

May 2, 1997

To the Graduate Council:

I am submitting herewith a thesis written by Jonathan Lemuel Coltrane entitled "Growth and Survival of Enrichment Plantings of Northern Red Oak (*Quercus rubra* L.)." I have examined the final 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.

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Growth and Survival of Enrichment
Plantings of Northern Red Oak
(*Quercus rubra* L.)

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee Knoxville

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May 1997

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Thesis
97
C64.

Dedication

This thesis is dedicated to my wife, parents, sister, and
best friend:

Lisa Yancey Coltrane

Janelle Burleson Coltrane

Donald Ray Coltrane

Andrea Janelle Coltrane

Richard Cleveland Free

Acknowledgments

The author would like to thank Dr. Ray Wells of the Department of Forestry for his help as my advisor.

Sincere appreciation is also extended to my committee members, Dr. Ron Hay of the Department of Forestry, Dr. Oscar Fowler Head of the Department of Management and Dr. Dudley Dewhirst of the Department of Management.

I would like to thank the Hobart Ames Foundation and the Trustees without whom none of this research would have been accomplished. I would like to thank Dr. Allan Houston, and the whole staff at Ames Plantation.

Thanks is also extended to Dr. Scott Schlarbaum and the Tree Improvement program for providing the seedlings and encouragement.

Abstract

In 1995, an enrichment planting of northern red oak (*Quercus rubra* L.) was established in a recently harvested upland hardwood stand in West Tennessee. Five known genetic families were used from a 190 family seed orchard on the Watuga Ranger District of the Cherokee National Forest. Seedlings were obtained from the University of Tennessee Tree Improvement Program and were grown at the Tennessee Division of Forestry Nursery under a protocol developed by the USDA Forest Service Institute of Tree Root Biology. Seedlings from several genetic family sources were field tested in this year in several other southern states. This study is an early trial of selected families for the western part of the State and assumes that artificial regeneration of northern red oak may be feasible. The study obtained responses of these quality seedlings under field conditions and several site preparation techniques. It was hypothesized that all variability in seedling growth (height and basal diameter) and early seedling survival can be explained either by genetic family or by the site preparation treatment.

The enrichment plantings were superimposed onto an established natural oak regeneration study. Twenty circular

plots were established. Five post-harvest treatments, both mechanical and chemical, were then assigned to the 20 plots using a randomized block design. A buffer area surrounding each of the 20 natural regeneration plots was divided into four cardinal direction quadrants in which the artificial regeneration seedlings were planted. Measurements of (height growth, basal caliper, and The introduced seedlings were analyzed for hypothesis testing.

All northern red oak seedlings produced height growth during the first growing season. There was a significant difference at the .05 level between the plot treatments and height growth. There were no significant differences at the .05 level between the plot treatments and survivability. There were no significant differences between the genetic families and survivability. There was a significant difference at the .05 level between genetic families and height growth. Minimal deer or other animal damage was found.

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I. INTRODUCTION

In the early 1930's, discussions began about the lack of mature oak stands regenerating with an oak component. Oaks were not naturally regenerating or at least not to the extent that they were present prior to harvest. Many hypotheses have been developed over the years as to why oaks are not regenerating. This problem has generally been given the name oak decline.

Why is Oak Important

Oak-hickory stands comprise 75% of the forested land in Tennessee. Oak is vital to the hardwood timber industry. Northern red oak is the most valuable of all red oaks that are marketed as Appalachian red oak. Oak also provides large amounts of hard mast that are vital to many species of wildlife.

Artificial Regeneration

Artificial regeneration has been proposed as an answer to regenerating oak. Planting failures of standard northern red oak nursery seedling stock on upland sites have been the norm, not the exception. McGee and Loftis(1986) found that seedlings would either not grow or grew at such a slow rate that once control of competing vegetation was stopped, the seedlings were quickly overtopped. Johnson (1984) reported similar results with out planted northern red oak seedlings.

While the survival of the planted oak seedlings were usually high, the ability to have rapid stem elongation was lacking in these studies.

This study utilized graded northern red oak seedlings that differ from seedlings used in earlier planting attempts. Earlier planting attempts used seedlings that were grown from mixed seed sources and were under cut and top pruned to yield a uniform seedling. A dibble bar was used for the planting technique. While survival was usually high, the seedlings did not have the ability to grow at a rate that would compete with surrounding vegetation.

The seedlings used in this study were from a half-sibling progeny test started by the Tennessee Valley Authority in 1973. The location of the selected mother trees in this half-sibling progeny test was known. The acorns that produced the seedlings were grown by genetic families at the East Tennessee State Nursery. A protocol developed by Paul Kormanik, chief silviculturist at the Tree and Root Biology Laboratory in Athens, Georgia was followed to grow and grade these seedlings. Due to the larger size of the seedlings being used in this study, power augers or post hole diggers were used to dig large planting holes.

Enrichment Plantings

The northern red oak seedlings utilized in this study

were planted as enrichment plantings. This decision was based upon two things; the larger size of the seedlings and the high cost of producing these seedlings. Enrichment plantings involve a fewer number of seedlings being planted than in plantation plantings. Because more care is given to how and where the seedlings are planted, the attrition rate of the seedlings is low.

Site Selection

It is generally held that for oak to have a chance of becoming a major component of the mature stand, advanced oak regeneration must be present prior to harvest. The site selected for this study had to meet certain requirements in hopes of achieving oak regeneration. It had to have advanced oak regeneration that met the minimum requirements of being at least one-inch diameter at breast height. The site also had to be an above average upland site for oak, site index 60 or greater, base age 50 years.

Studies have shown that even in sites where advanced regenerations met the above minimum requirements, silvicultural practices have been unable to consistently ensure oak as a dominant component of a mature stand. The shelterwood has had the most success in producing natural stands of oak after harvest. However, even the shelterwood does not always ensure oak as a component in a mature stand.

Loftis (1983) stated that the ability of a shelterwood to create a new oak stand is mixed and that often the new stands have a species composition similar to a clear-cut.

Study Objectives

The objectives of the current study were:

1. To plant protocol grown and graded northern red oak seedlings.
2. To assess whether the seedlings went into survival mode versus stem elongation.
3. Identify the impacts of the five different site treatments on the first year survival and growth of the northern red oak seedlings.
4. Examine the five different genetic families of northern red oak seedlings to see if genetic families had an effect on early survival and growth.
5. Assess the impact of extraneous variables on seedlings survival.

From these objectives the hypotheses formed and tested in this study were as follows.

Ho = Treatment has an effect upon growth or survival on these out planted northern red oak seedlings.

Hu = Treatment has no effect upon growth or survival on these out planted northern red oak seedlings.

Ho = Genetic family has an effect upon growth or survival on these out planted northern red oak seedlings.

Hu = Genetic family has no effect upon growth or survival on these out planted northern red oak seedlings.

II. Literature Review

Natural Oak Regeneration

The Problem

In the early 1930's, it was noticed that many mature upland oak stands on above average and good sites were not regenerating to oak after harvest or after some natural disturbance (Lorimer, 1992). Current silvicultural practices have been unable to consistently ensure oak as a component of a mature stand. When stands dominated by oak are harvested, why do they not regenerate into new stands dominated by oak? Understanding how and why the present stands were created may help to answer why the new stand may not be dominated by oak. The literature contains three main theories about the way in which oak were initially established as the dominant component of a stand.

This literature section examines the oak regeneration problems on primarily upland sites as opposed to bottom land hardwood sites. Artificial regeneration options are restricted to northern red oak, where oak plantings have not been successful.

How Current Stands Were Created

Repeated fires have often created ideal environments for oak regeneration. Fire has been suggested as one of the main stimuli for oak becoming established in new stands.

However, there are differences in the literature on the effects of fire and the establishment of oak. Single fires in a forest stand often create a situation of more competition. Single fires unlike multiple fires create an environment where large numbers of seeds can germinate. By creating such an environment, the fire has increased under story competition. This increase in under story competition is detrimental to obtaining advanced oak regeneration.

(Johnson, 1974; McGee, 1979; Wendel and Smith, 1986)

However, the studies that have been conducted that use fire on multiple trials and at different times during the year, found that fire does help to establish oak. In these studies, the use of fire favors the oak species because they have an adaptation to fire that allows them not to be as readily killed as some other tree species and other vegetation (Swan, 1970; Brown, 1960; Carvell & Maxey, 1969; Kruger, 1992).

Continuous clearcutting followed by fire favored the oak species which are more tolerant of fire and are prolific sprouters. The iron and brick industries created this kind of environment. Since these two industries needed wood to make charcoal, they had to own or lease large amounts of land. These areas were cut on short rotations, every 30 to 40 years, since quantity was needed rather than size. The

cutting practices utilized by these industries were similar to a silvicultural clear-cut because everything was removed. This continuous cutting practice favored species that were prolific spouters. After cutting, these areas would often catch fire or be set on fire. These fires would kill many of the less fire tolerant species such as hemlock (*Tsuga canadensis*, L.), maple (*Acer* species) and ironwood (*Carpinus caroliniana*, Walt.) (Swan, 1970; Brown, 1960; Kruger, 1992) and favor the more fire tolerant species of oak and hickory (Hammond, 1880; Oosting, 1942; Lutz and Cline, 1947). The two practices of clearcutting and burning heavily favored oak species regeneration. These areas were so wide spread that they were noted on forest cover type maps as the "Sprout Hardwood Region" (Hawley and Hawes 1912).

Many of the current oak stands began under pine stands on old field sites. Many of these old fields seeded into pine once they were abandoned. These pine forests were not uniform in stocking and had sufficient light below the canopy for oak to become established while keeping competition from other vegetation at a minimum. Once the pine was harvested, the advanced oak regeneration grew and created many of the oak stands that are being harvested today (Raup, 1938; Abrams and Nowacki, 1992).

All of the above ways in which oaks become established

share one common theme, control of competition in the under story. It is this elimination of the under story that allows the proliferation of oak seedlings that are already in place to develop into regeneration that will be able to compete once the over story is removed (Beck, 1970; Sander, 1972; Beck and Hooper, 1986). Conventional wisdom in the literature is that advanced oak regeneration must be a minimum of 1 inch in diameter at the root collar and 4.5 feet tall to become a dominant component of the new canopy after cutting (Sander, 1972). It is this thinking that has led to the "ideology" of shelterwoods.

Reasons Oak Have Not Come to Dominate a Stand

Many believe that the dominance of oak in many stands is explained by the chestnut blight. These individuals believe that the oak was only a limited component of the forest until the loss of the American chestnut. This ideology believes that oak was never a major component of the forest and that the release after the American chestnut death only increased oak numbers to higher levels than would be naturally found. From this viewpoint, the decline of oak in forest compositions is a stabilization back to naturally occurring numbers of oak species in forest stands. While the loss of the American chestnut did create a shelterwood effect and probably did aid in the establishment of oak in

many forest stands, oak has dominated forest stands for 6,000 to 9,000 years (Craig, 1969; Watts, 1979; Delcourt and Delcourt, 1985), well before the chestnut blight. The oak decline is also happening well outside the range of the American chestnut not lending much credence to the American chestnut theory (Lorimer, 1992).

Problems with Oak Regeneration

Large numbers of natural seedlings do not ensure oak as a component in a mature stand. Red oaks have bumper acorn crops every 5 years, while white oaks have bumper crops every 4 years. After these bumper crops, large numbers of oak seedlings develop (Lorimer, 1992). The number of seedlings is often in the thousands. These seedlings are usually less than 6 inches tall. Upon initial evaluation of the regeneration in the stand, it would appear that the stand has a high potential to regenerate to oak. However, these seedlings are unable to grow under the parent stand, and upon over story removal, these seedlings are unable to grow fast enough to compete with surrounding vegetation.

Oak regeneration has slow early height growth and slow response to release. This slow height growth facilitates other vegetation to over top the oak seedlings. Oak seedlings, unlike surrounding vegetation, allocate nutrients to root growth and survival instead of stem elongation.

When advanced regeneration is released without an adequate root system, the seedlings grow slowly in height if at all until the root system develops. (Hodges and Gardiner, 1992)

Effects of Harvest Cuttings on Forest Composition

There has been much examination on the effects of cutting levels and the species composition that cutting levels create. Two main harvest cutting levels will be reviewed in this section. They are clearcutting and shelterwood. Both of these cutting levels have many different variations among them.

In a silvicultural clear-cut, all above ground competition is removed because all stems are cut down, not only the merchantable stems. The silvicultural clear-cut removes the tolerant species that have been growing under the upper canopy. It also removes the low quality, suppressed and intermediates species that are often left after a commercial clear-cut. By removing all stems, the area is exposed to 100% sunlight. In a silvicultural clear-cut, all new growth starts equally on an above ground level. This gives the stems that can produce early height growth an edge in becoming dominant in the mature stand. (Smith, 1962)

A commercial "clear-cut" only removes trees that have merchantable value thus leaving stems that are not merchantable (Smith, 1962). This cutting method only

releases sapling size trees that have been growing under the upper canopy. These are usually the more tolerant species such as maple and dogwood (*Cornus florida* L.) or suppressed and intermediate stems that would die over time if the parent stand was not removed. The inherent problem with the commercial clear-cut is this release of suppressed, intermediate, and tolerant trees. These released trees take up valuable growing area, nutrients, and moisture. By allowing these lower quality species to use up these elements, the nutrients available for more desirable species are limited. By releasing the suppressed and intermediate trees, commercial clearcuts also attempt to produce dominate stems from the lower quality genetic trees. (O'Hara, 1986)

Clearcutting on xeric sites, where advanced oak regeneration builds up naturally, has been shown to be a viable means of regenerating oak (Johnson, 1993; Roach and Gingrich, 1968; and Sander 1977). However, on better sites there is more under story competition which precludes the build-up of advanced oak regeneration. On these better sites, with the exclusion of advanced oak regeneration, clearcutting is not a viable silvicultural method to regenerate oak. (Johnson, 1976, Loftis, 1988, & McGee & Hooper, 1975) Clearcutting on these better sites gives rise to the species composition of the more tolerant

species.(Abrams & Nowacki, 1992)

A shelterwood uses cuttings or herbicides to reduce stand density. Shelterwoods are utilized to obtain advanced oak regeneration, trying to create the right balance of light in the under story to stimulate the oak without increasing undesirable species. This reduction in stand density is most effective towards the upper end of the stand's rotation. By allowing light into the stand, the forest manager is trying to stimulate the small oak seedling sprouts that develop after bumper acorn years to begin height growth. The success of a shelterwood in being able to create a new stand is mixed(Loftis, 1983). Loftis (1983) found that shelterwoods often developed species compositions similar to ones produced by clearcuts. This lack of success is due to the inherent problems of the shelterwood. There can be no set protocols for a shelterwood since every lighting situation is different. However, it appears that much of the success of the shelterwood is highly correlated with the control of under-story competition. Much of the new research attempts to control light by reducing more basal area on better sites than poorer ones.

Artificial Oak Regeneration

The Problem

One of the problems with artificial oak regeneration is the physiological characteristic of the oak seedling to enter a survival mode where height growth ceases. In this survival mode, the seedlings allocate their energy towards survival and root expansion. In planted seedlings, it is important for the seedlings to have a balance between absorbing and transpiring area (Parker, 1949). When seedlings do not have enough root development, they are unable to begin shoot elongation.

One of the leading problems with oak regeneration is competition from surrounding vegetation. While oak seedlings spend time putting down a strong root system, surrounding vegetation is obtaining height growth. This early height growth by competing vegetation quickly overtakes the slow growing oak regeneration.

Slow shoot elongation of northern red oak in the seedling stage only complicates the problem of competing vegetation. While oak seedlings possess the ability to have rapid height growth, standard oak seedlings are unable to produce rapid height growth. Standard nursery stock do not have a root system that can absorb the water and nutrients needed for leaf and shoot elongation (Johnson 1984).

However, seedlings grown in green houses have produced between six to eight flushes with a height growth of 1 to 1.5 meters. Recently, northern red oak grown in nurseries have shown potential to produce early height growth.

In many areas, wildlife damage to oak seedlings has become a limiting factor. Damage by wildlife on terminal buds and on new growth of oak seedlings only further exacerbates the problems of slow height growth and competition from surrounding vegetation. The effects of animal damage must always be considered when planting seedlings. Deer damage is the largest wildlife problem with oak seedlings. Oak seedlings in some areas, such as Pennsylvania, have had so much browse damage that planting was not considered a possibility. In many areas, deer populations are so high that the area has a park or savanna like look. Johnson (1986) stated that due to deer damage, planting seedlings in some areas is not a viable alternative. Two other northern red oak artificial regeneration studies at Ames Plantation during the same time frame as this study had 100% deer damage (Wells et al., 1996). In areas where deer damage is a great problem, the use of tree shelters or chemical repellants might aid in the establishment of oak.

Nursery Protocols For Growing Seedlings

Paul Kormanik has developed a nursery protocol for growing oak seedlings that controls fertilizing, watering and acorn planting density. This protocol allows seedlings to be grown so that their genetic qualities such as rapid height growth and root development can be expressed and judged by their physical appearance.

The protocol calls for the establishment of a base line fertility level of the nursery bed soil. The base line fertilization is as follows: calcium 500ppm, potassium 80ppm, phosphorus 80ppm, magnesium 50ppm, copper 0.3-3.0ppm, zinc 3.8 and bromide 0.4-1.2ppm. (Kormanik et al., 1993)

During the growing season, at regular intervals, ammonium nitrate is applied up to 1345 kg/ha. The added nitrogen keeps the nitrogen level at the needed requirement for height growth of the oak seedlings. This constant availability of nitrogen to the seedlings during the growing season allows for expression of the genetic predisposition for first order lateral roots that are correlated to height growth potential. (Kormanik et al., 1993)

Water is controlled once the seedlings enter their second flush. Water supply is stopped and is only applied when tensionmeters read 30 to 50 centibars. Controlling the water reduces the leaching of nutrients from the soil.

Also, oaks as a species do not like overly wet root systems. (Kormanik et al., 1993)

Beds are planted at a density of six acorns per linear foot or 32 acorns per square foot. (Kormanik et al., 1993) When the seedlings reach dormancy, they are root pruned. They are never top pruned. Top pruning only produces uniform seedlings. This uniformity among seedlings only penalizes the superior species. (Kormanik et al., 1993) The seedlings are lifted from the beds and graded in late February or early March. The trees are graded by the number of first order lateral roots. The range of first order lateral roots has been anywhere from 1-23. The mean height has been between 24 and 147 cm. A relationship between the number of first order lateral roots and the ability of the seedlings to survive and have rapid height growth has been found. (Kormanik et al., 1993) Because of this relationship of early rapid height growth to number of first order lateral roots, the seedlings can be graded after removal from the nursery beds. Kormanik (1986) has found that the minimum number of first order lateral roots a seedling must possess to be competitive is six. Grading the seedlings produces a cull rate of around 2/3. (Ruehle & Kormanik, 1986) While this is high, the seedlings that are being planted are more likely to survive and become a dominant part of the

over story. This cull ratio is equal to the ratio of dead trees in two studies by Johnson (1984 & 1986). Both of these studies showed that after a number of years only 1/3 of the seedlings were growing acceptably. This fraction is the number of good seedlings when grading on the number of first order laterals roots leaving a 2/3 cull rate (Ruehle et al., 1986). The 2/3 mortality rate lends much credence to Kormanik's theory that the best way to grade oak seedlings is by the root system since this also produces a cull rate of 2/3.

Grading seedlings based on the number of first order lateral roots greatly helps offset some of the physiological problems of northern red oak seedlings. By planting seedlings that have strong root systems with the ability to absorb enough water and nutrients to support the stem and leaves, the seedlings do not go into a survival mode but are allowed to begin stem elongation. It is this height growth along with the above average original height of the seedling that allows it to be competitive with surrounding vegetation.

Planting Protocol

Procedures have been developed for planting these larger rooted seedlings. The planting of these northern red oak seedlings is different from standard protocols for

planting seedlings. The seedlings must be planted using a post hole digger or six inch auger. The hole must be at least 14 inches wide and 8 inches deep. Care must be taken to avoid curling the roots when seedlings are placed in the holes. The dirt should be pushed back around the roots by hand to ensure that sufficient soil surrounds the seedling.

Advantages of Artificial Regeneration

One of the primary advantages of artificial regeneration of northern red oak is its high survival rate. When the characteristics of high survival is combined with rapid early height growth, the number of seedlings needed to regenerate an area will be decreased. Another advantage of artificial regeneration is the ability to control placement and spacing of the seedlings. By being able to choose placement, the land manager can ensure that the seedlings are planted in the best possible sites. It also allows complete stocking of the site with the minimal number of seedlings of the preferred species of genetically improved growing stock. Artificial regeneration in itself is crucial for rapid gains in forest genetics.

Artificial Regeneration Case Studies

Early regeneration trials of planted northern red oak species have had limited or no success. While the survival of the planted oaks were usually good, in the low 90's and

high 80's (Olson & Hooper, 1968 & 1972), the seedlings either would not grow or grew at such slow rates that once competing vegetation control was stopped, the seedlings were quickly overtopped (McGee & Loftis, 1986; Beck, 1970). The fertilization and irrigation of planted oaks have also failed (Buckner & Maki, 1977). The early conclusion was that oak plantings would not be a viable means of offsetting poor natural regeneration until improvements were made in the initial growth of seedlings (McGee and Loftis, 1986). Oak seedlings do have the physiological potential to obtain multiple flushes, up to six or eight a year but under ideal conditions seedlings can obtain heights of 1.5 to 2 meters in one growing season (Crow, 1988).

In the late 1970's and early 1980's, experiments began to look at the effects of under planting oak seedlings and then removing the upper canopy. The experiments used a variety of planting stocks. The experiments also examined different types of over story removal.

In (1984), Dr. Paul S. Johnson began a study to examine four different planting stocks of northern red oak in three different treatments. The planting stock consisted of small 1+0, large 1+0, transplants 1+1, and container grown seedlings. Half of the planting stock was clipped. The seedlings were out planted in early November using mattocks.

The three treatments where the seedling stocks were planted were a clear-cut, a 60% stocked shelterwood that was clear-cut 3 years after planting, and a 60% stocked shelterwood. An 84% survival rate after five growing years was consistent with the literature. Height growth results showed that improved stock such as large 1+0 and transplants 1+1 could have good initial height growth. The clipped stocked proved to have the best growth. Among the three treatments, the clear-cut yielded the tallest seedlings after 6 years with the clipped 1+1 measuring 123.4 cm. The shelterwood that was later clear-cut had the most height growth in the last 2 years of the 6 year period with a height of 75.2 cm. This study showed that northern red oak seedlings could be planted in shelterwoods and clearcuts and survive and grow well, but the seedlings had to be better than the average planting stock. (Johnson, 1984)

After the success with planting northern red oaks, Dr. Johnson (1986) began a study to develop a prescription for planting guidelines. In this experiment three types of planting stock were used, large 1+0, 2+0, and 1+1. Only planting stock in the above types that were larger than $\frac{1}{2}$ inch, 1 inch above the root collar were used. The stock was under cut 8 inches in the nursery and was top pruned to 8 inches two weeks before planting. In this study the

planting stocks were planted only in shelterwoods. A clear-cut treatment was not utilized. This study produced a protocol for under planting northern red oak. The procedure called for controlling the under story vegetation, creating a shelterwood of medium density, and planting above average seedling stock as specified above. Three years after planting, the shelterwood was harvested, thus releasing the seedlings. It is believed that the planting of the seedlings under the shelterwoods mimics natural regeneration. Even though the seedlings do not grow much in height under the shelterwood, they establish strong root systems. The findings showed that 2 years after these procedures $1/3$ to $1/2$ of the seedlings were growing well. (Johnson et al., 1986)

Around the same time that Dr. Paul Johnson was working on planting northern red oak, Dr. T. J. Tworkoski (1986) was also working on under planting northern red oak, white oak, and white pine. The planting stock that was used was 1+0 for northern red oak, 1+0 for white oak, and 2+0 for white pine. Half of the white oak planting stock was clipped at the base of the seedlings. The seedlings were planted in 1977 and 1978 and 2 years later the plots received one of three treatments. They were either clear-cut or cut to

create a light shelterwood. No treatments were applied to the control. (Tworkoski et al., 1986)

As expected by past literature, there were no differences in survival of the oaks between these treatments. However, large growth differences were found in the height growth of the oak seedlings. The oak seedlings had a growth rate of 13.5 inches for white oak and 23.0 inches for northern red oak in the clearcuts 3 years after release, while the oaks left in the shelterwood had about half that amount of growth. The clipped oak seedlings had less height growth than the unclipped oak. (Tworkoski et al., 1986)

In (1984), R. K. Myers tested the survival and development of six types of planting stock on four different stand treatments. The six stocking types were 1-0 containerized seedlings inoculated with Mycorrhizae, 1-0 containerized seedlings, bare root 1-0 stock inoculated with mycorrhizae, bare root 1-0 stock, bare root 1-0 stock growth in sub-irrigated nursery beds, bare root 2-0 stock growth in sub-irrigated nursery beds, and 1+1 stock. The different treatments that were applied to the experiments were unthinned stands with no under story control, unthinned under story controlled stands, thinned stands with no under

story control, and thinned under story controlled stands. (Myers et al., 1989)

The treatment that was thinned and had under story control had the highest growth and survival. The unthinned stand with under story control had the next highest survival and height growth. The containerized planting stock had the best height growth. However, this advantage does not outweigh the extra time and cost of planting this stock. The bare root non-inoculated seedlings had the best overall performance when costs were considered. The study found that there were no significant differences between the original height and the potential height growth. However, a seedling that started out taller usually stayed taller. (Myers et al., 1989)

The effect of water and gas exchange on northern red oaks was reviewed in (1992) by Crunkilton. The planting stock was composed of 2+0 bare root and inoculated containerized seedlings. Half of the seedlings were clipped above the root collar. The seedlings were planted in two treatments, a clear-cut and a shelterwood.

The study found that the seedlings in the clear-cut were matched more closely with the needs of the northern red oak. After 2 years, there was no difference between the clearcuts' and the shelterwoods' effect on water and gas

exchange. The 2 year period did allow the seedlings in the clear-cut to put down a better root system. The problem with the seedlings in the clear-cut was height growth. By the end of the second growing season the seedlings planted in the clear-cut were beginning to be over topped by the competing vegetation. (Crunkilton, 1992)

III. Study Area

Location

This study is located on the Ames Plantation in southwestern Tennessee, latitude 35°07' North, longitude 89°13' West. The Ames Plantation, located in Fayette and Hardeman Counties, consists of 18,548 acres. The plantation is north of Grand Junction, Tennessee. Memphis is 60 miles west of the plantation. The location of the study site on the plantation is in Fayette County close to the border of Hardeman County. The Ames Plantation is a nonprofit trust that has donated the research rights to The University of Tennessee.

Climate

Mild winters and hot summers result in a 210 day growing season. First and last frost dates average October 24 and April 12, respectfully. The mean temperature is 61.3°F, 42.6°F in January and 80.2°F in July. Annual rainfall is 61 inches with 24.1 inches of that coming during the growing season. The year of 1995, when the study seedlings were planted, consisted of either periods of excessive rainfall or periods of no rainfall. A dry period followed the planting period in April. May and June were wet months. July was dry. The first part of August was wet followed by a dry period from the middle of August until the end of September.

Soils

The soil on the study area is comprised mainly of Lexington and Ruston series. The Lexington series is found along ridge tops and side slopes. Slopes range anywhere from 2% to 12% grade. The Lexington series is characterized by deep, well-drained soil. The nutrient level of the soil is moderate to high with particularly high levels of potassium and phosphorus. Lexington soils have developed under hardwood forests. The Ruston series is associated with the Lexington series but is often intermixed with Eustis series soil. The Ruston soils are found further down slope from the Lexington series. The predominate vegetation on these soils is oak. The fertility levels are generally low. Both soils are generally acidic and are loess deposited on the coastal plain. (Flowers et al., 1964)

Site

The site is a above average upland site where small veneer logs were harvested ten years earlier. However, the site is of poor enough quality to have advanced oak regeneration that meet Sanders (1972) minimum requirements of 4.5 feet tall and 1 inch at the root collar. It took 5 years for Dr's. Ray Wells and Allan Houston to find this appropriate site. These sites are not overly prevalent on UT Experiment Station land. The problem was finding 20

acres or more of uniformity with advanced reproduction for post harvest treatments. This was a very old stand that once contained veneer logs. The site selected for this study is only one of two that were found out of the 9,000 acres of forested land on the Ames Plantation. A similar site was unable to be located on the 20,000 acres of forest UT Experiment Station land in middle and eastern Tennessee.

Timber Management History

Hobart Ames allowed no timber cutting for commercial purposes on the Ames Plantation from 1903 until his death in 1945. The tenant farmers were allowed to gather firewood on the plantation and cattle were allowed to graze in the forested areas. After his's death, several timber contracts were made with private loggers. The contracts allowed the loggers to cut timber on the plantation. They had to split the value of the timber with the plantation. This created many areas on the plantation with high grade forest because the loggers would only take the most valuable timber.

In 1952 when the Ames Project was being planned, the forests of the plantation were in the same condition as most of the forests in the South during that time period. This condition was one of overall low productivity. Over 2,000 acres of the hardwood forest were of such low quality that

the hardwoods were killed, and the area was planted with pine.

The stand that this particular study was conducted on was first cut by Jim Warmbrod using a group selection cutting of $\frac{1}{2}$ acre in size. In 1979, the stand was a two-aged stand. A cutting that removed the small veneer logs was conducted. The stand was commercially clear-cut in the fall of 1994 as part of this current study. The loggers were allowed to cut anything greater than 5 inches in diameter. Due to excessive rain and wet conditions, the logging crew had to pull out before logging the entire site. A follow-up cutting by the Ames Plantation field crew fell all remaining trees 5 inches and up to produce a uniform stand except in the plots where herbicide, Accord, was used to kill trees 5 inches and up previously left by the loggers.

IV. Methods

Natural Regeneration Plots

Study Design

The study design is a complete randomized block design. Five different treatments were assigned at random and replicated four times, for a total of 20 plots. A control area with four additional uncut plots with advanced oak regeneration were also established. The plots were .01 acre circular plots. Each hundredth acre circular plot had a radius of 11.7 feet. Around each of the .01 acre plots, a 1-chain buffer circular plot was established. This buffer area contained the same treatment as the plot it surrounded. See Figure 1.

Treatment Establishment

A stand of timber which was ready to harvest and had oak regeneration large enough to meet the criteria of 1 inch diameter at breast height and height greater than 4.5 feet was located. Most of the trees diameters at breast height ranged from 1 inch to 3 inches. In the fall of 1993, Drs. Ray Wells and Allan Houston established 24 plots on this site. The criteria for plot establishment were that the plot center would have advanced oak regeneration larger than 1 inch diameter at breast height and taller than 4.5 feet

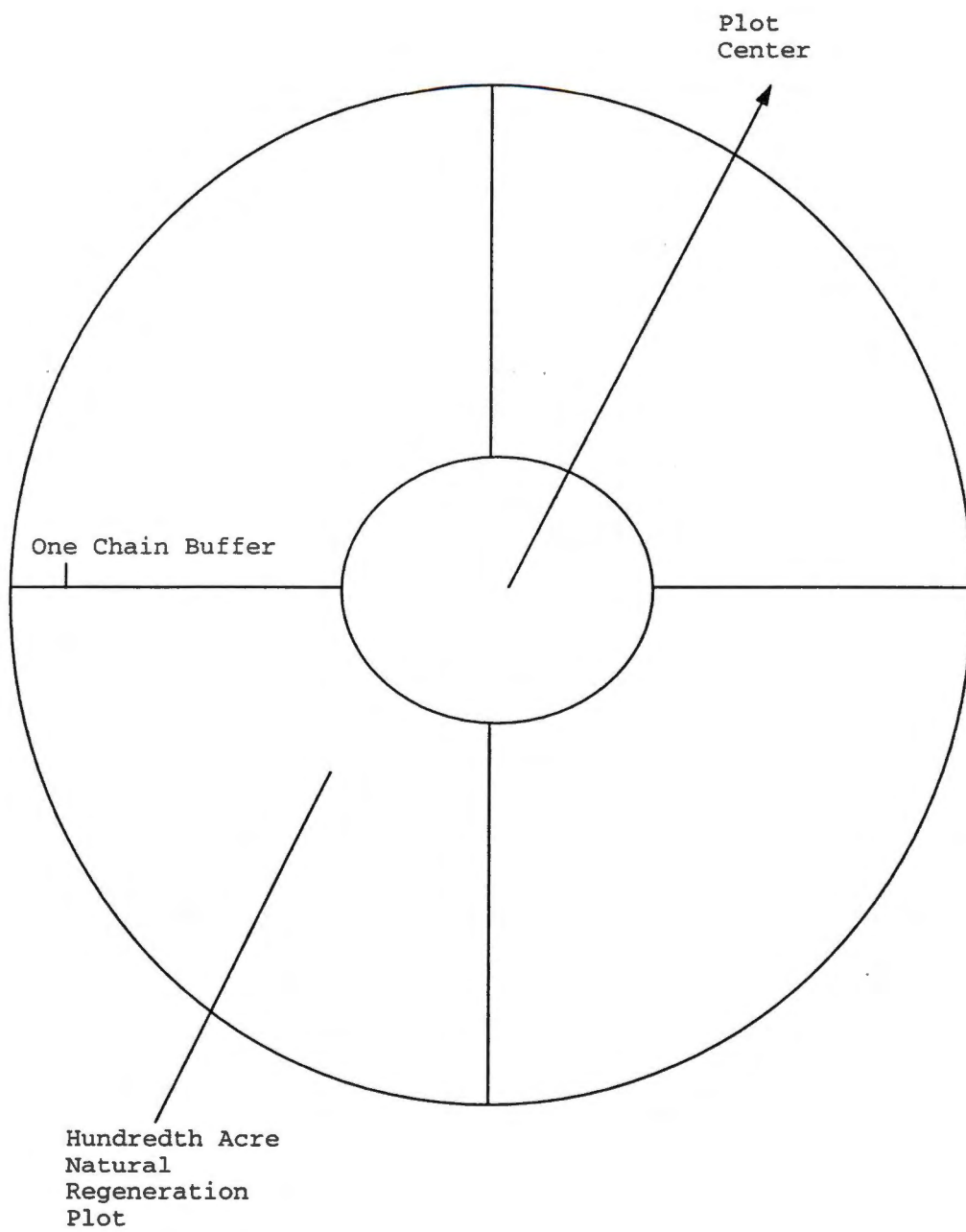


Figure 1. The layout of the natural regeneration plots at Ames Plantation.

and all plots would be at least 2 chains apart. This criteria was based upon the recommended size that oak regeneration must achieve prior to overstory removal to try to ensure oak as a component of the next stand. The plots were established by measuring inward 200 feet from the road and locating one regenerated oak that met the 1 inch diameter at breast height and the 4.5 feet height requirements. Once an oak of sufficient size was located, plot center was marked. The plot centers were marked with cedar stakes painted florescent green, orange, and blue. From one plot center, 200 feet were measured and another oak of sufficient size was identified to establish the next plot center. This process was replicated across the ridge until 24 plots were located. See Figure 2.

It was decided that all species greater than 5 inches in diameter would be removed from the site since the area has a market for hardwood pulp. The logging crew had to pull out early due to wet conditions, leaving a stand which was not uniform in treatment. To offset this nonuniformity, the remaining trees on the plots greater than 5 inches in diameter were either cut or injected with Accord, a herbicide, for their removal. The study design required plots 3, 6, 8, 9, 10, 12, 14, and 19 to have all species

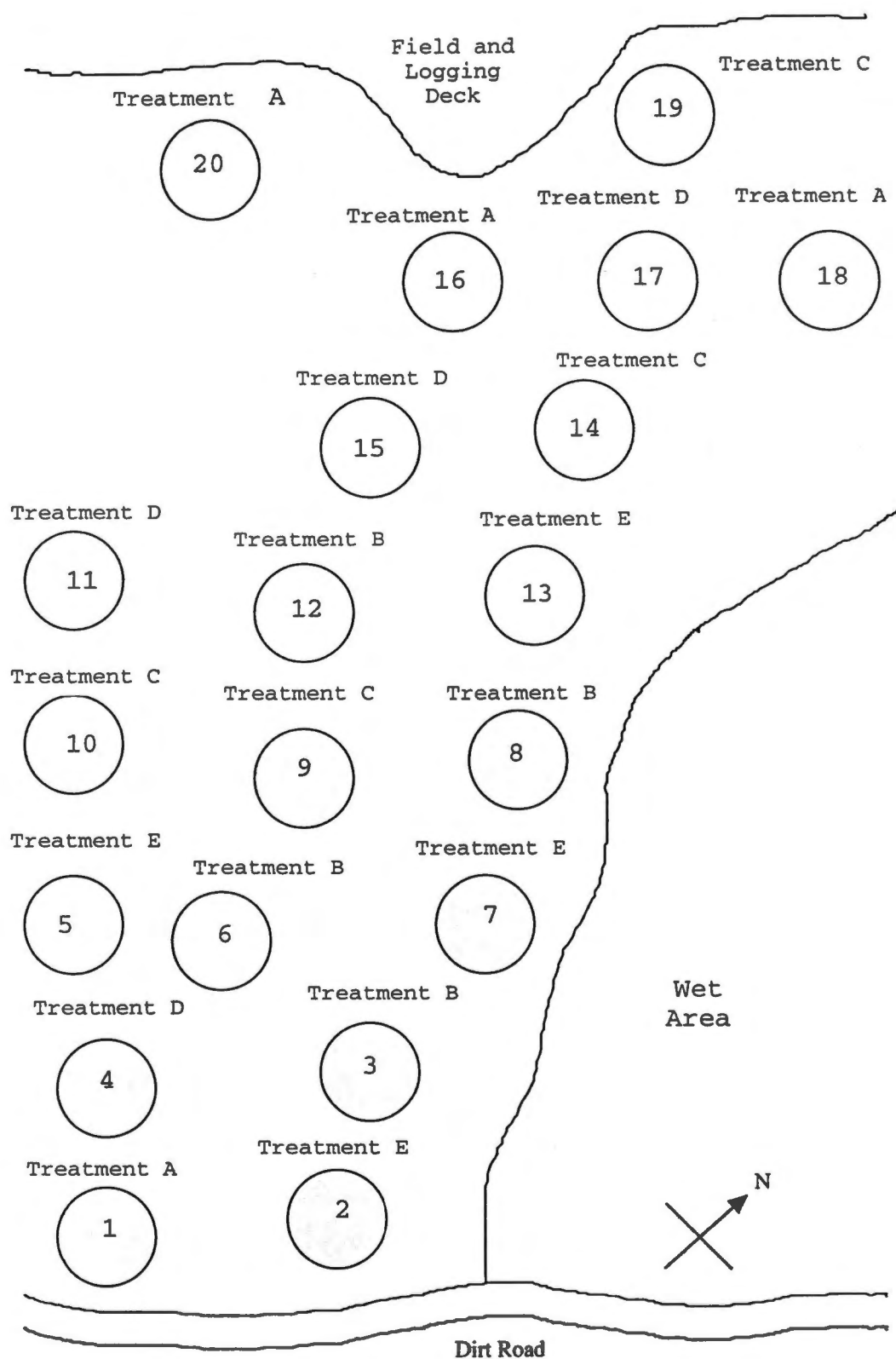


Figure 2. Layout of the plots and treatments over the 20 acre site at Ames Plantation.

except oak injected with Accord. These plots were also injected at this time.

Treatments

The treatments utilized to examine the effects upon seedling survival and growth were borrowed from previous studies as well as being introduced by this researcher. Michael Countess (1972) and Alan Salmon (1989) utilized three post harvest treatments, a silvicultural clearcut or coppice plot, a commercial clearcut, and a liberation with cleaning. In this study, three additional treatments were added by the researcher to the above treatments. The added treatments were a liberation cleaning with oak coppice, an oak coppice or wildlife plot, and a control plot. The six treatments in this study are defined below.

1. **Silvicultural Clearcut;** Treatment A, all trees regardless of size were cut to the ground.
2. **Commercial Clearcut;** Treatment E, all trees smaller than 5 inches D.B.H. remained on the site. This site represented what would be left after commercial logging with a pulpwood and firewood market.
3. **Liberation Cleaning;** Treatment B, all non-oaks were injected with the herbicide Accord™ by Monsanto for removal.
4. **Oak Coppice;** Treatment D, all oak species were cut to

ground level. This treatment is called a wildlife plot, due to the soft mast production of species which remain such as dogwood, blackgum, and blackcherry.

5. **Liberation Cleaning with Oak Coppice;** Treatment C, all trees were injected with the herbicide Accord™ except for oak species which were cut to the ground.

6. **Control;** No trees were cut. A control treatment was an added recommendation of the consultant statisticians.

These four plots were located in the western portion of the stand. No northern red oak seedlings were planted, on the control sites.

Artificial Regeneration Plots

Study Design

The artificial regeneration study was overlaid on the natural regeneration plots. The artificial regeneration was established in the buffer area around each of the .01 acre natural plots. The buffer area was divided into four quadrants. Four of the five genetic families were randomly selected without replacement for each of the five different treatments. This allowed each of the five genetic families to be represented on each of the different treatments. See Figure 3 entitled.

Treatment Establishment

The artificial regeneration plot treatments were

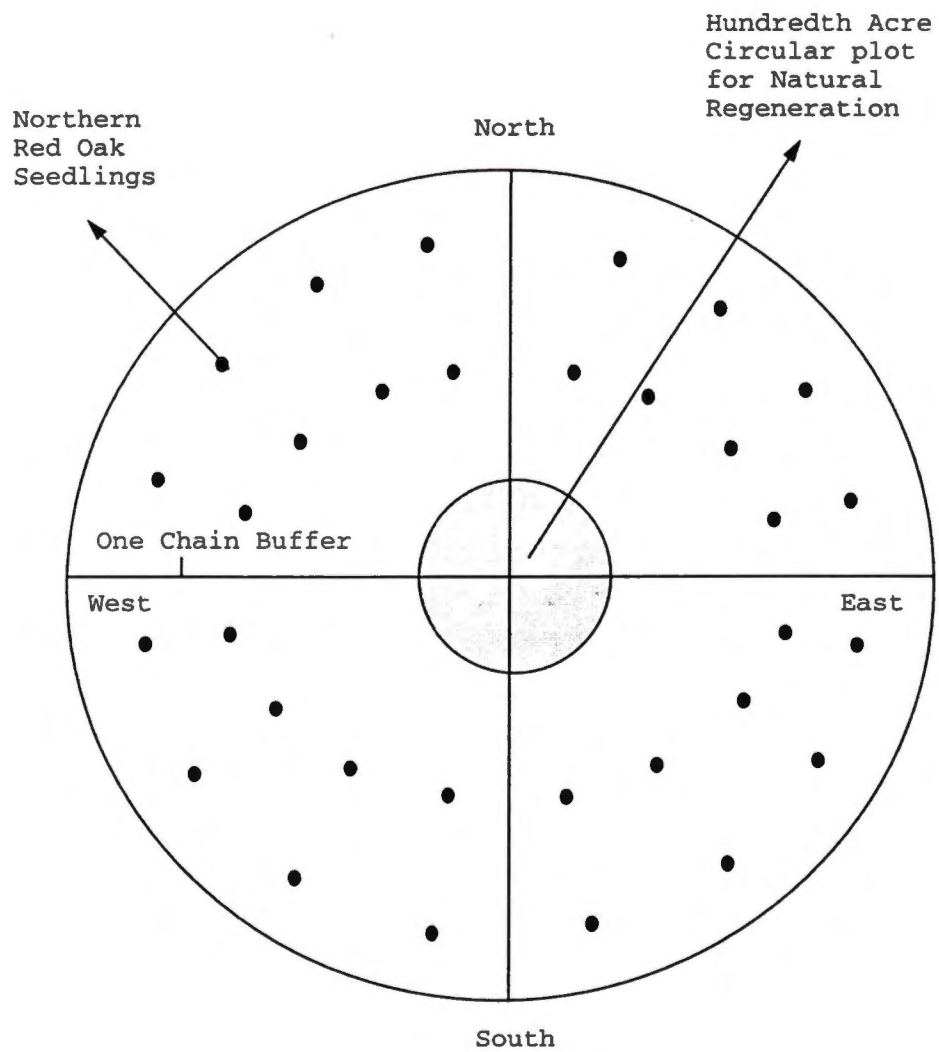


Figure 3. The plot layout of the enrichment planting regeneration at Ames Plantation.

established in the 1 chain buffer area around the natural regeneration plots. This buffer area received the same treatment as the natural plot. The buffer area was divided into four quadrants. The sides of the quadrants were established along the four cardinal directions, North, South, East, and West. Within each quadrant, eight seedlings of one genetic family were planted. A total of 32 seedlings were planted per plot, for a total of 640 seedlings planted in this study.

A radius of three feet around each seedling was sprayed with Round-Up™. This application was done to free the seedlings from competing vegetation. The Round-Up™ was applied on May 8, 1995. Each seedling was flagged at this time. To identify individual seedlings, a metal tag with the plot number 1-20, treatment letter A-E, family number 200, 323, 728, 913, and 2459, and seedling number 1-8 was placed on the flag adjacent to each seedling.

Seedling Planting Stock

The seedlings being used in this study were collected at the northern red oak seed orchard in the Watagua District of the Cherokee National Forest near Elizabethton, TN. The orchard was established in 1973 as a progeny test by the Tennessee Valley Authority. The orchard contains some 220

\open-pollinated families from throughout the Tennessee Valley area. See Table 1.

The collection was done by the United States Forest Service in a cooperative agreement with the University Of Tennessee Tree Improvement Program. The collection of acorns was accomplished by placing nets under and around the trees. The net under the tree served to aid in the collection of the acorns. Vertical nets around the trees served to protect against the mixing of acorns between trees, i.e. between different families.

Once the acorns were collected from the nets, they were sorted as "sinkers" or "floaters". Sinkers were acorns that sunk in water; showing solidity of the acorn. Floaters, on the other hand, float in water because of a hollow space within the acorn. Floating acorns signal inner damage to the acorn. This damage was caused by malformation, wildlife damage, insect damage, or fungus damage.

The "sinkers" were then planted at the East Tennessee State Nursery in Etowah, Tennessee. The acorns were grown using the protocol developed by Dr. Kormanik (1993) at the Institute of Tree Root Biology in Athens, Georgia. There the acorns were planted six per linear foot or 32 per square foot. The protocol called for a baseline fertility level of

Table 1. Location of the five families mother trees and the location of the planting site of the northern red oak seedlings at Ames Plantation.

Family	County	State	Latitude	Longitude	Elevation
200	Limestone	AL	34°55' North	86°55' West	700
323	Trigg	KY	36°50' North	88°00' West	500
728	Franklin	TN	35°12' North	86°03' West	1500
913	Henderson	TN	35°43' North	88°17' West	500
2459	Claiborne	TN	36°20' North	83°35' West	1200
Site	Fayette	TN	35°13' North	89°13' West	500

Ca, K, P, Mg, Cu, Zn, and B of 500, 80, 80, 50, 0.3-3, 3-8 and 0.4-1.2 p.m. The seedlings were given small amounts of nitrogen in the form of NH_4NO_3 from mid May until the end of September of 1994. The total amount of added nitrogen was 1345 Kg/ha. Watering of the seedlings was stopped at the beginning of the second flush. The seedlings were then only watered when tensionmeters registered 30 to 50 centibars.

The seedlings were not grown exactly per protocol in the nursery, and because of this, the seedlings were not as tall as ones grown in the same year by Dr. Kormanik and his nursery. There were three main problems. The first was that the last few nitrogen fertilizations were not applied. The second problem arose from a nursery flood, which left the seedlings under water for a week. This affected the watering protocol as well as soil fertility levels. Lastly, the seedlings were planted on the outside rows of the nursery bed. This created an edge effect.

After the seedlings were lifted, they were graded according to the number of first order lateral roots. A first order lateral root is defined as a root off of the main tap root larger than 1 millimeter. Dr. Kormanik has shown in his research that each oak species has an average number of first order lateral roots; in northern red oak this number was six. Dr. Kormanik also showed in his

research that this average number of roots was the minimum number of first order lateral roots the seedlings need to survive and produce optimal height growth. The seedlings selected for this study had a minimum of six first order lateral roots. The first order lateral roots were then pruned to a length of 6 inches. This helps to keep the roots from being curled or j rooted when planted, facilitating easier planting.

Once the seedlings were graded and clipped, they were grouped into bundles of 8 trees by genetic family. In this study eighty bundles consisting of five different genetic families, a total of 640 seedlings were obtained. These bundles were then placed in seedling bags marked with the plot number, 1-20, the treatment, A-E, and the family numbers, 200, 323, 728, 913, or 2459. The roots were sprayed with a gel to keep the roots moist during storage prior to planting. The bags were then placed in coolers until they were transported to Ames Plantation for planting.

Planting Procedures

The planting procedures for the northern red oak seedlings in the artificial regeneration plots were changed from the standard protocol for planting seedlings due to the larger size of their roots. The seedlings were planted using a shovel or 6 inch arguer. Eight seedlings were

planted in each of the four quadrants for a total of 32 seedlings per plot on all 20 plots. A flag was placed next to each seedling and a metal tag was placed on the flag. The metal tag contained the tree number (1-8), the plot number (1-20), the treatment letter (A-E), and the family number (200, 323, 728, 913, and 2459). Round-Up™, was sprayed around each seedling in a radius of 3 feet to help release the seedlings primarily from Japanese honeysuckle (*Lonicera japonica*).

Data Collection - Natural Regeneration Plots

Baseline data were recorded for each of the 20 natural regeneration plots on April 15, 1995. The diameter at breast height and the species were recorded for each tree in the plots. Height was not measured on the natural plots because the trees were cut, bent, pushed over, or in some way damaged from logging which at this time would not allow for an accurate height measurement.

Data Collection - Artificial Regeneration Plots

On May 8, 1995 each seedling in the artificial regeneration plots was measured. Total height was measured for each northern red oak seedling to the nearest centimeter. The original height of the northern red oak seedlings was determined by measuring from the base of the seedling to the bottom of the first flush. The basal

caliper of each seedling was measured at the lowest point on the seedling where the caliper could be held level. The measurements were made to the nearest millimeter. While measuring the seedlings, it was also noted if the seedling had any damage from wildlife such as deer browse on the leaves or on the terminal bud.

On September 8, 1995, the height and basal caliper of the northern red oak seedlings were remeasured so growth calculations could be performed and assessed. During this remeasurement, the overall condition of the trees was determined, and wildlife damage was noted. See Appendix A for data sheets of the planted northern red oak.

Statistical Analysis

First year results of survival, height growth, and basal caliper growth by treatment and by family were examined in this study. These variables were examined using an analysis of covariance. An analysis of covariance adjusts for initial differences even when randomization procedures are utilized. The analysis of covariance combines features of ANOVA and regression. The analysis of covariance helps to permit statistical control of extraneous variables. This control of extraneous variables permits a more precise estimate of group differences. This allows the

final analysis to reflect more precisely the effect of the experimental intervention.

VI. Results

Natural Regeneration

The baseline data on the natural plots are represented in Appendix B. This data will aid in the future evaluation of the natural plots and in comparisons with the artificial regeneration plots initiated in this study. Appendix C contains the results from Countess's (1971) and Salmon's (1989) studies of three of the site treatments utilized in this study.

Artificial Regeneration

Survivability of Seedlings

Survival of the northern red oak seedlings dependent upon the five different treatments is represented in Table 2. The overall percent survival of the northern red oak seedlings was 87.7%. There were no significant differences in survival between the experimental treatments at the .05 level.

Survival of the seedlings by the five genetic families is represented in Table 2. There were no significant differences in survival at the .05 level by the genetic families.

Basal Caliper Growth of Seedlings

Basal caliper growth by family is illustrated in Table

Table 2. Survival of the northern red oak seedlings planted at Ames Plantation on April 15, 1995 with measurement on Sept. 8, 1996 by plot treatments and genetic families.

Treatments	Survival in percents	Families	Survival in percents
A	91.2%	200	96.4%
B	89.2%	323	83.0%
C	91.1%	728	85.8%
D	81.3%	913	86.4%
E	84.4%	2459	83.9%

Notes:

Using an analysis of covariance there were no significant differences at the .05 level between survival and plot treatment or genetic family

Plot Treatments

A = Silvicultural Clearcut

B = Liberation Cleaning

C = Liberation Cleaning with Oak Coppice

D = Oak Coppice

E = Commercial Clearcut

Genetic Families: Location of Mother Trees

200 = Limestone, AL

323 = Trigg, KY

728 = Franklin, TN

913 = Henderson, TN

2459 = Claiborne, TN

Table 3. Basal caliper measurements taken on the northern red oak seedlings planted at Ames Plantation by genetic families.

Families	Average Original Basal Caliper May 8, 1995	Average Basal Caliper Growth	Average Total Basal Caliper Sept. 8, 1995
	in millimeters	in millimeters	in millimeters
200	8.4	0.7	9.1
323	8.5	0.7	9.2
728	8.4	0.3	8.7
913	8.4	0.5	8.9
2459	8.3	0.1	8.4

Notes:

Using an analysis of covariance there were no significant differences at the .05 level between basal caliper growth and families.

Genetic Families: Location of Mother Trees

200 = Limestone, AL
 323 = Trigg, KY
 728 = Franklin, TN
 913 = Henderson, TN
 2459 = Claiborne, TN

Table 4. Basal caliper measurements taken on the northern red oak seedlings planted at Ames Plantation by plot treatments.

Treatments	Average Original Basal Caliper May 8, 1995	Average Basal Caliper Growth	Average Total Basal Caliper Sept. 8, 1995
	in millimeters	in millimeters	in millimeters
A	8.4	0.3	8.7
B	8.4	0.3	8.7
C	8.4	0.2	8.6
D	8.4	0.5	8.9
E	8.4	0.9	9.3

Notes:

Using an analysis of covariance there were no significant differences at the .05 level between basal caliper growth and plot treatments.

Plot Treatments

A = Silvicultural Clearcut

B = Liberation Cleaning

C = Liberation Cleaning with Oak Coppice

D = Oak Coppice

E = Commercial Clearcut

Table 5. Height measurements taken on the northern red oak seedlings planted at Ames Plantation by plot treatments.

Treatments	Average Original Height May 8, 1995	Average Height Growth	Average Total Height May 8, 1996
	in centimeters	in centimeters	in centimeters
A	64.6	17.2	81.8
B	64.7	15.0	79.7
C	64.6	18.7	83.3
D	64.6	16.8	81.4
E	64.7	17.9	82.6

Notes:

Using an analysis of covariance there was a significant differences at the .05 level between height growth and plot treatments

Plot Treatments

- A = Silvicultural clearcut
- B = Liberation Cleaning
- C = Liberation Cleaning with Oak Coppice
- D = Oak Coppice
- E = Commercial Clearcut

Table 6. Height measurements taken on the northern red oak seedlings planted at Ames Plantation by genetic families.

Families	Average Original Height May 8, 1995	Average Height Growth	Average Total Height Sept. 8, 1995
	in centimeters	in centimeters	in centimeters
200	64.6	22.2	86.8
323	64.7	13.8	77.5
728	64.6	18.8	83.4
913	64.6	15.4	79.9
2459	64.7	14.7	79.4

Notes:

Using an analysis of covariance there was a significant differences at the .05 level between height growth and genetic families.

Genetic Families: Location of Mother Trees

200 = Limestone, AL
 323 = Trigg, KY
 728 = Franklin, TN
 913 = Henderson, TN
 2459 = Claiborne, TN

3. There were no significant differences in basal caliper by families at the .05 level. Basal caliper growth by treatment is represented in Table 4. The various treatments had no significant differences in basal caliper growth at the .05 level.

Height Growth of Seedlings

Table 5 represents height growth by treatment. There was a statistical significant difference at the .05 level noted in height growth by the different plot treatments at the P value of .0462.

Height growth by family is illustrated in Table 6. There was a significant difference between height growth and family at the .05 level with a P value of .0231.

VII. Discussion

Data collected during this study yielded preliminary results on the height growth, basal caliper growth, survival, and animal damage on planted northern red oak seedlings. The natural and planted northern red oak data serve as a baseline for future studies. The study has created a unique situation where natural oak regeneration and planted oak regeneration occur side by side within the same treatments.

Survivability of Seedlings

While survival of the northern red oak seedlings by the five different treatments was not significant at the .05 level, there were noted trends. The seedlings that had the highest survival were located in the silvicultural clear-cut treatments, with a 91.2% survival. This plot treatment was given the most direct exposure to sunlight. The treatment with the next highest exposure to sunlight was the liberation cleaning with oak coppice. It had the second highest survival rating at 91.1%. This treatment had no upper canopy competition and limited below ground competition because all the tree species except oak were injected with the herbicide Accord™ and subsequently died. The liberation cleaning treatment had limited tree root competition and only limited upper canopy competition from

the oak species. The treatments that had the lowest survival, 84.4% and 81.3% respectfully, were the treatments which had the highest competition, the commercial logging and oak coppice, and thus the least amount of exposure to sunlight.

Survival by the five families also had no significant differences at the .05 level. However, the survival by families demonstrates a similar pattern to the height growth by family which was significant at the .05 level with a P value of .0231. It was believed by this author that this was due to better matching of the planting site with the site where the mother tree seedlings were collected.

Basal Caliper Growth of Seedlings

Basal caliper growth by family and treatment had no significant differences at the .05 level. There were no trends in the data that were noticeable. If basal caliper growth was effected by family or treatment, it will take longer than one year for these differences to emerge.

Height Growth of Seedlings

Height growth by treatment was significant at the .05 level. The seedlings located in the plots with the most exposure to sunlight had the greatest height growth. Treatment C, liberation cleaning with oak coppice, had seedlings with the most height growth. These seedlings had

higher amounts of sunlight and lower amounts of below ground competition. The commercial clearcut, treatment E, yielded the second highest growth of the planted northern red oak seedlings. This treatment allowed a high amount of sunlight but also had enough shade to limit rapid regeneration of herbaceous vegetation. Treatment A, silvicultural clearcut, had the third highest height growth of the planted northern red oak seedlings. This site had high initial exposure to sunlight. However, these sites were rapidly regenerated by herbaceous vegetation. Treatment D, oak coppice, consisted of a number of soft mast trees such as dogwood, blackgum, and blackcherry. This site allowed a limited amount of sunlight to reach the seedlings. This site had the second least height growth of the planted northern red oak seedlings. The liberation cleaning, treatment B, had the least height growth of the planted northern red oak seedlings with one of the lowest amounts of exposure to sunlight.

Height growth by family was significant at the .05 level with a P value of .0231. The trend of height growth by families was similar to the percent survival of the five families. Family 200 had both the highest growth and the highest percent survival, 22.2 centimeters and 96.4% respectfully. Family 728 had the second highest growth at

18.8 centimeters but it had the third highest percent survival at 85.8%. Family 913 had the third highest growth at 15.4 centimeters but had the second highest survival at 86.4%. Family 2459 had the second lowest height growth and survival at 14.7 centimeters and 83.9% respectively. Family 323 had the lowest height growth and survival at 13.8 centimeters and 83.0% respectively.

Animal Damage

The extraneous variable of animal damage in this study was low compared to damage noted on the seedlings from the same lot planted in other studies during this time frame. Other studies planted these seedlings in the same year as this study throughout the state of Tennessee in open fields. Deer damage was noted between 90% to 100% (Wells et. al., 1996). The northern red oak seedlings in this study experienced only 10.0% deer damage from planting until May 8, 1995 and only 4.2% between May 8, 1995 and Sept. 8, 1995. Table 7 shows the percent of deer damage by treatments in both May and September. Table 7 also shows the percent of animal damaged seedlings which died between being damaged in May and the reevaluation in September.

Table 7. Deer damage on northern red oak seedlings planted at Ames Plantation, on April 15, with measurements taken on May 8, 1995 and Sept. 8, 1995 by plot treatments.

	Treatment A		Treatment B		Treatment C		Treatment D		Treatment E	
	May 8, 1995	Sept. 8, 1995	May 8, 1995	Sept. 8, 1995	May 8, 1995	Sept. 8, 1995	May 8, 1995	Sept. 8, 1995	May 8, 1995	Sept. 8, 1995
Total Number of seedlings	n = 118	n = 103	n = 123	n = 108	n = 124	n = 109	n = 119	n = 95	n = 127	n = 111
Number of Deer Damaged Seedlings	n = 7	n = 1	n = 14	n = 5	n = 7	n = 4	n = 14	n = 2	n = 19	n = 10
Percent Damaged by Deer	5.9%	1.0%	11.4%	4.6%	5.6%	3.6%	11.8%	2.1%	15.0%	9.0%
Percent of Damaged Seedlings that Died	0%		14.3%		28.6%		14.3%		15.8%	

Notes:

Plot Treatments

A = Silvicultural Clearcut
 B = Liberation Cleaning
 C = Liberation Cleaning with Oak Coppice
 D = Oak Coppice
 E = Commercial Clearcut

VII. Conclusion

Enrichment Plantings of Northern Red Oak

This study showed that the height growth of these planted northern red oak seedlings was significantly different at the .05 level between the five treatments. Treatments which provided the most exposure to sunlight yielded the greatest height growth.

There were no significant differences at the .05 level between survival and treatment. However, a trend was beginning to develop where the treatments that had the most exposure to sunlight also had the highest survival.

Survival and height growth had no significant differences at the .05 level with genetic families. There were also no significant differences at the .05 level between basal caliper growth by genetic family and treatments.

It was also learned that these planted seedlings with a minimum of six first order lateral roots retained the high survivability that was expected from the literature. The difference between this study and those cited by the literature was the number of first order lateral roots of the planted seedlings. It was valuable to find that seedlings with six first order lateral roots could be out planted and could attain an 80% survival rate.

Deer browse was an extraneous variable examined in this study. Northern red oak seedlings from the same lot as those in this study that were planted in open agricultural fields had 90% to 100% damage due to deer (Wells et. al., 1996). The seedlings in this study experienced only 10% deer damage and had low mortality rate due to this damage.

Natural Oak Regeneration

The data collected on the natural oak regeneration and the northern red oak seedlings form the baseline data for a later comparison study of natural oak regeneration. This study facilitates a direct comparison of natural and artificial oak regeneration because the two occur side by side on 20 plots with five different treatments. This baseline study will allow future researchers to answer questions about how natural regeneration and artificial regeneration interact.

The data collected on the natural regeneration plots recreates the studies conducted by Micheal Countess and Alan Salmon. This study should either verify or reject their work on oak regeneration and the effects that different under story cleaning levels have upon natural oak regeneration in this area. The validation part of this study added three treatments to those in Countess's and Salmon's studies. The first added treatment was a control

treatment. The control treatment will give the study more validity. It will remove the question of chance occurrence from the results. If the control plot does not regenerate oak and some of the other treatments do, the control will allow the researcher to draw conclusions that are not due to random chance. The second added treatment, liberation cleaning with oak coppice, will allow for examination of tree form in comparison to liberation cleaning alone. The third added treatment was an oak coppice. In this treatment, all oak were cut to the ground to further examine the effects of surrounding vegetation on the oak coppice.

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APPENDICES

A1. Enrichment planting data sheet plot 1

Planted Plots													
Plot & Treatment A	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Animal	Overall	Total Height
	Centimeter	Decimeters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Damage	Condition	Growth
Family 728													
Tree 1	0.8	6.1	8.3	2.2		0.77	9	Yes	Yes			Average	2.9
Tree 2	0.9	5.2	5.3	0	Growth Retten	0.89	8	Slight				Good	2.7
Tree 3	0.9	6.8	8	1.2		0.94	11	Yes				Average	5.4
Tree 4	1	7	7	0	Terminal Bud Missing	1.13	8.8		Heavy	Both		Fair	1.8
Tree 5	1.4	8	9.3	1.3		1.55	10.4	Yes	Yes			Average	3.7
Tree 6	0.9	9.3	9.9	0.4		1.25	11.5		Yes			Good	2.8
Tree 7	0.9	8.2	8.2	0								Dead	
Tree 8	0.8	7.2	7.2	0		0.75	8.7					Average	1.5
Average	0.91	7.275	7.9	0.625		1.034285714	9.428571429						2.971428571
Family 2459													
Tree 1	0.7	5.5	7.5	2		0.45	8.3					Average	4.8
Tree 2	0.6	5.2	5.7	0.5		0.58	5.5					Average	0.8
Tree 3	0.6	5.1	5.5	0		0.52	6.4	Yes				Average	0.9
Tree 4	0.7	5	5.3	0.3		0.82	5	Yes				Fair	0.7
Tree 5	0.6	4.8	4.8	0		0.55	6.7					Fair	1.9
Tree 6	0.7	5	5	0								Dead	
Tree 7	0.9	7.4	7.7	0.3		0.42	7.9					Average	0.8
Tree 8	0.9	6.1	7	0.9		0.8	7					Fair	1.8
Average	0.725	5.5625	6.8625	0.5		0.62	6.742857143						1.471428571
Family 200													
Tree 1					Dead No Dist								
Tree 2	0.9	8.7	9.2	0.5		0.77	10	Heavy				Average	1.8
Tree 3	0.6	6	6.5	0.5		0.6	6.5					Average	1
Tree 4					Dead Poor Planting								
Tree 5	1.3	8.6	9.3	0.7	Missing Terminal Bud	1.24	10.2			Both		Average	2.3
Tree 6	0.9	6.3	10	3.7		0.92	11.3					Poor	8.5
Tree 7	0.7	4.9	6.3	1.4	Top Chewed	0.71	6.1		Yes			Average	2.4
Tree 8	0.8	5.3	6.9	1.6	Top Chewed	0.89	6.9	Slight	Yes			Average	3.2
Average	0.866	6.633	8.033	1.4		0.855	8.4666						7.2333
Family 913													
Tree 1					Missing								
Tree 2	0.6	5.6	6.2	0.6		0.62	6.9					Good	1.9
Tree 3	0.9	8	8			0.88	8.8					Poor	0.8
Tree 4	0.9	6	7.7	1.7		0.77	9.1	Slight				Good	4.8
Tree 5	0.7	5.2	7.9	2.7		0.61	7.9	Yes		TBD		Fair	5.4
Tree 6					Dead No Dist								
Tree 7	0.7	4.5	5.1	0.6		0.6	5.1		Yes			Good	1.4
Tree 8	0.7	5.2	7.6	2.4		0.65	7.6		Yes			Average	4.8
Average	0.75	5.75	7.0833	1.33		0.724285714	8.257142857						3.2167

A2. Enrichment planting data sheet plot 2

Planted Plots													
Plot 2 Treatment 2	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Decimeters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	1	5.9	6.1	0.2		1.02	6.9				Good	1	0.02
Tree 2	0.7	4.3	7.7	3.4		0.81	9.8				Average	5.5	0.11
Tree 3	0.7	5.6	7.9	2.3		0.74	7.9	Yes			Average	2.3	0.04
Tree 4	1	8.8	9.3	0.5		1.04	10	Yes			Good	1.2	0.04
Tree 5	1.1	10.3	12	1.7		1.16	12.5				Good	2.2	0.06
Tree 6	1.1	7.9	7.9	0		1.26	8.5				Good	0.6	0.16
Tree 7	0.8	8	8.7	0.7		0.73	9.4				Fair	1.4	-0.07
Tree 8	0.8	5.2	7.2	2		0.87	8				Average	2.8	0.07
Average	0.9	7	8.35	1.35		0.95375	9.125					2.125	0.05375
Family 323													
Tree 1	1.1	8	10.6	2.6		1.19	10.6	Yes			Good	2.6	0.09
Tree 2	0.98	5.9	6.8	0.9		0.84	6				Good	0.1	-0.06
Tree 3	0.8	5.7	6.1	0.4	Top Eaten	0.62	6.3		Slight		Good	0.6	-0.18
Tree 4	0.6	3.7	6	2.3		0.79	8.4				Good	4.7	0.19
Tree 5	0.7	6.3	8.3	2		1.08	7.6				Good	1.3	0.38
Tree 6	0.8	5.8	7.5	1.7	Top Eaten		8.4				Dead		
Tree 7	0.5	4.3	5.4	1.1		0.65	6.2	Yes			Average	1.9	0.15
Tree 8	0.2	4	6.1	2.1		0.91	7.9	Heavy			Average	3.9	0.71
Tree 9	0.8	6.3	8.7	2.4									
Average	0.6625	5.25	6.8625	1.6125		0.815	7.06666					2.1571629	0.055714
Family 728													
Tree 1	0.9	5.9	7.7	1.8		0.98	9				Fair	0.08	0.08
Tree 2	0.7	4.8	8.2	3.4		0.98	7.9				Good	-6.42	-0.42
Tree 3	1	7.2	8.8	1.6		1.03	9.2				Average	0.03	0.03
Tree 4	1.1	5.8	6.3	0.5		1.03	6.6				Average	-0.07	-0.07
Tree 5	1	6.8	6.9	0.1		1.45	8.7	Heavy			Good	0.45	0.45
Tree 6	1.5	7.9	7.9	0	Terminal Bud Missing	1.64	9.5			LBD	Good	0.14	0.14
Tree 7	0.9	7.3	7.3	0		0.86	7.6				Poor	-7.94	-0.94
Tree 8	0.9	7.2	9	1.8		1.16	9.3				Good	-8.24	-0.24
Average	3.8875	6.6125	7.7625	1.15		1.14125	8.475					-2.74625	-0.125
Family 200													
Tree 1	0.9	10.9	10.9	0		1.04	11.5			Both	Good	0.4	0.14
Tree 2	0.8	6	7.7	1.7		1.05	9	Yes			Good	3	0.25
Tree 3	0.5	4.8	5.9	1.1		0.53	5.9				Good	1.1	0.03
Tree 4	0.8	6.9	9	2.1		1.03	9.4				Average	2.5	0.23
Tree 5	0.6	5.9	7.2	1.3		0.74	9.6	Yes			Average	3.7	0.14
Tree 6	0.7	5.4	5.5	0.1		0.68	5.4				Good	0	-0.02
Tree 7	1	6	7.3	1.3		0.89	7.8				Good	1.8	-0.11
Tree 8	0.9	7	7.8	0.8		0.97	7.8	Yes			Good	0.8	0.07
Average	0.775	6.6125	7.6625	1.05		0.86625	8.3					1.6875	0.091258

A3. Enrichment planting data sheet plot 3

Planted Plots													
Plot 3 Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	0.8	7.1	7.1	0	Terminal Bud Missing	0.73	8.6		yes		Average +	1.5	-0.07
Tree 2	1.4	11.9	13.9	2		1.45	15.6	Heavy			Fair	2.7	0.05
Tree 3	0.7	6	6	0	Dear Eaten	0.85	7.2				Good	1.2	0.15
Tree 4	0.6	5.2	6.8	1.6		0.5	6.5	Yes	YES		Poor	1.3	-0.1
Tree 5	0.6	7	7.9	0.9	Looks Poor	0.55	7.4		yes		Poor	0.4	-0.05
Tree 6					Dead No Dirt						Sprouted	0	0
Tree 7	0.8	4.8	4.8	0		0.68	5				Average	0.2	-0.12
Tree 8	1.2	8.8	8.8	0	Dear Eaten	1.32	10.5		YES	Both	Average	1.7	0.12
Average	0.871428571	7.2571429	7.9	0.642857143		0.868571	8.6857					1.25	-0.0025
Family 913													
Tree 1	1.4	4.3	6.3	2		1.99	Forked	6.8	Heavy		Poor	2.5	
Tree 2	0.6	6.2	8.2	2		0.64	8		Yes		Average	1.8	0.04
Tree 3	0.8	6.9	7.2	0.3	Eaten	0.8	7.2				Fair	0.3	0
Tree 4	0.6	5.3	5.6	0.3		0.66	6.3				Poor	1	0.06
Tree 5	0.9	4.9	7.2	2.3		0.83	7.8				Fair +	2.9	-0.07
Tree 6	0.8	7.9	8.8	0.9		0.75	10.3	Yes	Yes		Average -	2.4	-0.05
Tree 7	0.5	4.9	5.2	0.3							Dead		
Tree 8	0.5	5.3	5.3	0		0.5	5.4				Poor	0.1	0
Average	0.7625	5.7125	6.725	1.0125		0.696666	7.4					1.571428	
Family 728													
Tree 1	0.9	9.3	9.3	0		0.94	11.4		Yes		Average	2.1	0.04
Tree 2	0.9	6.6	6.6	0	Top Dead	0.86	5.7			Both	Missing		
Tree 3	0.9	5.7	8.9	3.2		1	8.9	Yes	Heavy		Average	3.2	0.1
Tree 4	1	6.7	9.2	2.5		1	11.5				Good	4.8	
Tree 5	0.5	4.2	4.2	0		0.54	6				Average +	1.8	0.04
Tree 6	1	5.7	8.3	2.6		0.84	8.7			Both	Good	3	-0.16
Tree 7	0.9	5.2	5.8	0.6	Top Eaten	0.77	8.5			LBD	Average +	3.3	-0.13
Tree 8	1	6	6.7	0.7		0.94	7.5				Average	1.5	-0.06
Average	0.8875	6.175	7.375	1.2		0.86125	8.525					2.35	-0.03
Family 2459													
Tree 1	0.7	5.3	5.3	0		0.68	7.3	Yes	Yes		Poor	2	6.1
Tree 2	0.9	6.2	6.2	0		0.82	8.5		Yes		Fair	2.3	-0.08
Tree 3	0.6	5.2	5.2	0	Clipped	0.62	6.2			LBD	Average	1	0.02
Tree 4	0.5	6.3	6.3	0	Terminal Bud Dead	0.52	7.1			Both	Fair	0.8	0.02
Tree 5	0.6	6	6	0	No Top	0.56	7	Yes			Fair	1	-0.04
Tree 6	0.8	6.3	6.9	0.6		0.65	7.6	Heavy			Average -	1.3	-0.15
Tree 7	0.7	5.3	5.3	0	Top Eaten	0.69	6.5	Slight		LBD	Average +	1.2	-0.01
Tree 8	0.9	7.3	7.3	0		0.95	10.4	Slight	Yes		Average	3.1	0.05
Average	0.7125	5.9875	6.0625	0.075		1.45125	7.575					1.5875	0.73875

A4. Enrichment planting data sheet plot 4

Planted Plots													
Plot & Treatment D	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Decimeters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 2459													
Tree 1	0.9	7.9	9.1	1.2		0.96	10				Good	2.1	0.06
Tree 2	1.1	7.5	7.5	0							Dead		
Tree 3	0.7	2.4	3.7	1.3	Snipped	0.73	3.7				Fair	1.3	0.03
Tree 4	1	10.3	10.8	0.5		1.3	12	Yes			Good	1.7	0.3
Tree 5	0.5	3.2	4.2	1		0.64	4.3				Fair	1.1	0.16
Tree 6	0.6	6.7	7.9	1.2		0.95	9.4				Good	2.7	0.35
Tree 7													
Tree 8													
Average	0.8	6.32	7.2	0.8666		0.92	7.88					1.78	0.18
Family 913													
Tree 1	0.9	7	7.3	0.3	Top Eaten	0.98	7.5	Light		LBD	Average	0.5	0.08
Tree 2	0.8	4.8	8.2	3.4		0.9	8.4	Yes			Average	3.6	0.1
Tree 3	1.1	11	11.3	0.3		1.34	13		Yes		Average -	2	0.24
Tree 4	0.7	5.9	5.9	0		0.98	7.4	Yes	Both		Average	1.5	0.28
Tree 5	0.7	4.3	5	0.7		0.8	6.8				Good	2.5	0.1
Tree 6	0.6	5.9	6.2	0.3	Terminal Bud Eaten	1.04	6.4			LBD	Average	0.5	0.44
Tree 7	0.8	5.3	6.4	1.1							Dead		
Tree 8	0.8	6.9	7.2	0.3		1.1	7.5	Yes	Yes		Average	0.6	0.3
Average	0.8	6.3875	7.1875	0.8		1.02	8.14285					1.6	0.22
Family 728													
Tree 1	0.7	7.8	7.8	0		0.88	8.6				Good	0.8	0.18
Tree 2	0.7	6.8	7.2	0.4	Terminal Bud Dead						Dead		
Tree 3	0.8	5.8	6.1	0.3		0.74	6	Yes	Yes		Average	0.2	-0.06
Tree 4	0.8	6.3	8.2	1.9							Dead		
Tree 5	0.8	6.1	6.1	0	Eaten	0.8	6.2	Yes	Yes		Poor	0.1	0
Tree 6	0.7	5.2	5.9	0.7		0.87	6.8	Yes			Good	1.6	0.17
Tree 7	0.6	5.9	6.2	0.3							Dead		
Tree 8					No Tree								
Average	0.7285714	6.2714286	6.7857142	0.514285		0.8225	6.9					0.675	0.0725
Family 200													
Tree 1	0.8	8.9	10.1	1.2		1.05	10.7		Yes		Good	1.8	0.25
Tree 2	0.7	8.2	8.2	0		0.76	9.5	Yes			Average	1.3	0.06
Tree 3	0.8	9.7	9.7	0		0.89	10.3				Average	0.6	0.09
Tree 4	1.2	10	10	0		1.52	10				Good	0	0.32
Tree 5	0.9	8	8.5	0.5		1.15	8.8				Good	0.8	0.25
Tree 6	0.8	6.2	9.2	3		1.12	10				Good	3.8	0.32
Tree 7	0.9	8.3	11.2	2.9		1.42	11.2	Yes	Yes		Average	2.9	0.52
Tree 8													
Average	0.8714285	8.4714286	9.55714	1.085714		1.13	10.07142					1.86666	0.258571

A5. Enrichment planting data sheet plot 5

Planted Plots													
Plot 5 Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	0.8	4.1	5.3	1.2	Eaten	0.9	4.8				Poor	0.7	0.1
Tree 2	1	9.9	9.9	0	Eaten	1.08	9.9			LBD	Average	-0.1	0.08
Tree 3	1	7.7	7.7	0	Eaten						Dead		
Tree 4	1.3	10.2	10.7	0.5		1.59	12.2		Yes		Good	2	0.29
Tree 5	1	6.6	8.3	1.7		0.82	6.2				Poor	-0.4	-0.18
Tree 6	0.7	5	6	1									
Tree 7	0.8	7.9	7.9	0		0.86	8.3	Heavy	Yes		Fair	0.4	0.06
Tree 8	1.2	6.1	6.9	0.8		1.2	8.7				Poor	2.6	0
Average	0.975	7.1875	7.8375	0.65		1.075	8.3333					0.86666	0.058333
Family 200													
Tree 1	0.9	6.2	7.8	1.5		0.88	8				Good	1.7	-0.02
Tree 2	0.8	6.3	8.2	1.9		0.95	8.3		Yes		Good	2	0.15
Tree 3	0.9	7.2	7.8	0.6		0.82	8.9		Yes		Average +	1.7	-0.08
Tree 4	0.7	5.8	6.3	1.5		0.7	7	Heavy			Fair	1.2	0
Tree 5	0.7	6.2	6.2	0	Dead Terminal Bud	0.93	7.2		Few	Both	Good	1	0.23
Tree 6	0.9	5.2	8	2.8	Top Eaten	1.02	9.9			Both	Good	4.7	0.12
Tree 7	0.9	6	7.3	1.3	Top Eaten	0.75	8.2				Good	2.2	-0.15
Tree 8	0.7	5.1	7.3	2.2		0.87	8.1				Good	3	0.17
Average	0.8125	6.0125	7.3625	1.36		0.865	8.2					2.1875	0.0525
Family 2459													
Tree 1	0.6	4.3	4.3	0	Top Eaten						Dead		0.15
Tree 2	1	9	9.9	0.9		1.15	11.6	Heavy			Poor	2.6	0.1
Tree 3	0.9	5.9	7.2	1.3		1	7.5				Good	1.6	0.19
Tree 4	0.8	8.1	9.3	1.2		0.99	9.4				Good	1.3	
Tree 5	0.8	6.3	6.3	0	Dead Terminal Bud						Dead		
Tree 6	0.6	4.7	6.3	1.6							Dead		
Tree 7	0.7	5.2	5.7	0.5							Dead		
Tree 8	0.9	6.3	6.3	0							Dead		
Average	0.7875	6.225	6.9125	0.6875		1.046666	9.5					1.83333	0.146666
Family 728													
Tree 1	0.7	5.8	5.8	0		1.15	8.3				Good	2.5	0.45
Tree 2	0.8	5.3	6.7	1.4		0.94	7.3		Yes		Good	2	0.14
Tree 3	1.3	8.2	9.1	0.9	Top Eaten	1.2	10.5			Both	Good	2.3	-0.1
Tree 4	0.8	6.2	9.2	3		0.9	9.2		Yes		Good	3	0.1
Tree 5	0.9	6.7	7.3	0.6	Top Eaten	0.96	7.3				Average +	0.6	0.06
Tree 6	0.7	5.3	7.2	1.9		0.79	7.8	Slight			Good	2.5	0.09
Tree 7	0.8	4	6.4	2.4		1.06	6.2				Average +	2.2	0.26
Tree 8	1	6.4	6.4	0	Top Broken	0.9	7.3				Good	0.9	-0.1
Average	0.875	5.9875	7.2625	1.275		0.9875	7.9875					2	0.1125

A6. Enrichment planting data sheet plot 6

Planted Plots													
Plot 6 Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	1	8	9.2	1.2		1	9.6				Poor	1.6	0
Tree 2	1.2	9.9	11	1.1		1.35	11.5	Yes			Good	1.6	0.15
Tree 3	0.8	7.3	10	2.7		0.86	9				Poor	1.7	0.06
Tree 4	0.9	6.7	8.3	1.6		1.1	8.5	Yes			Poor	1.8	0.2
Tree 5	0.8	6.8	7.9	1.1		0.96	8.2		Yes		Good	1.4	0.15
Tree 6													
Tree 7													
Tree 8													
Average	0.94	7.74	9.28	1.54		1.07125	9.36					1.62	0.112
Family 323													
Tree 1	0.7	6.4	10.1	3.7		0.72	7.4				Good	1	0.02
Tree 2	1	8.2	8.2	0		1.32	9.2	Yes		Both	Good	1	0.32
Tree 3	0.7	5.3	7	1.7		0.83	7.6				Good	2.3	0.13
Tree 4	1	8.3	9	0.7		1.28	9.5				Good	1.2	0.28
Tree 5	1	8.3	8.3	0		1.4	9.8	Yes		Both	Good	1.5	0.4
Tree 6	1.3	10.3	10.3	0		1.4	12.2				Good	1.9	0.1
Tree 7	0.8	5.2	6.5	1.3		0.9	6.6	Yes			Average	1.4	0.1
Tree 8	0.7	6.8	7.9	1.1		0.72	7.8				Average	1	0.02
Average	0.9	7.35	8.4125	1.0625		1.07125	8.7625					1.4125	0.17125
Family 728													
Tree 1	1.2	9.3	9.3	0		1.22	11.2				Average	1.9	0.02
Tree 2	0.9	6.6	6.6	0		0.85	6.6	Yes			Fair	0	-0.05
Tree 3	0.7	6	6	1.4		0.8	8.5	Yes			Average +	2.5	0.1
Tree 4	1.2	7.8	7.8	0 Eaten		1.2	9.5		Yes		Average	1.7	0
Tree 5	0.9	6.3	7.6	1.3		1.05	8.6	Yes			Average +	2.3	0.15
Tree 6	0.7	6.5	8.1	1.6		0.91	9.8	Yes			Average	2.3	0.21
Tree 7	1.1	7	8.2	1.2		1.15	10				Average	3	0.05
Tree 8	1.2	7.1	9.8	2.7		1.45	10.3				Good	3.2	0.25
Average	0.9875	7.075	8.1	1.025		1.07875	9.3125					2.2375	0.09125
Family 913													
Tree 1	1	7.2	7.6	0.4		1.04	8				Average	0.8	0.04
Tree 2	0.7	6.3	6.3	0 Top Eaten		0.9	6.6		Yes		Average	0.3	0.2
Tree 3	0.9	7	7.6	0.6 Top Eaten		1.07	8.4	Yes			Average	1.4	0.17
Tree 4	0.7	5.4	5.4	0 Top Eaten		0.94	7.5				Good	2.1	0.24
Tree 5	0.6	6.3	6.3	0 Terminal Bud Dead		0.86	6.8				Good	0.5	0.26
Tree 6	0.6	6.3	6.3	0		0.86	6.6			LBD	Good	0.3	0.26
Tree 7	0.9	7.7	7.7	0 Terminal Bud Dead		1.02	8		Yes	Both	Good	0.3	0.12
Tree 8	0.9	6	7.8	1.8		0.9	7.8				Poor	1.8	0
Average	0.7875	6.525	6.875	0.35		0.94875	7.4625					0.9175	0.16125

A7. Enrichment planting data sheet plot 7

Planted Plots													
Plot 7 Treatment A	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	1.1	6.9	9.8	2.9		1.27	10.1				Good	3.2	0.17
Tree 2	0.8	6.9	7.4	0.5		0.89	8.1				Good	1.2	0.09
Tree 3	0.8	6.9	9.3	2.4		0.88	10.9				Good	4	0.08
Tree 4	1.1	8.2	9.2	1		1.35	10.3				Good	2.1	0.24
Tree 5	1.4	10.3	10.3	0		1.15	11.6	Yes			Good	1.3	-0.25
Tree 6	0.4	5.2	6.2	1		0.59	6.7				Good	1.5	0.19
Tree 7	0.6	5.3	8.2	2.9		0.58	8				Good	2.7	-0.02
Tree 8	1	7.8	9.2	1.4		1	9.8				Good	2	5
Average	0.9	7.1875	8.7	1.5125		1.5875	9.4375					2.25	0.6875
Family 728													
Tree 1	1	9.2	9.2	0	Terminal Bud Miss	1	10.4			Both	Good	1.2	0
Tree 2	0.9	7.8	8.3	0.5		1.05	9.7				Good	1.9	0.15
Tree 3	0.8	6	6	0	Terminal Bud Miss						Dead		
Tree 4	1.3	7	9	2		1.2	9				Fair	2	-0.1
Tree 5	0.7	7.2	7.2	0	Dead Terminal Bud						Dead		
Tree 6	1.2	9	9	0									
Tree 7	0.9	5	6.5	1.5		0.84	7.1				Fair	2.1	-0.06
Tree 8	0.8	6.8	7.2	0.4		1.02	8.4				Good	1.76	0.22
Average	0.95	7.25	7.8	0.55		1.022	8.92						
Family 913													
Tree 1	0.7	7.2	8.2	1		0.68	9	Yes			Fair	1.8	-0.02
Tree 2	0.7	6.2	6.2	0							Dead		
Tree 3	0.8	4.9	7	2.1	Dead Terminal Bud	0.86	7.6	Yes			Fair +	2.7	0.06
Tree 4	0.5	4.8	4.8	0							Dead But Spr		
Tree 5													
Tree 6													
Tree 7													
Tree 8													
Average	0.675	5.775	6.55	0.775		0.77	8.3					2.25	0.02
Family 323													
Tree 1	0.6	3	4.9	1.9		0.67	5.1				Average	2.1	0.07
Tree 2	0.9	4.2	7.1	2.9		0.86	8.1				good	3.9	-0.04
Tree 3	0.9	7	8.4	1.4							Dead		
Tree 4	0.6	3.8	5.2	1.4							Dead		
Tree 5	0.5	4.3	6	1.7		0.4	5.9				Average +	1.6	-0.1
Tree 6	1.1	5.3	8.9	3.6							Dead		
Tree 7	0.9	6.2	8.9	2.7		0.91	8.7				Good	2.5	0.01
Tree 8					Dead No Dirt								
Average	0.785714286	4.82857143	7.057142857	2.22857		0.71	6.95					2.525	-0.015

A8. Enrichment planting data sheet plot 8

Planted Plots													
Plot # Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	0.6	6.1	8.2	2.1		1.25	11.1				Good	5	0.65
Tree 2	0.9	5.6	8.4	2.8		0.7	8.3	Yes			Good	2.7	-0.2
Tree 3	0.8	5	6.9	1.9		0.82	8.9				Average	3.9	0.02
Tree 4	0.9	7.7	9.1	1.4		1.08	10.3				Good	2.6	0.18
Tree 5	1	10	10.9	0.9		1.04	7.6				Average	-2.4	0.04
Tree 6	0.8	5.2	7.4	2.2		0.69	6.3				Average	1.1	-0.11
Tree 7	0.6	5.8	6.2	0.4		1	5.7				Average	-0.1	0.4
Tree 8	0.61	2.7	5.3	2.6		0.61	5.3				Poor	2.6	0
Average	0.77625	6.0125	7.8	1.7875		0.89875	7.9375					1.925	0.1225
Family 200													
Tree 1	1	5.8	6.2	0.4		0.61	7	Yes			Average	1.2	-0.39
Tree 2	0.5	5.8	6.7	0.9		0.9	8.1				Good	2.3	0.4
Tree 3	0.8	4.2	6	1.8		1.05	8.6				Fair	4.4	0.25
Tree 4	0.9	8.7	9	0.3		1	9.3	Yes	Yes		Fair	0.6	0.1
Tree 5	0.8	8	8.3	0.3		1.13	12				Good	4	0.33
Tree 6	0.5	5.8	5.8	0		0.86	10.5				Good	4.7	0.46
Tree 7	0.8	6.5	8.8	2.3									
Tree 8	0.5	5.7	8.2	2.5									
Average	0.725	6.3125	7.375	1.0625		0.941666	9.25					2.866666	0.1916666
Family 323													
Tree 1	0.4	6.7	8.3	1.6		0.85	7.2				Fier	0.5	0.45
Tree 2	0.2	2.2	2.9	0.7		0.86	5.2				Average	3	0.66
Tree 3	0.6	5.9	6.7	0.8		0.83	5.5				Fir	-0.4	0.23
Tree 4						0.45	3				Sprouting	3	0.45
Tree 5	1.2	8.8	9.8	1		1.22	8.3				Average	-0.5	0.02
Tree 6	0.7	3.1	4.3	1.2							Dead		
Tree 7	0.6	5.1	7.9	2.8		1.25	8.3	Blight			Good	3.2	0.65
Tree 8	0.7	3.2	5	1.8							Dead		
Average	0.628571	5	6.4142857	1.414285714		0.91	6.25					1.466666	0.41
Family 2459													
Tree 1	1.1	6.5	6.5	0 Broken		1.24	7				Good	0.5	0.14
Tree 2	1.1	7.1	8.2	1.1		1.1	7.6				Good	0.5	0
Tree 3	0.6	3.8	6.8	1		0.97	7.6				Good -	3.8	0.37
Tree 4	1.3	7.5	8	0.5		0.69	7.9				Average	0.4	-0.61
Tree 5	0.5	4	6.2	2.2 Dead Terminal Bud							Dead		
Tree 6	0.7	6.3	8	1.7 Dead Terminal Bud							Dead		
Tree 7	0.6	5.8	6.8	1		0.74	7				Good	1.2	0.14
Tree 8	0.7	5.9	7.1	1.2		0.71	7.2				Good	1.3	0.01
Average	0.825	5.8625	6.95	1.0875		0.9083333	7.383333					1.28333	0.083333

A9. Enrichment planting data sheet plot 9

Planted Plots													
Plot 9 Treatment C	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	0.5	5.1	7	1.9		1.16	10.2	Yes			Average	5.1	0.66
Tree 2	0.7	6.2	8.2	2		0.56	7.4	Heavy	Heavy		Poor	1.2	-0.14
Tree 3	0.8	5.9	8.9	3		1	6.5	Heavy	Heavy		Poor	0.6	0.2
Tree 4	0.8	5.3	6.3	1		0.95	11.1			LBD	Good	5.8	0.15
Tree 5	0.9	9.8	10.9	1.1		0.76	9	Heavy			Fair	-0.8	-0.14
Tree 6	0.9	10	10.8	0.8		0.46	5.9				Fair	-4.1	-0.44
Tree 7	0.9	8	8	0		0.83	9.9		Yes		Average	1.9	-0.07
Tree 8	0.59	8.3	8.3	0		0.59	8.3	Yes			Average	0	0
Average	0.76125	7.325	8.55	1.225		0.78875	8.5375					1.2125	0.0275
Family 913													
Tree 1	0	8.3	10	1.7		0.89	8.5				Good	0.2	-0.11
Tree 2	0.7	5.8	8.3	2.5							Dead		
Tree 3	0.7	5.7	9	3.3		0.94	8				Average	2.3	0.24
Tree 4	0.9	7	7.5	0.5		0.96	9.5	Heavy	Heavy		Fair	2.5	0.06
Tree 5	0.7	7.3	7.7	0.4		1.16	12.9			Both	Average	5.6	0.46
Tree 6	0.7	5.5	4	0.5		0.89	8.4				Average	2.9	0.19
Tree 7	0.7	6.5	4.5	0 Chewed							Dead		
Tree 8	0.6	4.9	5.4	0.5			5.4						
Average	0.75	6.125	7.3	1.175		0.968	8.78333					2.7	0.168
Family 2459													
Tree 1	0.9	6.2	7.2	1		1.03	9.9				Good	3.7	0.13
Tree 2	0.9	5.8	6.8	1		0.62	7.4				Good	1.6	-0.28
Tree 3	0.7	6.8	7.8	1		0.55	5.5				Fair	-1.3	-0.15
Tree 4	0.6	6.7	8	3.3		1.32	9				Average	4.3	0.72
Tree 5	0.6	4.5	6.3	1.8							Dead		
Tree 6	0.6	4.3	5.1	0.8		0.84	8.1	Heavy			Fair	3.8	0.24
Tree 7	0.6	5.2	6.8	1.6		0.59	7.1	Heavy	Heavy		Fair	1.9	-0.01
Tree 8	0.5	5.2	6.2	1		0.72	7.6		Heavy		Average	2.4	0.22
Average	0.675	5.3375	6.775	1.4375		0.81	7.8					2.34285	0.12285
Family 323													
Tree 1	0.8	4.8	7.3	2.5		0.86	8.1		Yes		Average	3.3	0.06
Tree 2	0.8	5.1	5.2	0.1							Dead		
Tree 3	0.7	4.5	5.9	1.4		0.68	7.1		Slight		Good	2.6	-0.02
Tree 4	0.5	2.8	3.2	0.4		1.14	6.7	Yes	Yes	Both	Fair	3.9	0.64
Tree 5	1.3	7.9	7.9	0		1.04	11.4			Both	Good	3.5	-0.26
Tree 6	0.9	4.7	5.8	1.1		0.59	5.2	Heavy			Poor	0.5	-0.31
Tree 7	0.9	3.8	5.9	2.1		0.69	8				Good	4.2	-0.21
Tree 8	0.6	3.8	5.1	1.3		0.74	6.4	Yes			Average	2.6	0.14
Average	0.8125	4.675	5.7875	1.1125		0.82	7.55714					2.94285	0.005714286

A10. Enrichment planting data sheet plot 10

Planted Plots													
Plot 10 Treatment C	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 813													
Tree 1	0.8	4.8	5.8	1		0.8	6				Good	1.2	0
Tree 2	1	7	8.8	1.8		1.09	7.5				Average	0.5	0.09
Tree 3	0.9	8	9.2	1.2		0	0				Dead		
Tree 4	0.8	6.9	8.1	1.2		0	0				Dead		
Tree 5	0.7	6.3	7.8	1.5		1	7.8				Good	1.5	0.3
Tree 6	0.8	4.9	8	3.1		0.65	7.8				Poor	2.9	-0.15
Tree 7	1	8	9	1							Dead		
Tree 8	0.9	4.8	8.7	3.9		1.03	7	Yes			Average	2.2	0.13
Average	0.8625	6.3375	8.175	1.8375		0.8957142	7.628571429					1.66	0.074
Family 2459													
Tree 1	0.7	3.2	6	2.8		0.75	6.8				Good	3.6	0.05
Tree 2	1	7.2	8.2	1	Dead Terminal Bud	0.83	9			Both	Average	1.8	-0.17
Tree 3	0.9	5.3	7	1.7	Dead Terminal Bud	0.6	8.3				Average	3	-0.3
Tree 4	0.8	4.9	5.9	1	Dead Terminal Bud						Dead		
Tree 5	0.7	4.3	4.3	0		0.7	6				Good	1.7	0
Tree 6	0.9	6.1	7.3	1.2		1.1	8	Yes			Fair	1.9	0.2
Tree 7	0.7	4.9	6.2	1.3		0.8	7				Good	2.1	0.1
Tree 8	0.8	6.4	8.1	1.7		0.85	8.6	Yes	Yes		Fair +	2.2	0.05
Average	0.8125	5.2875	6.625	1.3375		0.804285	7.671428571					2.32857143	-0.01
Family 200													
Tree 1	1.2	10	10	0		1.25	11				Average	1	0.05
Tree 2	0.7	4.8	7.4	2.6		0.75	8	Yes			Average +	3.2	0.05
Tree 3	0.9	5	7.4	2.4		0.9	9		Yes	Both	Average	4	0
Tree 4	0.8	6	8.3	2.3		0.88	12.5				Good	6.5	0.08
Tree 5	0.9	9.8	9.8	0		1.03	10.4	Yes	Yes		Average	8.8	0.13
Tree 6	0.9	5.2	7.9	2.7		1.05	8.8				Good	3.6	0.15
Tree 7	0.7	5.9	8	2.1		0.8	8.5	Slight					
Tree 8													
Average	0.871428571	6.6714286	8.4	1.7285714		0.951428571	9.742857143					3.07142857	0.08
Family 323													
Tree 1	0.6	3.2	5.3	2.1		1.3	10.5	Yes	Yes		Fair	7.3	0.7
Tree 2	0.7	4.2	7.2	3		0.93	7				Average	2.8	0.23
Tree 3	0.6	7.5	8.5	1		0.5	7.8				Poor	0.3	-0.1
Tree 4	0.2	9.2	10.3	1.1	Dead Terminal	0.67	5				Fair	-4.2	0.47
Tree 5	0.9	5.2	8.2	3		1.05	6.8				Average	1.6	0.15
Tree 6	0.9	5.1	7.3	2.2		0.94	8.4	Yes			Average	3.3	0.04
Tree 7	0.6	5	6.3	1.3		0.75	6.3	Yes			Average	1.3	0.15
Tree 8	0.8	4.4	6.8	2.4							Dead		
Average	0.6625	5.475	7.4875	2.0125		0.877142857	7.4					1.77142857	0.23428571

All. Enrichment planting data sheet plot 11

Planted Plots													
Plot 11 Treatment D	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	0.8	5.5	8.9	3.4			7.3				Dead		
Tree 2	0.8	5	7.2	2.2		0.75	9				Fair+	2.3	-0.05
Tree 3	0.8	5.2	8.3	3.1		0.8	8.5				Average-	3.3	0
Tree 4	1	6.2	9.2	3		0.87	9				Fair-	2.8	-0.13
Tree 5	0.9	6.9	8.2	1.3		0.99	8.2				average	1.3	0.09
Tree 6	0.7	4.8	5.2	0.4	Dead Terminal Bud	0.69	5.5			Both	Average	0.7	-0.01
Tree 7	1.2	6.3	6.7	0.4	Dead Terminal Bud						Dead		
Tree 8													
Average	0.885714286	5.7	7.671428571	1.971428571		0.82	7.7					2.08	-0.02
Family 200													
Tree 1	0.8	8.2	8.7	0.5		0.91	8.9			Both	Good	0.7	0.11
Tree 2	1	8.8	9.7	0.9		1.05	10				Good	1.2	0.05
Tree 3	0.8	6.9	8.9	2	Terminal Bud Chewed						Missing Bria		
Tree 4	1	7.8	10.2	2.4							Missing Bria		
Tree 5	1	5	7.8	2.8							Missing Bria		
Tree 6	0.7	4.3	7.8	3.5		0.82	7.2				Average +	2.9	0.12
Tree 7	0.9	8.9	10.6	1.7		1.04	11.3				Good	2.4	0.14
Tree 8	0.8	6.2	6.8	0.6		0.72	8.3				Good	2.1	-0.08
Average	0.875	7.0125	8.8125	1.8		0.908	9.14					1.86	0.068
Family 323													
Tree 1	0.7	3.9	6.2	2.3							Dead		
Tree 2	0.7	4.2	6.1	1.9		0.67	5.7				Average	1.5	-0.03
Tree 3	1.3	8.2	10	1.8	Dead Terminal Bud	1.42	10.5				Good	2.3	0.12
Tree 4	1	5.9	7.3	1.4		0.93	7.6				Average+	1.7	-0.07
Tree 5	0.8	5.9	8.2	2.3		0.81	7.8				Fair+	1.9	0.01
Tree 6	0.9	5.4	8.4	3		1	8.8	Yes			Average	3.4	0.1
Tree 7	0.8	2.5	5.8	3.3		1.06	7				Good	4.5	0.26
Tree 8													
Average	0.885714286	5.1428571	7.428571429	2.285714286		0.9816666	7.9					2.55	0.065
Family 2459													
Tree 1	1	5.9	8.1	2.2		0.85	8.7				Good	2.8	-0.15
Tree 2	0.8	5.6	6.1	0.5		0.87	6.9	Yes			Good	1.3	0.07
Tree 3	0.7	5.2	6.8	1.6	Dead Terminal Bud	0.67	6.5			Both	Average	1.3	-0.03
Tree 4	0.8	6.1	7.1	1	Dead Terminal Bud	0.9	7.5			Both	Good	1.4	0.1
Tree 5	0.7	5.2	5.2	0		0.67	5.7				Average	0.5	-0.03
Tree 6	0.6	3.8	5.8	2		0.65	5.9	Yes			Average	2.1	0.05
Tree 7	0.8	5	5.8	0.8		0.83	6.5				Average+	1.5	0.03
Tree 8	0.6	5.2	5.8	0.6		0.61	5.6	Heavy			Poor	0.4	0.01
Average	0.75	5.25	6.3375	1.0875		0.75625	6.6625					1.4125	0.0625

A12. Enrichment planting data sheet plot 12

Planted Plots													
Plot 12 Treatment B	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	1	4.2	5.1	0.9	Chewed						Dead		
Tree 2	1.1	7.3	7.3	0		1.07	8.4				Good	1.1	-0.03
Tree 3	0.9	8.1	10.3	2.2		0.97	5.6	Yes			Average	-2.5	0.07
Tree 4	0.7	6.1	6.1	0	Dead Terminal Bud	0.62	5.6				Fair	-0.5	-0.08
Tree 5	1.2	6.9	7.4	0.5							Dead		
Tree 6	0.8	7.2	8.2	1		0.68	7.9	Yes			Average	0.7	-0.12
Tree 7	0.8	6.1	7.1	1		0.64	7.2	Yes			Average	1.1	-0.16
Tree 8	1	5.9	7.2	1.3		0.61	7.4				Fair	1.5	-0.39
Average	0.9375	6.475	7.3375	0.8625		0.765	7.01666666					0.2333	-0.1183333
Family 2459													
Tree 1	0.7	5.2	5.9	0.7							Dead		
Tree 2	0.6	4.1	5.3	1.2		0.42	5.6				Poor	1.5	-0.18
Tree 3	0.8	6.9	7.2	0.3		0.53	7.4				Poor	0.5	-0.27
Tree 4	0.8	5.8	6.9	1.1		0.71	6.9				Poor	1.1	-0.09
Tree 5	1.3	5.3	6.2	0.9	Chewed						Dead		
Tree 6	0.9	4.2	5.3	1.1		0.77	6.4				Average	2.2	-0.13
Tree 7	0.8	4.3	5.3	1		0.56	5.9				Poor	1.6	-0.24
Tree 8	1	5.8	7.2	1.4							Dead		
Average	0.8625	5.2	6.1625	0.9625		0.598	6.44					1.38	-0.182
Family 728													
Tree 1	4.7	7.2	7.2	0		4.7	9.6				Average	2.4	0
Tree 2	0.9	5.3	6.3	1	Chewed	0.62	7			LBD	Average	1.7	-0.28
Tree 3	0.8	5.6	6.8	1.2		0.62	7.3	Heavy			Fair	1.7	-0.18
Tree 4	0.7	5.3	7.1	1.8							Dead		
Tree 5	0.8	5.8	5.2	-0.6		0.69	8.6		Yes		Fair	2.8	-0.11
Tree 6	0.9	5.3	8.1	2.8		0.66	8.8		Yes		Fair	3.5	-0.24
Tree 7	0.9	4.2	5.9	1.7		0.61	6.7		Yes		Average	2.5	-0.29
Tree 8	0.7	5.9	6.8	0.9		0.45	6.8				Average	0.9	-0.25
Average	1.3	5.575	6.675	1.1		1.192857143	7.828571429					2.21428571	-0.19285714
Family 200													
Tree 1	1	8.9	10	1.1		0.91	11	Yes			Average	2.1	-0.09
Tree 2	0.9	5.3	6.2	0.9		0.82	6.7	Yes			Fair	1.4	-0.08
Tree 3	1.1	6.8	7.2	0.4		0.88	7.6				Fair	0.8	-0.22
Tree 4	0.8	6	7.9	1.9		0.8	8.1		Yes		Average	2.1	0
Tree 5	1.1	8.2	9	0.8	Chewed	1.02	10.3				Average	2.1	-0.08
Tree 6	1.1	7.2	7.2	0		1.06	7.9			Both	Good	0.7	-0.04
Tree 7	1.1	7.2	7.6	0.4							Dead		
Tree 8	1.3	8.3	9.2	0.9		1.22	10.2				Good	1.9	-0.08
Average	1.05	7.2375	8.0375	0.8		0.958571429	8.828571429					1.58571429	-0.08428571

A13. Enrichment planting data sheet plot 13

Planted Plots													
Plot 13 Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	0.9	9.8	10.2	0.4		1.08	10.4	Yes			Average	0.6	0.18
Tree 2	0.9	8.3	8.8	0.5		0.91	9.2	Yes			Average+	0.9	0.01
Tree 3	1.2	7.8	8.9	1.1		1.11	9.5	Heavy		LBD	Fair	1.7	-0.09
Tree 4	0.9	7	9.2	2.2		1	10.1				Average	3.1	0.1
Tree 5	0.8	5.9	6.1	0.2	Chewed	0.88	6.5	Slight			Average	0.6	0.08
Tree 6	1.1	11.2	11.9	0.7		1.31	12.7				Average	1.5	0.21
Tree 7	0.9	8.1	9.6	1.5		1	10				Poor	1.9	0.1
Tree 8	0.7	6.9	6.9	0		0.66	7.3				Fair	0.4	-0.04
Average	0.925	8.125	8.95	0.825		0.99375	9.4625					1.3375	0.06875
Family 323													
Tree 1	1	12	12.9	0.9		1.17	13.3	Yes	Yes		Average	1.3	0.17
Tree 2	0.9	5.8	7.1	1.3	Chewed	1.06	7.2				Average+	1.4	0.16
Tree 3	1	9.2	9.2	0	Chewed	1.33	10			LBD	Good	0.8	0.33
Tree 4	0.9	7	7	0		1.02	7.2	ee			Average	0.2	0.12
Tree 5	1	7.8	9	1.2		0.95	9.5	Yes			Poor	1.7	-0.05
Tree 6	0.6	5.3	5.9	0.6		0.65	7.2				Good	1.9	0.05
Tree 7													
Tree 8													
Average	0.9	7.85	8.51666	0.6666		1.03	9.06666					1.21666	0.13
Family 913													
Tree 1	1	8.3	8.8	0.5		1.07	9.2	Heavy			Average	0.9	0.07
Tree 2	0.6	6.5	6.8	0.3	Chewed	0.72	6.7			LBD	Good	0.2	0.12
Tree 3	0.6	5.2	6.7	1.5							Dead		
Tree 4	0.6	5	6.3	1.3		0.86	7.2		Yes		Good	2.2	0.26
Tree 5	0.8	6	8.4	2.4		0.81	8.9	Yes			Average	2.9	0.01
Tree 6	0.6	4.8	5.3	0.5	Chewed	0.86	5.1	Heavy			Fair	0.3	0.26
Tree 7	0.5	4.4	6.3	1.9		0.62	6.5	Yes			Fair+	2.1	0.12
Tree 8	0.6	4.5	5.2	0.7		0.73	5.3	Yes	Yes		Fair	0.8	0.13
Average	0.6625	5.5875	6.725	1.1375		0.81	6.98571426					1.342857	0.138571429
Family 2459													
Tree 1	0.9	7.2	7.6	0.4		0.91	7.6	Slight	Yes		Average	0.4	0.01
Tree 2	0.4	4.7	5.1	0.4		0.45	5.4				Poor	0.7	0.05
Tree 3	0.8	5.9	6.4	0.5		0.82	7.3	Yes			Average	1.4	0.02
Tree 4	0.7	3	5	2		0.68	5				Average	2	-0.02
Tree 5	0.6	5.9	7.3	1.4		0.69	7	Yes			Average+	1.1	0.09
Tree 6	0.8	5.2	6.2	1		0.96	7	Yes	Yes		Average	1.8	0.16
Tree 7	0.5	4.3	6	1.7		0.54	5.9	Yes			Average+	1.6	0.04
Tree 8	0.8	7.2	7.2	0	Chewed	0.87	8				Average	0.8	0.07
Average	0.6875	5.425	6.35	0.925		0.74	6.65					1.225	0.0525

A14. Enrichment planting data sheet plot 14

Planted Plots													
Plot 14 Treatment C	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 728													
Tree 1	1.3	8.2	9.1	0.9		1.21	11.2	Yes			Good	3	-0.09
Tree 2	0.9	6.9	8.1	1.2		0.85	9.3	Yes			Good	2.4	-0.05
Tree 3	1.1	7.3	11.8	4.5		1.11	12	Yes			Average	4.7	0.01
Tree 4	1.1	8.7	8.9	0.2		1.02	10.5	Yes			Average	1.8	-0.08
Tree 5	0.8	6.3	7.3	1		0.85	8.5				Good	2.2	0.05
Tree 6	1.1	6.1	8.2	2.1		0.92	7				Average	0.9	-0.18
Tree 7	0.9	7.8	8.1	0.3		0.88	10.6				Good	2.8	-0.02
Tree 8	0.9	5.2	8.3	3.1		0.7	8.4	Yes			Good	3.2	6.1
Average	1.0125	7.0625	8.725	1.6625		1.73	9.6875					2.625	0.7175
Family 200													
Tree 1	1.1	7.4	7.7	0.3		0.96	8.8	Yes			Average	1.4	-0.14
Tree 2	0.8	9		-0.9	Eaten	0.9	9	Yes			Average	8.1	0.1
Tree 3	1	8.2	8.9	0.7							Dead		
Tree 4	0.8	5.9	6.3	0.4	Dead Terminal	1.1	10.9			Both	Good	5	0.3
Tree 5	1	7.2	10.3	3.1	Dead Terminal	1.31	8.2			Both	Good	1	0.31
Tree 6	1	7.9	9.8	1.9		0.97	8.8				Average	0.9	-0.03
Tree 7	1	9.8	10.2	0.4		0.98	11	Yes			Average	1.2	-0.02
Tree 8	0.8	9.2	9.8	0.6		0.89	10.1	Yes			Good	0.9	0.09
Average	0.9375	7.0625	9	1.9375		1.01571428	9.542857143					2.642857	0.087142857
Family 913													
Tree 1	1.3	10.9	10.9	0	Dead Terminal	1.35	12.4	Slight		Both	Average	1.5	0.05
Tree 2	0.8	4.3	4.3	0		0.72	7.5	Heavy			Fair	3.2	-0.08
Tree 3	1.1	9.1	10	0.9	Terminal Bud	1.15	9.3			Both	Average	0.2	0.05
Tree 4	0.6	5.2	5.4	0.2	Chewed	0.55	5.9			LBD	Average	0.7	-0.05
Tree 5	0.9	5.9	6.3	0.4	Dead Terminal	0.89	7			Both	Good	1.1	-0.01
Tree 6	1	9.8	9.8	0	Dead Terminal	1.06	9.7			Both	Average	-0.1	0.06
Tree 7	1.1	5.3	5.3	0	Chewed	1.21	9				Good	3.7	0.11
Tree 8	0.9	5.9	8.2	2.3		1.02	7.4	Yes			Average	1.5	0.12
Average	0.9625	7.05	7.525	0.475		0.99375	8.525					1.475	0.03125
Family 2459													
Tree 1	0.8	3.9	5.4	1.5									
Tree 2	0.6	5.1	6.3	1.2		0.76	10.2	Slight			Average	5.1	0.16
Tree 3	0.7	6	7.3	1.3		0.67	7.3	Yes			Average	1.3	-0.03
Tree 4	0.9	4.9	6.1	1.2		0.92	7			LBD	Average	2.1	0.02
Tree 5	0.8	5.1	5.1	0	Chewed	0.61	5.7	Heavy			Fair	0.6	-0.19
Tree 6	0.6	4.9	5.1	0.2	Chewed	0.72	8	Slight			Good	3.1	0.12
Tree 7	0.5	4.2	5.3	1.1		0.58	5.2	Yes			Average	1	0.08
Tree 8	0.9	5	6	1		0.7	5.2			Both	Poor	0.2	-0.2
Average	0.725	4.8875	5.825	0.9375		0.708571429	6.942857					1.9142857	-0.00571429

A15. Enrichment planting data sheet plot 15

Planted Plots													
Plot 15 Treatment D	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 2459													
Tree 1	0.9	6	6	0	Dead Terminal Bud	0.84	6.8			LBD	Poor		
Tree 2	0.7	6	6.8	0.8							Dead		
Tree 3	0.8	6.2	7.1	0.9	Dead Terminal Bud	0.68	7			LBD	Average		
Tree 4	0.7	6.2	7.8	1.6		0.62	8				Poor		
Tree 5	0.7	6.2	6.9	0.7		0.44	7				Poor		
Tree 6	1.2	7.8	8.3	0.5		1.32	8.6				Average		
Tree 7	1	6	7.1	1.1		0.92	8.4				Average		
Tree 8	0.6	5.1	5.8	0.7				Yes			Dead		
Average	0.825	6.1875	6.975	0.7875		0.803333	7.6333						
Family 913													
Tree 1	1.2	7.1	9.1	2		1.34	12.9				Good	0.8	-0.06
Tree 2	1	5.6	7	1.4		0.97	7.5				Good		
Tree 3	0.8	6.3	6.9	0.6		0.95	7				Average	0.8	-0.12
Tree 4	0.8	7.8	8.3	0.5		0.78	8.4	Yes			Average	1.8	-0.08
Tree 5	1.1	8.9	8.9	0	Chewed	1.36	9				Good	0.8	-0.26
Tree 6	1	7	7.8	0.8							Dead	0.8	0.12
Tree 7	0.8	5.8	5.8	0	Dead Terminal Bud	0.69	5.7			LBD	Average	2.4	-0.08
Tree 8	0.6	3.2	5	1.8		0.56	4.8				Poor		
Average	0.9125	6.4625	7.35	0.8875		0.95	7.9					1.23333	-0.08
Family 728													
Tree 1	0.5	8.2	8.2	0	Dead Terminal Bud						Dead	5.8	0.14
Tree 2	1.1	7.7	7.7	0	Dead Terminal Bud	0.91	7.7			LBD	Average	1.9	-0.03
Tree 3	1	6.1	6.9	0.8	Dead Terminal Bud						Dead	0.7	0.15
Tree 4	0.9	6.2	6.2	0	Eaten						Dead	0.6	-0.02
Tree 5	1.3	8.2	9	0.8		0.82	6.2				Poor	0.1	0.26
Tree 6	0.9	6.1	7.9	1.8	Dead Terminal Bud	0.88	8.9			LBD	Good		
Tree 7					Dead						Dead	-0.1	-0.11
Tree 8	1.2	7.8	8.9	1.1							Dead	1.6	-0.04
Average	0.98571429	7.1857143	7.828571	0.642857		0.87	7.6					1.5142857	0.05
Family 208													
Tree 1	1.3	12.3	13.2	0.9	Dead Terminal Bud	0.72	7.9	Yes			Average	-4.4	-0.58
Tree 2	1.4	8	9	1	Chewed						Dead		
Tree 3	1.1	9	9.9	0.9		0.65	7.3				Poor	-1.7	-0.45
Tree 4	0.8	7.2	10	2.8		0.93	9.8				Good	2.6	0.13
Tree 5	0.8	7.1	8.3	1.2							Dead		
Tree 6	0.8	69	7.8	0.9		0.78	7.9				Poor	1	-0.02
Tree 7	0.8	7.2	8	0.8		1.3	14.5				Good	7.3	0.5
Tree 8	1	6.8	9.9	3.1	Chewed	0.94	9.9				Good	3.1	-0.06
Average	1	8.0625	9.5125	1.45		0.88866	9.55					1.316666	-0.08

A16. Enrichment planting data sheet plot 16

Planted Plots													
Plot 16 Treatment A	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	0.8	7.2	8.8	1.6		0.82	11.1			Both	Good	3.9	0.02
Tree 2	0.7	6.9	8	1.1		0.94	8.4	Slight			Average	1.5	0.24
Tree 3	0.8	7	8.3	1.3		0.66	8.2				Average	1.2	-0.14
Tree 4	0.8	8	8.2	0.2		0.9	8.2				Good	0.2	0.1
Tree 5	1	8.8	8.8	0		0.92	9.3	Yes			Average	0.5	-0.08
Tree 6	1	8.3	11.4	3.1		1.04	12.2	Slight			Average	3.9	0.04
Tree 7	0.8	5.3	6	0.7		0.73	5.5				Good	0.2	-0.07
Tree 8	0.9	8.2	9.7	1.5		0.93	9.4	Heavy		LBD	Average-	1.2	0.03
Average	0.85	7.4625	8.65	1.1875		0.8675	9.0375					1.575	0.0175
Family 728													
Tree 1	1	5	6.4	1.4		0.79	6.4				Good	1.4	-0.21
Tree 2	1.1	5	6.3	1.3		1.25	6.5				Poor	1.5	0.15
Tree 3	0.7	4.9	5.9	1		0.68	6				Average	1.1	-0.02
Tree 4	0.8	5.1	6.8	1.7		0.65	7.6				Average	2.5	-0.15
Tree 5	0.8	5.3	6.3	1		0.7	3.7				Poor	-1.6	-0.1
Tree 6	0.8	5.3	7.4	2.1		0.76	7.8				Good	2.5	-0.04
Tree 7	0.8	5	7.3	2.3							Dead		
Tree 8	0.6	4.2	5.3	1.1		0.55	5				Poor	0.8	-0.05
Average	0.825	4.975	6.4625	1.4875		0.768571429	6.142857143					1.171428571	-0.06
Family 2459													
Tree 1	0.9	7	9.2	2.2		0.96	9.3	Yes			Average	2.3	0.06
Tree 2	1.1	5.9	9	3.1		1.06	9				Good	3.1	-0.04
Tree 3	0.7	5.2	5.2	0	Top Dead	0.74	5.6				Average	0.4	0.04
Tree 4	0.5	5.2	6.3	1.1		0.51	6.3				Average	1.1	0.01
Tree 5	0.5	4.3	4.9	0.6		0.48	4.8				Average	0.5	-0.02
Tree 6	0.6	5	5.9	0.9		0.74	6.5	Slight			Average	1.5	0.14
Tree 7	0.7	3.3	5.2	1.9		0.63	4.9				Average	1.6	-0.07
Tree 8	0.6	5.3	6.3	1		0.47	6.7				Poor	1.4	-0.13
Average	0.7	5.15	6.5	1.35		0.69875	6.6375					1.4875	-0.00125
Family 913													
Tree 1	0.8	6	7.8	1.8		1.06	7.8				Good	1.8	0.26
Tree 2	0.7	7	8.8	1.8		0.61	8.9	Heavy			Fair	1.9	-0.09
Tree 3	0.9	6.9	7.6	0.7		1.17	7.5	Yes			Average	0.6	0.27
Tree 4	1	6.2	7.2	1		1	7.7				Good	1.5	0
Tree 5	1	6	7.8	1.8		1.17	8.5				Good	2.5	0.17
Tree 6	0.9	7.3	7.7	0.4		1.04	7.9				Average	0.6	0.14
Tree 7	0.8	5.3	6.9	1.6		0.79	6.6				Average	1.3	-0.01
Tree 8	0.5	5	5.3	0.3							Dead		
Average	0.825	6.2125	7.3875	1.175		0.977142857	7.842857143					1.457142857	0.105714286

A17. Enrichment planting data sheet plot 17

Planted Plots													
Plot 17 Treatment D	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	1.1	7	11.9	4.9		1.01	12.5	Heavy			Fair	5.5	-0.09
Tree 2	0.7	9	10.9	1.9		1.04	12.2	Heavy			Fair	3.2	0.34
Tree 3	0.9	6.1	9.3	3.2		0.81	9.9		Yes		Average	3.8	-0.09
Tree 4	0.6	5.8	7.2	1.4		0.6	6.9				Average	1.1	0
Tree 5	1	7.2	9.9	2.7		0.66	7.6				Good	0.4	-0.34
Tree 6	0.7	6.1	7	0.9							Dead		
Tree 7	0.6	4.2	6.8	2.6		0.7	8.3				Average	4.1	0.1
Tree 8					Dead	0.57	6.7				Average	6.7	0
Average	0.77125	6.4257142	9	2.5142857		0.77	9.157142857					3.542857	-0.01142857
Family 913													
Tree 1	0.9	7.9	8.3	0.4		0.85	8.5	Slight			Good	0.6	-0.05
Tree 2	0.5	6	7	1		0.67	6.6				Poor	0.6	0.17
Tree 3	1	7.2	7.9	0.7		1.03	8.6				Good	1.4	0.03
Tree 4	0.6	5.9	6.2	0.3							Dead		
Tree 5	0.8	6.8	7	0.2	Chewed	0.75	7.3				Good	0.5	-0.05
Tree 6	1	8	8	0	Chewed	0.93	7.9		LBD		Good	-0.1	-0.07
Tree 7	0.9	9.5	9.5	0		0.94	9.6				Good	0.1	0.04
Tree 8	0.7	4.5	7	2.5							Dead		
Average	0.8	6.975	7.6125	0.6375		0.861666	8.083333					0.516666	0.0116666
Family 728													
Tree 1	0.9	7.3	7.3	0	Dead Terminal	0.89	8			LBD	Good	0.7	-0.01
Tree 2	1	7	7.5	0.5	Chewed	0.91	8.4	Yes		LBD	Average	1.4	-0.09
Tree 3	0.8	6.2	6.2	0		0.75	7	Yes			Average	0.8	-0.05
Tree 4	1	10.6	10.8	0		1	10.9				Good	0.3	0
Tree 5	1	8.9	9.3	0.4		1.21	12.7	Heavy			Fair	3.8	0.21
Tree 6	0.8	6.8	7.8	1		0.78	7.5				Average	0.7	-0.02
Tree 7	1	7.9	8.8	0.9							Dead		
Tree 8	1	6.8	8.8	2		1.08	8.8				Good	2	0.08
Average	0.9375	7.6875	8.2875	0.6		0.945714286	9.042857					1.38571	0.017142857
Family 323													
Tree 1	0.7	3.6	5.8	2.2		0.62	5.8				Average	2.2	-0.08
Tree 2	1.2	6.8	6.8	0	Top Broken	1.2	7.1				Good	0.3	0
Tree 3	1	8.3	9.8	1.5		0.85	9.7	Yes			Average	1.4	-0.15
Tree 4	1.3	6.3	8.2	1.9		1.16	8				Average	1.7	-0.14
Tree 5							5.2						
Tree 6	0.8	3.2	4.3	1.1		0.64	4.3				Poor	1.1	-0.16
Tree 7	0.6	4.9	4.9	0	Eaten	0.74	5.2				Poor	0.3	0.14
Tree 8	1.1	7.3	7.3	0	Eaten	1.14	7.4	Yes			Average	0.1	0.04
Average	0.957142857	5.771428571	6.7285714	0.957142		0.907142857	6.5875					1.0142857	-0.05

A18. Enrichment planting data sheet plot 18

Planted Plots													
Plot 18 Treatment A	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Decimeters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 913													
Tree 1	0.9	6.8	7.2	0.4		0.96	8.2				Average	1.4	0.06
Tree 2	0.8	5.9	6.6	0.7		0.9	7			TBD	Average	1.1	0.1
Tree 3	0.9	6.2	7.3	1.1		0.96	7.2				Average	1	0.06
Tree 4	0.8	6.2	6.2	0	Eaten	1.06	7.4	Yes			Average	1.2	0.26
Tree 5	0.7	6.2	6.2	0	Eaten	0.88	7.2				Average	1	0.18
Tree 6	0.9	7.5	7.9	0.4		0.98	8.8	Slight			Average	1.3	0.08
Tree 7	0.8	5.7	7.2	1.5		0.79	7.2				Average	1.5	-0.1
Tree 8	0.9	8.8	9	0.2		0.9	9.1	Slight			Average	0.3	0
Average	0.8375	6.6625	7.2	0.5375		0.92875	7.7625					1.1	0.09125
Family 200													
Tree 1	0.9	7.8	9.8	2		1.15	15	Heavy			Average	7.2	0.25
Tree 2	0.6	6.8	7.4	0.6		0.72	7.8			TBD	Good	1	0.12
Tree 3	0.8	7.4	7.4	0	Eaten	1.2	8.4				Poor	1	0.4
Tree 4	0.6	5.6	7	1.4		0.68	7.2				Good	1.6	0.08
Tree 5	1	7.9	7.9	0	Eaten	1.06	7.8	Heavy			Fair	-0.1	0.06
Tree 6	0.7	6.9	7.1	0.2		0.89	7.5				Average	0.6	0.19
Tree 7	0.7	6.1	6.8	0.7	Dead Terminal Bud	0.66	7.2				Average	1.1	-0.04
Tree 8	0.9	7.8	7.8	0									
Average	0.775	7.0375	7.65	0.6125		0.9075	8.7					1.77142	0.1514285
Family 728													
Tree 1	0.7	8.1	8.1	0		1.11	9.7				Good	1.6	0.41
Tree 2	0.7	6.5	7.9	1.4		1	8.6				Good	2.1	0.3
Tree 3	0.9	4.8	5	0.2		1.02	6.8				Average	2	0.12
Tree 4	0.6	5.5	6.9	1.4		0.65	7.3				Good	1.8	0.05
Tree 5	0.7	6.1	7.3	1.2		0.5	7.3				Average	1.2	-0.2
Tree 6	0.9	6.1	7.7	1.6		0.7	8				Average	1.9	-0.2
Tree 7	0.9	5	7.9	2.9		1.02	8.2				Average	3.2	0.12
Tree 8	0.8	6.2	8	1.8							Dead		
Average	0.775	6.0375	7.35	1.3125		0.857142	7.985714					1.9714285	0.085714
Family 2459													
Tree 1	0.8	8.1	9.1	1		0.81	9.5				Good	1.4	0.01
Tree 2	0.7	9	10.2	1.2		1.12	12.1	Slight			Good	3.1	0.42
Tree 3	0.9	5.5	6.8	1.3		0.8	7.5				Good	2	-0.1
Tree 4	0.7	5	5	0		0.56	5.1				Average	0.1	-0.14
Tree 5											Dead		
Tree 6	0.9	6.1	7.3	1.2		0.73	6				Poor	-0.1	-0.17
Tree 7	0.7	6	7.8	1.8							Dead		
Tree 8	0.9	7.3	7.3	0		0.96	9				Average	1.7	0.06
Average	0.8	6.714285	7.642857	0.9285714		0.83	8.2					1.36666	0.01333

A19. Enrichment planting data sheet plot 19

Planted Plots													
Plot 19 Treatment C	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 200													
Tree 1	0.7	7.2	8.5	1.3		0.85	9				Average	1.8	0.15
Tree 2	0.7	5.9	7.1	1.2							Dead		
Tree 3	0.9	8.2	8.7	0.5		1	9.3		Yes		Good	1.1	0.1
Tree 4	0.6	7.9	8.2	0.3		0.56	8.4	Yes			Average	0.5	-0.04
Tree 5	0.7	6.2	8.2	2		0.8	8.2				Good	2	0.1
Tree 6	0.8	7.2	8.2	1		0.71	9				Good	1.8	-0.09
Tree 7	0.8	6	8.2	2.2		0.9	10.2				Good	4.2	0.1
Tree 8													
Average	0.74285714	6.94285714	8.157142857	1.2142857		0.803333	9.016666					1.9	0.053333
Family 2459													
Tree 1	0.7	6	6.2	0.2		0.5	6.3				Average	0.3	-0.2
Tree 2	0.8	6	7.3	1.3		1.06	8.3	Blight			Average	2.3	0.26
Tree 3	0.8	6.2	6.9	0.7		0.57	6.5				Good	0.3	-0.23
Tree 4	0.7	4.2	6	1.8		0.55	5.8				Average	1.6	-0.15
Tree 5					Dead						Dead		
Tree 6	0.7	5.6	7.3	1.7		0.78	7.7				Good	2.1	0.08
Tree 7	0.9	6.8	7	0.2		0.8	8.2	Yes			Average	1.4	-0.1
Tree 8	0.8	7	7.7	0.7		0.71	7.9	Yes			Average	0.9	-0.09
Average	0.77142857	5.97142857	6.914285714	0.942857143		0.71	7.242857143					1.27142857	-0.06142857
Family 913													
Tree 1	1.2	9.8	10.2	0.4		1.11	10.1	Yes			Average	0.3	-0.09
Tree 2	1	7	8.5	1.5		1.01	12.7				Good	5.7	0.01
Tree 3	0.7	5.5	5.9	0.4		0.57	5.8				Average	0.3	-0.13
Tree 4	1	7.8	9.2	1.4		0.84	9	Heavy			Poor	1.2	-0.14
Tree 5	0.8	7	7.3	0.3		0.78	7.1	Yes			Average	0.1	-0.02
Tree 6	0.9	7.3	7.9	0.6		0.88	8.4				Good	1.1	-0.02
Tree 7	1	6.8	8.2	1.4		1.01	8.4	Yes			Average	0.9	0.01
Tree 8	0.9	6.4	7.3	0.9	Top Broken	0.81	7.7	Heavy		L&D	Fair	-6.4	-0.09
Average	0.9375	7.2	8.9142857	0.8625		0.87625	8.685714286					0.4	-0.06125
Family 323													
Tree 1	0.7	4.8	5.8	1		0.7	4.9			Both	Average	-0.9	0
Tree 2	0.8	6.4	9	2.6		0.67	8.7				Good	-0.3	-0.13
Tree 3	1	5.2	7.9	2.7		1	8.2	Heavy			Average	0.3	0
Tree 4	0.7	7.3	7.3	0	Baten						Dead		
Tree 5	0.5	3.8	4.3	0.5		0.56	5.2	Heavy			Average	0.9	0.06
Tree 6	0.9	8	9	1		0.85	8.8	Heavy			Average	-0.2	-0.05
Tree 7	0.8	4.2	6.3	2.1		0.78	5.5				Average	-0.8	-0.02
Tree 8	0.7	6.2	9.6	3.4							Dead		
Average	0.7625	5.7375	7.4	1.6625		0.76	6.88333					1.48333	-0.023333

A20. Enrichment planting data sheet plot 20

Planted Plots													
Plot 20 Treatment #	Basal Caliper	Height	First Flush	First Flush		Basal Caliper As	Height As Of	Bug Damage	Black Spots	Terminal Bud Damage	Overall	Total Height	Basal Caliper
	Centimeter	Dekameters	May 8, 95	Growth	Condition	of Sept. 8, 1995	Sept. 8, 1995			Lateral Bud Damage	Condition	Growth	Growth
Family 728													
Tree 1 -	1.2	7.9	9.1	1.2		0.9	6.8				Poor	-3.1	-0.3
Tree 2	0.8	6.8	8.8	2		1.08	9.8			LBD	Average	3	0.28
Tree 3	0.8	6.7	8.8	2.1							Dead		
Tree 4	0.9	5.5	6.8	1.3		1.5	12.2		Yes		Good	6.7	0.6
Tree 5	1.2	8.1	9.4	1.3		0.82	6.2				Poor	-1.9	-0.38
Tree 6	1.1	7.8	7.8	0	Terminal Bud Missing								
Tree 7	1.1	6.8	6.8	0	Top Broken	0.86	8.3		Yes		Fair	1.5	-0.24
Tree 8	1.1	8.9	8.9	0		1.2	8.7				Poor	-0.2	0.1
Average	1.025	7.3125	8.3	0.9875		1.06	8.3333					1	0.01
Family 913													
Tree 1	1	5.4	8.8	3.4		0.88	8				Good	2.6	-0.12
Tree 2	1.1	4.3	8.4	4.1		0.95	8.3		Yes		Good	4	-0.15
Tree 3	1	6.3	9.2	2.9		0.82	8.9		Yes		Average+	2.6	-0.18
Tree 4	1.1	6.2	7.9	1.7		0.7	7	Heavy			Fair	0.8	-0.4
Tree 5	0.8	6	9.3	3.3		0.93	7.2		Slight	LBD	Good	1.2	0.13
Tree 6	1.3	7.3	8.3	1		1.02	9.9			LBD	Good	2.6	-0.28
Tree 7	0.8	4.3	6.3	2		0.75	8.2				Good	3.9	-0.05
Tree 8	0.7	6.9	8.7	1.8		0.87	8.1				Good	1.2	0.17
Average	0.975	5.8375	8.3625	2.525		0.865	8.2					2.3625	-0.11
Family 2459													
Tree 1	0.6	5.2	6	0.8							Dead		
Tree 2	0.7	6	6.9	0.9		1.15	11.6				Poor	5.6	0.45
Tree 3	0.5	5.3	6.3	1		1	7.5				Good	2.2	0.5
Tree 4	0.9	6.2	6.9	0.7	Dead Terminal Bud	0.99	9.4				Good	3.2	0.09
Tree 5	0.5	5	6.2	1.2							Dead		
Tree 6	0.8	7	7	0							Dead		
Tree 7	0.8	7.9	7.9	0							Dead		
Tree 8	0.6	5.3	5.9	0.6							Dead		
Average	0.675	5.9875	6.6375	0.65		1.046666	9.5					3.66666	0.346666
Family 208													
Tree 1	0.7	5.2	9	3.8		1.15	8.3				Good	3.1	0.45
Tree 2	0.7	7.4	8	0.6	Eaten	0.94	7.3		Yes		Good	-0.1	0.24
Tree 3	0.9	6.9	6.9	0	Top Dead	1.2	10.5			LBD	Good	3.6	0.3
Tree 4	1.3	6.9	10	3.1		0.9	9.2		Yes		Good	2.3	-0.4
Tree 5	0.7	10	10.9	0.9	Looked Poor	0.96	7.3				Average+	-2.7	0.26
Tree 6	1	8.2	9.2	1	Eaten	0.79	7.8	Slight			Good	-0.4	-0.21
Tree 7	0.9	9.2	9.2	0	Eaten	1.06	6.2				Average+	-3	0.16
Tree 8	0.9	7.7	7.7	0	Dead Terminal Bud	0.9	7.3				Good	-0.4	0
Average	0.8875	7.6875	8.8625	1.175		0.9875	7.9875					0.3	0.1

Table B1. Baseline data of the natural plots for the silvicultural clearcut treatments.

Plot 1		Plot 16		Plot 18		Plot 20	
Species	Diameter	Species	Diameter	Species	Diameter	Species	Diameter
	Centimeters		Centimeters		Centimeters		Centimeters
Elm	01.9	Hickory	1.6	Black oak	06.7	Elm	2.1
Elm	22.7	Hickory	2.4	Red oak	11.3	White oak	4.2
Hickory	02.6	Hickory	5.4	White oak	04.7	White oak	2.2
White oak	03.0	Black oak	5.2	White oak	01.9	White oak	8.6
White Oak	10.3	White Oak	2.6	Dogwood	01.0	White oak	2.1
				Dogwood	02.3		
				Hickory	3.6		
				Hickory	2.2		
				Hickory	5.5		
				Hickory	3.9		

Table B2. Baseline data of the natural plots for the liberation cleaning treatments.

Plot 3		Plot 6		Plot 8		Plot 12	
Species	Diameter	Species	Diameter	Species	Diameter	Species	Diameter
	Centimeters		Centimeters		Centimeters		Centimeters
Hickory	1.8	Black oak	13.0	White oak	9.5	Elm	1.6
Hickory	5.4	White oak	05.9	White oak	6.8	White oak	8.1
Hickory	4.8	Blackgum	02.9	Hickory	6.4	White oak	9.1
Elm	5.9	Hickory	04.1	Hickory	3.5	Hickory	2.7
Dogwood	2.2	Hickory	04.4	Hickory	5.9	Hickory	3.4
Dogwood	3.7	Hickory	03.1	Hickory	2.0	Hickory	1.8
		Hickory	02.9	Hickory	5.7		
		Hickory	03.9	Hickory	2.9		

Table B3. Baseline data of the natural plots for the liberation cleaning with oak coppice treatments.

Plot 9		Plot 10		Plot 14		Plot 19	
Species	Diameter Centimeters	Species	Diameter Centimeters	Species	Diameter Centimeters	Species	Diameter Centimeters
Elm	8.4	Hickory	2.3	Elm	02.2	Hickory	03.2
Elm	5.3	Hickory	7.5	Hickory	03.2	Hickory	16.0
Elm	2.9	Hickory	4.5	Hickory	03.5	Hickory	03.4
Elm	4.7	Hickory	3.8	White oak	13.7	Hickory	01.4
White oak	7.9	Hickory	2.9	White oak	02.9	Hickory	04.6
Hickory	3.4	Hickory	2.7			Hickory	01.6
Hickory	6.8	White oak	4.1			Hickory	08.4
Ash	4.1	White oak	4.2			Hickory	10.9
		Sourwood	7.7			White oak	07.0
		Elm	1.9			White oak	08.5
		Dogwood	2.1			Elm	03.5
		Blackgum	2.8			Elm	08.5

Table B4. Baseline data of the natural plots for the oak coppice treatments.

Plot 4		Plot 11		Plot 15		Plot 17	
Species	Diameter Centimeters	Species	Diameter Centimeters	Species	Diameter Centimeters	Species	Diameter Centimeters
Elm	4.2	White oak	05.6	Dogwood	04.1	Ash	7.6
Elm	1.8	Red Cedar	04.1	Hickory	03.3	Dogwood	3.5
Elm	6.3	Hickory	04.2	Hickory	01.5	Dogwood	3.4
Elm	3.3	Hickory	02.4	Red oak	08.1	Dogwood	2.2
White oak	5.5	Hickory	02.8	Red oak	14.7	Elm	1.2
Blackgum	8.8	Elm	01.7			Elm	1.0
Blackgum	6.8	B. Cherry	10.4			Elm	1.7
						Elm	2.9
						Elm	3.7
						Elm	0.8
						Elm	1.0
						Hickory	1.6
						Hickory	0.9
						Red Cedar	6.7
						Red oak	7.7
						White oak	4.1

Table B5. Baseline data of the natural plots for the commercial clearcut treatments.

Plot 2		Plot 5		Plot 7		Plot 13	
Species	Diameter	Species	Diameter	Species	Diameter	Species	Diameter
	Centimeters		Centimeters		Centimeters		Centimeters
Dogwood	1.5	Hickory	3.3	Black oak	8.3	Dogwood	06.3
Elm	0.9	Hickory	3.2	Blackgum	2.4	Hickory	04.5
Blackgum	3.6	White oak	7.1	Dogwood	6.1	White oak	07.9
Blackgum	4.8			Hickory	3.6	White oak	13.7
Dogwood	3.2			White oak	3.9	White oak	02.5
Dogwood	1.2			Y-Poplar	3.7	White oak	04.4
Dogwood	4.8					White oak	12.9
Dogwood	1.0						
Red maple	2.3						
Sweetgum	2.2						
White oak	7.2						

Table C1. Composition of species expected in the silvicultural clearcut treated plots 1, 6, and 18 years after the treatment.

Species group	Trees per Acre		
	1 year	6 years	18 years
white oak group	400	833	200
red oak group	400	1600	133
hickory group	667	767	0
common persimmon	100	333	33
black cherry	133	567	233
blackgum	100	200	33
American elm	67	33	0
sassafras	0	33	0
flowering dogwood	367	1122	100
eastern redcedar	0	0	0
red mulberry	33	0	0
redbud	100	333	0
red maple	0	0	0

Source: A. Salmon, "Growth of Hardwood Reproduction After Mechanical and or Chemical Release: 19-year Results From Southwestern Tennessee." Master's Thesis in Forestry Management, The University of Tennessee, Knoxville, December 1989.

Table C2. Composition of species expected in the commercial clearcut treated plots 1, 2, 3, 7, and 18 years after treatment.

Species group	Trees per Acre				
	1 year	2 years	3 years	7 years	18 years
white oak group	2033	2133	2333	2233	433
red oak group	1800	1867	1933	1533	267
hickory group	1133	1200	1200	1000	133
common persimmon	0	0	0	0	0
black cherry	33	0	0	0	0
blackgum	67	0	100	33	0
American elm	0	0	0	0	0
sassafras	67	0	33	0	0
Flowering dogwood	867	0	33	0	33
eastern redcedar	0	0	0	0	0
red mulberry	0	0	0	0	0
redbud	0	0	0	0	0
red maple	0	0	0	0	0

Source: A. Salmon, "Growth of Hardwood Reproduction After Mechanical and or Chemical Release: 19-year Results From Southwestern Tennessee." Master's Thesis in Forestry Management, The University of Tennessee, Knoxville, December 1989.

Table C3. Composition of species expected in the liberation treated plots 1, 2, 3, 7, and 18 years after treatment.

Species group	Trees per Acre				
	1 year	2 years	3 years	7 years	18 years
white oak group	3000	2867	2600	2367	433
red oak group	600	567	567	400	167
hickory group	667	600	633	533	67
common persimmon	67	67	33	33	0
black cherry	267	167	233	267	100
blackgum	133	167	100	100	33
American elm	100	33	33	33	0
sassafras	0	0	0	0	0
flowering dogwood	833	733	633	433	33
eastern redcedar	33	33	67	33	0
red mulberry	100	100	100	0	0
redbud	33	0	0	0	0
red maple	67	33	67	33	0

Source: A. Salmon, "Growth of Hardwood Reproduction After Mechanical and or Chemical Release: 19-year Results From Southwestern Tennessee." Master's Thesis in Forestry Management, The University of Tennessee, Knoxville, December 1989.

VITA

Jonathan Lemuel Coltrane was born in Chapel Hill, North Carolina in 1970. He attended high school at Cleveland High School in Cleveland, TN. After graduation in 1989 he attended Birmingham Southern College where he earned a Bachelor of Science degree in Sociology/Biology in 1993. Mr. Coltrane enrolled at The University of Tennessee where he served as a graduate teaching assistant. Mr. Coltrane will earn a major in Forestry in May 1997.

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