24	0.0000
fer	37.77168000	4.23283038	12	8.92	0.0000
r/f	46.06336000	4.23283038	12	10.88	0.0000
con v rel	-11.70262000	5.63292709	12	-2.08	0.0599
con v fer	-10.35356000	5.63292709	12	-1.84	0.0909
con v r/f	-18.64524000	5.63292709	12	-3.31	0.0062
rel v fer	1.34906000	5.63292709	12	0.24	0.8148
rel v r/f	-6.94262000	5.63292709	12	-1.23	0.2414
fer v r/f	-8.29168000	5.63292709	12	-1.47	0.1668

Appenix B-2. Cubic foot volume growth per acre comparisons using Mixed Model Least Square Means, values adjusted for differences in initial volume.

YEAR 1 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	0.62	0.6140
VOLUME93	1	11	12.42	0.0048

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	15.15410605	1.56867353	11	9.66	0.0000
rel	16.87517512	1.47403793	11	11.45	0.0000
fer	16.37181587	1.47704632	11	11.08	0.0000
r/f	18.25698296	1.55291507	11	11.76	0.0000
con v rel	-1.72106908	2.13499588	11	-0.81	0.4373
con v fer	-1.21770983	2.18384325	11	-0.56	0.5883
con v r/f	-3.10287692	2.32516987	11	-1.33	0.2090
rel v fer	0.50335925	2.09063590	11	0.24	0.8142
rel v r/f	-1.38180784	2.15708888	11	-0.64	0.5349
fer v r/f	-1.88516709	2.11602944	11	-0.89	0.3921

YEAR 2 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	2.52	0.1121
VOLUME93	1	11	28.48	0.0002

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	17.31681216	1.70911052	11	10.13	0.0000
rel	22.89546826	1.60600257	11	14.26	0.0000
fer	20.30604183	1.60928030	11	12.62	0.0000
r/f	23.19757775	1.69194127	11	13.71	0.0000
con v rel	-5.57865610	2.32613341	11	-2.40	0.0353
con v fer	-2.98922967	2.37935389	11	-1.26	0.2350
con v r/f	-5.88076559	2.53333290	11	-2.32	0.0405
rel v fer	2.58942643	2.27780206	11	1.14	0.2798
rel v r/f	-0.30210949	2.35020430	11	-0.13	0.9000
fer v r/f	-2.89153592	2.30546899	11	-1.25	0.2358

CUMULATIVE 2 YEAR VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	2.03	0.1687
VOLUME93	1	11	29.04	0.0002

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	32.47091708	2.71803738	11	11.95	0.0000
rel	39.77062324	2.55406246	11	15.57	0.0000
fer	36.67783794	2.55927510	11	14.33	0.0000
r/f	41.45452174	2.69073272	11	15.41	0.0000
con v rel	-7.29970616	3.69930293	11	-1.97	0.0741
con v fer	-4.20692086	3.78394068	11	-1.11	0.2899
con v r/f	-8.98360466	4.02881701	11	-2.23	0.0475
rel v fer	3.09278529	3.62244049	11	0.85	0.4114
rel v r/f	-1.68389850	3.73758342	11	-0.45	0.6611
fer v r/f	-4.77668379	3.66643983	11	-1.30	0.2193

Appenix B-3. Cubic foot volume growth per acre comparisons using Mixed Model Least Square Means, values adjusted for differences in initial volume and differences in volume due to ice damage.

YEAR 1 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	4.40	0.0289
VOLUME93	1	11	27.81	0.0003

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	14.25648287	1.19377749	11	11.94	0.0000
rel	16.59273269	1.17836238	11	14.08	0.0000
fer	15.72752616	1.19527005	11	13.16	0.0000
r/f	20.08133828	1.17845201	11	17.04	0.0000
con v rel	-2.33624982	1.67819633	11	-1.39	0.1914
con v fer	-1.47104329	1.71186779	11	-0.86	0.4085
con v r/f	-5.82485541	1.67561050	11	-3.48	0.0052
rel v fer	0.86520653	1.67761128	11	0.52	0.6162
rel v r/f	-3.48860559	1.66658784	11	-2.09	0.0603
fer v r/f	-4.35381212	1.68044548	11	-2.59	0.0251

YEAR 2 VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	16.72	0.0002
VOLUME93	1	11	61.64	0.0000

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	15.63298358	1.20790315	11	12.94	0.0000
rel	22.43690103	1.19347685	11	18.80	0.0000
fer	19.45529029	1.20930071	11	16.09	0.0000
r/f	26.19072510	1.19356070	11	21.94	0.0000
con v rel	-6.80391744	1.55724268	11	-4.37	0.0011
con v fer	-3.82230671	1.59158656	11	-2.40	0.0351
con v r/f	-10.55774151	1.55460240	11	-6.79	0.0000
rel v fer	2.98161073	1.55664535	11	1.92	0.0818
rel v r/f	-3.75382407	1.54538656	11	-2.43	0.0335
fer v r/f	-6.73543480	1.55953885	11	-4.32	0.0012

CUMULATIVE 2 YEAR VOLUME GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	18.11	0.0001
VOLUME 93	1	11	95.18	0.0000

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	29.97363795	1.63417953	11	18.34	0.0000
rel	39.02651005	1.61307756	11	24.19	0.0000
fer	35.09462176	1.63622272	11	21.45	0.0000
r/f	46.27913023	1.61320026	11	28.69	0.0000
con v rel	-9.05287210	2.29730760	11	-3.94	0.0023
con v fer	-5.12098381	2.34340095	11	-2.19	0.0514
con v r/f	-16.30549228	2.29376781	11	-7.11	0.0000
rel v fer	3.93188829	2.29650672	11	1.71	0.1149
rel v r/f	-7.25262018	2.28141657	11	-3.18	0.0088
fer v r/f	-11.18450847	2.30038649	11	-4.86	0.0005

APPENDIX C

Appendix C-1. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year diameter growth of white oak crop trees, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	**NDF**	**DDF**	**Type III F**	**Pr > F**
TRMT	3	12	4.96	0.0182

The MIXED Procedure
ESTIMATE Statement Results

Parameter	**Estimate**	**Std Error**	**DDF**	**T**	**Pr > |T|**
con v rel	-0.05813284	0.02719476	12	-2.14	0.0538
con v fer	-0.01650094	0.02687257	12	-0.61	0.5507
con v r/f	-0.09939157	0.02842893	12	-3.50	0.0044
rel v fer	0.04163191	0.02669186	12	1.56	0.1448
rel v r/f	-0.04125873	0.02825433	12	-1.46	0.1699
fer v r/f	-0.08289064	0.02793962	12	-2.97	0.0118

Least Squares Means

Level	**LSMEAN**	**Std Error**	**DDF**	**T**	**Pr > |T|**
con	0.18072550	0.02007397	12	9.00	0.0000
rel	0.23885834	0.01982840	12	12.05	0.0000
fer	0.19722644	0.01938477	12	10.17	0.0000
r/f	0.28011707	0.02148803	12	13.04	0.0000

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	**NDF**	**DDF**	**Type III F**	**Pr > F**
TRMT	3	12	24.24	0.0000

The MIXED Procedure
ESTIMATE Statement Results

Parameter	**Estimate**	**Std Error**	**DDF**	**T**	**Pr > |T|**
con v rel	-0.11537249	0.02176431	12	-5.30	0.0002
con v fer	-0.05617090	0.02139354	12	-2.63	0.0222
con v r/f	-0.18562521	0.02303858	12	-8.06	0.0000
rel v fer	0.05920159	0.02122350	12	2.79	0.0164
rel v r/f	-0.07025272	0.02287160	12	-3.07	0.0097
fer v r/f	-0.12945431	0.02250785	12	-5.75	0.0001

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.21390251	0.01656807	12	12.91	0.0000
rel	0.32927500	0.01634037	12	20.15	0.0000
fer	0.27007342	0.01584547	12	17.04	0.0000
r/f	0.39952772	0.01799777	12	22.20	0.0000

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	26.31	0.0000

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.17296454	0.03226965	12	-5.36	0.0002
con v fer	-0.07343947	0.03167229	12	-2.32	0.0389
con v r/f	-0.28436300	0.03429444	12	-8.29	0.0000
rel v fer	0.09952506	0.03141039	12	3.17	0.0081
rel v r/f	-0.11139846	0.03402915	12	-3.27	0.0067
fer v r/f	-0.21092353	0.03343452	12	-6.31	0.0000

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.39472781	0.02614978	12	15.09	0.0000
rel	0.56769235	0.02581353	12	21.99	0.0000
fer	0.46816729	0.02506857	12	18.68	0.0000
r/f	0.67909082	0.02829168	12	24.00	0.0000

Appendix C-2. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year diameter growth of scarlet oak crop trees, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	3.01	0.0764

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.05107671	0.05327715	11	-0.96	0.3583
con v fer	-0.05753016	0.05576775	11	-1.03	0.3244
con v r/f	-0.16529069	0.05612280	11	-2.95	0.0133
rel v fer	-0.00645346	0.05500318	11	-0.12	0.9087
rel v r/f	-0.11421398	0.05536314	11	-2.06	0.0635
fer v r/f	-0.10776052	0.05776386	11	-1.87	0.0890

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.18719639	0.03823053	11	4.90	0.0005
rel	0.23827310	0.03710635	11	6.42	0.0000
fer	0.24472656	0.04060134	11	6.03	0.0001
r/f	0.35248708	0.04108766	11	8.58	0.0000

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	4.77	0.0230

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.08347181	0.04397717	11	-1.90	0.0842
con v fer	-0.05717041	0.04832580	11	-1.18	0.2617
con v r/f	-0.17257170	0.04625568	11	-3.73	0.0033
rel v fer	0.02630140	0.04758314	11	0.55	0.5915
rel v r/f	-0.08909988	0.04788697	11	-1.86	0.0897
fer v r/f	-0.11540129	0.05116280	11	-2.26	0.0454

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.24347468	0.03458722	11	7.04	0.0000
rel	0.32694649	0.03465923	11	9.43	0.0000
fer	0.30064509	0.03885871	11	7.74	0.0000
r/f	0.41604638	0.03874727	11	10.74	0.0000

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	4.78	0.0228

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.12861618	0.09029075	11	-1.42	0.1821
con v fer	-0.11724368	0.09404056	11	-1.25	0.2384
con v r/f	-0.35339973	0.09479771	11	-3.73	0.0033
rel v fer	0.01137250	0.09248421	11	0.12	0.9044
rel v r/f	-0.22478355	0.09325400	11	-2.41	0.0346
fer v r/f	-0.23615605	0.09688920	11	-2.44	0.0330

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.43337109	0.06497199	11	6.67	0.0000
rel	0.56198727	0.06269817	11	8.96	0.0000
fer	0.55061477	0.06798727	11	8.10	0.0000
r/f	0.78677082	0.06903077	11	11.40	0.0000

Appendix C-3. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year diameter growth of black oak crop trees, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	3.01	0.1330

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	0.06580977	0.07350192	5	0.90	0.4116
con v fer	-0.05105927	0.08688609	5	-0.59	0.5823
con v r/f	-0.11077695	0.06268505	5	-1.77	0.1374
rel v fer	-0.11686904	0.09023079	5	-1.30	0.2518
rel v r/f	-0.17658672	0.06218569	5	-2.84	0.0363
fer v f/f	-0.05971768	0.08388898	5	-0.71	0.5084

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.20060212	0.05352739	5	3.75	0.0133
rel	0.13479235	0.05715923	5	2.36	0.0649
fer	0.25166139	0.07774328	5	3.24	0.0230
r/f	0.31137907	0.04238150	5	7.35	0.0007

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	4.95	0.0588

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.10482840	0.08760928	5	-1.20	0.2851
con v fer	-0.02378828	0.10340019	5	-0.23	0.8272
con v r/f	-0.26455919	0.07628249	5	-3.47	0.0179
rel v fer	0.08104012	0.10475458	5	0.77	0.4741
rel v r/f	-0.15973078	0.07810853	5	-2.04	0.0963
fer v r/f	-0.24077091	0.09548379	5	-2.52	0.0531

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.17621172	0.06080075	5	2.90	0.0339
rel	0.28104012	0.06307658	5	4.46	0.0067
fer	0.20000000	0.08363533	5	2.39	0.0623
r/f	0.44077091	0.04606829	5	9.57	0.0002

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	4.96	0.0586

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.00239393	0.14149380	5	-0.02	0.9872
con v fer	-0.06372681	0.15254665	5	-0.42	0.6935
con v r/f	-0.39075989	0.12788767	5	-3.06	0.0282
rel v fer	-0.06133289	0.14928161	5	-0.41	0.6982
rel v r/f	-0.38836597	0.12397490	5	-3.13	0.0259
fer v r/f	-0.32703308	0.13645424	5	-2.40	0.0619

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.40293985	0.10248409	5	3.93	0.0111
rel	0.40533378	0.09755772	5	4.15	0.0089
fer	0.46666667	0.11299333	5	4.13	0.0091
r/f	0.79369974	0.07650011	5	10.38	0.0001

Appendix C-4. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year diameter growth of scarlet oak crop trees, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	1.36	0.3404

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.15000000	0.10777737	6	-1.39	0.2134
con v fer	-0.05000000	0.07959886	6	-0.63	0.5530
con v r/f	-0.16666667	0.09566593	6	-1.74	0.1321
rel v fer	0.10000000	0.09748830	6	1.03	0.3446
rel v r/f	-0.01666667	0.11099531	6	-0.15	0.8856
fer v r/f	-0.11666667	0.08390457	6	-1.39	0.2138

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.20000000	0.06499220	6	3.08	0.0217
rel	0.35000000	0.08597660	6	4.07	0.0066
fer	0.25000000	0.04595642	6	5.44	0.0016
r/f	0.36666667	0.07019960	6	5.22	0.0020

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	1.94	0.2251

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.20000000	0.08885522	6	-2.25	0.0654
con v fer	-0.05714286	0.06562393	6	-0.87	0.4174
con v r/f	-0.11666667	0.07887015	6	-1.48	0.1896
rel v fer	0.14285714	0.08037257	6	1.78	0.1258
rel v r/f	0.08333333	0.09150820	6	0.91	0.3976
fer v r/f	-0.05952381	0.06917370	6	-0.86	0.4226

The Mixed Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.20000000	0.05358172	6	3.73	0.0097
rel	0.40000000	0.07088195	6	5.64	0.0013
fer	0.25714286	0.03788799	6	6.79	0.0005
r/f	0.31666667	0.05787487	6	5.47	0.0016

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	2.65	0.1430

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	0.35000000	0.14908810	6	-2.35	0.0572
con v fer	-0.10714286	0.11010886	6	-0.97	0.3681
con v r/f	-0.28333333	0.13233438	6	-2.14	0.0760
rel v fer	0.24285714	0.13485526	6	1.80	0.1218
rel v r/f	0.06666667	0.15353947	6	0.43	0.6793
fer v r/f	-0.17619048	0.11606493	6	-1.52	0.1798

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.40000000	0.08990351	6	4.45	0.0043
rel	0.75000000	0.11893116	6	6.31	0.0007
fer	0.50714286	0.06357138	6	7.98	0.0002
r/f	0.68333333	0.09710689	6	7.04	0.0004

APPENDIX D

Appendix D-1. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year basal area growth of white oak crop trees, Hardeman County, Tennessee.

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	4.08	0.0327

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.00773089	0.00390032	12	-1.98	0.0708
con v fer	-0.00208922	0.00385319	12	-0.54	0.5976
con v r/f	-0.01283630	0.00407686	12	-3.15	0.0084
rel v fer	0.00564168	0.00382741	12	1.47	0.1662
rel v r/f	-0.00510540	0.00405251	12	-1.26	0.2317
fer v r/f	-0.01074708	0.00400717	12	-2.68	0.0200

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02053797	0.00277583	12	7.40	0.0000
rel	0.02826887	0.00273994	12	10.32	0.0000
fer	0.02262719	0.00267242	12	8.47	0.0000
r/f	0.03337427	0.00298590	12	11.18	0.0000

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	13.22	0.0004

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.01470473	0.00375530	12	-3.92	0.0021
con v fer	-0.00711241	0.00371414	12	-1.91	0.0796
con v r/f	-0.02330803	0.00391555	12	-5.95	0.0001
rel v fer	0.00759232	0.00369036	12	2.06	0.0621
rel v r/f	-0.00860330	0.00389271	12	-2.21	0.0473
fer v r/f	-0.01619562	0.00385266	12	-4.20	0.0012

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02346744	0.00272945	12	8.60	0.0000
rel	0.03817217	0.00269677	12	14.15	0.0000
fer	0.03057985	0.00263920	12	11.59	0.0000
r/f	0.04677547	0.00291566	12	16.04	0.0000

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	12	13.43	0.0004

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.02243713	0.00582740	12	-3.85	0.0023
con v fer	-0.00918855	0.00574768	12	-1.60	0.1359
con v r/f	-0.03611781	0.00611930	12	-5.90	0.0001
rel v fer	0.01324858	0.00570618	12	2.32	0.0386
rel v r/f	-0.01368068	0.00607933	12	-2.25	0.0440
fer v r/f	-0.02692926	0.00600173	12	-4.49	0.0007

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.04400854	0.00429127	12	10.26	0.0000
rel	0.06644567	0.00423472	12	15.69	0.0000
fer	0.05319709	0.00412453	12	12.90	0.0000
r/f	0.08012634	0.00462766	12	17.31	0.0000

Appendix D-2. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year basal area growth of southern red oak crop trees, Hardeman County, Tennessee.

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	3.98	0.0381

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.00698910	0.00638796	11	-1.09	0.2973
con v fer	-0.00808867	0.00682286	11	-1.19	0.2608
con v r/f	-0.02326016	0.00682529	11	-3.41	0.0058
rel v fer	-0.00109958	0.00684477	11	-0.16	0.8753
rel v r/f	-0.01627106	0.00684719	11	-2.38	0.0367
fer v r/f	-0.01517148	0.00725461	11	-2.09	0.0605

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02045838	0.00450037	11	4.55	0.0008
rel	0.02744748	0.00453352	11	6.05	0.0001
fer	0.02854706	0.00512817	11	5.57	0.0002
r/f	0.04371854	0.00513140	11	8.52	0.0000

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	3.66	0.0475

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.01046726	0.00703405	11	-1.49	0.1648
con v fer	-0.00940225	0.00752968	11	-1.25	0.2377
con v r/f	-0.02467170	0.00746340	11	-3.31	0.0070
rel v fer	0.00106501	0.00747758	11	0.14	0.8893
rel v r/f	-0.01420444	0.00750433	11	-1.89	0.0850
fer v r/f	-0.01526945	0.00793851	11	-1.92	0.0807

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02633877	0.00510587	11	5.16	0.0003
rel	0.03680603	0.00507502	11	7.25	0.0000
fer	0.03574102	0.00569331	11	6.28	0.0001
r/f	0.05101047	0.00570699	11	8.94	0.0000

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	11	4.78	0.0227

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.01892588	0.01256152	11	-1.51	0.1601
con v fer	-0.01913933	0.01326202	11	-1.44	0.1768
con v r/f	-0.05013274	0.01330758	11	-3.77	0.0031
rel v fer	-0.00021344	0.01315454	11	-0.02	0.9873
rel v r/f	-0.03120686	0.01320047	11	-2.36	0.0375
fer v r/f	-0.03099341	0.01386873	11	-2.23	0.0471

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.04584011	0.00896190	11	5.12	0.0003
rel	0.06476599	0.00880206	11	7.36	0.0000
fer	0.06497944	0.00977577	11	6.65	0.0000
r/f	0.09597285	0.00983749	11	9.76	0.0000

Appendix D-3. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year basal area growth of black oak crop trees, Hardeman County, Tennessee.

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	1.53	0.3151

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	0.00984949	0.00897308	5	1.10	0.3224
con v fer	-0.00771934	0.01184456	5	-0.65	0.5433
con v r/f	-0.00646270	0.00734749	5	-0.88	0.4193
rel v fer	-0.01756883	0.01225975	5	-1.43	0.2113
rel v r/f	-0.01631219	0.00798981	5	-2.04	0.0967
fer v r/f	0.00125665	0.01113154	5	0.11	0.9145

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02712707	0.00594341	5	4.56	0.0060
rel	0.01727758	0.00672981	5	2.57	0.0502
fer	0.03484641	0.01025970	5	3.40	0.0193
r/f	0.03358976	0.00433059	5	7.76	0.0006

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	5.35	0.0511

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.01581222	0.01026051	5	-1.54	0.1839
con v fer	-0.00730556	0.01357338	5	-0.54	0.6135
con v r/f	-0.03210634	0.00839306	5	-3.83	0.0123
rel v fer	0.00850667	0.01404978	5	0.61	0.5713
rel v r/f	-0.01629412	0.00914348	5	-1.78	0.1348
fer v r/f	-0.02480078	0.01274997	5	-1.95	0.1093

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.01865778	0.00678669	5	2.75	0.0403
rel	0.03447000	0.00769538	5	4.48	0.0065
fer	0.02596333	0.01175489	5	2.21	0.0782
r/f	0.05076412	0.00493804	5	10.28	0.0001

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	5	4.42	0.0716

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.00515130	0.01491737	5	-0.35	0.7439
con v fer	-0.01513243	0.01857939	5	-0.81	0.4524
con v r/f	-0.04075680	0.01266638	5	-3.22	0.0235
rel v fer	-0.00998113	0.01904317	5	-0.52	0.6226
rel v r/f	-0.03560550	0.01333738	5	-2.67	0.0444
fer v r/f	-0.02562436	0.01733642	5	-1.48	0.1994

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.04569757	0.01012619	5	4.51	0.0063
rel	0.05084887	0.01095391	5	4.64	0.0056
fer	0.06083000	0.01557735	5	3.91	0.0114
r/f	0.08645436	0.00760903	5	11.36	0.0001

Appendix D-4. Summary of treatment comparisons using Mixed Model Estimates and Least Square Means for year 1, year 2, and cumulative 2 year basal area growth of scarlet oak crop trees, Hardeman County, Tennessee.

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	1.14	0.4070

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.01310821	0.01399153	6	-0.94	0.3850
con v fer	-0.00747786	0.01033343	6	-0.72	0.4965
con v r/f	-0.02213905	0.01241924	6	-1.78	0.1249
rel v fer	0.00563036	0.01265582	6	0.44	0.6720
rel v r/f	-0.00903083	0.01440928	6	-0.63	0.5539
fer v r/f	-0.01466119	0.01089239	6	-1.35	0.2269

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.02100429	0.00843721	6	2.49	0.0472
rel	0.03411250	0.01116138	6	3.06	0.0223
fer	0.02848214	0.00596601	6	4.77	0.0031
r/f	0.04314333	0.00911323	6	4.73	0.0032

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	2.08	0.2044

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.02327786	0.01057123	6	-2.20	0.0699
con v fer	-0.01064357	0.00780737	6	-1.36	0.2217
con v r/f	-0.01838452	0.00938329	6	-1.96	0.0978
rel v fer	0.01263429	0.00956203	6	1.32	0.2346
rel v r/f	0.00489333	0.01088685	6	0.45	0.6689
fer v r/f	-0.00774095	0.00822969	6	-0.94	0.3832

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.01849714	0.00637469	6	2.90	0.0273
rel	0.04177500	0.00843292	6	4.95	0.0026
fer	0.02914071	0.00450759	6	6.46	0.0006
r/f	0.03688167	0.00688545	6	5.36	0.0017

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT	3	6	2.13	0.1972

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
con v rel	-0.03638714	0.01986989	6	-1.83	0.1168
con v fer	-0.01811857	0.01467488	6	-1.23	0.2631
con v r/f	-0.04051548	0.01763702	6	-2.30	0.0613
rel v fer	0.01826857	0.01797299	6	1.02	0.3486
rel v r/f	-0.00412833	0.02046315	6	-0.20	0.8468
fer v r/f	-0.02239690	0.01546869	6	-1.45	0.1978

The MIXED Procedure
Least Squares Means

Level	LSMEAN	Std Error	DDF	T	Pr > |T|
con	0.03950286	0.01198199	6	3.30	0.0165
rel	0.07589000	0.01585069	6	4.79	0.0030
fer	0.05762143	0.00847255	6	6.80	0.0005
r/f	0.08001833	0.01294203	6	6.18	0.0008

APPENDIX E

Appendix E-1. Species comparisons for white oak (WO), black oak (BO), scarlet oak (SO) and southern red oak (SRO) crop trees for diameter and basal area growth of the control treatment, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.21	0.8885

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO v BO	-0.03987964	0.05836576	6	-0.68	0.5199
WO V SO	-0.02902831	0.05900217	6	-0.49	0.6402
WO V SRO	-0.00795024	0.04192594	6	-0.19	0.8559
BO V SO	0.01085133	0.07610096	6	0.14	0.8913
BO V SRO	0.03192940	0.06377998	6	0.50	0.6345
SO V SRO	0.02107807	0.06436288	6	0.33	0.7544

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.88	0.5029

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.04818482	0.04347576	6	1.11	0.3102
WO V SO	0.01485149	0.04884667	6	0.30	0.7714
WO V SRO	-0.02862678	0.02887480	6	-0.99	0.3598
BO V SO	-0.03333333	0.06298288	6	-0.53	0.6156
BO V SRO	-0.07681159	0.04913858	6	-1.56	0.1690
SO V SRO	-0.04347826	0.05394864	6	-0.81	0.4510

CUMULATIVE 2 YEAR DIAMTER GROWTH

The MIXED Procedure
Tests of Fixed Effect

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.77	0.5527

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.03270356	0.06690569	6	-0.49	0.6423
WO V SO	-0.03231161	0.07274821	6	-0.44	0.6725
WO V SRO	-0.06465146	0.04389607	6	-1.47	0.1912
BO V SO	0.00039195	0.09511643	6	0.00	0.9968
BO V SRO	-0.03194789	0.07540069	6	-0.42	0.6865
SO V SRO	-0.03233985	0.07858895	6	-0.41	0.6950

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.26	0.8500

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00648560	0.00769276	6	-0.84	0.4315
WO V SO	-0.00171038	0.00802583	6	-0.21	0.8383
WO V SRO	0.00039112	0.00533068	6	0.07	0.9439
BO V SO	0.00477523	0.01041556	6	0.46	0.6628
BO V SRO	0.00687673	0.00851448	6	0.81	0.4501
SO V SRO	0.00210150	0.00875379	6	0.24	0.8183

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.77	0.5534

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.00497133	0.00566603	6	0.88	0.4140
WO V SO	0.00513197	0.00636601	6	0.81	0.4509
WO V SRO	-0.00297741	0.00376315	6	-0.79	0.4590
BO V SO	0.00016063	0.00820833	6	0.02	0.9850
BO V SRO	-0.00794874	0.00640405	6	-1.24	0.2609
SO V SRO	-0.00810938	0.00703093	6	-1.15	0.2926

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	6	0.25	0.8604

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00356111	0.01011428	6	-0.35	0.7368
WO V SO	0.00269275	0.01107036	6	0.24	0.8159
WO V SRO	-0.00485415	0.00665274	6	-0.73	0.4931
BO V SO	0.00625386	0.01443634	6	0.43	0.6800
BO V SRO	-0.00129304	0.01140768	6	-0.11	0.9135
SO V SRO	-0.00754690	0.01201411	6	-0.63	0.5530

Appendix E-2. Species comparisons for white oak (WO), black oak (BO), scarlet oak (SO) and southern red oak (SRO) crop trees for diameter and basal area growth of the release treatment, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	1.75	0.2264

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.09560440	0.05747029	9	1.66	0.1306
WO V SO	-0.11153846	0.07499164	9	-1.49	0.1711
WO V SRO	0.00664336	0.03453861	9	0.19	0.8517
BO V SO	-0.20714286	0.09224970	9	-2.25	0.0514
BO V SRO	-0.08896104	0.06386843	9	-1.39	0.1971
SO V SRO	0.11818182	0.08000055	9	1.48	0.1737

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	0.46	0.7197

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.03339892	0.05541945	9	0.60	0.5616
WO V SO	-0.06846164	0.07104793	9	-0.96	0.3604
WO V SRO	0.00307547	0.03288123	9	0.09	0.9275
BO V SO	-0.10186056	0.08782631	9	-1.16	0.2760
BO V SRO	-0.03032345	0.06174590	9	-0.49	0.6351
SO V SRO	0.07153711	0.07594835	9	0.94	0.3708

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	1.89	0.2021

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.13969780	0.08498786	9	1.64	0.1346
WO V SO	-0.18173077	0.11089867	9	-1.64	0.1357
WO V SRO	0.00463287	0.05107618	9	0.09	0.9297
BO V SO	-0.32142857	0.13642012	9	-2.36	0.0429
BO V SRO	-0.13506494	0.09444952	9	-1.43	0.1865
SO V SRO	0.18636364	0.11830591	9	1.58	0.1496

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	0.74	0.5526

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.01072661	0.00793922	9	1.35	0.2096
WO V SO	-0.00582086	0.01031072	9	-0.56	0.5862
WO V SRO	0.00080391	0.00475461	9	0.17	0.8695
BO V SO	-0.01654747	0.01270044	9	-1.30	0.2250
BO V SRO	-0.00992270	0.00882899	9	-1.12	0.2901
SO V SRO	0.00662477	0.01100484	9	0.60	0.5620

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	0.11	0.9502

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.00181868	0.00817801	9	0.22	0.8290
WO V SO	-0.00277383	0.01043006	9	-0.27	0.7963
WO V SRO	0.00221650	0.00483470	9	0.46	0.6575
BO V SO	-0.00459251	0.01291101	9	-0.36	0.7303
BO V SRO	0.00039782	0.00911870	9	0.04	0.9662
SO V SRO	0.00499033	0.01115746	9	0.45	0.6653

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	9	0.47	0.7120

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.01351636	0.01332016	9	1.01	0.3367
WO V SO	-0.00888647	0.01721302	9	-0.52	0.6181
WO V SRO	0.00224873	0.00794815	9	0.28	0.7836
BO V SO	-0.02240283	0.02123183	9	-1.06	0.3189
BO V SRO	-0.01126763	0.01482351	9	-0.76	0.4666
SO V SRO	0.01113520	0.01838208	9	0.61	0.5596

Appendix E-3. Species comparisons for white oak (WO), black oak (BO), scarlet oak (SO) and southern red oak (SRO) crop trees for diameter and basal area growth of the fertilization treatment, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.90	0.4750

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.08535655	0.08420201	10	-1.01	0.3346
WO V SO	-0.05183589	0.04309788	10	-1.20	0.2568
WO V SRO	-0.03470284	0.04028563	10	-0.86	0.4092
BO V SO	0.03352066	0.09198099	10	0.36	0.7231
BO V SRO	0.05065371	0.09018974	10	0.56	0.5867
SO V SRO	0.01713305	0.05426824	10	0.32	0.7587

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.53	0.6742

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.07018032	0.07790397	10	0.90	0.3888
WO V SO	0.01278697	0.03937576	10	0.32	0.7521
WO V SRO	-0.02616453	0.03665971	10	-0.71	0.4917
BO V SO	-0.05739336	0.08466036	10	-0.68	0.5132
BO V SRO	-0.09634485	0.08343178	10	-1.15	0.2750
SO V SRO	-0.03895149	0.04941946	10	-0.79	0.4489

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.43	0.7366

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00574910	0.12543987	10	-0.05	0.9643
WO V SO	-0.03835976	0.06636455	10	-0.58	0.5760
WO V SRO	-0.06661144	0.06259643	10	-1.06	0.3123
BO V SO	-0.03261066	0.13641422	10	-0.24	0.8159
BO V SRO	-0.06086234	0.13427712	10	-0.45	0.6600
SO V SRO	-0.02825168	0.08212124	10	-0.34	0.7380

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.94	0.4581

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.01507170	0.01184793	10	-1.27	0.2321
WO V SO	-0.00561030	0.00579645	10	-0.97	0.3559
WO V SRO	-0.00410823	0.00533163	10	-0.77	0.4588
BO V SO	0.00946139	0.01296715	10	0.73	0.4823
BO V SRO	0.01096347	0.01269452	10	0.86	0.4080
SO V SRO	0.00150207	0.00743116	10	0.20	0.8439

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.40	0.7528

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	0.00457639	0.01129170	10	0.41	0.6938
WO V SO	0.00144824	0.00572281	10	0.25	0.8053
WO V SRO	-0.00489684	0.00533235	10	-0.92	0.3801
BO V SO	-0.00312816	0.01226997	10	-0.25	0.8039
BO V SRO	-0.00947323	0.01209279	10	-0.78	0.4516
SO V SRO	-0.00634508	0.00717522	10	-0.88	0.3973

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	10	0.37	0.7778

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.01034442	0.01944517	10	-0.53	0.6064
WO V SO	-0.00376958	0.00960024	10	-0.39	0.7028
WO V SRO	-0.00797497	0.00886703	10	-0.90	0.3896
BO V SO	0.00657484	0.02125618	10	0.31	0.7634
BO V SRO	0.00236945	0.02083323	10	0.11	0.9117
SO V SRO	-0.00420539	0.01225067	10	-0.34	0.7385

Appendix E-4. Species comparisons for white oak (WO), black oak (BO), scarlet oak (SO) and southern red oak (SRO) crop trees for diameter and basal area growth of the release and fertilization treatment, Hardeman County, Tennessee.

YEAR 1 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	1.37	0.3205

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00948529	0.03925371	8	-0.24	0.8151
WO V SO	-0.08791667	0.06221468	8	-1.41	0.1953
WO V SRO	-0.06242647	0.03925371	8	-1.59	0.1504
BO V SO	-0.07843137	0.06979561	8	-1.12	0.2937
BO V SRO	-0.05294118	0.05041443	8	-1.05	0.3243
SO V SRO	0.02549020	0.06979561	8	0.37	0.7244

YEAR 2 DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	0.79	0.5348

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.04053980	0.05891221	8	-0.69	0.5108
WO V SO	0.08457170	0.07821197	8	1.08	0.3111
WO V SRO	-0.02802773	0.05558118	8	-0.50	0.6277
BO V SO	0.12511150	0.08704728	8	1.44	0.1886
BO V SRO	0.01251207	0.06744912	8	0.19	0.8575
SO V SRO	-0.11259943	0.08482834	8	-1.33	0.2210

CUMULATIVE 2 YEAR DIAMETER GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	0.68	0.5912

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.08205223	0.08999100	8	-0.91	0.3885
WO V SO	0.00524357	0.11859826	8	0.04	0.9658
WO V SRO	-0.10470993	0.08482353	8	-1.23	0.2521
BO V SO	0.08729580	0.13171774	8	0.66	0.5261
BO V SRO	-0.02265770	0.10236721	8	-0.22	0.8304
SO V SRO	-0.10995350	0.12824279	8	-0.86	0.4162

YEAR 1 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	1.38	0.3173

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00022992	0.00569509	8	-0.04	0.9688
WO V SO	-0.00981796	0.00902636	8	-1.09	0.3084
WO V SRO	-0.01019757	0.00569509	8	-1.79	0.1111
BO V SO	-0.00958804	0.01012623	8	-0.95	0.3714
BO V SRO	-0.00996765	0.00731433	8	-1.36	0.2101
SO V SRO	-0.00037961	0.01012623	8	-0.04	0.9710

YEAR 2 BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	0.74	0.5588

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00643333	0.00893883	8	-0.72	0.4922
WO V SO	0.00973872	0.01171255	8	0.83	0.4298
WO V SRO	-0.00669985	0.00842049	8	-0.80	0.4492
BO V SO	0.01617204	0.01298295	8	1.25	0.2481
BO V SRO	-0.00026652	0.01011325	8	-0.03	0.9796
SO V SRO	-0.01643856	0.01263168	8	-1.30	0.2294

CUMULATIVE 2 YEAR BASAL AREA GROWTH

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
SPECIES	3	8	0.76	0.5481

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
WO V BO	-0.00697083	0.01142301	8	-0.61	0.5586
WO V SO	0.00026081	0.01596829	8	0.02	0.9874
WO V SRO	-0.01582703	0.01089595	8	-1.45	0.1844
BO V SO	0.00723164	0.01791174	8	0.40	0.6970
BO V SRO	-0.00885620	0.01358549	8	-0.65	0.5328
SO V SRO	-0.01608784	0.01758030	8	-0.92	0.3869

APPENDIX F

Appendix F-1. Comparison of year 1 versus year 2 diameter growth by treatment and crop tree species, Hardeman County, Tennessee.

White Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	28	1.97	0.1417

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	-0.03352732	0.02490721	28	-1.35	0.1891
release	-0.09038314	0.02456589	28	-3.68	0.0010
fert	-0.07298455	0.02387555	28	-3.06	0.0049
rel/fert	-0.11994239	0.02697127	28	-4.45	0.0001

Black Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	13	2.84	0.0792

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	0.05555556	0.06206194	13	0.90	0.3870
release	-0.14285714	0.07037163	13	-2.03	0.0633
fert	0.06666667	0.10749443	13	0.62	0.5459
rel/fert	-0.12941176	0.04515669	13	-2.87	0.0132

Scarlet Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	16	0.17	0.9134

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	-0.00000000	0.08423174	16	-0.00	1.0000
release	-0.05000000	0.11142812	16	-0.45	0.6597
fert	-0.00714286	0.05956084	16	-0.12	0.9060
rel/fert	0.05000000	0.09098068	16	0.55	0.5902

Southern Red Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	26	0.12	0.9471

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	-0.05414641	0.04920835	26	-1.10	0.2813
release	-0.09220674	0.04856650	26	-1.90	0.0688
fert	-0.05858759	0.05419601	26	-1.08	0.2896
rel/fert	-0.07376123	0.05444503	26	-1.35	0.1871

Appendix F-2. Comparison of year 1 versus year 2 basal area growth by treatment and crop tree species, Hardeman County, Tennessee.

White Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	28	1.26	0.3069

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	-0.00297738	0.00375767	28	-0.79	0.4348
release	-0.00992872	0.00370885	28	-2.68	0.0123
fert	-0.00795165	0.00361652	28	-2.20	0.0363
rel/fert	-0.01337563	0.00404407	28	-3.31	0.0026

Black Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	13	2.43	0.1115

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	0.00851444	0.00900689	13	0.95	0.3617
release	-0.01717286	0.01021285	13	-1.68	0.1165
fert	0.00890667	0.01560039	13	0.57	0.5778
rel/fert	-0.01720882	0.00655348	13	-2.63	0.0209

Scarlet Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	16	0.22	0.8822

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	0.00250714	0.01057465	16	0.24	0.8156
release	-0.00766250	0.01398895	16	-0.55	0.5914
fert	-0.00065857	0.00747741	16	-0.09	0.9309
rel/fert	0.00626167	0.01142193	16	0.55	0.5911

Southern Red Oak

The MIXED Procedure
Tests of Fixed Effects

Source	NDF	DDF	Type III F	Pr > F
TRMT*YEAR	3	26	0.05	0.9839

The MIXED Procedure
ESTIMATE Statement Results

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
control	-0.00611884	0.00663926	26	-0.92	0.3652
release	-0.00960497	0.00666693	26	-1.44	0.1616
fert	-0.00685642	0.00752951	26	-0.91	0.3709
rel/fert	-0.00687991	0.00753678	26	-0.91	0.3697

VITA

Dwight David O'Neal was born in Jackson, Tennessee on May 10, 1969. He attended schools in the Jackson City School System and graduated from Jackson Central Merry High School in June, 1987. In September, 1987 he entered Mississippi State University in Starkville and received a Bachelor of Science degree in Forestry in May, 1992. He entered The University of Tennessee at Knoxville in August, 1992 and received a Master of Science degree in Forestry in August, 1995.

He is presently employed as a Forestry Technician by International Paper Company, Yazoo Logging and Fiber Supply in Redwood, Mississippi.