Consortium for Accelerated Pine Production Studies (CAPPS) 25 Years of Intensive Loblolly Pine Plantation Management

by

Stephen Matthew Kinane

(Under the direction of Bruce E. Borders)

Abstract

After two and a half decades under the influence of intensive cultural management, the trends and stand dynamics of loblolly pine plantations in the Piedmont and Coastal Plain of Georgia are reported in this study. Annual fertilization, complete competition control, and a combination of the two treatments are applied to understand how loblolly pine plantations develop under lack of nutrition deficits and inter-species competition. Site indices for control treatments ranged from 73 to 93 base age 25 across the nine study sites with maximum mean annual increments in green tons ranging from 6.3 tons/acre/year to 12.0 tons/acre year. Overall treatment maximum mean annual increments reached 15.5 tons/acre/year in the combination treatment on the Waycross - Dry site. The majority of the site maximums for mean annual increment occurred in the combination treatment. Basal area per acre reached a maximum of 252.1 ft^2/acre in the complete competition control treatment on the Dawsonville - Top site at age 25. Maximum total green weight achieved across the sites occurred on the Waycross - Wet site, where at age 23, an average of 275 tons/acre were on site. Productivity was good across all sites regardless of treatment. Coastal Plain sites saw the greatest gains in fertilization treatments throughout the duration of the study due to nutrient limitations. Piedmont sites saw the greatest gains in sites receiving competition control from establishment until crown closure, where fertilization regimes began to have greater gains.

INDEX WORDS: Forest management, silviculture, loblolly pine, plantation forestry, competition control, fertilization

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Chapter 1

Introduction and Literature Review

1.1 Introduction

Increasing pine productivity is an important issue for forest researchers due to current trends in global markets and a dynamic economic landscape that put pressure on timberlands to meet increasing wood products demand. In 1997, the southern United States (US) supplied 58% of the timber for the US and 15.8% of the world's supply (Wear and Greis, 2002). In 2008, the capacity of mills for pulping in the South was approximately 125,000 tons per day, or 73% the US total (Johnson et al., 2011). Georgia was the leading pulpwood producing state, generating almost 9.8 million cords of softwood pulp (Johnson et al., 2011). Forecasters predicted that between 1995 and 2040, United States timber production would increase by one-third, with softwood production increasing by 56% (Wear and Greis, 2002). While net forestland in the south has remained fairly stable since the 1970s, population growth forecast in the South is expected to grow between 40 and 60% by 2060 (Wear and Greis, 2013). To accommodate this increased growth, it is expected that forestland in the South will be reduced by 11-23 million acres (Wear and Greis, 2013). It was also predicted that total area of pine plantations in the US would increase by 67% by 2040 to 54 million acres (Wear and Greis, 2002). As markets have changed throughout time, forest managers must be able to cope with the changing demands by manipulating forest resources. Regulations throughout the world, mainly Europe, require increased use of bioenergy to meet energy production. Forestland in the southern US is helping to meet bioenergy objectives by the production of pellets, manufactured with loblolly pine. With these expected changes, forest managers must be able to maximize loblolly pine growth potential on all acres available for plantation grown timber.

Loblolly pine (*Pinus taeda* L.) is a very important commercial tree species in the southern US. It is a favorable species to manage because it responds well to cultural treatments, produces a variety of products, can grow on a variety of sites, and has a high ease of establishment (Schultz, 1997). Its native range extends from New Jersey to Texas (Figure 1.1). Loblolly pine is the most planted species in the South and a 2002 survey estimated that over 1.1 billion loblolly pine seedlings were planted annually (McKeand et al., 2003). As a species, loblolly pine directly or indirectly is responsible for providing the economy with $30 billion (Schultz, 1997; Fox et al., 2007). The popularity of loblolly pine as a commercial species increased due to government programs in the 1930s that provided nursery and planting operations (Schultz, 1997). Historical growth rates in the southeastern United States are less that 6 tons/acre/year for loblolly pine plantations (Allen et al., 2005). These lower growth rates are a result from landowners' desire to minimize management costs (Allen et al., 2005). Elsewhere in the world, loblolly pine has reached high growth rates due to intensive cultural regimes (Borders and Bailey, 2001). Intensive cultural regimes in the southeastern US can provide plantations that have similar growth rates, compared with some international sites (Borders and Bailey, 2001).

Current loblolly pine intensive management regimes include use of mechanical and chemical site preparation, enhanced genetics, artificial regeneration, fertilization regimes, competition control, density management through thinning, and pruning. These treatments have varying tree and stand responses based on site characteristics and levels of intensity.

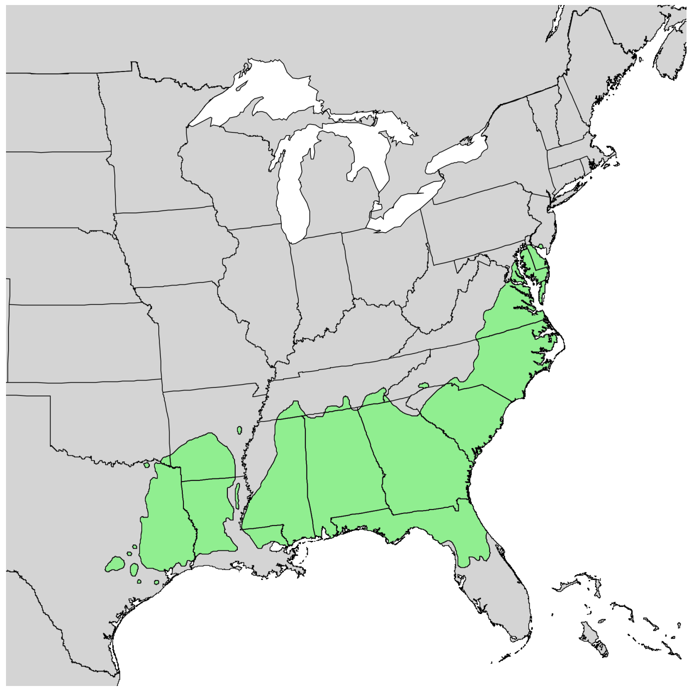


Figure 1.1: Natural distribution of loblolly pine in the United States (Little, 1971)

1.2 Literature Review

Long Term Studies

Several papers have examined long term studies of loblolly pine stand dynamics. Borders and Bailey (2001) looked at the first twelve years of development expressed by three of the sites that this thesis covers. In that study, it was shown that growth rates were higher in treatment plots that received more intensive management. It was also shown that on all but one of their sites, the effects of complete competition control trumped those of annual fertilization (Borders and Bailey, 2001). Another trend reported was that the combination treatment, fertilization plus complete competition control, produced the most basal area, volume, and largest individual tree size (Borders and Bailey, 2001). Jokela and others (2010) conducted a 25 year study of loblolly and slash pines located in north central Florida. Overall, they showed that a combination treatment of fertilization and competition control with use of herbicide produces the most basal area compared with individual treatments of complete competition control or fertilization and a control. Treatments with a fertilization component produced larger average diameters at age 25 (Jokela et al., 2010). Jokela and others (2010) also showed that intensively managed stands had higher rates of fusiform rust infections. When looking at stand development patterns in their study, the most intensively managed treatments reached a peak in basal area earlier than the less intensive treatments (Jokela et al., 2010).

Genetic Improvements

Planting genetically improved seedling stock provides on average a 10-30 % increase in volume over unimproved planting stock (McKeand et al., 2003). Gains due to genetic improvement strategies provide various levels of volume improvement. Planting single genotype clonal families provides the most genetic gain, but comes at the cost of limited genetic diversity (McKeand et al., 2003). Alternatively, bulk mixes of seed orchard seeds may provide the most genetic diversity at the cost of the least genetic gain (McKeand et al., 2003). Genetically improved seedlings were shown to increase the level of the site index curve, providing greater heights for the stand (Buford and Burkhart, 1987; Sabatia and Burkhart, 2013). Sabatia and Burkhart (2013) showed that, while genetic improvements provide greater heights, increases in diameter are not proportional, which may lead to lower basal area growth rates. Genetic improvements of loblolly pine also produced greater resistance to cronartium infection (Schultz, 1997). Loblolly pine genetic improvements have also shown increased sawtimber potential, providing higher value stands (Cumbie et al., 2012). Forking in loblolly pine trees has been shown to be mainly influenced by genetics, which will allow for future improvements to reduce overall rates by proper family selection (Xiong et al., 2010). Research has also shown that wood quality characteristics, such as density, can be used for tree improvement selections (Antony et al., 2014).

Fertilizer Effects

Fertilization is another important component to improving pine productivity potential for a plantation. Most common nutrient deficiencies found the southeastern United States consist of nitrogen and phosphorus (Fox et al., 2007). In 2004, 1.2 million acres of pine plantations were fertilized (Fox et al., 2007). Nutrient limitations on established stands reduce stand productivity by lowering growth efficiency and leaf area development (Fox et al., 2007). Fertilizations are typically performed at stand establishment and/or at mid-rotation. Two common fertilization regimes at plantation establishment are a nitrogen-plus-phosphorus mix and phosphorus alone. Studies have shown that height and diameter were significantly increased by nitrogen and nitrogen-plus-phosphorous fertilization regimes (Gent et al., 1986a; Bolstad and Allen, 1987). A phosphorus-only regime applied at time of planting in a loblolly pine plantation showed significant gains in height and diameter on phosphorous deficient sites (Gent et al., 1986b). Mid-rotation fertilization regimes also provide significant growth benefits (Jokela et al., 2000; Liechty and Fristoe, 2013). Sayer and others (2004) showed that fertilization reduced stem density and increased stand basal area on unthinned sites due to increased rates of stem mortality. A 1990 study showed that fertilization at plantation establishment significantly increased individual tree volume and mean diameter for pines for 11 growing seasons (Haywood and Tiarks, 1990). Late rotation application of fertilizer on certain sites has been shown to increase basal area and volume in lobolly plantations, with the greatest increases occurring on the larger trees (Williams and Farrish, 2000). In terms of stand development, Miller (1981) described the addition of fertilizers as ”...a reduction in rotation length”. Fertilizers increase the rate of stand development by moving fertilized stands along the growth curve at a faster rate than similar stands that do not receive fertilization (Miller, 1981). This response of fertilizers on stand development rates can also be achieved by other appropriate cultural treatments (Oliver et al., 1996).

Competition Control Effects

Herbicides are used to control woody and herbaceous competition in timber plantations. On loblolly pine plantations that have just been established, grasses and other herbaceous competitors are the biggest threat to the crop trees for the first few years due to their high productivity (Haywood and Tiarks, 1990). For plantation establishment, it is important to control these grasses and other herbaceous material through the use of appropriate herbicides. Herbicide regimes have been shown to increase gains in sites compared with those receiving no herbicide treatments (Bacon and Zedaker, 1987; Zutter et al., 1987; Pienaar and Shiver, 1993). One study showed that after four growing seasons, ground-line diameter, height, and volume index were significantly greater for sites receiving first-year herbaceous vegetation control (Knowe et al., 1985). In the same study, a first- and second-year broadcast application of herbaceous vegetation control doubled heights and ground-line diameters of trees compared with the control treatment by age four (Knowe et al., 1985). Sites receiving first-year herbaceous vegetation control had significant positive gains in height and diameter (Creighton et al., 1987; Haywood and Tiarks, 1990). It was demonstrated that an additional second-year herbicide treatment significantly increased heights and diameters in 60 and 70% of treatments, respectively (Creighton et al., 1987). These findings were repeated in the Georgia Piedmont, where competition control provided significant gains in basal area and height (Yin and Sedjo, 2001). Effects of an herbicide treatment also showed increases in stem survival (Creighton et al., 1987; Haywood and Tiarks, 1990). Evidence indicates that herbaceous competition is only problematic for early stand development and that post-crown closure, grasses and herbaceous competitors do not inhibit future stand development because crown closure in a stand will shade them out (Haywood and Tiarks, 1990). Woody competition, mainly hardwoods, is a problem for older stands if it is not controlled early (Haywood and Tiarks, 1990). Competition from waxy leaved shrubs commonly found in the lower Coastal Plain, such as wax myrtle (*Myrica cerifera* L.) and titi (*Cyrilla racemiflora* L.), are very intense competitors that also need to be controlled. Quicke (1996a) showed that in Arkansas, 1 ft^2 of hardwood basal area replaces approximately 3 ft^2 of pine basal area in a ten year old stand. Early hardwood competition control has been shown to provide growth response in basal area, volume, height, and diameter in loblolly pine plantations (Quicke et al., 1996b; South and Miller, 2007). Herbicide applied to control hardwoods in the second growing season showed pine response increases of up to 46% in DBH, 83% in basal area per acre, and 22% in height (Quicke et al., 1996b). Combination treatments of herbaceous and woody control resulted in significant responses of groundline diameter (Bacon and Zedaker, 1987).

While herbicide application at stand establishment has its proven benefits, there are plantations in the southeastern United States that did not receive these treatments. Without proper competition control, hardwood competition in a mid-rotation pine plantation can significantly reduce pine volumes and negatively effect the distribution of pine products (Clason, 1993). Pine plantations receiving total competition control from herbicide-only regimes at mid-rotation have also been shown to have significant pine growth response for a variety of slope sites in the Piedmont and Coastal Plain of Georgia and Alabama (Fortson et al., 1996). Late rotation applications of herbicides on stands greater than 25 years old was not shown to provide any significant responses on certain sites in Louisiana (Williams and Farrish, 2000).

Fertilizer x Competition Control Effects

Other methods for improving pine productivity potential include the combination of fertilization and herbicide treatments. Combination fertilization and herbicide regimes have been shown to produce greater average heights at age 15 compared with herbicide-only or control regimes with no cultural treatments (Borders et al., 2004). The same responses were seen with respect to stand-level basal area (Borders et al., 2004). At five years, heights for pines receiving total herbaceous and woody competition control were 59% greater than pines with no competition control (Miller et al., 1991). Increases in basal area with total competition control produce significant results as well as increases in volume (Miller et al., 1991). Mid-rotation fertilization-herbicide regimes were shown to significantly increase basal area growth (Fortson et al., 1996; Liechty and Fristoe, 2013). Growth responses for an annual fertilization and herbaceous weed control treatment were highly significant for leaf area index and dry matter accumulation in a four year old stand (Colbert et al., 1990). The combination treatment has been shown to significantly increase stem mortality by the third growing season on sites receiving annual fertilization and woody plant control (Haywood and Tiarks, 1990). Late rotation applications of a fertilizer-herbicide treatment were shown to provide significant increases in diameter and volume growth on stands greater than 25 years old (Williams and Farrish, 2000).

Stand Density

Stand density can be described by several variables, such as stand density index (SDI), relative spacing (RS), and basal area per acre (BA). Reineke first defined SDI as a "...method of determining density of stocking in even-aged stands, which has been described, has the advantages of simplicity, freedom from correlation with age and site index, and general applicability" (Reineke, 1933). This method uses an average stand diameter and trees per acre to determine the SDI, or the number of 10 inch diameter trees that can be supported on the site given the current stand conditions. Stand density index allows for comparisons between sites with the same species, which gives a quantitative and "...better visualization of stand conditions" (Reineke, 1933). Since Reineke has reported on this index, it has been used in a variety of applications, such as timber or wildlife management and accessing risk of pests and disease problems (Ducey and Larson, 1997). The original SDI equation has been modified over time to fit different interpretations (Long and Daniel, 1990; Ducey and Larson, 2003). Maximum SDI for loblolly pine was first reported to be 450 (Reineke, 1933). Further studies showed that unthinned loblolly pine plantations in Louisiana have a maximum SDI of 400 (Williams, 1996). Williams (1996) reported that current stand SDI, as a percentage of maximum reported SDI, can be used as a thinning guide to better ensure that density targets are remained, compared with only using basal area. Stages of stand dynamics have been reported to occur at specific percentages of SDI. In loblolly pine plantations, crown closure begins at approximately 25% of maximum SDI, while self-thinning has been reported to begin at approximately 50 to 55% of maximum SDI (Dean and Baldwin, 1993). Optimal density for thinning in loblolly pine plantations was reported to occur at 45% of maximum SDI (Harrington, 2001). Standard look up tables were developed to easily find SDI values for a given basal area and trees per acre (Harrington, 2001).

Relative spacing (RS) is another measure of stand density that has been suggested to indicate stand conditions. RS was defined by Beekhuis (1966) as"...the average distance between trees expressed as a percentage of the predominant mean height of the stand...". RS assumes square spacing and differs from stand density index in that age and site quality are used in its definition (Zhao et al., 2012). Typical RS development exhibits an inverse-J shaped curve (Zhao et al., 2012). It also differs from stand density index because, where a higher stand density index implies a more crowded stand, a higher RS value reflects a stand with lower crowding. Relative spacing values are affected by height growth in the early stages of the stand, due to lower rates of stem mortality, but once crown closure occurs, stem mortality rates and height growth occur at proportional rates, indicating a stabilization of relative spacing (Beekhuis, 1966; Zhao et al., 2012).

Fusiform Rust

Fusiform rust is a disease that affects loblolly pines throughout the Southeast and is caused by the fungus *Cronartium quercuum*f. sp.*fusiforme* (Froelich and Snow, 1986; Quesada et al., 2014). Millions of dollars worth of damage to loblolly pine trees is caused annually by the disease (Cubbage et al., 2000). Fusiform infection occurs on immature shoot and needle tissues and eventually cause cankers and galls at the infection site (Froelich and Snow, 1986). These galls and cankers increase levels of stress in a tree, which can lead to loss of growth, degrade in timber products, or increased stem mortality (Froelich and Snow, 1986). Studies have reported that sites with high growth rates lead to greater infection rates within the stand (Zutter et al., 1987). Many times, these increased growth rates are attributed to cultural treatments, but it is not the treatment that increases infection rates (Zutter et al., 1987; Zhao and Kane, 2012). Increased growth rates provide the fungus with greater area of immature tissues on the trees, which leads to greater infection rates. To prevent, or at least lower, infection rates of loblolly pine plantations, Froelich (1986) developed a site hazard guide for site selection. Sites that had few oaks, which are necessary for the life cycle of the fungus, in the surrounding 800 meters of the site and poorly drained, phosphorus deficient soils are considered to be of "low hazard" for fusiform rust (Froelich and Snow, 1986). Sites that have many oaks within 800 meters, well-drained soils, occurrences of fog during the spring, or near rivers and streams are considered "high hazard" for rust infection (Froelich and Snow, 1986). Other ways to prevent or reduce fusiform infection is to breed loblolly pines for rust resistance qualities (Schultz, 1997; McKeand et al., 1999; Isik et al., 2008).

Physiographic Regions

Two physiographic regions were used in this study, the Piedmont and Coastal Plain. The Piedmont is a physiographic region located between the Coastal Plain and mountains of the eastern United States. Elevations in this region range between 300 and 1200 feet above sea level (Barrett, 1980). The majority of soils in the Piedmont are slightly acidic clay loams or sandy loams (Barrett, 1980). Studies have reported average site indices for cutover, site prepared Piedmont sites to be 62 feet at age 25 (Amateis and Burkhart, 1985). The Coastal Plain physiographic region is located parallel to the coastline of the Atlantic Ocean and Gulf of Mexico and was once under sea level. Sites found in the lower Coastal Plain are flat and tend to be poorly drained (Barrett, 1980). As sites get closer to the Piedmont region, variation in topography increases, as well as elevation and drainage. Elevations in this region reach maximums of approximately 300 feet above sea level. Soils are loamy sands, fine loamy sands, and sandy loams which are typically acidic and suffer from high rates of nutrient leaching, which leads to nutrient deficiencies (Barrett, 1980; Ducey and Allen, 2001). Soils in the Coastal Plain are mainly spodosols and alfisols (Barrett, 1980). Average site indices for the Coastal Plain region have been reported to be 68 at age 25 (Amateis and Burkhart, 1985).

Stages of Stand Development

The four main stages of stand development are: stand initiation, stem exclusion, understory reinitiation, and old growth (Oliver et al., 1996). The four stages are used to describe different patterns and trends seen in a stand during its development. The first stage, stand initiation, occurs after all trees are killed due to a large disturbance. Species that exhibit rapid growth are first to occupy the newly opened space, usually the same species that first occupied the previous stand (Oliver et al., 1996). Typically these species are herbaceous grasses and shrubs, as well as shade intolerant woody species. Once species begin competing for resources, the stem exclusion stage begins (Oliver et al., 1996). Competition is characterized by individual stem mortality or reduced growth rates. As the trees continue to grow, those that cannot reach heights of competitors are shaded out. In single species stands, such as loblolly pine plantations, individual trees begin to grow at varying rates, leading to crown differentiation (Oliver et al., 1996). During crown differentiation, classes are formed that describe individual trees as either, dominant, codominant, intermediate, and suppressed (Oliver et al., 1996). Competition between trees continues to develop as dominant trees, the tallest, begin to overtake the suppressed trees, which eventually die. This mortality of the suppressed trees is the beginning of self thinning (Oliver et al., 1996). The next stage of stand development, understory reinitiation, begins when new species begin to occur on the forest floor, usually when openings in the canopy provide sunlight (Oliver et al., 1996). Once the trees that initiated the stand begin to die and trees that developed during the understory reinitiation stage begin to become a part of the main canopy is when the old growth stage begins. This stage is characterized by having a wide range in vertical structure, tree ages, and tree sizes (Oliver et al., 1996). Due to the age of the stand in which old growth occurs, generally in the hundreds of years, a large scale disturbance, such as fire, is likely to destroy the stand and restart the stages of stand development (Oliver et al., 1996).

Many management activities in commercial pine plantations occur in the stand initiation stage. When managing for timber, treatments such as site preparation, planting, competition control, and fertilization all affect how the stand will development and the rate at which it will occur. Forest managers control species composition in the stand initiation stage through use of planting and competition control (Oliver et al., 1996). The length of this stage is also controlled by foresters, who can shorten the stage length by reducing competition, proper selection of initial densities, and use of fast growing species that will dominate the site (Oliver et al., 1996). Competition that is not controlled and continues to compete with crop trees for the same growing space may result in a mixed species stand (Oliver et al., 1996). Because a stand has a finite amount of resources, planted trees and uncontrolled, naturally regenerated competition are all competing to maximize their individual growing spaces. At some point during the stand's development, all growing space becomes occupied and induced mortality begins. Managers that understand that sites have a defined carrying capacity will use competition control methods to promote the crop trees and remove competing vegetation. In the Piedmont, hardwoods are the main competition for planted pines and waxy hardwoods are the main competition in the Coastal Plain. If not controlled, these species will remain in the stand, displacing crop trees. Foresters can also manage the stem exclusion stage through use of density management. Foresters use thinnings to remove the intermediate and suppressed trees, allowing for the residual trees to increase growth rates. Allowing a stand to reach the stem exclusion stage for an extended amount of time, where competition related stem mortality occurs, may lead to lower growth rates, or even the possibility of stagnation if crown differentiation does not occur (Oliver et al., 1996). Multiple thinnings may be carried out depending on a variety of factors, such as initial density and stand objectives, before a final harvest occurs. Typically in southern pine plantations a complete harvest of all planted trees, a clearcut, is the final management regime that occurs. These usually occur prior to significant understory development. In pine plantations in the southern US, the final two stages, understory reinitiation and old growth, are rarely reached.

1.3 Project Objectives

The objectives of this project are to:

- Determine the effects of cultural treatments on loblolly pine plantations in Piedmont and Coastal Plain sites.
- Improve understanding of site responses to intensive cultural treatments.

Chapter 2

Study

The Consortium for Accelerated Pine Production Studies (CAPPS) was established in 1998 to continue study of sites established as an acid rain study beginning in 1987. The original study was initiated to provide information on the effects of acid rain on loblolly pine plantations. At that time, researchers were drawing conclusions on the effects of acid rain even though there was inadequate information on the growth and mortality rates of these stands. As the original researchers for this project, Borders and Bailey wanted to provide more comprehension of stand and tree growth dynamics, which are very complex and understudied, to better understand how stands developed under certain conditions. They also wanted to see how stands with different growth rates were affected by atmospheric deposition. Once that study concluded, the CAPPS study was developed to take over the original study sites and to continue the treatment application and tree measurement. The CAPPS study lasted until 2005, where the Plantation Management Research Cooperative at the University of Georgia assumed responsibility of the study.

Greater understanding of loblolly pine responses to various cultural treatments and the interaction of those treatments will allow forest managers to increase growth and yield of future stands. As it is predicted that the total amount of forestland will continue to decrease while the demand for forest products will increase, it is important to maximize pine productivity. The objectives of this study are to synthesize the data from the 25 year CAPPS study and report on trends related to all aspects of stand productivity in relation to intensive management regimes.

2.1 Methods

The treatment plots that were established were 3/8 acre in size. The treatment plots were double planted with bare-root loblolly pine seedlings at a planting spacing of 8 feet by 8 feet, for a density of 681 trees per acre. Each site was planted with a single genetic family to reduce genetic variation. Planting spots with two live seedlings had one removed at the end of the first growing season. At each site is a replicated study with a combination (or all) of the following four treatments applied to the 3/8 acre treatment plots:

1. Control (C) - no additional treatments aside from site preparation.

2. Fertilization (F) - included the site specific site preparation method along with a spring-time application of 250 lbs/ac diammonium phosphate (DAP) with 100 lbs/ac potassium chloride (KCl) in growing seasons one and two. A mid-summer application of 50 lbs/ac of ammonium nitrate was applied also in growing seasons one and two. For each subsequent growing season, 150 lbs/ac of ammonium nitrate was applied in early spring. In early spring in growing season 10, 300 lbs/ac of ammonium nitrate with 125 lbs/ac of triple super phosphate was applied. In early spring in growing season 11, 500 lbs/ac Super Rainbow™ (Agrium, 2013) with micro nutrients plus 150 lbs/ac of ammonium nitrate was applied. In growing season 12 and continuing until growing season 25, 300 lbs/ac of ammonium nitrate was applied in early spring.

3. Herbicide (H) - complete vegetation control for the entire length of the study through use of non-soil active herbicides.

4. Fertilization and herbicide (HF)- combination of the fertilization (F) and herbicide (H) treatments.

Two complete blocks were originally planned to be established at each site, with each one on a distinct site type. In each replicated block, two or four treatment groups were applied, depending on the size of the block. Treatment plots were also replicated over time. These time replicates were established at each site to reduce the effects of any seasonal anomalies that may interfere with the study of stand dynamics. This method allows for the averaging of the treatments at the same age but in different years to reduce yearly effects an allows for greater understanding of stand dynamics. Year of establishment and number of blocks for each location can be seen in Table 2.3. At each time replicate, all four treatments were installed unless noted. Initial planting densities for all sites was 681 trees per acre. All trees planted were improved 1-0 loblolly pine seedlings from the Bellville, Georgia Union Camp Corporation nursery (Borders and Bailey, 2001). Genetic families were sourced from the North Carolina State University Tree Improvement Cooperative. The families used were 7-56 and 10-25. The 7-56 family was a first generation selection out of Williamsburg County, South Carolina. Known for having good stem straightness, and being an overall good grower, the 7-56 family also above average rust resistance (S.E. McKeand, personal communication, July 6, 2014). Under intensive culture, the 7-56 family does have incidence of forking. The 10-25 family was a first generation selection from Chatham County, Georgia. It was tested on sites in the Coastal Plain and has average growth and rust resistance (S.E. McKeand, personal communication, July 6, 2014). The 10-25 family was reported to have below average straightness. All sites were established on cutover forestland.

Within each treatment plot, a 1/8 ac measurement plot was used for data collection. Within these measurement plots, all trees were tagged and measured. Annual measurements for every tree included diameter at breast height (DBH) and presence of cronartium infection. Every third tree was measured for total height. Measurements were repeated annually until the 20^{th} growing season, after which measurements were taken every two years until the 25^{th} growing season.

At each site, treatments were averaged at the time replicate level to look at trends in trees per acre, basal area, dominant height, quadratic mean diameter, total green weight, total pulpwood weight, total chip-n-saw weight, total sawtimber weight, mean annual increment, stand density index, relative spacing, and cronartium infection rates. SAS 9.4 software (SAS

Institute, Cary NC), was used for all analysis in this study. The analysis of variance (ANOVA) structure can be seen in Table 2.1, and all references to significance throughout the rest of the paper is at the $\alpha = .05$ level. Comparisons between ages, treatments, and time replicates that do not indicate significance are not necessarily insignificant, only the trends are being observed.

Table 2.1: ANOVA structure used in analysis for a single site/time replicate.

Source	Degrees of Freedom
Block (B)	1
Herbicide (H)	1
Fertilization (F)	1
H x F	1
Error	3
Total	7

Throughout the analysis, tree descriptions falling into the pulpwood category include trees with diameters between 4.6 to 8.5 inches, chip-n-saw between 8.6 and 12.5 inches, and sawtimber greater than 12.5 inches. The following equations were used to calculate total total green weight (TGW), pulpwood green weight (PULP), chip-n-saw green weight (CNS), and sawtimber green weight (SAW) with coefficients based on location seen in Table 2.2 (Pienaar et al., 1996):

$$TGW = \beta_0 \cdot DBH^{\beta_1} \cdot HT^{\beta_2}$$

$$PULP = TGW - \beta_3 \cdot (2^{\beta_4}/DBH^{\beta_5}) \cdot (HT - 4.5)$$

$$CNS = TGW - \beta_3 \cdot (6^{\beta 4}/DBH^{\beta_5}) \cdot (HT - 4.5)$$

$$SAW = TGW - \beta_3 \cdot (8^{\beta 4}/DBH^{\beta_5}) \cdot (HT - 4.5)$$

Where:

DBH = diameter at breast height (inch), HT = total height (feet)

Table 2.2: Coefficients used for total and product green weight equations for lower Coastal Plain (LCP), upper Coastal Plain (UCP), and Piedmont sites (PIE).

	β_0	β_1	β_2	β_3	β_4	β_5
LCP	0.0740959	1.829983	1.247669	0.123329	3.523107	1.449947
UCP	0.141534	1.917146	1.038452	0.0932063	3.589155	1.413061
PIE	0.110069	1.935455	1.080621	0.0775771	3.439954	1.178473

The CAPPS study has nine study sites located in six different geographic areas, see Figure 2.1. Two study sites each are located near Dawsonville, Eatonton, and Waycross, Georgia. Locations that have one study site are located near Athens, Tifton, and Thompson, Georgia.

The Athens site is located in the Piedmont of Georgia, on the Warnell School of Forestry and Natural Resources' Whitehall Forest in Clarke and Oconee Counties. This site had a total of four blocks installed to account for two time replicates. Slopes on this site are less that 20% and the predominant soil series is Pacolet. Blocks 3 and 4 on this site, which were more level, were located on Cecil series. Mechanical site preparation included a shear, rake, pile, and disc. Half-sib family 10-25 was planted. Blocks 1 and 2 were established in 1989 with all four treatments (C, F, H, HF). Blocks 3 and 4 were established in 1993 with only two treatment plots each, C and H. The oldest time replicate, 1989, had final measurements taken after the 23rd growing season and the 1993 time replicate had final measurements after the 20th growing season.

The Dawsonville - Top and Bottom sites are located in Dawson County, Georgia. These sites are in the foothills, in between the Piedmont and Blue Ridge physiographic regions. The Bottom site treatment blocks are located in the floodplain of the Etowah River. The Congaree series are found on blocks 1 and 2 of the Bottom site and the Starr series is found on blocks 3 and 4 of the Bottom site. Both of these series are considered moderately well drained to well drained. The Top site was primarily located on hillsides, with some have slopes greater than 25%. These sites have predominantly Hayesville series soils. Loblolly pine family 10-25 was established on the sites. The Bottom and Top sites each had a total of four blocks installed. Each block on the Bottom site had all four treatments. The Top site had only the C and H treatments installed. For both sites, blocks 1 and 2 where established in 1987 and blocks 3 and 4 were established in 1989. The 1987 time replicates on both sites had final measurements after the 25th growing season and the 1989 time replicates had final measurements after the 23rd growing season.

The Eatonton sites are located in the Piedmont of Georgia (Putnam County) on Warnell School of Forest Resources' B.F. Grant Memorial Forest. The slopes on these sites are less than 15%, Cecil is the predominant soil series on the Powerline site. The Monitor site, located on more sloping terrain, is associated with Pacolet and Appling soils, which are well-drained. This site was prepared with a shear, rake, pile, and disc operation (Borders et al., 2001). Seedlings from the the 10-25 family were planted on both sites. This site exhibited erosion issues on several plots. Both sites, Powerline and Monitor, had five blocks installed. The Monitor and Powerline sites both had blocks 1 and 2 installed in 1988 with all four treatments in each block. Blocks 3 and 4 on each site were established in the 1990 growing season, also with all four treatments on each block. Block 5 in each site was established in 1995 with all four treatments. Final measurements occurred on the 1988 time replicate after the 25th growing season, after the 23rd growing season on the 1990 time replicate, and after the 18th growing season on the 1995 time replicate.

The Thompson site is located in the upper Coastal Plain of Georgia in McDuffie County. The slopes on site are less than 10% and the soil series found on most of the site is Wagram. Loblolly pine family 7-56 was planted on site. There were a total of six blocks installed. Each block had the C and H treatments. Blocks 1 and 2 were established in 1988, blocks 3 and 4 were established in 1990, and blocks 5 and 6 were established in 1995. Final measurements for the 1988 time replicate were taken after the 18th growing season, after the 16th growing season on the 1990 time replicate, and after the 11th growing season on the 1995 time replicate.

The Tifton site is located in the upper Coastal Plain of Georgia in Tift County on the University of Georgia Agricultural Experiment Station, near Tifton, Georgia. Slopes on the site are less than 5%. A total of four blocks were installed on the Tifton site. The Pelham soil series was predominantly found on blocks 1 and 3. Blocks 2 and 4 were predominantly Tifton soil series. Site preparation included a shear-rake operation and planting rows were bedded. Loblolly pine family 7-56 was planted. Blocks 1 and 2 had all four treatments established in 1988. Blocks 3 and 4 were both installed in 1990 and only have C and H treatments. Final measurements were taken after the 25^{th} growing season in the 1988 time replicate and after the 23^{rd} growing season in the 1990 time replicate.

Waycross Wet and Dry sites are located in the lower Coastal Plain of Georgia (Ware County) on Dixon Memorial Forest, managed by the Georgia Forestry Commission. The Dry site is composed primarily of Bonifay soils and is well to moderately well-drained. Pelham soils are predominate on the Wet site and it is classified as poorly to somewhat poorly drained. The Wet and Dry sites both have slopes less that 1%. The previously forested, now cutover, sites were mechanically site prepared with a shear-rake operation and planting rows were bedded. Loblolly pine family 7-56 was planted on site. The Wet and Dry sites both had six blocks installed, each having all four treatments applied. Blocks 1 and 2 on both sites were established in 1987, blocks 3 and 4 were established in 1989, and blocks 5 and 6 were established in 1993. Final measurements were taken after the 25^{th}, 23^{rd}, and 20^{th} growing seasons for the 1987, 1989, and 1993 time replicates, respectively.

Table 2.3: Attributes of the CAPPS study sites.

Site	Physiographic Location	County	Soil Classification	Genetics	Treatments	Time Replicates (Number of Blocks)
Athens	Piedmont	Clarke	Pacolet/Cecil	10-25	C,H,F,HF	1989(2), 1993(2)
Eatonton - Monitor	Piedmont	Putnam	Pacolet/Appling	10-25	C,H,F,HF	1988(2), 1990(2), 1995(1)
Eatonton - Powerline	Piedmont	Putnam	Cecil	10-25	C,H,F,HF	1988(2), 1990(2), 1995(1)
Dawsonville - Bottom	Foothills	Dawson	Congaree/Starr	10-25	C,H,F,HF	1987(2), 1989(2)
Dawsonville - Top	Foothills	Dawson	Hayesville	10-25	C,H	1987(2), 1989(2)
Thompson	Upper Coastal Plain	McDuffie	Wagram	7-56	C,H	1988(2), 1990(2), 1995(1)
Tifton	Upper Coastal Plain	Tift	Pelham/Tifton	7-56	C,H,F,HF	1988(2), 1990(2)
Waycross - Dry	Lower Coastal Plain	Ware	Bonifay/Pacolet	7-56	C,H,F,HF	1987(2), 1989(2), 1993(2)
Waycross - Wet	Lower Coastal Plain	Ware	Pelham	7-56	C,H,F,HF	1987(2), 1989(2), 1993(2)

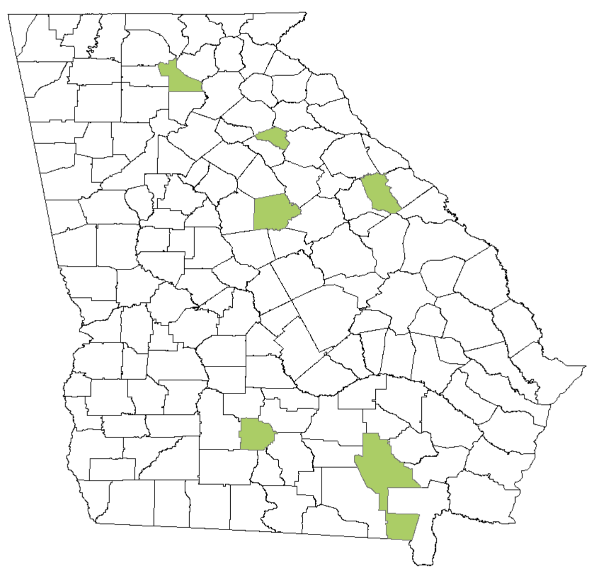


Figure 2.1: County locations of the CAPPS study sites in Georgia.

Chapter 3

Results

3.1 Athens

The Athens site had one treatment plot removed due to an insect infestation. The F treatment in block 2, which is part of the 1989 time replicate was removed after the 18th growing season. It should be noted that after this plot was removed, the F treatment development in this time replicate was based off of only one plot for the remainder of the study.

Inherent site quality is very good on the Athens site. Site quality can be measured by base site index of the C treatment, which shows approximately 80 feet at age 23 on the 1989 time replicate, and is expected to be higher at base age 25 (Table 3.1). The 1993 time replicate shows slightly lower implied site index values (Table 3.1). Until age 13, HF and H treatments on the 1989 time replicate followed similar trajectories, until the H treatment slowed down (Figure 3.1). As the stand continued to develop, the H treatment fell in line with the development of the F and C treatments, ending the study at 79.8, 80.0, and 80.9 feet, respectively (Table 3.1). Treatments receiving vegetation control (HF and H) had significantly greater dominant height than those not receiving vegetation control until age 18. By the 21st growing season, the F treatment surpassed the H treatment and the 23rd growing season saw the C treatment also surpass the H treatment.

The Athens site showed basal area per acre (BA) develop most quickly on HF and H treatments (Table 3.2; Figure 3.2). The H treatment on the 1989 time replicate eventually catches up and surpasses the HF treatment following a BA crash after the 18th growing season (Table 3.2; Figure 3.2). Another BA crash is seen in the F treatment at the same time. While the 1993 time replicate did not have HF and F treatments, comparisons can be made between the C and H treatments. The 1993 time replicate saw greater differences between the two treatments, with almost a 40 ft^2/acre H advantage over the C treatment at the end of the study, compared with a $\sim 15^2$/acre difference in the 1989 time replicate (Table 3.2). Also of note is that on the 1993 time replicate, the C and H treatments are approaching an upper asymptote at the end of the study while on the 1989 time replicate, they are continuing to increase, even with two extra years of growth.

Stand density index (SDI) development is consistent with BA development for all treatments in both time replicates (Tables 3.2, 3.3). As BA increases over time for the treatments, so does the SDI. In treatments that experience a crash in BA, SDI also reflects the crash (Figures 3.2 and 3.3). The HF and F treatments on the 1989 treatment, which both experience BA crashes, reached maximum SDI values of 386 and 306 at ages 14 and 18, respectively (Table 3.3). The C and H treatments both have continually increasing SDI values on the 1989 time replicate, reaching 392 and 414, respectively. SDI values for the C and H treatments for the 1993 time replicate reflect the slight decline in BA experienced at age 20. Prior to this decline, SDI values reached the maximums of 366 and 444 for the C and H treatments, respectively, at age 19.

Relative spacing (RS) reached minimum values of .12 on the C, H, and HF treatments and .16 on the F treatment for the 1989 time replicate (Table 3.4; Figure 3.4). The F treatment did not reach the lower values, indicating a higher density and height relationship, like those reached on the other treatments because even though it faced a BA crash (a large mortality event) like the HF treatment, it did not experience the height advantage expressed by the HF treatment. In this case, higher mortality and a lower average dominant height lead to a lower density rating.

Trees per acre development showed similar trends in the C, H, and HF treatments until the HF treatment experienced its BA crash in the 1989 time replicate (Table 3.5; Figure 3.5). In this time replicate, the F treatment starts at a lower age 5 density, but still follows the same trajectory as the other treatments until its crash after year 15. One interesting note is that the H and C treatments in the 1993 time replicate had much lower overall stem mortality throughout the study compared with the same treatments in the 1989 time replicate. While stem mortality was high for the HF and F treatments, this is only a result of the high basal area levels that occurred on the site.

Total green tons per acre (GT) development patterns follow similarly to BA development patterns (Table 3.6; Figure 3.6). Within the time frame of the study, GT continued to increase, except for the stands which suffered BA crashes, where GT also experienced a similar crash. Because they did not suffer a large mortality event, the maximum GT for the H and C treatments occurred at the end of the study. The maximum GT for the C treatments were 197.5 (age 23) and 147.9 (age 20) tons/acre for the 1989 and 1993 time replicates, respectively (Table 3.6). H treatment maximum GTs were 208.1 and 195.6 tons/acre for the two time replicates. The HF treatment reached a maximum of 184.8 tons/acre at age 18, just before crashing in the 1989 time replicate. The F treatment reached a maximum of 132.6 tons/acre at age 18, just before crashing in the 1989 time replicate. Both treatments' GT crashes were not as severe as the BA crashes, which could be due to the larger trees not being affected by stem mortality. It is interesting to see that 5 years after their crashes, both the HF and F treatments have regained enough GT to be within approximately 10 tons/acre of the maximum values reached (Table 3.6). Mean annual increment (MAI) of GT shows the C treatment maximized at 8.6 and 7.7 tons/acre/year for the 1989 and 1993 time replicates at or near the the oldest age measurement (Table 3.7; Figures 3.7, 3.8). The H treatment saw maximum MAI at 9.5 and 10.1 tons/acre/year for the 1989 and 1993 time replicates. MAI reached its maximum at the 17 year mark for the H treatment on the 1989 time replicate and at the 19 year mark for the 1993 time replicate. The F treatment reached its maximum, 7.4 tons/acre/year, at the 17 and 18 year mark on the 1989 time replicate (Table 3.7). The highest MAI value was reached on the HF treatment, with 10.7 tons/acre/year at the 14 year mark. For treatments that experienced a BA crash, the greatest MAI values occurred very close to the time of that crash.

Quadratic mean diameter (DQ) development continuous increases for all treatments except for the F treatment in the 1989 time (Table 3.8; Figure 3.9). DQ showed a slight decrease in the F treatment on the 19th year, which corresponds with the BA crash that occurred. This decline in DQ does not occur on the HF treatment, which also had a BA crash, suggesting that the F treatment had higher mortality in the larger trees while the HF treatment mortality was concentrated in the smaller trees. The sites that experienced a BA crash saw higher DQ development from age 13 to the end of the study (Table 3.8, Figure 3.9). The remaining treatments saw the highest DQ values at the oldest age measurement, once again reflecting that stem mortality that occurs in the smaller diameter trees. Initial DQ development saw the H treatment progress similarly to the HF treatment until age 10 (Figure 3.9). After age 10, the H treatment development slowed and converged with the C treatment towards the end of the study.

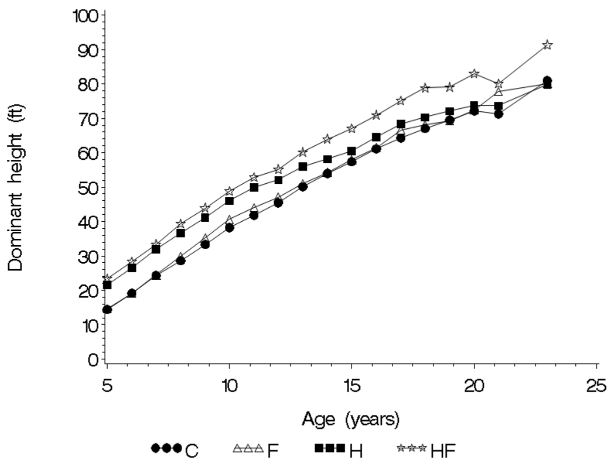
Product development shows pulpwood on site in the HF, H, and F treatments at age 5 (Table 3.9). Both time replicates saw pulpwood begin to develop at age 6 for the C treatment. Pulpwood rates peak earliest on the sites receiving competition control, with the H treatment peaking in age 13 and the HF treatment peaking at age 14 for the 1989 time replicate(3.9). An interesting note is that at the time of these peaks, these treatments have greater average dominant heights than the C and F treatments (Tables 3.9, 3.1). Chip-n-saw developed first on the HF treatment, starting at age 8 on the 1989 time replicate (Table 3.10). The F and H treatments both had chip-n-saw first develop at age 9, followed by the C treatment at age 11. The 1993 time replicate saw a slightly different development pattern with the C treatment first having chip-n-saw at age 10, followed by the H treatment at age 11 (Table 3.10). Chip-n-saw development peaks in the HF and F treatments at age 18 on both treatments in the 1989 time replicate. This peak and subsequent reduction of chip-n-saw on these sites corresponds with the BA crash that also occurred between ages 18 and 19 on these treatments (Tables 3.10, 3.2). C and H treatments on both time replicates continued to increase their chip-n-saw rates as the study progressed, having their highest amounts at the end of the study.

The HF treatment had the greatest chip-n-saw production among all of the treatments, which corresponds with higher average DQ and dominant height (Tables 3.8, 3.1). Sawtimber development started first in the HF treatment, at age 18, followed by the F treatment at age 19 (Table 3.11). Both C and H treatments in the 1989 time replicates began sawtimber development at the last measurement age, 23. It is interesting to see that sawtimber developed after the crash, showing that the larger trees were not affected by the BA crashes in the HF and F treatments.

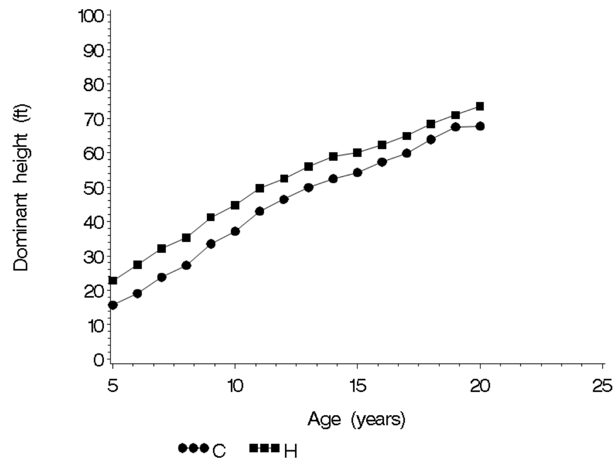
Cronartium infection rates were greatest in the first ten years of development for the treatments that exhibited the fastest development. On this site, the HF and H treatments had the greater development in the time period for MAI, BA, TGW, dominant height, and SDI (Tables 3.12). These higher growth rates, not necessarily treatments, lead to higher rates of cronartium infection on the sites due to the greater amount of immature tissue on the trees, which is the main site of infection. The H treatment saw higher average infection rates on the 1993 time replicate, which also had greater MAI values through the study (Tables 3.12, 3.7). The 1989 C treatment showed greater infection rates throughout the duration of the study compared with the 1993 time replicate (Table 3.12, Figure 3.11). MAI values were similar between the 1989 and 1993 C treatments for the first 14 years, suggesting that the higher cronartium infection rates are due to climatic differences between the two planting years that favor the infection (Table 3.7).

Table 3.1: Average dominant height (feet) development at the Athens site by time replicate.

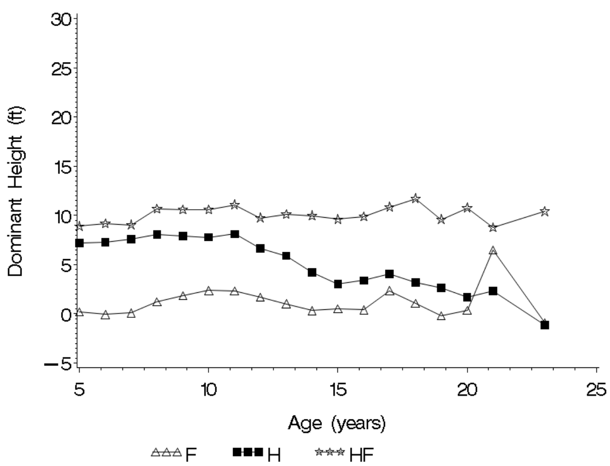
	1989				1993	
Age	C	F	H	HF	C	H
5	14.4	14.6	21.6	23.3	15.6	22.8
6	19.2	19.1	26.5	28.4	19.1	27.4
7	24.3	24.4	31.9	33.4	23.7	32.1
8	28.7	29.9	36.7	39.3	27.3	35.3
9	33.3	35.2	41.2	43.9	33.5	41.2
10	38.2	40.6	46.0	48.8	37.2	44.8
11	41.8	44.1	49.9	52.8	43.0	49.7
12	45.4	47.1	52.1	55.1	46.4	52.5
13	50.1	51.1	56.0	60.2	49.9	56.0
14	54.0	54.3	58.1	63.9	52.4	58.9
15	57.4	57.9	60.4	67.0	54.3	60.0
16	61.1	61.5	64.5	70.9	57.3	62.4
17	64.2	66.6	68.3	75.1	59.9	64.9
18	67.1	68.2	70.3	78.8	63.9	68.3
19	69.4	69.3	72.1	79.0	67.5	71.0
20	72.1	72.5	73.8	82.9	67.8	73.5
21	71.3	77.8	73.6	80.1	.	.
23	80.9	80.0	79.8	91.3	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993

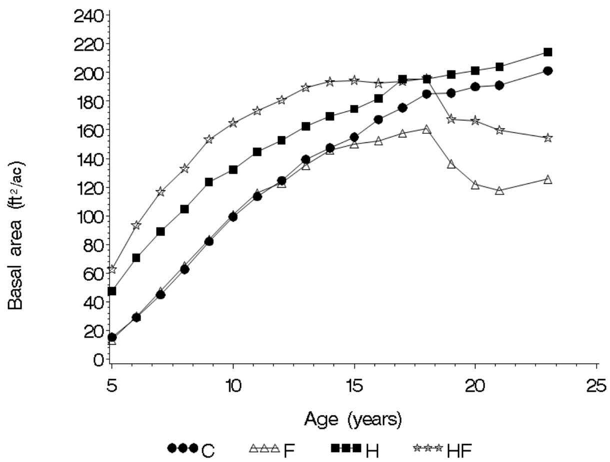


(c) 1989 Treatment Effects

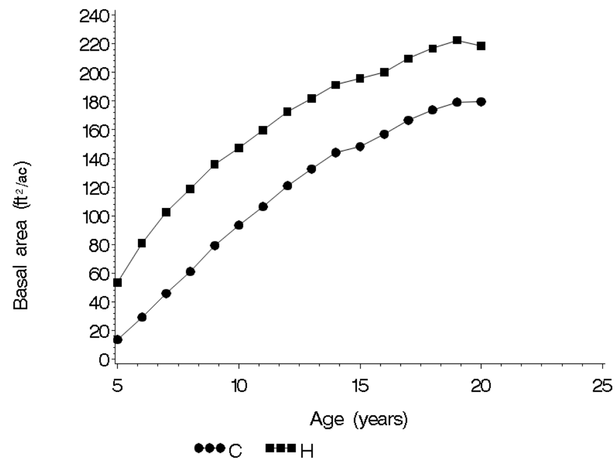
Figure 3.1: Average dominant height (feet) over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.1(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.2: Average basal area (ft^2/acre) at the Athens site by time replicate.

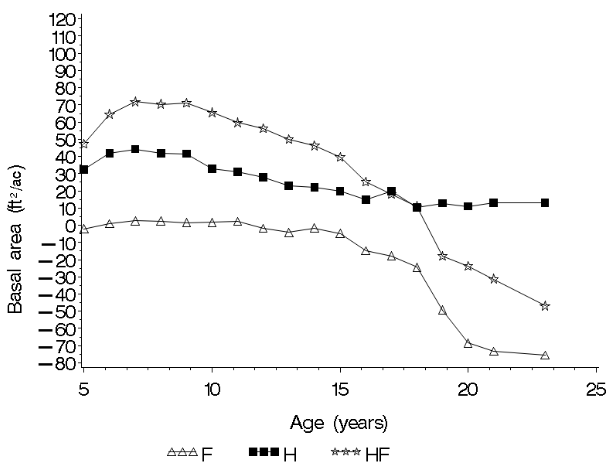
	1989				1993	
Age	C	F	H	HF	C	H
5	15.3	13.3	47.6	62.6	13.7	53.6
6	28.9	29.8	70.7	93.4	29.2	80.9
7	44.9	47.5	89.2	116.7	45.7	102.5
8	62.6	65.0	104.5	133.0	61.1	118.8
9	82.1	83.7	123.7	153.1	79.2	135.9
10	99.3	100.9	132.3	164.8	93.4	147.5
11	113.5	115.8	144.7	173.1	106.6	159.8
12	124.5	122.8	152.6	180.8	121.1	172.9
13	139.4	135.2	162.3	189.4	132.5	181.8
14	147.3	145.7	169.4	193.5	144.1	191.3
15	154.8	150.1	174.5	194.5	148.3	195.8
16	167.1	152.3	182.0	192.4	156.8	200.2
17	175.4	157.6	195.4	193.6	166.6	209.6
18	184.9	160.5	195.3	195.9	173.9	216.7
19	185.6	136.3	198.4	167.5	179.4	222.6
20	190.2	121.7	201.2	166.4	179.4	218.6
21	191.0	117.7	204.1	159.8	.	.
23	201.1	125.5	214.4	154.2	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993

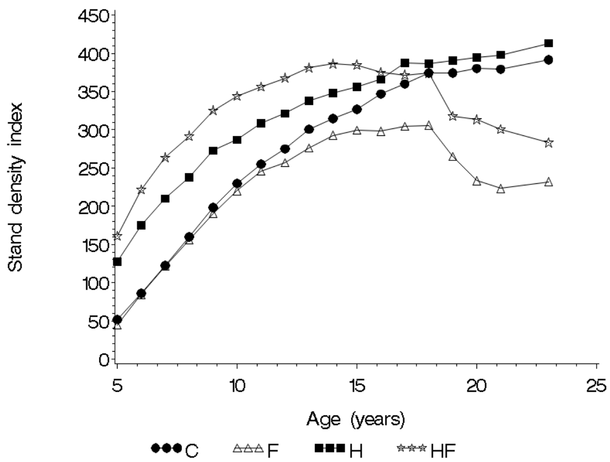


(c) 1989 Treatment Effects

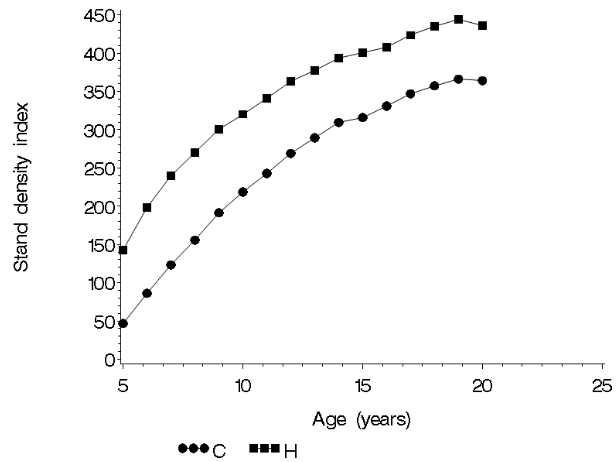
Figure 3.2: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Athens site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.3: Average stand density index development at the Athens site by time replicate.

	1989				1993	
Age	C	F	H	HF	C	H
5	51.8	44.3	127.2	160.7	46.8	142.5
6	85.9	84.5	174.7	221.3	86.1	198.3
7	122.4	121.8	209.9	263.6	123.2	239.6
8	159.8	155.8	238.1	291.6	155.3	269.9
9	198.4	190.5	272.7	325.2	191.4	300.6
10	230.0	220.3	286.9	343.7	218.5	320.2
11	255.4	245.6	308.3	356.0	242.8	341.1
12	274.8	257.1	321.3	367.6	269.0	363.2
13	300.9	276.2	337.6	381.0	289.3	377.7
14	314.5	292.8	348.4	386.0	309.4	393.6
15	326.9	299.3	355.8	384.7	316.1	401.0
16	346.6	298.1	365.8	374.9	330.7	408.1
17	359.8	304.6	387.2	371.6	346.6	423.5
18	374.4	305.8	386.5	373.9	357.3	434.9
19	374.3	264.9	390.2	317.6	365.8	444.3
20	380.2	233.3	394.7	313.2	363.9	435.7
21	379.2	223.2	398.0	300.3	.	.
23	391.6	232.1	413.2	282.9	.	.
25	.	.	.	.	.	.



(a) 1989

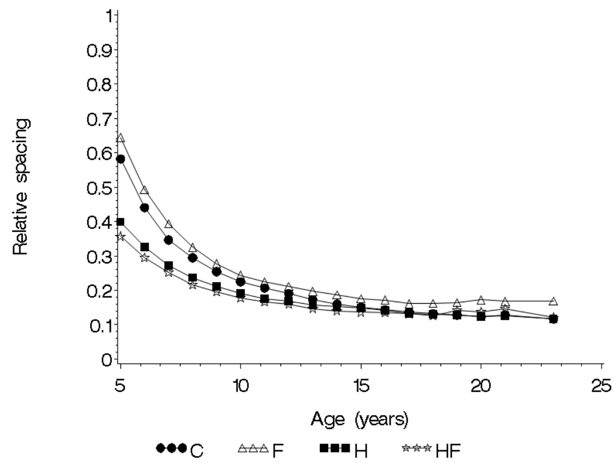


(b) 1993

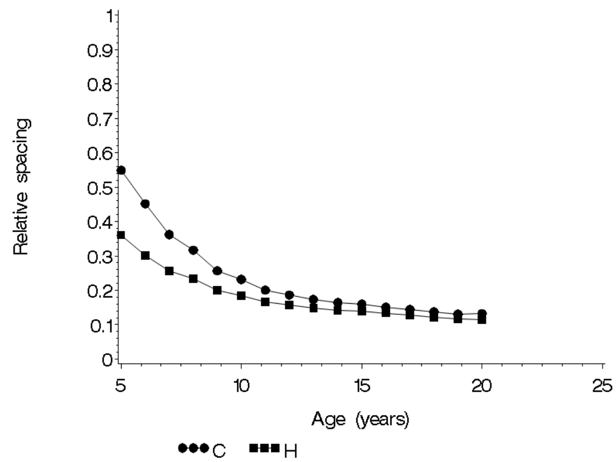
Figure 3.3: Average stand density index over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.3(a)-(b).

Table 3.4: Average relative spacing development at the Athens site by time replicate.

	1989				1993	
Age	C	F	H	HF	C	H
5	0.58	0.64	0.40	0.36	0.55	0.36
6	0.44	0.49	0.33	0.29	0.45	0.30
7	0.35	0.39	0.27	0.25	0.36	0.26
8	0.29	0.33	0.24	0.22	0.32	0.23
9	0.25	0.28	0.21	0.20	0.26	0.20
10	0.22	0.24	0.19	0.18	0.23	0.18
11	0.21	0.23	0.18	0.17	0.20	0.17
12	0.19	0.21	0.17	0.16	0.19	0.16
13	0.17	0.20	0.16	0.15	0.17	0.15
14	0.16	0.19	0.15	0.14	0.16	0.14
15	0.15	0.18	0.15	0.14	0.16	0.14
16	0.14	0.17	0.14	0.13	0.15	0.13
17	0.14	0.16	0.13	0.13	0.14	0.13
18	0.13	0.16	0.13	0.13	0.14	0.12
19	0.13	0.16	0.13	0.14	0.13	0.12
20	0.12	0.17	0.12	0.14	0.13	0.11
21	0.13	0.17	0.13	0.15	.	.
23	0.12	0.17	0.12	0.12	.	.
25	.	.	.	.	.	.



(a) 1989

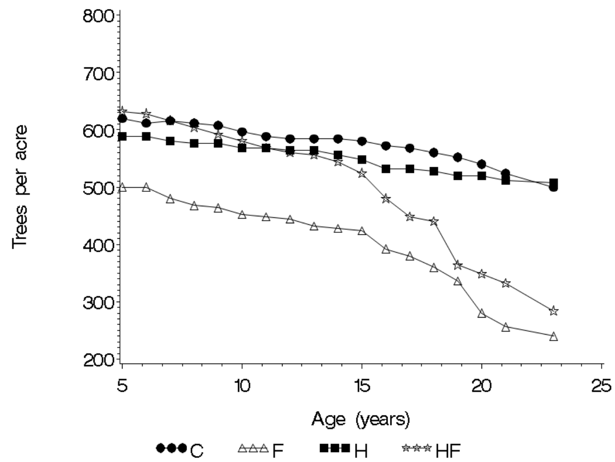


(b) 1993

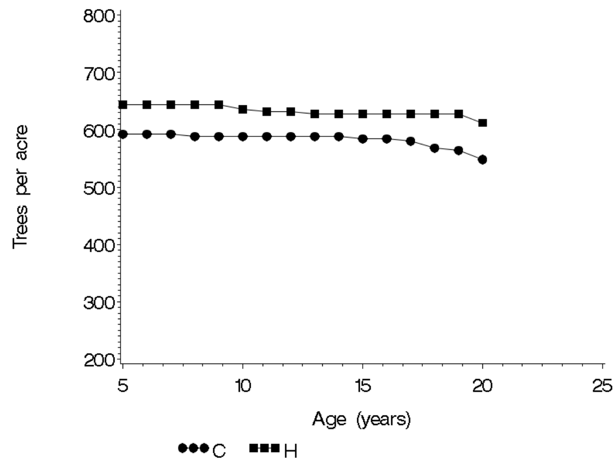
Figure 3.4: Average relative spacing development over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.4(a)-(b).

Table 3.5: Average trees per acre development at the Athens site by time replicate.

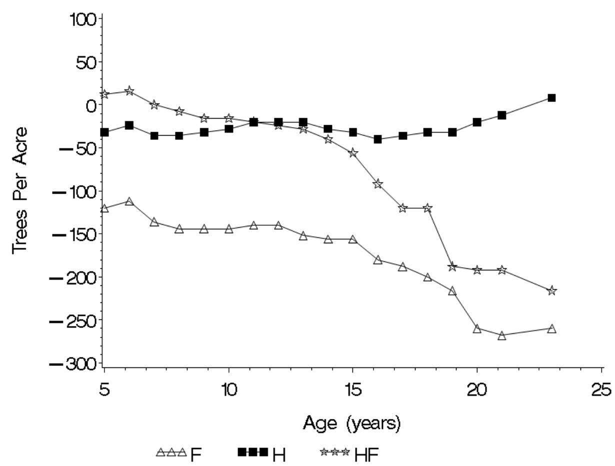
	1989				1993	
Age	C	F	H	HF	C	H
5	620	500	588	632	592	644
6	612	500	588	628	592	644
7	616	480	580	616	592	644
8	612	468	576	604	588	644
9	608	464	576	592	588	644
10	596	452	568	580	588	636
11	588	448	568	568	588	632
12	584	444	564	560	588	632
13	584	432	564	556	588	628
14	584	428	556	544	588	628
15	580	424	548	524	584	628
16	572	392	532	480	584	628
17	568	380	532	448	580	628
18	560	360	528	440	568	628
19	552	336	520	364	564	628
20	540	280	520	348	548	612
21	524	256	512	332	.	.
23	500	240	508	284	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993

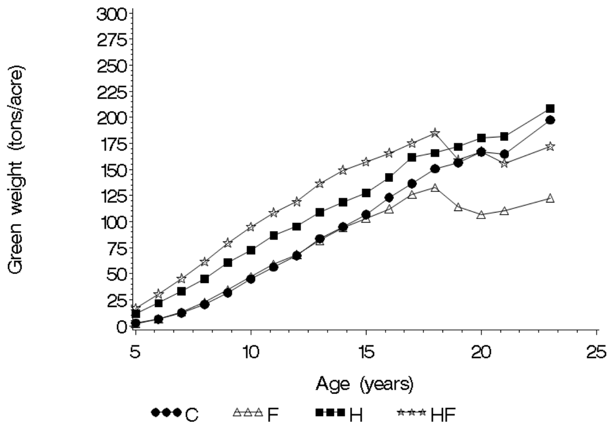


(c) 1989 Treatment Effects

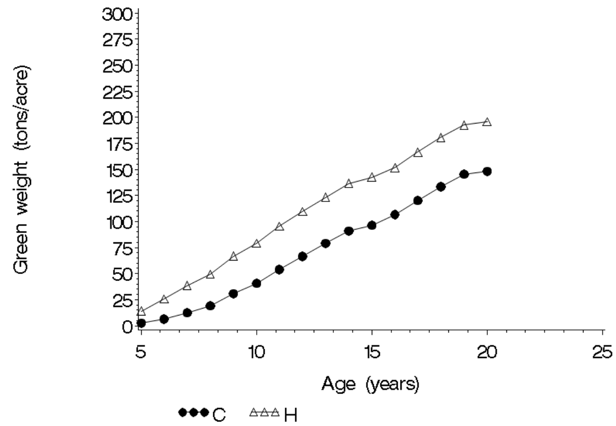
Figure 3.5: Average trees per acre development over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.5(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.6: Average total green weight (tons/acre) development at the Athens site by time replicate.

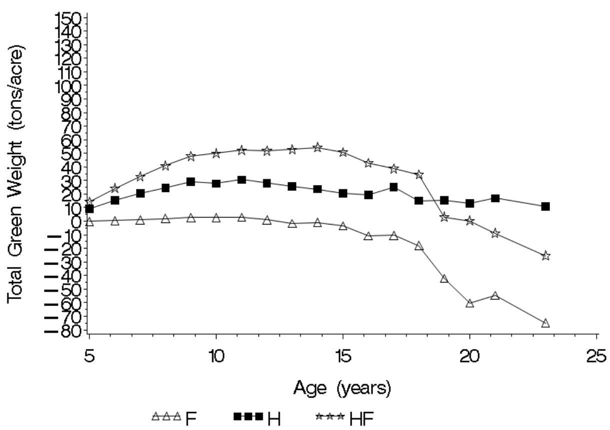
	1989				1993	
Age	C	F	H	HF	C	H
5	2.4	2.2	11.6	16.6	2.4	14.1
6	6.2	6.5	21.6	30.3	6.3	25.8
7	12.3	13.2	33.0	45.1	12.5	38.5
8	20.5	22.4	45.1	61.3	19.3	49.5
9	31.6	34.2	60.6	79.3	30.7	66.9
10	44.6	47.3	72.2	94.5	40.8	79.1
11	56.2	59.0	86.7	108.4	54.0	95.5
12	67.3	68.2	95.2	118.9	66.5	109.5
13	83.5	81.9	108.9	136.2	78.9	123.2
14	95.0	94.0	118.5	149.2	90.9	136.7
15	106.6	103.2	127.2	157.2	96.3	142.5
16	123.0	112.1	142.2	165.6	106.6	151.6
17	136.4	125.9	161.6	174.9	120.1	166.4
18	150.6	132.6	165.6	184.8	133.4	180.6
19	156.0	113.9	171.6	159.1	145.6	192.5
20	166.7	106.5	179.9	167.0	147.9	195.6
21	164.8	110.1	181.6	155.9	.	.
23	197.5	122.5	208.1	172.0	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993

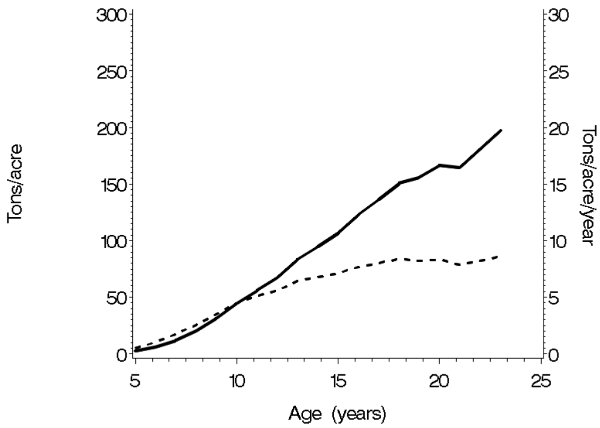


(c) 1989 Treatment Effects

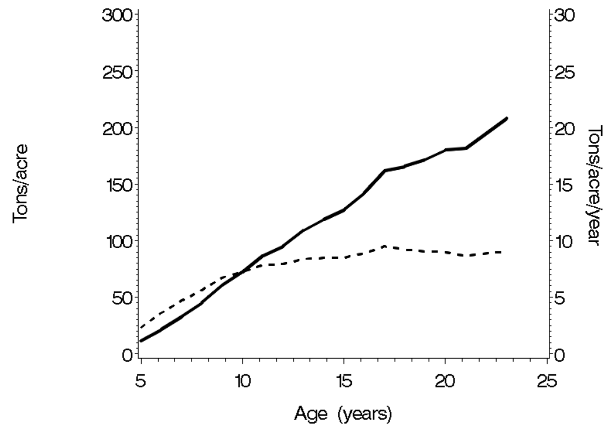
Figure 3.6: Average total green weight weight (tons/acre) over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.6(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.7: Mean annual increment (tons/acre/year) development at the Athens site by time replicate.

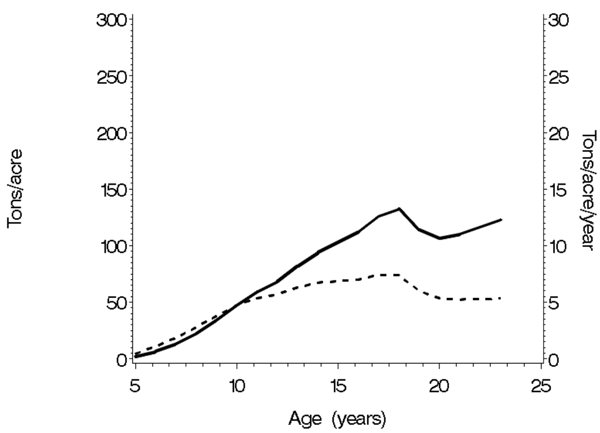
	1989				1993	
Age	C	F	H	HF	C	H
5	0.5	0.4	2.3	3.3	0.5	2.8
6	1.0	1.1	3.6	5.1	1.1	4.3
7	1.8	1.9	4.7	6.5	1.8	5.5
8	2.6	2.8	5.6	7.7	2.4	6.2
9	3.5	3.8	6.7	8.8	3.4	7.4
10	4.5	4.7	7.2	9.5	4.1	7.9
11	5.1	5.4	7.9	9.9	4.9	8.7
12	5.6	5.7	7.9	9.9	5.5	9.1
13	6.4	6.3	8.4	10.5	6.1	9.5
14	6.8	6.7	8.5	10.7	6.5	9.8
15	7.1	6.9	8.5	10.5	6.4	9.5
16	7.7	7.0	8.9	10.4	6.7	9.5
17	8.0	7.4	9.5	10.3	7.1	9.8
18	8.4	7.4	9.2	10.3	7.4	10.0
19	8.2	6.0	9.0	8.4	7.7	10.1
20	8.3	5.3	9.0	8.4	7.4	9.8
21	7.9	5.2	8.7	7.4	.	.
23	8.6	5.3	9.1	7.5	.	.
25	.	.	.	.	.	.



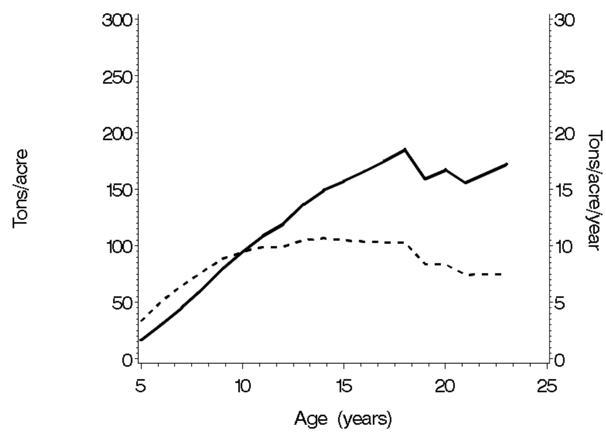
(a) C



(b) H

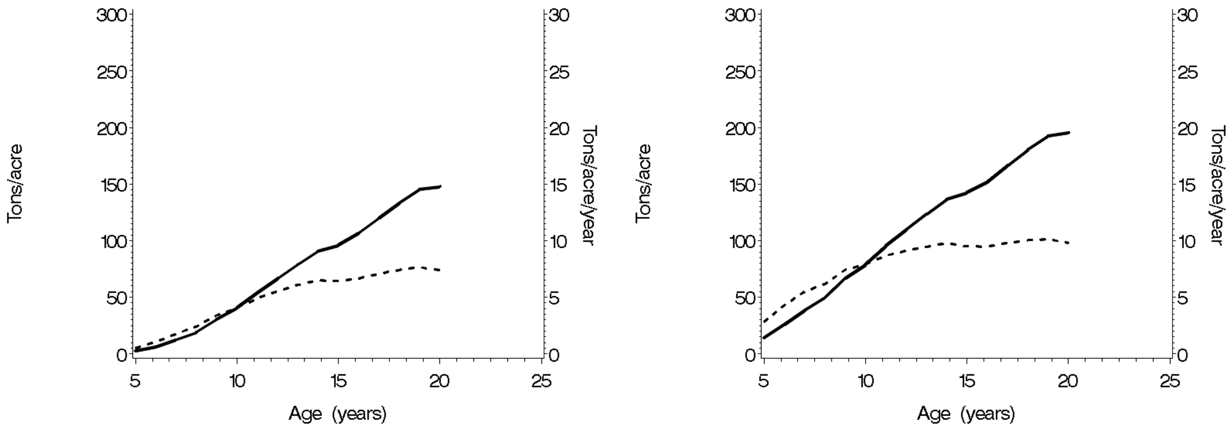


(c) F



(d) HF

Figure 3.7: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Athens 1989 time replicate.



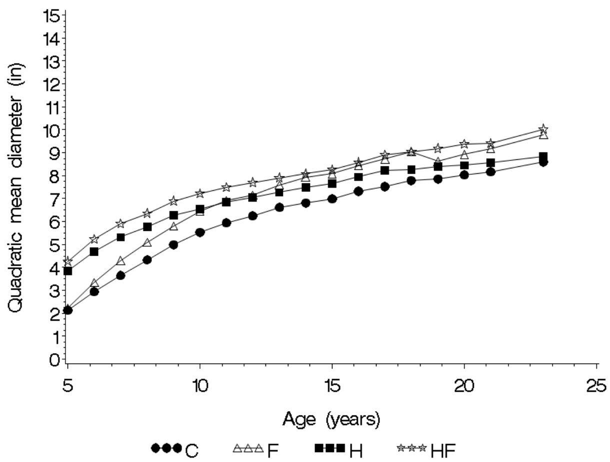
(a) C

(b) H

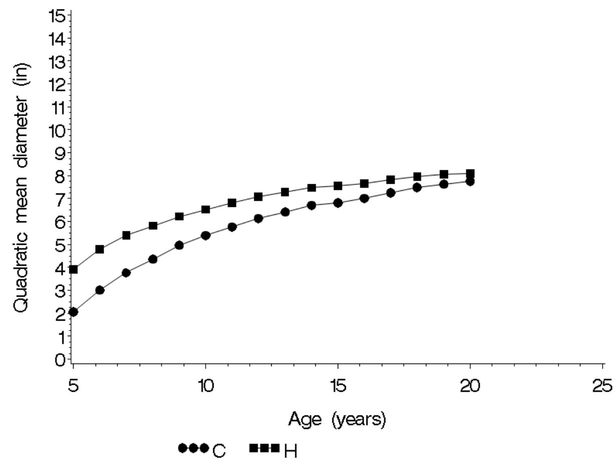
Figure 3.8: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Athens 1993 time replicate.

Table 3.8: Average quadratic mean diameter (inches) development at the Athens site by time replicate.

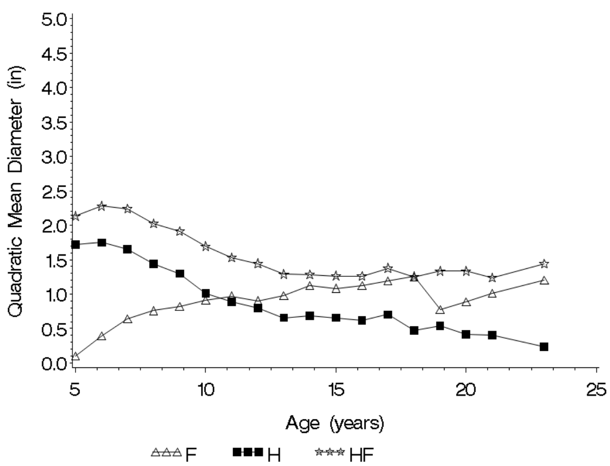
	1989				1993	
Age	C	F	H	HF	C	H
5	2.1	2.2	3.9	4.3	2.1	3.9
6	2.9	3.3	4.7	5.2	3.0	4.8
7	3.7	4.3	5.3	5.9	3.8	5.4
8	4.3	5.1	5.8	6.4	4.4	5.8
9	5.0	5.8	6.3	6.9	5.0	6.2
10	5.5	6.4	6.5	7.2	5.4	6.5
11	6.0	6.9	6.8	7.5	5.8	6.8
12	6.3	7.2	7.1	7.7	6.1	7.1
13	6.6	7.6	7.3	7.9	6.4	7.3
14	6.8	7.9	7.5	8.1	6.7	7.5
15	7.0	8.1	7.7	8.3	6.8	7.6
16	7.3	8.4	7.9	8.6	7.0	7.7
17	7.5	8.7	8.2	8.9	7.3	7.8
18	7.8	9.0	8.3	9.0	7.5	8.0
19	7.9	8.6	8.4	9.2	7.6	8.1
20	8.0	8.9	8.5	9.4	7.7	8.1
21	8.2	9.2	8.6	9.4	.	.
23	8.6	9.8	8.8	10.0	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993



(c) 1989 Treatment Effects

Figure 3.9: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Athens site is shown in subfigures 3.9(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.9: Average pulpwood development (tons/acre) at the Athens site by time replicate.

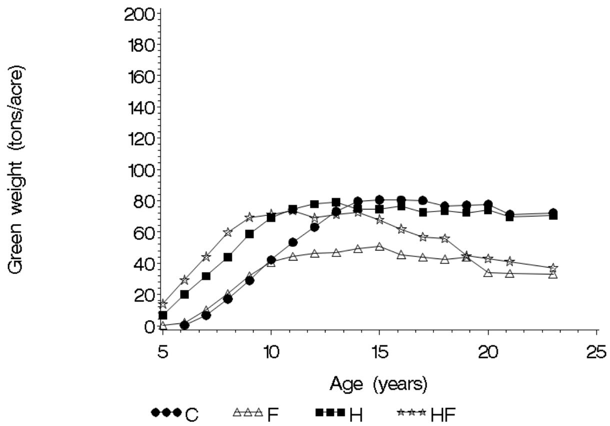
	1989				1993	
Age	C	F	H	HF	C	H
5	.	0.2	6.9	13.9	.	8.0
6	0.5	1.9	19.9	29.3	0.6	24.0
7	6.6	10.1	31.7	44.1	6.8	37.3
8	17.1	20.6	43.7	59.6	15.8	48.2
9	28.9	31.9	58.6	69.3	28.4	65.6
10	42.1	40.7	69.0	71.2	37.8	78.0
11	53.3	44.4	74.4	73.5	50.8	91.4
12	63.0	46.3	77.8	68.9	61.1	97.2
13	73.0	46.8	79.2	71.0	70.0	102.7
14	79.4	49.4	74.8	72.5	77.1	104.8
15	80.5	50.9	74.4	67.8	79.3	102.5
16	80.4	45.5	76.7	61.8	81.3	101.0
17	80.2	43.9	72.6	56.8	84.2	94.9
18	76.6	42.5	73.4	55.6	83.2	97.4
19	77.1	43.9	72.3	44.6	81.9	97.6
20	77.7	34.1	74.0	42.9	81.7	101.2
21	71.3	33.4	69.3	41.1	.	.
23	72.1	32.9	70.7	36.8	.	.
25	.	.	.	.	.	.

Table 3.10: Average chip-n-saw development (tons/acre) at the Athens site by time replicate.

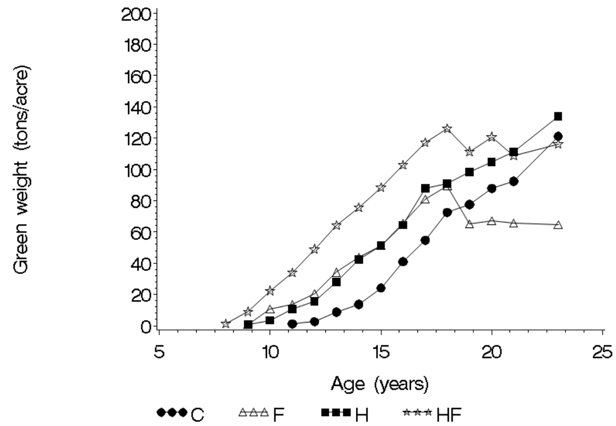
	1989				1993	
Age	C	F	H	HF	C	H
5	.	.	.	.	.	.
6	.	.	.	.	.	.
7	.	.	.	.	.	.
8	.	.	.	1.1	.	.
9	.	0.8	1.0	9.0	.	.
10	.	10.7	3.5	22.3	1.8	.
11	1.0	13.4	10.7	33.9	2.4	2.8
12	2.5	20.7	15.7	48.9	3.5	11.0
13	8.8	34.2	28.0	64.1	7.0	19.2
14	13.7	43.7	42.2	75.5	11.7	30.5
15	24.2	51.3	51.4	88.3	15.0	38.7
16	41.0	65.7	64.4	102.8	23.4	49.2
17	54.6	81.0	87.8	117.2	34.0	70.1
18	72.3	89.4	91.0	125.9	48.6	81.7
19	77.5	65.2	98.2	111.3	62.1	93.4
20	87.8	67.2	104.8	120.7	64.9	92.9
21	92.3	65.6	111.1	108.6	.	.
23	121.3	64.7	133.8	116.2	.	.
25	.	.	.	.	.	.

Table 3.11: Average sawtimber development (tons/acre) at the Athens site by time replicate.

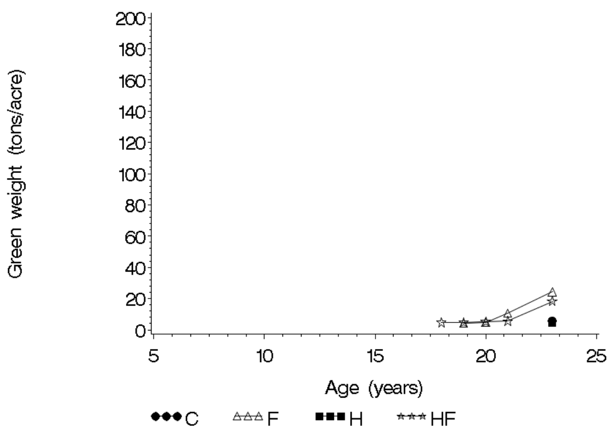
	1989				1993	
Age	C	F	H	HF	C	H
5	.	.	.	.	.	.
6	.	.	.	.	.	.
7	.	.	.	.	.	.
8	.	.	.	.	.	.
9	.	.	.	.	.	.
10	.	.	.	.	.	.
11	.	.	.	.	.	.
12	.	.	.	.	.	.
13	.	.	.	.	.	.
14	.	.	.	.	.	.
15	.	.	.	.	.	.
16	.	.	.	.	.	.
17	.	.	.	.	.	.
18	.	.	.	4.6	.	.
19	.	4.2	.	4.7	.	.
20	.	4.6	.	5.2	.	.
21	.	10.6	.	5.5	.	.
23	5.6	24.3	4.8	18.3	.	.
25	.	.	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw

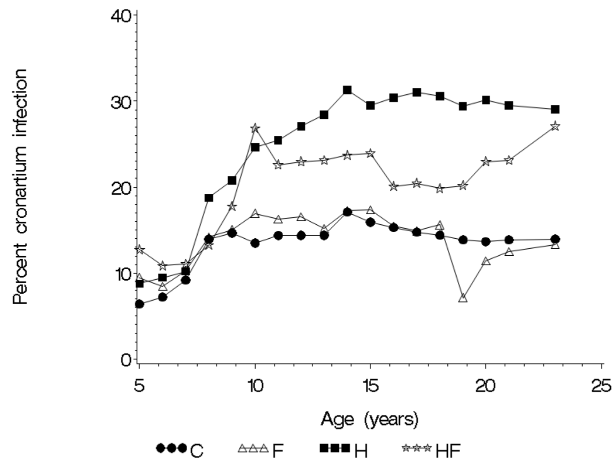


(c) Sawtimber

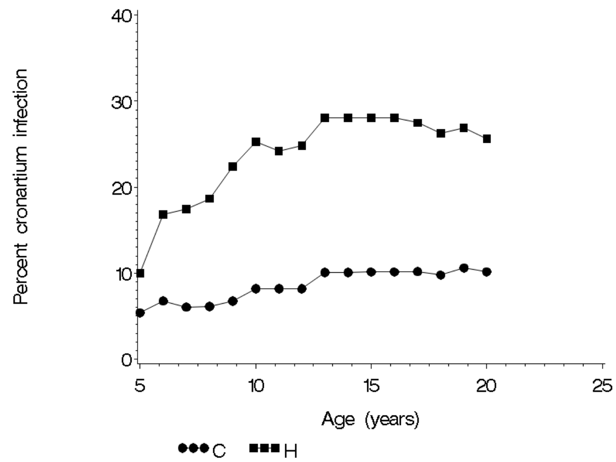
Figure 3.10: Average product distribution (tons/acre) over the course of the study for the Athens 1987 time replicate. Pulpwood is shown in 3.10(a), Chip-N-Saw in 3.10(b), and sawtimber in 3.10(c).

Table 3.12: Average cronartium infection rates (%) at the Athens site by time replicate.

	1989				1993	
Age	C	F	H	HF	C	H
5	6.4	9.5	8.8	12.7	5.4	10.0
6	7.2	8.4	9.5	10.8	6.8	16.8
7	9.2	10.2	10.2	11.0	6.1	17.4
8	14.0	14.2	18.8	13.3	6.1	18.7
9	14.7	15.1	20.8	17.8	6.8	22.4
10	13.5	16.9	24.6	26.9	8.2	25.3
11	14.4	16.3	25.4	22.6	8.2	24.2
12	14.4	16.6	27.1	23.0	8.2	24.8
13	14.4	15.2	28.4	23.1	10.1	28.1
14	17.1	17.3	31.3	23.7	10.1	28.1
15	15.9	17.4	29.5	23.9	10.1	28.1
16	15.3	15.5	30.4	20.1	10.1	28.1
17	14.8	14.9	31.1	20.5	10.2	27.5
18	14.4	15.6	30.6	19.8	9.8	26.2
19	13.9	7.1	29.4	20.2	10.6	26.9
20	13.6	11.4	30.1	23.0	10.1	25.6
21	13.9	12.5	29.5	23.1	.	.
23	14.0	13.3	29.0	27.1	.	.
25	.	.	.	.	.	.



(a) 1989



(b) 1993

Figure 3.11: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Athens site are shown in subfigures 3.11(a)-(b).

3.2 Eatonton - Monitor

The Eatonton - Monitor site had two plots affected by insects and were subsequently dropped due to excessive damage. One of the 1988 HF treatments was ended after the 20^{th} growing season. The other plot was one of the 1990 F treatments that was ended after the 8^{th} growing season. There were also two plots that were removed due to a thinning treatment that was applied after the 10^{th} growing season. These plots were one of the 1990 HF and 1990 H treatments.

Site index on the Eatonton - Monitor shows good site quality (Tables 3.13, 3.14; Figure 3.12). The 1988 time replicate shows a site index of approximately 78 on the C treatment, while the 1990 treatment showed a slightly lower implied site index (Table 3.13). Development patterns are similar for the HF and H treatments until approximately age 10, when the H treatment development began to slow. By the end of the study, the F treatment had surpassed the H treatment. The oldest time replicate, 1988, showed ending site index values of 78.4 for C, 90.8 for F, 85.5 for H, and 96.0 for HF (Table 3.13). These higher site index values for the sites receiving fertilization treatments showed that the site was nutrient limiting.

On these nutrient limiting sites, stand development patterns are advancing more quickly on sites receiving fertilization treatments (HF and F). Basal area (BA) development showed faster growth in the HF and H treatments early on in the study (Figure 3.13). On the two younger time replicates, BA development slows for the H treatment after age 10 while on the oldest time replicate, the H and HF treatments follow similar trajectories for the entire study (Figure 3.13). BA crashes were observed only in the F treatments on the 1990 and 1995 time replicates, which can be attributed to insect problems observed on site. These crashes both occurred once the treatment reached approximately 140 ft^2/acre, occurring after age 21 for the 1990 time replicate and age 17 for the 1995 time replicate (Tables 3.15, 3.16). A slight decline in BA was observed between ages 16 and 19 on the 1988 HF treatment, but by age 21 it had reached the 199 ft^2/acre peak (Table 3.15; Figure 3.13). It is interesting to see that BA stabilizes for the HF treatments on all time replicates during the last few years compared with other locations that experienced a BA crash.

Stand density index (SDI) development for the Eatonton - Monitor site is consistent with BA development. Plots that experience BA crashes reflect that in their SDI values (Figures 3.14, 3.13). On sites that did not experience BA crashes, SDI continued to increase and begin to stabilize by the end of the study. The maximum SDI values for the HF treatments were 369, 430, and 443 at ages 20, 17, and 17 for the 1988, 1990, and 1995 time replicates, respectively (Tables 3.17, 3.18). The H treatment had SDI values of 414, 377, and 400 at or near the last measurement age for the three time replicates. Maximums for the F treatment were 397, 269, and 304 at age 21, 17, and 14 for the three time replicates. These peaks in SDI for the 1990 and 1995 time replicates correspond with the impending BA crashes. The C treatment had maximum SDI values of 398, 369, and 346 at or near the last measurement age on the three time replicates. It is interesting to see that sites receiving competition control have higher maximum SDI values than those without.

Relative spacing (RS) reaches minimums of approximately .11 on treatments that do not experience a BA crash and maintain those values (Tables 3.19, 3.20). The 1990 and 1995 F treatments, which experienced a BA crash, showed minimum RS values of .17 before they began to increase as the stand continued to develop. These higher RS values are a result of the greater stem mortality seen on site (Table 3.13). The sites that experience the stabilization of RS have proportion stem mortality to dominant height growth, allowing the RS relationship between the two to remain the same.

Development patterns in total green tons per acre (GT) show very similar development patterns when compared with BA on these treatments (Tables 3.23, 3.24, 3.15, 3.16). Declines in GT on certain sites can be attributed to BA crashes, which occurred on the 1990 and 1995 F treatments (Tables 3.23, 3.24, 3.15, 3.16). The C, H, and HF treatments all had the maximum GT totals occur near or at the last measurement age. The C maximums were 183.3, 155.2, and 127.9 tons/acre for the three time replicates (Tables 3.23, 3.24). The H maximums were 214.1, 142.6, and 153.1 tons/acre and the HF maximums were 225.8, 210.6, and 217.8 tons/acre for the three time replicates. The F treatment had maximum values occur at ages 25, 21, and 16, which corresponds with the BA crashes that occurred on the two youngest sites. The maximums reached for the F treatments were 215.2, 123.3, and 97.7 tons/acre for the three time replicates. The F treatment had much lower GT rates on the 1990 and 1995 time replicates leading up to the BA crash compared with F treatments on similar sites, which can be attributed to problems with insects. When the BA crashes did occur, BA loss was more severe than GT loss, suggesting that the larger trees were not affected as much as the smaller trees. Mean annual increment (MAI) showed faster initial growth rates in the treatments receiving competition control, HF and H, on all three time replicates compared with the F and C treatments (Tables 3.25, 3.26; Figures 3.18, 3.19, 3.20). The C treatment had maximum MAI values of 7.8, 6.8, and 7.1 tons/acre/year on the 1988, 1990, and 1995 time replicates occurring at or near the final measurement ages. The F treatment had maximum MAI values of 9.6, 5.9, and 6.2 tons/acre/year on the three time replicates at ages 23, 21, and 14. The 1990 and 1995 time replicate MAI values also represent where the BA crashes occurred with earlier peak MAI values. The H treatment had peak MAI values of 9.3, 6.2, and 8.7 tons/acre/year, occurring at ages 23, 23, 17, respectively. The HF treatment maximums were 10.6, 10.5, and 12.1 tons/acre/year at ages 21, 16, and 18, respectively. Overall, the HF treatment had the highest MAI values over all the time replicates and treatments. The 1995 time replicate showed a very productive site, with the HF treatment reaching the 12 tons/acre/year mark at age 17 (Table 3.26).

Quadratic mean diameter (DQ) development initially had the highest values in the HF and H treatments (Tables 3.27, 3.28; Figure 3.21). This trend only continued until approximately age 10, where DQ rates slowed for the H treatment while DQ increased for the F treatments. The H treatment saw a slight decline at age 11 in the 1990 time replicate. This decline in DQ corresponds with a slight decrease in BA, which shows that during this decline, larger trees were affected. DQ reaches the 8 inch average, which is the minimum diameter necessary for chip-n-saw classification, earliest on the HF and F treatments. This achievement shows that stand development is proceeding faster on the HF and F treatments compared with the control. The BA crash that occurred in the 1990 F treatment lead to fewer TPA which promoted greater DQ development (Table 3.27). Maximum DQ values for the HF treatment were 10.4, 9.2, and 8.4 inches for the 1988, 1990, and 1995 time replicates, respectively (Tables 3.27, 3.28). Maximums for the F treatment were 10.0, 9.7, and 8.1 inches for the time replicates. Development patterns for the H treatments showed a slight advantage over the C treatment during the course of the study for two out of the three time replicates (Figure 3.21). Maximum DQ values for the H treatments were 9.0, 7.4, and 7.6 inches and the C treatment had maximum DQ values were 7.9, 7.5, and 6.9 inches for the three time replicates (Tables 3.27, 3.28).

Product development on the Eatonton - Monitor site showed faster overall stand development in the HF and F treatments. Initial pulpwood development showed pulpwood on the HF and H treatments at age 5 on all three time replicates (Tables 3.29, 3.30). Pulpwood products develop on the C and F treatments at age 6 on the 1988 and 1990 treatments, and age 7 on the 1995 time replicate. Pulpwood development is delayed on these sites due to lower DQ values for the F and C treatments (Table 3.27). Pulpwood development peaks first on the HF and F treatments. HF treatments peak at age 13, 14, and 13 on the 1988, 1990, and 1990 time replicates, respectively. The F treatment had peak pulpwood values occur at age 15, 14, and 14 for the time replicates. The C treatment peak pulpwood values occurred at age 23, 19, and 18 for the three time replicates. Chip-n-saw development occurred first on the HF, occurring at age 8, 11, and 11 for the 1988, 1990, and 1995 time replicates, respectively (Tables 3.31, 3.32). The F treatment had chip-n-saw first develop at ages 10, 11, and 12 on the three time replicates. The H treatment had its first development of chip-n-saw at age 11, 10, and 11 for the three time replicates. On the 1990 time replicate, ages 11 and 12 saw the H treatment's development of chip-n-saw products removed, which corresponds with the reduction in BA that occurred at that time. This loss of chip-n-saw is due to the stem mortality being concentrated in the higher diameter trees, which is shown by a reduction in DQ (Table 3.27). Chip-n-saw developed the slowest in the C treatment, starting at age 14, 13, and 14 in the three time replicates. Sawtimber first develops on the HF treatment at age 17 on the 1988 time replicate (Table 3.33). This was the only time replicate where sawtimber was present for the HF treatment. The F treatment first developed sawtimber at age 18 on the 1988 time replicate and age 20 on the 1990 time replicate. There was no sawtimber development for any of the treatments on the 1995 time replicate. The 1988 time replicate saw sawtimber develop on the H treatment at age 23, which was the only time replicate with sawtimber in the H treatment. Product development is entirely dependent on diameter of the trees. The DQs of the treatments show that it isn't until age 14 on the HF treatment in the 1988 time replicate where their average crosses the 8 inch mark, the minimum diameter required for chip-n-saw classification. The ending averages of some of these treatments are nowhere near the 12 inch minimum sawtimber classification which results in little to now sawtimber products on site, such as the 1995 time replicate.

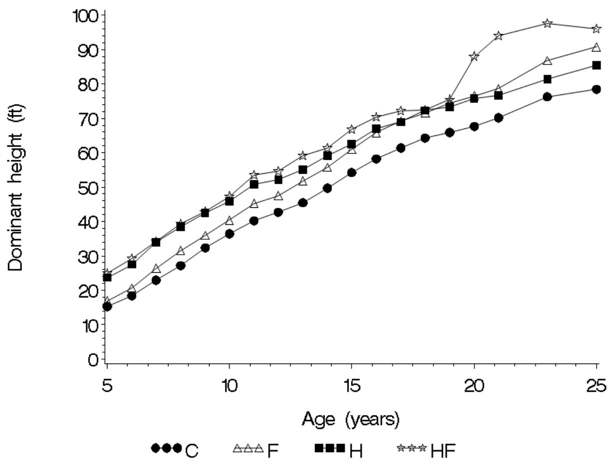
Cronartium infection rates are highest on the HF and H treatments across the three time replicates (Tables 3.34, 3.35). These higher cronartium rates can be attributed to the higher early growth rates expressed by these treatments in MAI (Tables 3.25, 3.26). The F and C treatments, which have lower overall infection rates also have lower initial growth rates compared with the H and HF treatments. The oldest time replicate has higher rates of infection for the HF and H treatments compared with the other time replicates (Figure 3.23). These higher rates could be due to climatic differences between planting years that favored cronartium.

Table 3.13: Average dominant height (feet) development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

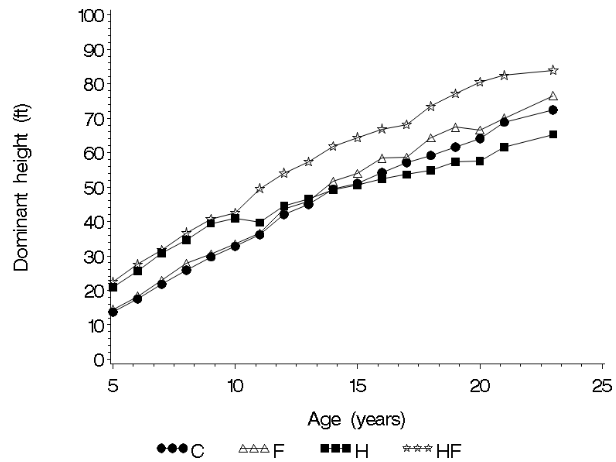
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	15.3	17.0	23.7	24.9	13.7	14.5	20.9	22.4
6	18.4	20.7	27.5	29.2	17.4	18.3	25.7	27.5
7	23.0	26.4	34.0	34.1	21.7	22.9	30.8	31.6
8	27.1	31.6	38.4	39.4	25.9	27.9	34.6	36.7
9	32.3	35.9	42.6	42.8	29.8	30.6	39.5	40.7
10	36.4	40.4	45.8	47.3	32.8	33.5	40.9	42.5
11	40.1	45.3	50.8	53.5	36.1	36.7	39.7	49.5
12	42.7	47.5	52.2	54.6	42.0	43.5	44.6	54.0
13	45.5	51.8	55.0	59.1	45.0	45.9	46.6	57.4
14	49.7	55.8	59.2	61.3	49.4	51.7	49.2	61.8
15	54.2	61.0	62.6	66.7	51.0	54.0	50.5	64.4
16	58.2	65.8	67.1	70.3	54.3	58.4	52.4	66.9
17	61.4	69.2	68.9	72.2	57.0	58.6	53.6	68.1
18	64.2	71.5	72.3	72.4	59.2	64.3	54.8	73.4
19	65.9	74.4	73.3	75.4	61.6	67.4	57.3	77.1
20	67.6	76.5	75.8	88.0	64.1	66.6	57.5	80.4
21	70.2	78.6	76.7	94.0	68.9	70.0	61.7	82.4
23	76.3	86.8	81.4	97.5	72.4	76.5	65.3	83.9
25	78.4	90.8	85.5	96.0	.	.	.	.

Table 3.14: Average dominant height (feet) development at the Eatonton - Monitor site for the 1995 time replicate.

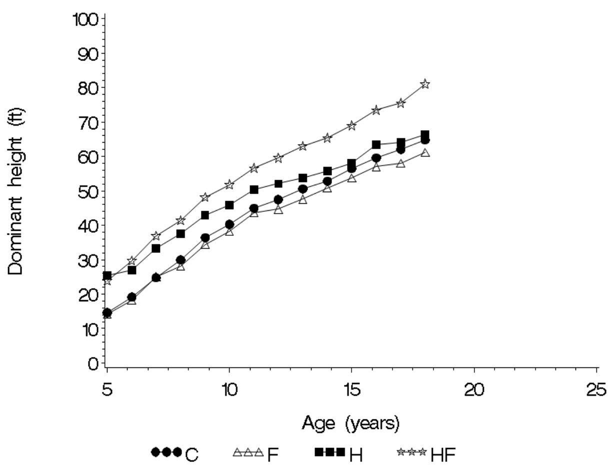
	1995			
Age	C	F	H	HF
5	14.6	14.2	25.3	23.9
6	19.1	18.2	26.9	29.7
7	24.8	25.0	33.3	36.8
8	30.0	28.2	37.5	41.4
9	36.3	34.5	42.9	48.1
10	40.2	38.3	45.9	51.8
11	44.9	43.7	50.4	56.6
12	47.4	44.6	52.1	59.5
13	50.5	47.6	53.8	62.9
14	52.8	50.8	55.8	65.3
15	56.5	53.8	58.0	68.9
16	59.5	57.0	63.4	73.4
17	62.0	58.0	64.1	75.4
18	64.8	61.2	66.3	81.0
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



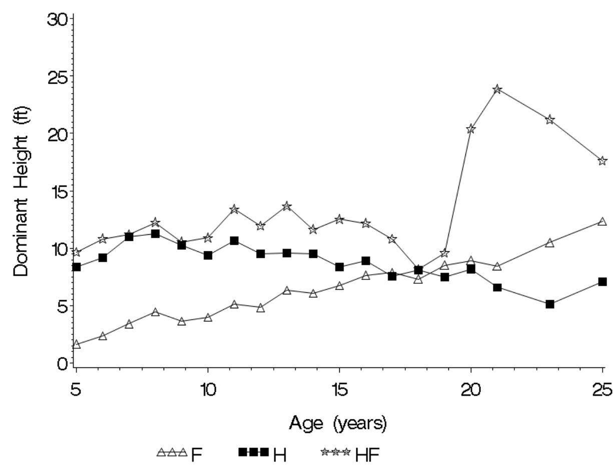
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

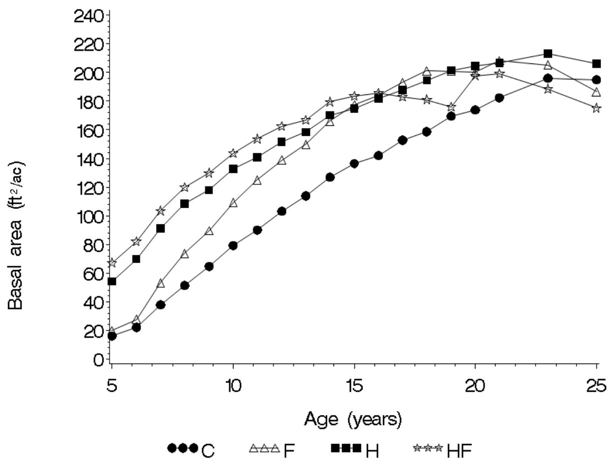
Figure 3.12: Average dominant height (feet) over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.12(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments. It should be noted that one of the treatment plots in the 1988 HF treatment was dropped, resulting in one treatment plot being left which caused the large increase in dominant height.

Table 3.15: Average basal area (ft^2/acre) at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

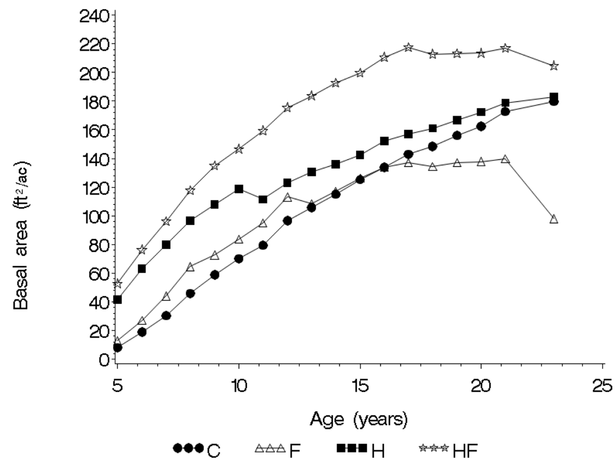
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	16.1	20.0	54.2	67.1	7.9	12.8	41.7	52.6
6	22.1	27.7	69.8	81.9	18.8	27.0	63.2	76.2
7	38.0	53.3	91.0	103.4	30.3	44.1	79.7	96.1
8	51.4	73.7	108.6	119.9	45.8	64.6	96.8	117.7
9	64.6	89.5	117.9	129.8	58.8	72.7	108.1	134.9
10	79.2	109.2	132.6	143.4	70.0	83.6	118.7	146.5
11	89.9	124.9	141.0	153.5	79.5	95.0	111.5	159.3
12	103.2	138.8	151.7	162.3	96.6	113.0	123.2	175.5
13	113.9	149.7	158.4	166.7	105.7	108.4	130.6	183.7
14	127.0	165.9	170.2	179.4	115.0	117.1	135.8	192.5
15	136.3	177.4	174.8	183.4	125.4	126.3	142.4	199.5
16	142.0	183.9	181.8	185.6	133.8	133.9	152.1	210.6
17	152.7	193.3	187.7	182.8	142.8	137.1	156.9	217.3
18	158.6	201.1	194.5	181.0	148.4	134.2	161.0	212.7
19	169.6	200.7	201.5	175.8	156.0	137.0	166.7	213.1
20	173.9	200.1	204.5	197.7	162.4	137.8	172.4	213.5
21	182.3	208.2	206.8	199.0	172.8	139.8	178.9	216.8
23	196.1	205.3	213.0	188.5	179.9	98.1	183.0	204.6
25	195.0	186.6	206.0	175.1	.	.	.	.

Table 3.16: Average basal area (ft^2/acre) at the Eatonton - Monitor site for the 1995 time replicate.

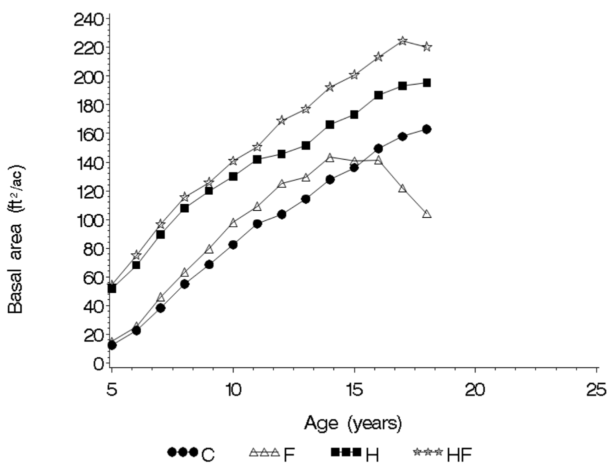
	1995			
Age	C	F	H	HF
5	12.4	14.9	51.8	54.2
6	22.6	25.6	68.2	75.2
7	38.4	46.1	89.6	96.7
8	55.0	63.3	108.0	115.6
9	68.6	79.7	120.0	125.9
10	82.3	98.0	130.2	140.8
11	97.0	109.2	141.7	150.4
12	103.6	125.2	145.7	169.1
13	114.2	129.6	151.5	176.8
14	127.8	143.3	166.2	192.3
15	136.2	140.7	173.2	200.8
16	149.5	141.5	186.8	213.4
17	157.8	121.9	193.3	224.4
18	162.9	104.1	195.3	220.3
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



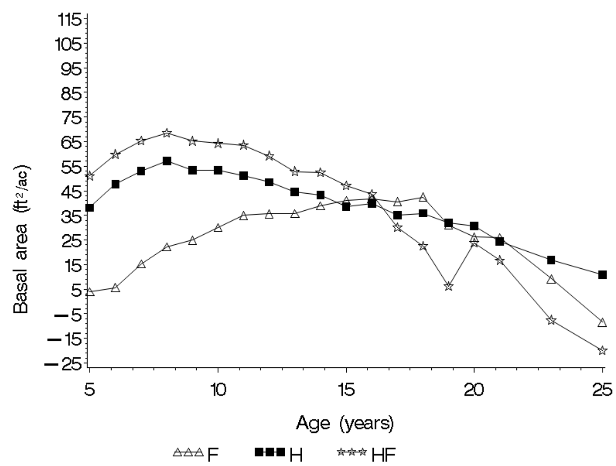
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

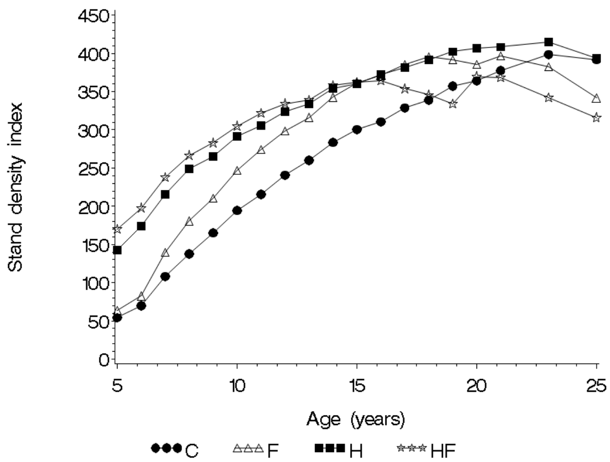
Figure 3.13: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.13(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.17: Average stand density index development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

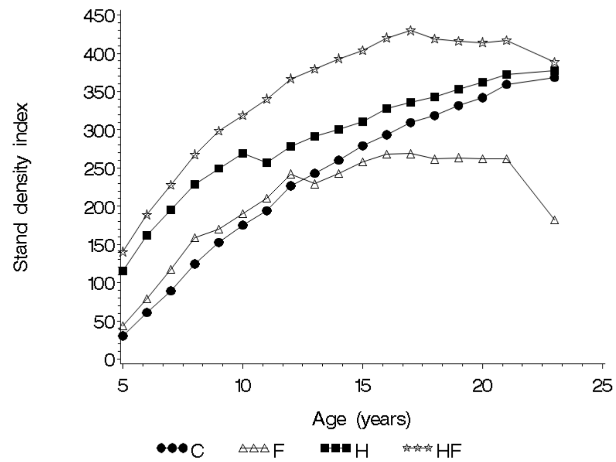
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	54.1	63.7	142.6	169.8	30.2	43.4	115.6	140.2
6	69.9	82.7	174.3	197.6	61.0	79.1	162.0	188.7
7	108.0	139.6	215.7	237.9	89.3	117.4	195.2	227.3
8	137.6	180.8	248.6	266.4	124.5	158.8	228.4	267.4
9	165.2	210.3	264.8	282.8	152.3	169.9	249.3	298.5
10	194.6	246.7	291.0	304.7	175.2	190.0	268.8	318.4
11	215.5	274.4	305.3	321.8	193.8	210.7	256.7	340.1
12	240.6	298.2	323.7	334.2	226.6	242.2	278.1	366.7
13	259.9	316.0	334.2	338.8	243.2	229.1	291.5	379.5
14	283.6	342.7	354.2	358.3	260.3	242.8	300.7	393.0
15	300.2	361.6	360.3	362.4	279.0	257.9	310.8	403.4
16	310.3	371.0	372.4	364.2	293.4	268.2	327.7	420.1
17	328.4	385.1	381.6	353.6	309.2	268.7	336.0	429.6
18	338.5	395.2	391.4	345.6	318.4	261.7	343.1	418.9
19	357.2	391.5	402.2	333.6	331.5	263.4	352.8	415.9
20	364.0	385.5	406.3	369.5	341.9	262.0	362.4	414.0
21	377.6	396.7	408.2	368.5	359.4	262.2	372.4	416.6
23	398.2	382.3	414.4	342.0	368.6	182.1	377.3	388.5
25	391.8	341.6	393.8	315.9	.	.	.	.

Table 3.18: Average stand density index development at the Eatonton - Monitor site for the 1995 time replicate.

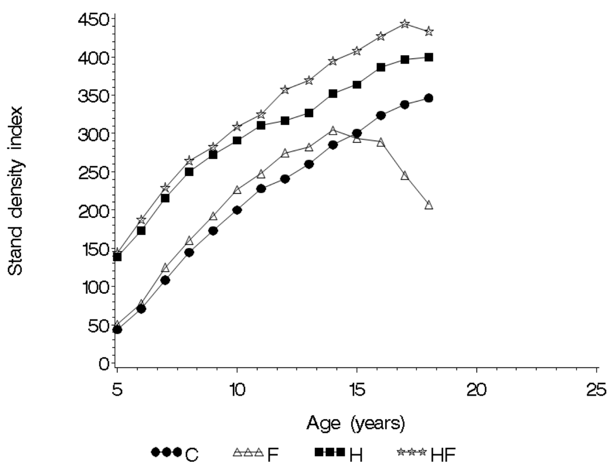
	1995			
Age	C	F	H	HF
5	43.7	50.6	138.9	144.0
6	70.9	77.8	173.1	187.1
7	108.3	124.7	215.4	229.0
8	144.5	160.1	250.2	264.2
9	172.6	192.0	272.4	282.4
10	199.8	226.9	290.8	308.9
11	227.8	247.4	310.5	324.9
12	240.3	274.6	316.6	356.9
13	259.7	282.3	326.7	369.0
14	285.1	304.2	352.0	394.6
15	300.0	293.6	363.8	407.6
16	323.3	289.1	386.6	426.8
17	337.6	245.6	396.3	443.2
18	346.4	207.0	399.6	433.3
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

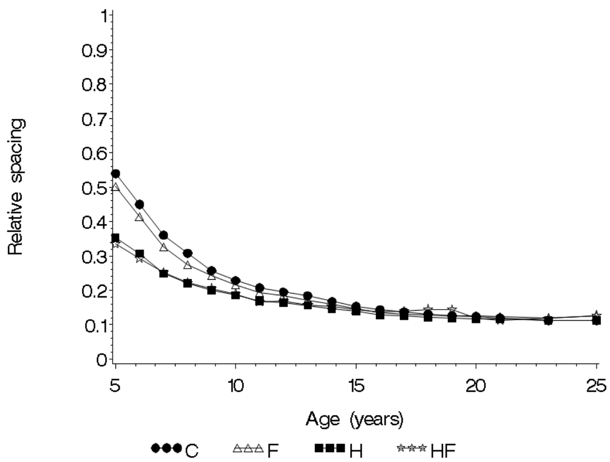
Figure 3.14: Average stand density index over the course of the study for the individual time replicates at the Eatonton - Monitor site are shown in subfigures 3.14(a)-(c).

Table 3.19: Average relative spacing development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

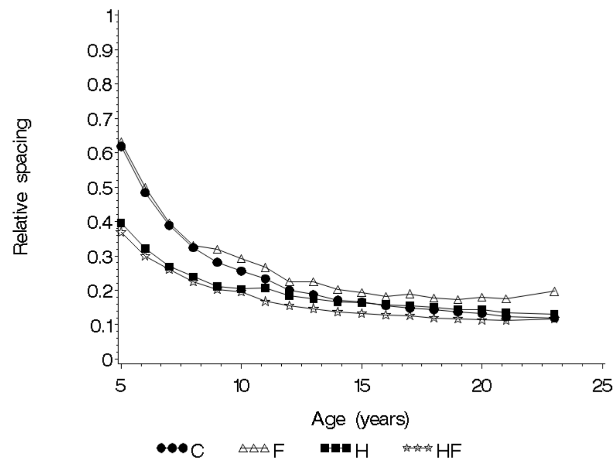
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	0.54	0.50	0.35	0.33	0.62	0.63	0.40	0.37
6	0.45	0.41	0.31	0.29	0.48	0.50	0.32	0.30
7	0.36	0.33	0.25	0.25	0.39	0.40	0.27	0.26
8	0.31	0.27	0.22	0.22	0.32	0.33	0.24	0.23
9	0.26	0.24	0.20	0.21	0.28	0.32	0.21	0.20
10	0.23	0.22	0.19	0.19	0.26	0.29	0.20	0.20
11	0.21	0.19	0.17	0.17	0.23	0.27	0.21	0.17
12	0.19	0.18	0.16	0.17	0.20	0.22	0.18	0.15
13	0.18	0.17	0.16	0.16	0.19	0.23	0.18	0.15
14	0.17	0.16	0.14	0.15	0.17	0.20	0.17	0.14
15	0.15	0.15	0.14	0.14	0.17	0.19	0.16	0.13
16	0.14	0.14	0.13	0.14	0.16	0.18	0.16	0.13
17	0.14	0.13	0.13	0.14	0.15	0.19	0.15	0.13
18	0.13	0.13	0.12	0.14	0.14	0.18	0.15	0.12
19	0.13	0.13	0.12	0.14	0.14	0.17	0.14	0.12
20	0.12	0.13	0.12	0.12	0.13	0.18	0.14	0.11
21	0.12	0.12	0.12	0.11	0.12	0.18	0.14	0.11
23	0.11	0.12	0.11	0.12	0.12	0.20	0.13	0.12
25	0.11	0.12	0.11	0.13	.	.	.	.

Table 3.20: Average relative spacing development at the Eatonton - Monitor site for the 1995 time replicate.

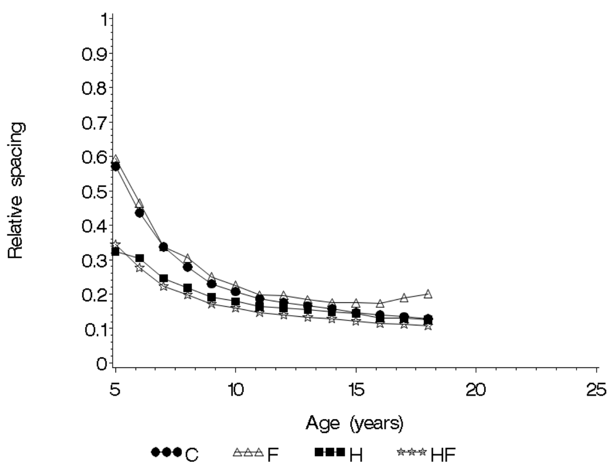
	1995			
Age	C	F	H	HF
5	0.57	0.59	0.32	0.34
6	0.44	0.46	0.30	0.28
7	0.34	0.34	0.25	0.22
8	0.28	0.30	0.22	0.20
9	0.23	0.25	0.19	0.17
10	0.21	0.23	0.18	0.16
11	0.19	0.20	0.16	0.15
12	0.18	0.20	0.16	0.14
13	0.17	0.18	0.15	0.13
14	0.16	0.17	0.15	0.13
15	0.15	0.17	0.14	0.12
16	0.14	0.17	0.13	0.12
17	0.13	0.19	0.13	0.11
18	0.13	0.20	0.13	0.11
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

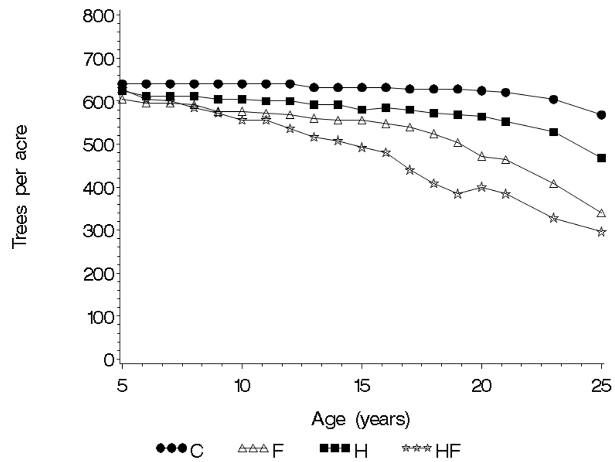
Figure 3.15: Average relative spacing development over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.15(a)-(c).

Table 3.21: Average trees per acre development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

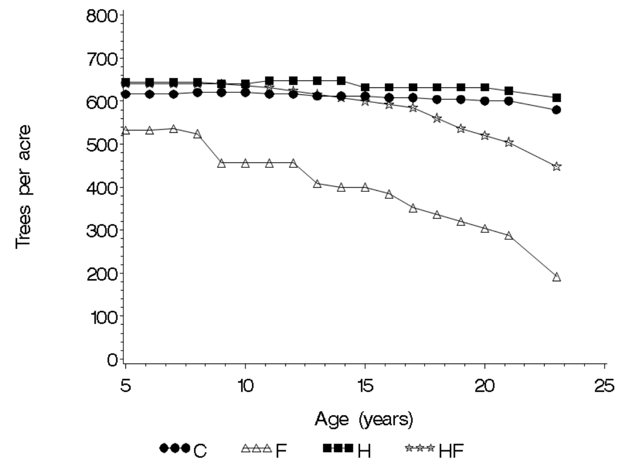
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	640	604	624	628	616	532	644	640
6	640	596	612	604	616	532	644	640
7	640	596	612	600	616	536	644	640
8	640	592	612	584	620	524	644	640
9	640	576	604	572	620	456	640	640
10	640	576	604	556	620	456	640	636
11	640	572	600	556	616	456	648	632
12	640	568	600	536	616	456	648	624
13	632	560	592	516	612	408	648	616
14	632	556	592	508	612	400	648	608
15	632	556	580	492	612	400	632	600
16	632	548	584	480	608	384	632	592
17	628	540	580	440	608	352	632	584
18	628	524	572	408	604	336	632	560
19	628	504	568	384	604	320	632	536
20	624	472	564	400	600	304	632	520
21	620	464	552	384	600	288	624	504
23	604	408	528	328	580	192	608	448
25	568	340	468	296	.	.	.	.

Table 3.22: Average trees per acre development at the Eatonton - Monitor site for the 1995 time replicate.

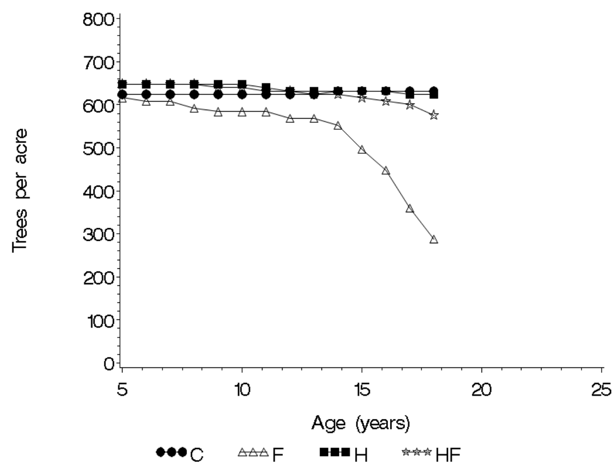
	1995			
Age	C	F	H	HF
5	624	616	648	648
6	624	608	648	648
7	624	608	648	648
8	624	592	648	648
9	624	584	648	648
10	624	584	648	648
11	624	584	640	640
12	624	568	632	632
13	624	568	632	632
14	632	552	632	632
15	632	496	632	632
16	632	448	632	632
17	632	360	624	624
18	632	288	624	624
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



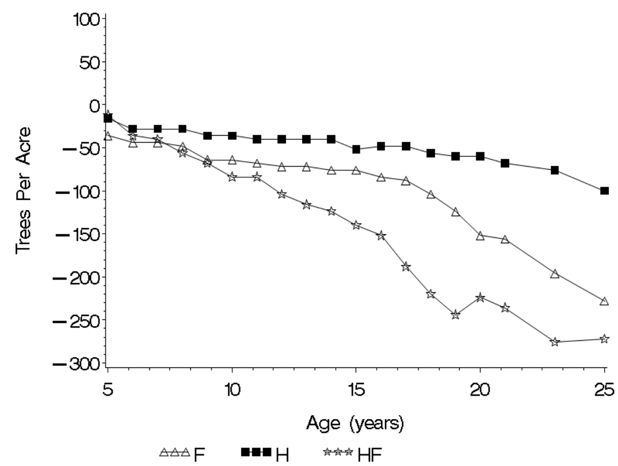
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

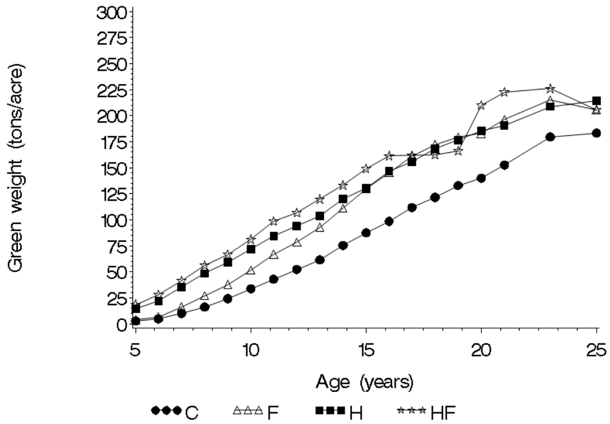
Figure 3.16: Average trees per acre development over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.16(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.23: Average total green weight (tons/acre) development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

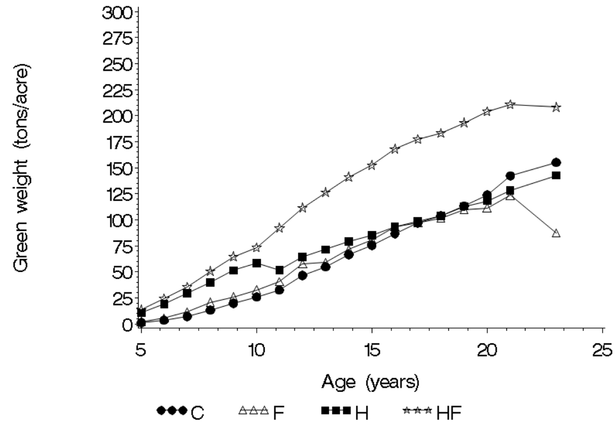
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	2.8	3.8	14.3	18.4	1.2	2.1	10.5	13.5
6	4.7	6.6	21.9	27.6	3.7	5.6	19.2	24.2
7	10.0	16.3	35.5	41.3	7.2	11.5	29.3	35.3
8	16.2	27.0	48.3	55.9	13.2	20.7	39.9	50.5
9	24.2	37.8	58.8	66.5	19.7	25.9	51.3	64.4
10	33.7	51.6	71.5	81.0	25.9	32.6	58.2	73.3
11	42.9	66.7	84.4	98.3	32.6	40.4	51.8	92.0
12	52.2	78.5	93.7	106.7	46.5	57.6	64.2	111.4
13	61.5	92.8	103.6	119.6	54.8	59.1	71.4	126.3
14	75.1	111.0	119.7	133.0	66.5	71.5	79.3	141.0
15	87.5	129.7	130.5	148.9	75.5	80.7	85.2	152.3
16	98.5	145.1	146.6	161.2	86.5	93.2	93.3	167.9
17	111.5	161.1	155.6	161.6	96.7	97.2	98.3	177.1
18	121.5	172.2	168.0	162.2	103.8	101.5	103.8	183.1
19	132.9	179.2	176.5	165.8	113.0	109.7	112.9	193.1
20	139.9	182.8	185.1	209.9	123.7	111.4	118.1	203.9
21	152.5	196.2	190.7	222.6	142.1	123.3	128.4	210.6
23	179.6	215.2	208.7	225.8	155.2	87.4	142.6	208.0
25	183.3	205.6	214.1	205.3	.	.	.	.

Table 3.24: Average total green weight (tons/acre) development at the Eatonton - Monitor site for the 1995 time replicate.

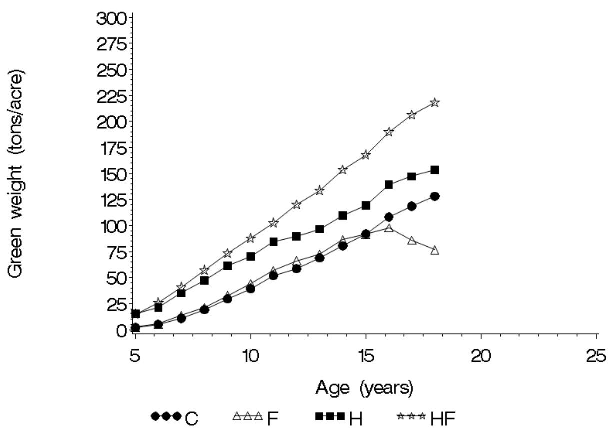
	1995			
Age	C	F	H	HF
5	2.0	2.4	15.3	14.8
6	5.0	5.3	21.4	26.0
7	10.8	13.5	35.0	40.7
8	19.1	21.0	47.3	57.0
9	29.6	32.6	61.0	73.1
10	39.4	44.3	70.1	87.7
11	51.8	56.5	84.2	102.4
12	58.5	66.0	89.4	120.0
13	68.9	72.6	96.5	133.5
14	80.3	86.3	109.3	153.4
15	92.0	91.5	119.3	167.9
16	108.1	97.7	139.4	189.9
17	118.6	85.8	147.1	206.1
18	127.9	76.6	153.1	217.8
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



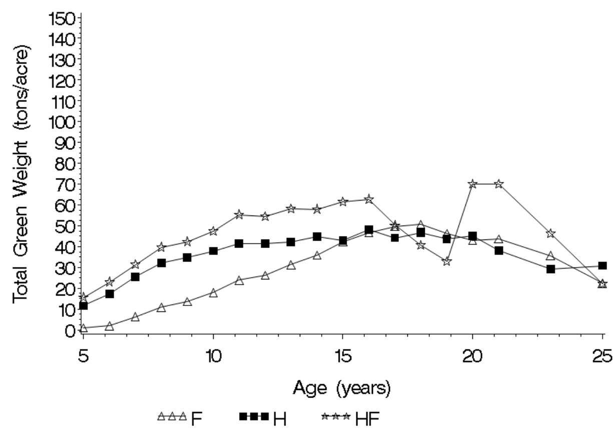
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

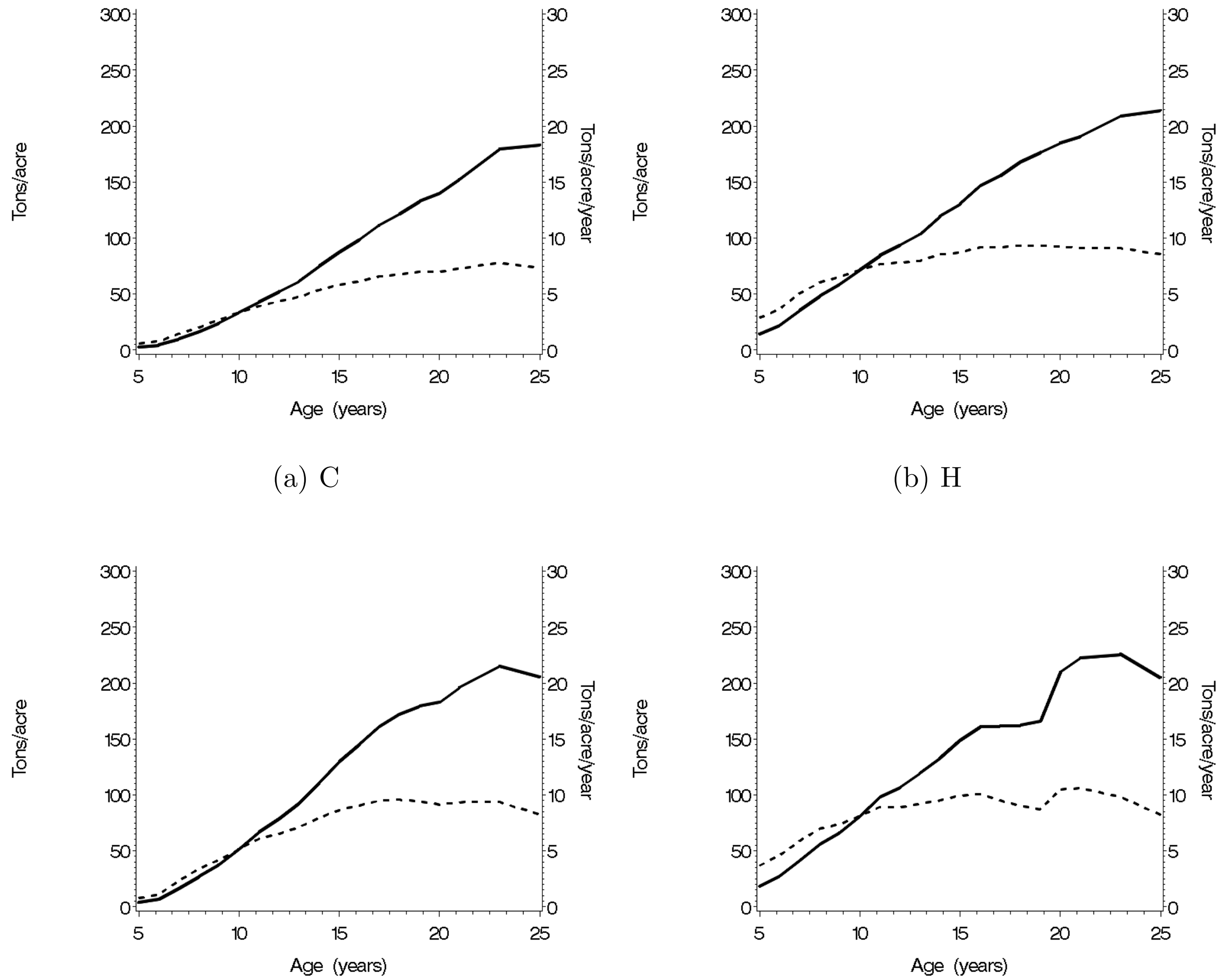
Figure 3.17: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.17(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.25: Mean annual increment (tons/acre/year) development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	0.6	0.8	2.9	3.7	0.2	0.4	2.1	2.7
6	0.8	1.1	3.7	4.6	0.6	0.9	3.2	4.0
7	1.4	2.3	5.1	5.9	1.0	1.6	4.2	5.1
8	2.0	3.4	6.0	7.0	1.7	2.6	5.0	6.3
9	2.7	4.2	6.5	7.4	2.2	2.9	5.7	7.2
10	3.4	5.2	7.2	8.1	2.6	3.3	5.8	7.3
11	3.9	6.1	7.7	8.9	3.0	3.7	4.7	8.4
12	4.4	6.5	7.8	8.9	3.9	4.8	5.4	9.3
13	4.7	7.1	8.0	9.2	4.2	4.6	5.5	9.7
14	5.4	7.9	8.6	9.5	4.8	5.1	5.7	10.1
15	5.8	8.7	8.7	9.9	5.0	5.4	5.7	10.2
16	6.2	9.1	9.2	10.1	5.4	5.8	5.8	10.5
17	6.6	9.5	9.2	9.5	5.7	5.7	5.8	10.4
18	6.8	9.6	9.3	9.0	5.8	5.6	5.8	10.2
19	7.0	9.4	9.3	8.7	6.0	5.8	5.9	10.2
20	7.0	9.1	9.3	10.5	6.2	5.6	5.9	10.2
21	7.3	9.3	9.1	10.6	6.8	5.9	6.1	10.0
23	7.8	9.4	9.1	9.8	6.8	3.8	6.2	9.0
25	7.3	8.2	8.6	8.2	.	.	.	.

Table 3.26: Mean annual increment (tons/acre/year) development at the Eatonton - Monitor site for the 1993 time replicate.

	1995			
Age	C	F	H	HF
5	0.4	0.5	3.1	3.0
6	0.8	0.9	3.6	4.3
7	1.6	1.9	5.0	5.8
8	2.4	2.6	5.9	7.1
9	3.3	3.6	6.8	8.1
10	3.9	4.4	7.0	8.8
11	4.7	5.1	7.7	9.3
12	4.9	5.5	7.5	10.0
13	5.3	5.6	7.4	10.3
14	5.7	6.2	7.8	11.0
15	6.1	6.1	8.0	11.2
16	6.8	6.1	8.7	11.9
17	7.0	5.1	8.7	12.1
18	7.1	4.3	8.5	12.1
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



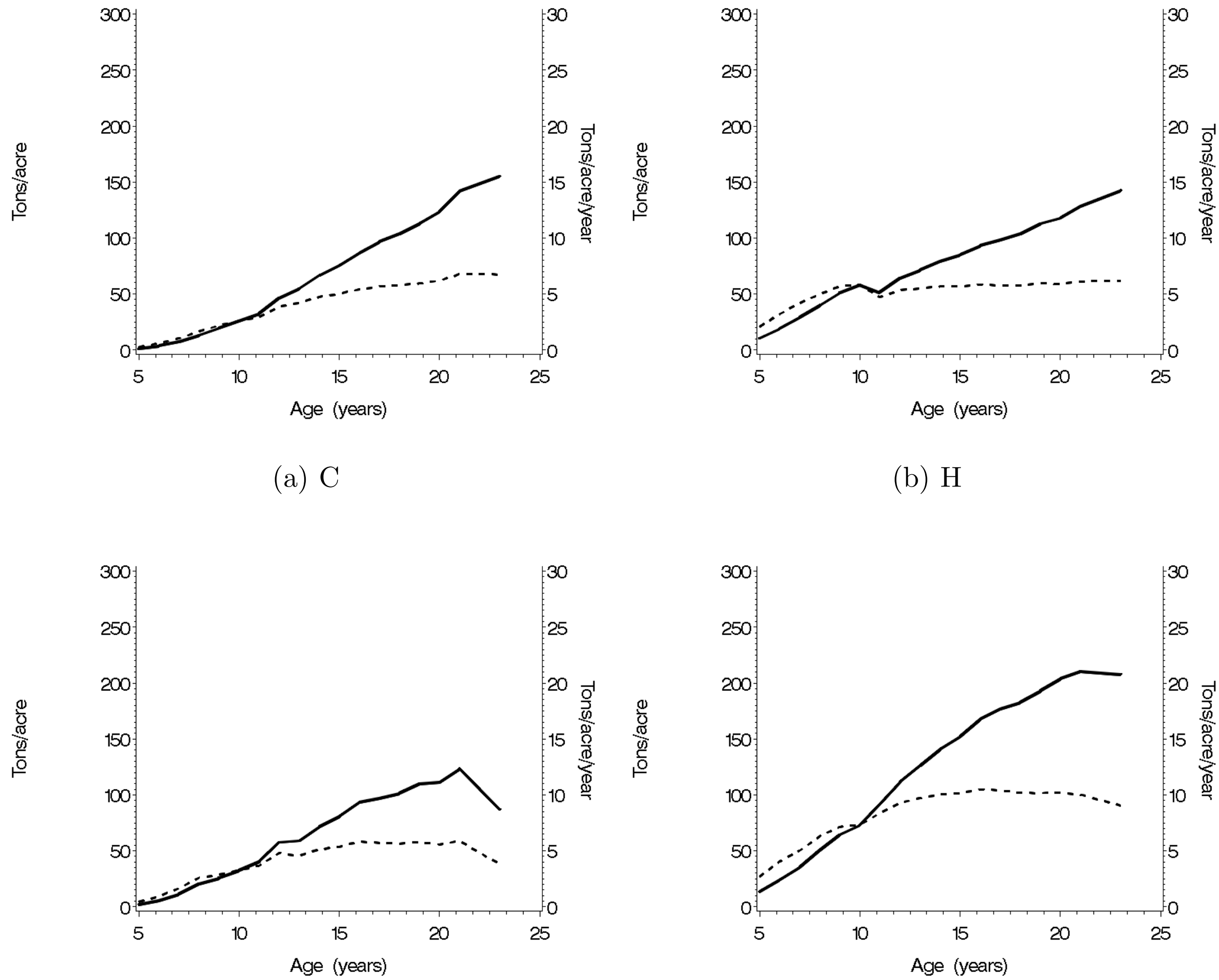
(a) C

(b) H

(c) F

(d) HF

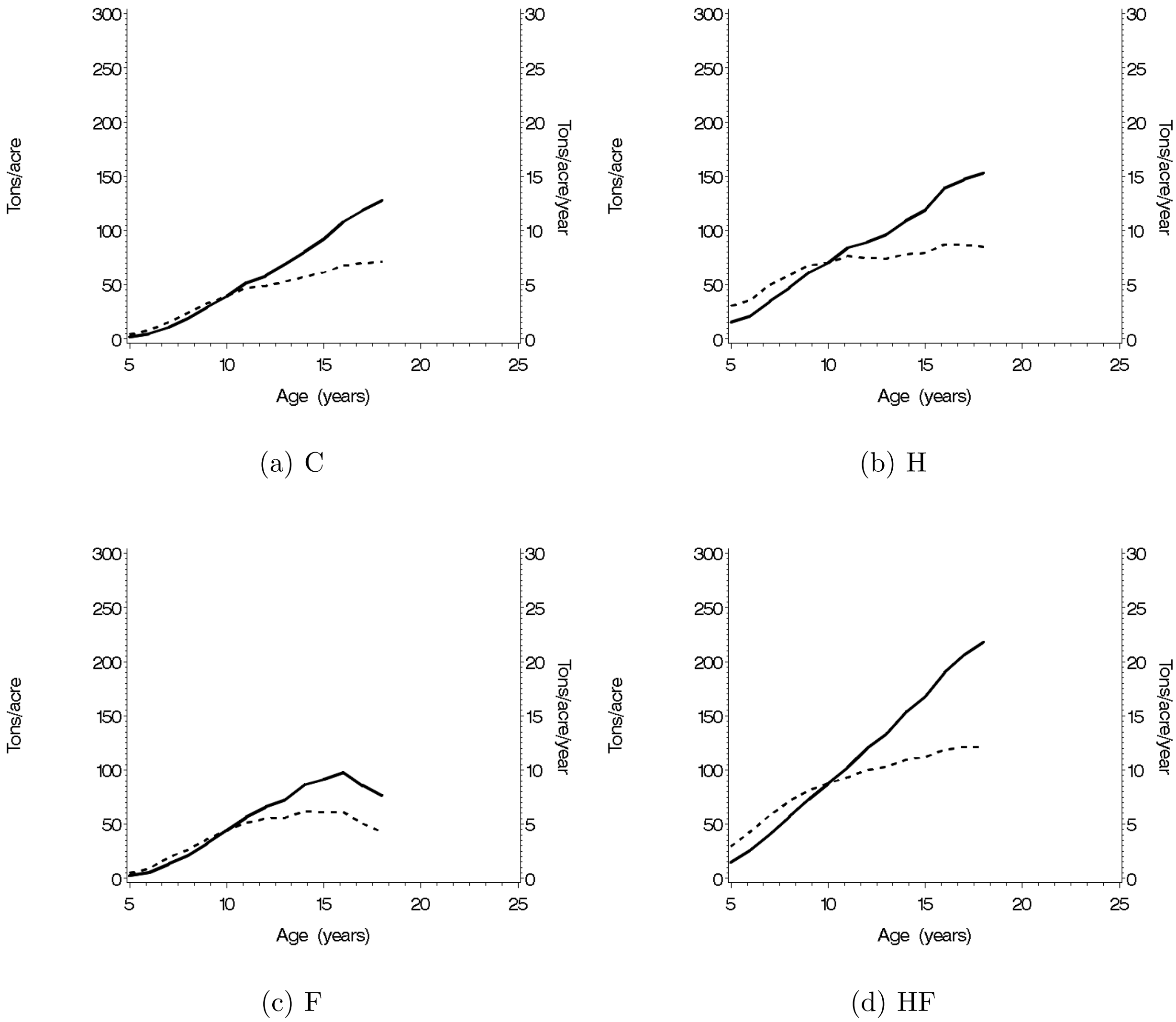
Figure 3.18: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Eatonton - Monitor 1988 time replicate.



(a) C (b) H

(c) F (d) HF

Figure 3.19: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Eatonton - Monitor 1990 time replicate.



(a) C (b) H

(c) F (d) HF

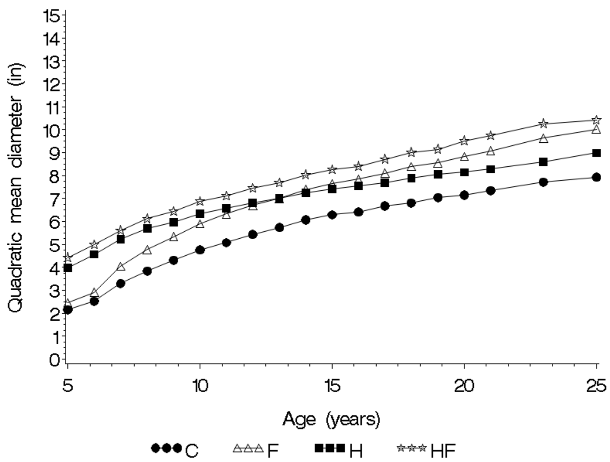
Figure 3.20: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (——–) by treatment for the Eatonton - Monitor 1995 time replicate.

Table 3.27: Average quadratic mean diameter (inches) development at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

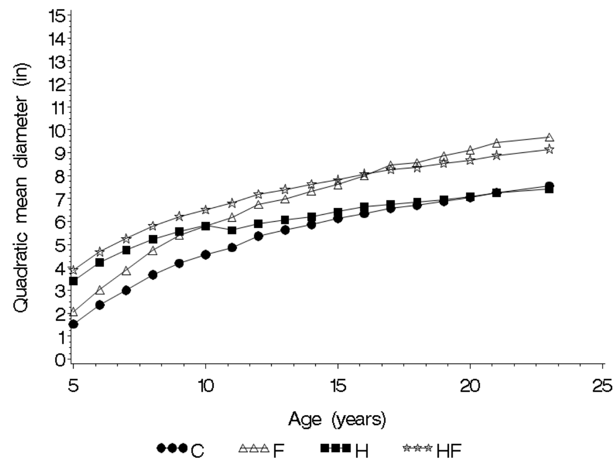
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	2.1	2.5	4.0	4.4	1.5	2.1	3.4	3.9
6	2.5	2.9	4.6	5.0	2.4	3.0	4.2	4.7
7	3.3	4.1	5.2	5.6	3.0	3.9	4.7	5.3
8	3.8	4.8	5.7	6.1	3.7	4.7	5.2	5.8
9	4.3	5.3	6.0	6.4	4.2	5.4	5.6	6.2
10	4.8	5.9	6.3	6.9	4.6	5.8	5.8	6.5
11	5.1	6.3	6.6	7.1	4.9	6.2	5.6	6.8
12	5.4	6.7	6.8	7.5	5.4	6.7	5.9	7.2
13	5.8	7.0	7.0	7.7	5.6	7.0	6.1	7.4
14	6.1	7.4	7.3	8.0	5.9	7.3	6.2	7.6
15	6.3	7.7	7.4	8.3	6.1	7.6	6.4	7.8
16	6.4	7.8	7.6	8.4	6.4	8.0	6.6	8.1
17	6.7	8.1	7.7	8.7	6.6	8.5	6.8	8.3
18	6.8	8.4	7.9	9.0	6.7	8.6	6.8	8.4
19	7.0	8.6	8.1	9.2	6.9	8.9	7.0	8.5
20	7.2	8.8	8.2	9.5	7.0	9.1	7.1	8.7
21	7.3	9.1	8.3	9.8	7.3	9.4	7.3	8.9
23	7.7	9.6	8.6	10.3	7.5	9.7	7.4	9.2
25	7.9	10.0	9.0	10.4	.	.	.	.

Table 3.28: Average quadratic mean diameter (inches) development at the Eatonton - Monitor site for the 1995 time replicate.

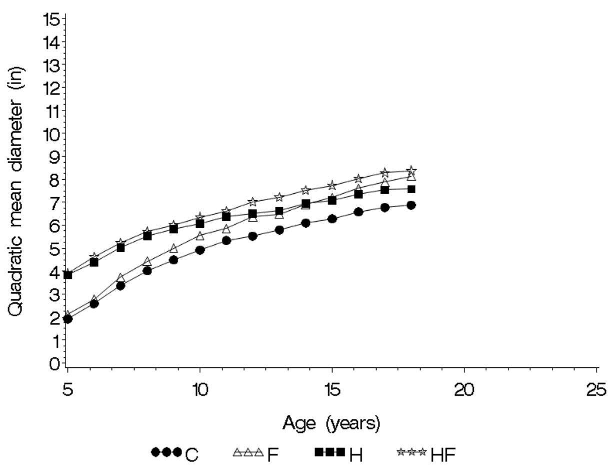
	1995			
Age	C	F	H	HF
5	1.9	2.1	3.8	3.9
6	2.6	2.8	4.4	4.6
7	3.4	3.7	5.0	5.2
8	4.0	4.4	5.5	5.7
9	4.5	5.0	5.8	6.0
10	4.9	5.6	6.1	6.4
11	5.3	5.9	6.4	6.6
12	5.5	6.4	6.5	7.0
13	5.8	6.5	6.6	7.2
14	6.1	6.9	6.9	7.5
15	6.3	7.2	7.1	7.7
16	6.6	7.6	7.4	8.0
17	6.8	7.9	7.5	8.3
18	6.9	8.1	7.6	8.4
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



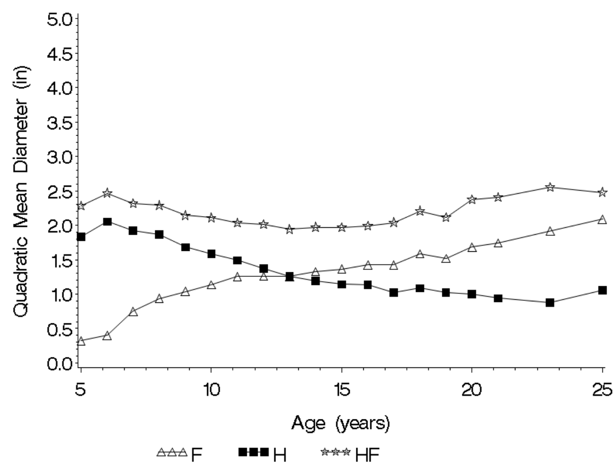
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

Figure 3.21: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Eatonton - Monitor site is shown in subfigures 3.21(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.29: Average pulpwood development (tons/acre) at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	.	9.4	15.9	.	.	4.2	7.3
6	0.2	0.5	19.2	25.8	0.2	0.3	15.3	22.3
7	1.9	12.0	34.2	39.9	1.3	7.3	26.3	33.7
8	10.1	24.3	47.2	53.1	6.8	18.5	37.9	49.2
9	18.8	35.9	57.6	60.6	14.0	24.7	49.3	63.1
10	30.5	48.3	70.3	64.5	22.3	31.4	55.1	72.0
11	39.4	61.4	80.1	70.5	29.1	37.7	49.3	83.8
12	48.9	66.6	82.8	69.6	44.3	45.8	61.4	86.9
13	59.3	73.7	84.4	71.5	51.6	45.4	66.9	89.6
14	71.2	75.7	87.5	64.9	61.5	47.2	74.4	91.3
15	79.0	79.3	85.7	66.9	66.7	42.1	77.8	87.2
16	86.0	78.2	88.2	66.8	74.5	41.7	84.1	81.1
17	89.9	74.1	86.5	61.2	75.6	39.3	87.3	77.7
18	91.5	70.4	89.7	52.2	77.0	39.5	86.9	77.4
19	91.2	70.3	85.2	48.4	79.5	38.2	90.2	73.7
20	92.7	61.6	87.5	57.0	76.7	35.4	87.8	73.2
21	93.5	58.4	84.0	55.9	78.7	40.2	88.5	71.3
23	94.9	53.0	78.2	50.6	76.9	24.3	94.4	63.7
25	88.1	41.0	66.4	46.3	.	.	.	.

Table 3.30: Average pulpwood development (tons/acre) at the Eatonton - Monitor site for the 1995 time replicate.

	1995			
Age	C	F	H	HF
5	.	.	6.4	8.0
6	.	.	18.4	23.8
7	1.3	6.0	33.9	39.3
8	12.1	18.3	46.1	55.8
9	25.9	30.8	59.8	71.7
10	37.1	42.5	68.8	86.3
11	49.5	55.0	81.8	98.2
12	56.7	63.6	86.8	107.9
13	67.4	66.8	93.9	116.4
14	77.6	73.6	98.5	114.7
15	87.6	69.9	99.1	109.2
16	101.4	62.4	108.1	94.7
17	106.6	49.7	107.1	92.2
18	111.7	39.7	107.6	87.7
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.31: Average chip-n-saw development (tons/acre) at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

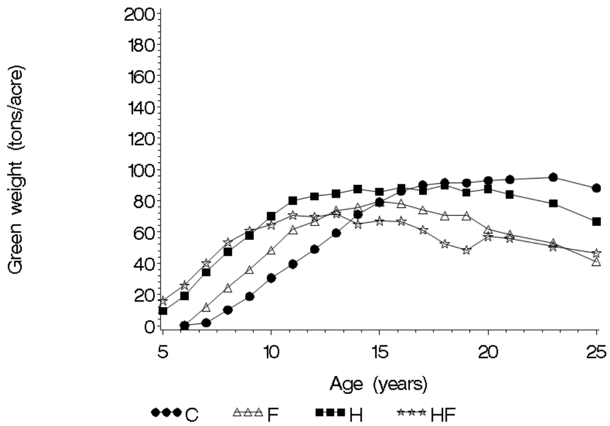
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	3.1	.	.	.	.
9	.	.	.	9.7	.	.	.	.
10	.	1.6	.	15.5	.	.	2.3	.
11	.	4.0	3.0	26.6	.	1.7	.	6.9
12	.	10.6	9.7	36.0	.	10.5	.	23.3
13	.	17.8	18.0	47.0	1.1	12.5	2.2	35.4
14	1.8	33.9	30.9	67.1	2.7	23.0	2.5	48.4
15	6.4	49.2	43.5	81.0	6.4	37.3	5.3	63.7
16	10.2	65.7	57.0	93.3	9.7	50.0	7.5	85.5
17	19.6	85.8	67.8	97.2	19.0	57.2	9.2	98.1
18	27.9	98.3	76.9	106.5	24.5	61.4	15.1	104.5
19	39.8	105.2	89.9	113.9	31.3	70.9	20.9	118.1
20	45.3	117.2	96.2	140.7	44.6	71.1	28.5	129.5
21	57.1	126.4	105.3	146.8	60.9	60.4	38.1	138.0
23	82.8	145.3	126.6	128.0	76.0	43.0	46.4	143.2
25	93.7	146.1	143.7	98.4	.	.	.	.

Table 3.32: Average chip-n-saw development (tons/acre) at the Eatonton - Monitor site for the 1995 time replicate.

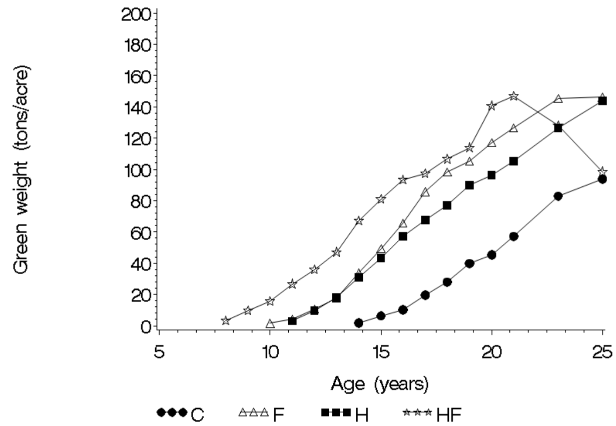
	1995			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	.	.	.	.
10	.	.	.	.
11	.	.	1.2	2.7
12	.	1.2	1.3	10.7
13	.	4.5	1.3	15.7
14	1.2	11.4	9.5	37.2
15	2.9	20.4	18.8	57.2
16	5.1	34.1	29.9	93.7
17	10.3	35.1	38.7	112.5
18	14.6	36.4	44.1	128.6
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.33: Average sawtimber development (tons/acre) at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

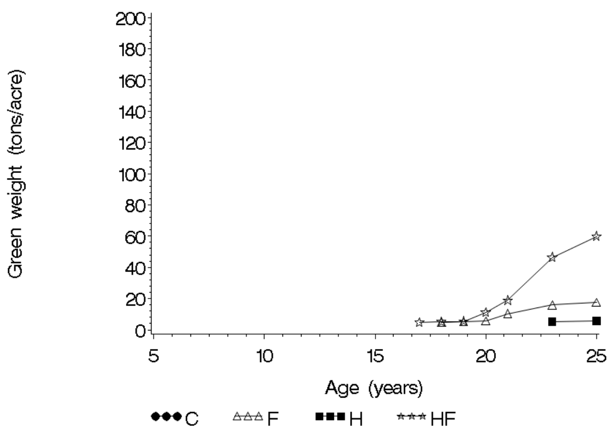
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.
17	.	.	.	4.65	.	.	.	.
18	.	4.7	.	5.16	.	.	.	.
19	.	5.15	.	5.43	.	.	.	.
20	.	5.63	.	11.22	.	4.22	.	.
21	.	10.33	.	18.88	.	22.11	.	.
23	.	15.97	5.19	46.4	.	19.77	.	.
25	.	17.7	5.55	59.84	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw



(c) Sawtimber

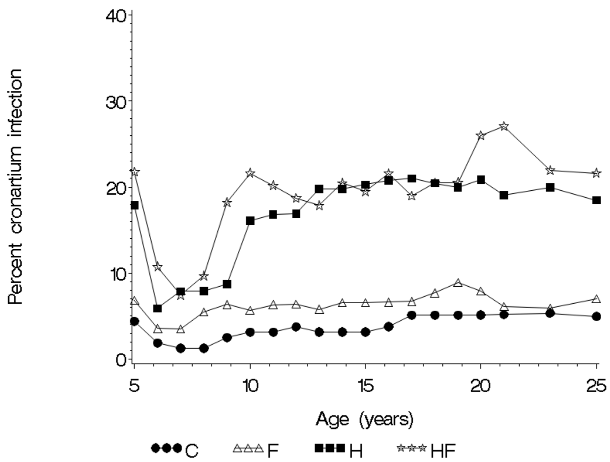
Figure 3.22: Average product distribution (tons/acre) over the course of the study for the Eatonton - Monitor 1988 time replicate. Pulpwood is shown in 3.22(a), Chip-N-Saw in 3.22(b), and sawtimber in 3.22(c).

Table 3.34: Average cronartium infection rates (%) at the Eatonton - Monitor site for the 1988 and 1990 time replicates.

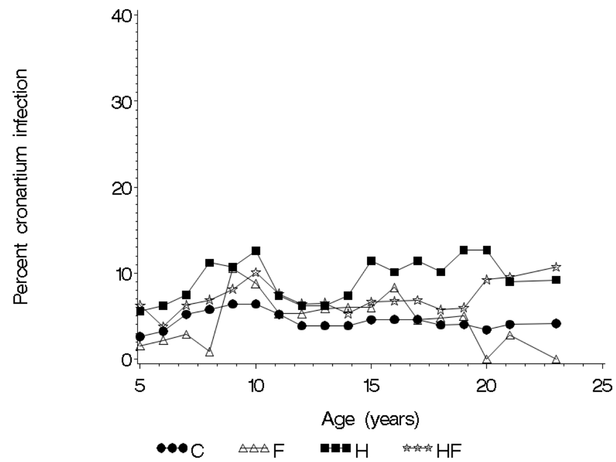
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	4.4	6.8	17.9	21.7	2.6	1.5	5.6	6.3
6	1.9	3.6	5.9	10.7	3.3	2.2	6.2	3.8
7	1.3	3.5	7.9	7.4	5.2	2.9	7.5	6.3
8	1.3	5.5	7.9	9.7	5.8	0.9	11.2	6.9
9	2.5	6.4	8.7	18.2	6.4	10.5	10.7	8.1
10	3.1	5.7	16.1	21.6	6.4	8.8	12.6	10.1
11	3.1	6.3	16.8	20.2	5.2	5.3	7.4	7.6
12	3.8	6.4	16.9	18.7	3.9	5.3	6.2	6.4
13	3.1	5.8	19.8	17.9	3.9	5.9	6.2	6.5
14	3.1	6.6	19.8	20.5	3.9	6.0	7.4	5.3
15	3.1	6.6	20.3	19.5	4.6	6.0	11.4	6.7
16	3.8	6.6	20.8	21.6	4.6	8.3	10.1	6.8
17	5.1	6.7	21.0	19.0	4.6	4.6	11.4	6.9
18	5.1	7.7	20.5	20.5	4.0	4.8	10.1	5.7
19	5.1	8.9	19.9	20.5	4.0	5.0	12.7	6.0
20	5.1	7.9	20.9	26.0	3.4	0.0	12.7	9.2
21	5.2	6.1	19.1	27.1	4.0	2.8	9.0	9.5
23	5.4	5.9	20.0	22.0	4.2	0.0	9.2	10.7
25	5.0	7.0	18.5	21.6	.	.	.	.

Table 3.35: Average cronartium infection rates (%) at the Eatonton - Monitor site for the 1995 time replicate.

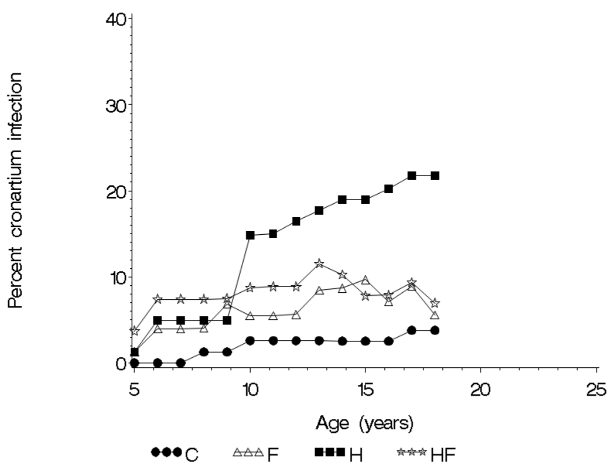
	1995			
Age	C	F	H	HF
5	0.0	1.3	1.2	3.7
6	0.0	4.0	4.9	7.4
7	0.0	4.0	4.9	7.4
8	1.3	4.1	4.9	7.4
9	1.3	6.9	4.9	7.5
10	2.6	5.5	14.8	8.8
11	2.6	5.5	15.0	8.9
12	2.6	5.6	16.5	8.9
13	2.6	8.5	17.7	11.5
14	2.5	8.7	19.0	10.3
15	2.5	9.7	19.0	7.8
16	2.5	7.1	20.3	7.9
17	3.8	8.9	21.8	9.3
18	3.8	5.6	21.8	6.9
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

Figure 3.23: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Eatonton - Monitor site are shown in subfigures 3.23(a)-(c).

3.3 Eatonton - Powerline

The Eatonton - Powerline site had two treatments ended early due to excessive damage caused by insects. These treatments were in the 1990 time replicate on the HF and F treatments. The 1990 HF treatment was removed after the 13th growing season and the F treatment was removed after the 10th growing season. This site also had three treatment plots removed due to thinning after the 10th growing season. These plots were one of the 1990 H, F, and HF treatments. It should be noted that after plots were removed, only one remaining plot was used for analysis.

The base site index for the Eatonton - Powerline site showed good site quality with a value of 75 feet at age 25 for the control treatment in the 1988 time replicate. The 1990 time replicate showed similar quality while the 1995 time replicate showed very high site quality (greater than 80 feet) (Tables 3.36, 3.37). Initial dominant height development showed the greatest growth in the HF and H treatments until approximately age 10, where the H rates slow down and are surpassed by the F treatment (Figure 3.24). As the study progressed, the HF and F treatments on the oldest time replicate had the greatest dominant heights, ending with values of 91 and 88 feet, respectively (Table 3.36). Until they were ended early, the F and HF treatments showed similar development patterns in the 1990 time replicate compared with the 1988 time replicate. The 1995 time replicate saw a slightly different development pattern, because at age 18, there were little differences between all treatments. This suggests that the 1995 time replicate was situated on a non-nutrient limiting site whereas the 1988 time replicate was on a nutrient limiting site.

Basal area (BA) development shows the HF treatment going through stand development faster compared with the other treatments. BA has the greatest growth on the HF treatments, followed by the H treatment for the early part of the study (Tables 3.38, 3.39); Figure 3.25). Between the ages of 13 and 15, development patterns change with the H treatment slowing and being overtaken and/or matched by the F treatment. The HF treatment sees BA crashes in the 1988 and 1990 time replicates. Prior to the crashes at ages 18 and 13, BA peaked at 200.8 and 182.7 tons/acre for the 1988 and 1990 time replicates, respectively. After the peak, BA seemed to stabilize on the 1988 time replicate around 140 ft^2/acre, and the study was ended after age 14 on the 1990 time replicate (Table 3.38). On treatments that did not have BA crashes, the peak BA values occurred at or near the final measurement year. The C treatment had maximum BAs of 177.3, 162.7, and 199.4 ft^2/acre. The F treatment reached 184.3 and 205.6 ft^2/acre in the 1988 and 1995 time replicates. The H treatment's maximum BA values were 186.6, 197.2, and 189.6 on the 1988, 1990, and 1995 time replicates.

Stand density index (SDI) development follows very similar patterns compared with BA for all treatments (Tables 3.40, 3.41, 3.38, 3.39). SDI values continued to increase over the time of the study for the C and H treatments on all time replicates, where there were no BA crashes (Figure 3.26). For the 1988 HF treatment that did experience a BA crash it is reflected by a decrease in SDI. The C treatment had maximum SDI values of 361, 338, and 394 at or near the last measurement age for the 1988, 1990, and 1995 time replicates (Tables 3.40, 3.41). The H treatment reached maximum SDI values of 377, 396, and 387 for the three time replicates. Maximums for the F treatment were 349, 242, and 414 for the 1988, 1990, and 1995 time replicates. The 1990 time replicate has such a low SDI value for the F treatment because of the insect damage that occurred and eventually led to its early demise. The HF treatment shows maximum SDI values of 393, 380, and 455 for the three time replicates, respectively. Even though it ended early, the 1990 HF treatment still reached a respectable maximum SDI value at the age of 12, which showed that the treatment was developing very fast on this site. The 1988 HF treatment also saw SDI maximize prior to its BA crash.

Relative spacing (RS) reached minimum values of .11 on only two treatments, the 1988 H treatment and the 1995 HF treatment (Tables 3.42, 3.43). These minimum RS values correspond with the low mortality rates and higher dominant heights seen on these treatments (Tables 3.44, 3.45). The higher RS values, indicating lower stand density, can be seen in the sites that had either low dominant height development or high stem mortality rates.

The 1988 HF treatment had higher RS values because, although it had very high dominant height growth, the site had very high rates of stem mortality, leading to a lower stand density (Tables 3.36, 3.44, 3.42). This specific treatment also saw a slight BA decline during its development, which was reflected in a rise in RS values after the 19^{th} growing season (Tables 3.38, 3.42). Sites that maintain the RS value as the stand continued to develop exhibit proportional height growth and stem mortality that allows it to maintain the RS value (Tables 3.36, 3.44, 3.42).

Trees per acre (TPA) development showed two different patterns on the Eatonton - Powerline site. The 1990 and 1995 time replicates both showed limited stem mortality for all treatments until age 10 (Tables 3.44, 3.45; Figure 3.28). The 1988 time replicate showed higher stem mortality rates for the HF and F treatments at the beginning of the study and continuing to age 25 (Table 3.44; Figure 3.28). Except for the 1995 C treatment, the H and C treatments showed little stem mortality for the first 23 years. The 1995 C treatment had the highest mortality rate for that time replicate, which seems to be an anomaly when comparing similar treatments at different sites. The 1988 HF treatment, which had the greatest stem mortality for the site, was the only treatment that experienced a BA crash (Table 3.38). The 1990 HF treatment also experienced a BA crash, but that specific treatment was removed from the study after the 14^{th} growing season due to insect issues. BA crashes are related to higher rates of stem mortality, which is usually concentrated on the lower diameter trees.

Total green tons per acre (GT) development showed similar trends compared with BA development (Figures 3.29, 3.25). Treatments that displayed continued increases in BA also showed showed continued increases in GT while treatments that experienced a BA crash also showed a decline in GT growth. Sites that did not have a BA crash had maximum GT values occur at or near the last measurement age. The C treatment had maximum GT values of 161, 136, and 181 tons/acre for the 1988, 1990, and 1995 time replicates, respectively (Tables 3.46, 3.46). The F treatment maximum GT values were 189, 49, and 181 tons/ acre for the three time replicates. It should be noted that the 1990 time replicate has a low maximum

GT due to insect damage that caused the plot to be abandoned. Maximum GT values for the H treatment were 176, 181, and 161 tons/acre. The HF treatment, which experienced a BA crash in the 1988 time replicate, had a maximum GT of 182 tons/acre at age 19. The GT maximums were 130 and 214 tons/acre at age 12 and 18 for the 1990 and 1995 time replicates, respectively. When comparing the BA and GT on sites that experienced a BA crash, it can be seen that GT losses were not as great as those that occurred in BA. This can be attributed to smaller trees being affected by mortality while the larger trees with greater individual GT survived. Mean annual increment (MAI), which is the average amount of GT added per year at a given age, showed stands that were developing faster have earlier and greater peaks. The C treatment MAI values peaked at or near the last measurement period, reaching 6.6, 6.1, and 10.4 tons/acre/year for the 1988, 1990, and 1995 time replicates, respectively (Tables 3.48, 3.49). The H treatment had maximum MAI values of 7.7, 8.5, and 9.4 tons/acre/year at ages 17, 16, and 16 for the three time replicates. Maximum MAI values for the F treatment were 8.5 and 10.5 tons/acre/year at ages 18 and 17 for the 1988 and 1995 time replicates, respectively. The HF treatment saw the earliest and highest peaks for this site, with MAI values reaching 10.7 and 12.6 tons/acre/year at age 17 for both the 1988 and 1995 time replicates. Comparing BA development with MAI increases show that sites with faster initial BA growth also have higher and earlier arrival of peak MAI values (Figures 3.25, 3.30-3.32).

Quadratic mean diameter (DQ) development on the Eatonton - Powerline site showed two different development patterns among its time replicates. On the 1988 time replicate, initial development showed higher DQ values for the sites receiving competition control (HF and H) until approximately age 10 (Table 3.50; Figure 3.33). It was at this time that the H treatment slowed in DQ development and crossed paths with the F treatment, whose rates began to increase and show an advantage over the H treatment after approximately age 15 (Table 3.50; Figure 3.33(a)). As stand development progressed, HF and F continued to develop at similar rates. C and H treatments follow their own similar trend after age 15 for the 1988 time replicate. The 1995 time replicate showed similar development patterns among all treatments for the length of the study (Table 3.51; Figure 3.33(c)). All treatments on the site showed continued increases in DQ as the study progressed with maximum DQ values occurring at the last measurement age. These continued increases in DQ show that it is the smaller trees that are affected by stem mortality. The maximum DQ values for the C treatment were 7.6, 7.3, and 8.3 inches. The F treatment had maximum DQ values of 9.5 and 7.9 inches for the 1988 and 1995 time replicates. The H treatment maximum DQs were 8.2, 8.1, and 7.6 inches for the three time replicates. Maximum DQs for the HF treatment were 10.3 and 8.3 for the 1988 and 1995 time replicates.

Product development for the sites is determined by diameter development for individual trees. Sites with greater amounts of the higher classified products also see higher DQs. Pulpwood is first on site on the HF and H treatments at the beginning of the study (age 5) for all time replicates (Tables 3.52, 3.53). Pulpwood first develops on the F treatment at age 5, 6, and 6 for the 1988, 1990, and 1995 time replicates, respectively. The C treatment first develops pulpwood at age 6, 6, and 5 for the three time replicates. Pulpwood development peaks first on the HF treatment at age 12, 12, and 13 on the 1988, 1990, and 1995 time replicates. The F treatment's pulpwood production peaks at age 15 and 16 for the 1988 and 1995 time replicates. The H treatment has peak pulpwood values at 17, 15, and 16 for the 1988, 1990, and 1995 time replicates. The C treatment has peak pulpwood values occur at age 23, 20, and 13 for the tree time replicates. Chip-n-saw first develops at age 8, 8, and 11 for the three time replicates (Tables 3.54, 3.55). The F treatment develops chip-n-saw at at age 9, 10, and 11 for the three time replicates. The H treatment has later development of chip-n-saw, occurring at age 11 for all three time replicates while the C treatment has chip-n-saw first on site at age 12, 13, and 9 for the three time replicates. Peak chip-n-saw values occur on all time replicates at or near the last measurement age except for the 1988 HF treatment, which peaked at age 19 (Table 3.54). Sawtimber only develops on the HF and F treatments on the 1988 time replicate (Table 3.56). Both of these treatments had sawtimber first occur at age 18. When comparing individual product development with DQ development, one can see that sites with earlier chip-n-saw and sawtimber development also have greater DQs (Tables 3.50, 3.51). There was no sawtimber development on the 1995 time replicate.

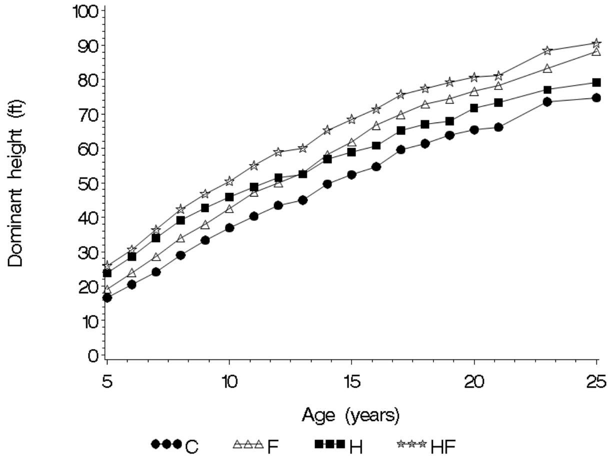
The Eatonton - Powerline site shows overall higher cronartium infection rates for stands with higher initial growth rates. The 1988 time replicate had the highest cronartium infection rates occur in the HF and H treatments, which also had the higher initial MAI values (Tables 3.57, 3.48). After age 10, these infection rates stabilized at approximately 25% for the HF treatment and 17% for the H treatment on the 1988 time replicate. This relationship was also seen in the 1990 time replicate, with the H treatment having a higher cronartium infection rate ($\sim$ 13% after age 10) compared with the C. The 1995 time replicate showed a slightly different story, with the H having higher growth rates and infection rates, but the HF did not have the typical high cronartium infection rate to accompany its high growth rate. This decrease in cronartium infection rates could be due to a difference in climatic attributes at time of planting that favor cronartium.

Table 3.36: Average dominant height (feet) development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

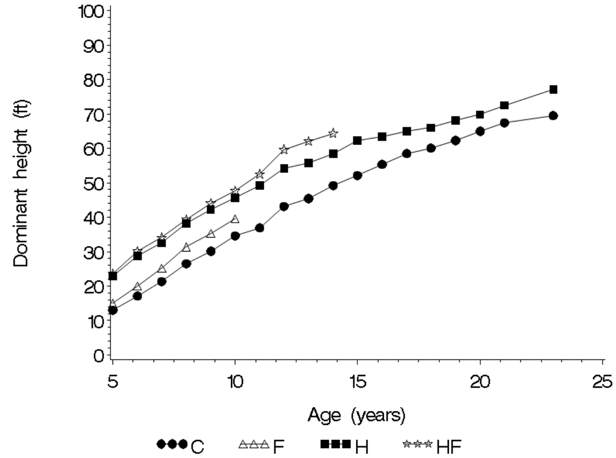
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	16.7	19.1	23.7	25.9	12.9	15.0	22.9	23.6
6	20.5	23.9	28.5	30.6	17.2	20.1	28.9	30.1
7	24.1	28.5	34.0	36.3	21.3	25.2	32.5	34.1
8	28.9	34.0	39.2	42.3	26.4	31.4	38.2	39.4
9	33.4	37.9	42.6	46.8	30.1	35.3	42.2	44.1
10	36.9	42.5	45.9	50.4	34.5	39.6	45.6	47.6
11	40.3	47.2	48.9	55.0	36.9	.	49.3	52.5
12	43.4	50.0	51.5	58.9	43.1	.	54.2	59.6
13	45.0	52.9	52.5	60.1	45.4	.	55.8	62.0
14	49.7	58.1	56.8	65.3	49.1	.	58.4	64.4
15	52.3	61.8	58.9	68.4	52.1	.	62.2	.
16	54.7	66.7	60.8	71.4	55.3	.	63.5	.
17	59.6	69.8	65.2	75.6	58.5	.	65.0	.
18	61.4	72.8	67.0	77.3	60.1	.	66.0	.
19	63.8	74.4	67.8	79.2	62.3	.	68.1	.
20	65.4	76.6	71.6	80.6	65.0	.	69.8	.
21	66.2	78.3	73.4	81.1	67.4	.	72.5	.
23	73.5	83.3	77.0	88.3	69.5	.	77.1	.
25	74.7	88.2	79.2	90.5	.	.	.	.

Table 3.37: Average dominant height (feet) development at the Eatonton - Powerline site for the 1995 time replicate.

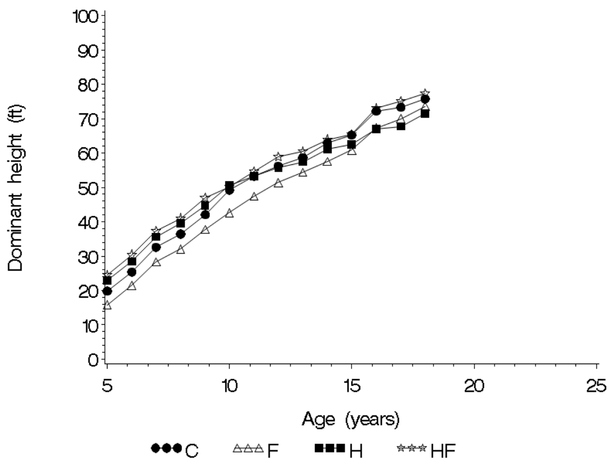
	1995			
Age	C	F	H	HF
5	19.9	15.8	22.9	24.4
6	25.3	21.5	28.5	30.4
7	32.5	28.3	35.6	37.3
8	36.4	32.1	39.6	41.0
9	42.1	37.8	44.8	47.0
10	49.1	42.6	50.5	50.2
11	53.2	47.4	53.3	54.6
12	56.2	51.4	55.8	58.9
13	58.6	54.4	57.4	60.4
14	63.1	57.6	61.2	63.9
15	65.3	60.9	62.4	65.4
16	72.3	67.3	66.9	73.0
17	73.4	70.0	67.8	75.1
18	75.7	73.6	71.6	77.4
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



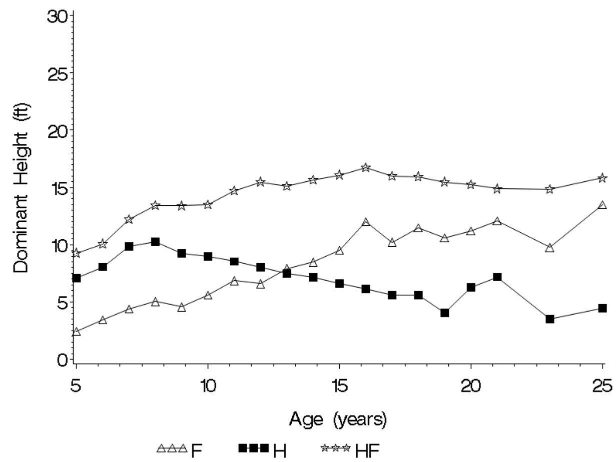
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

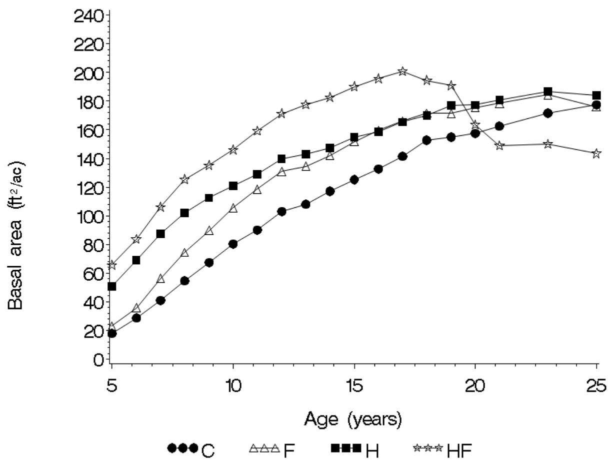
Figure 3.24: Average dominant height (feet) over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures 3.24(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.38: Average basal area (ft^2/acre) at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

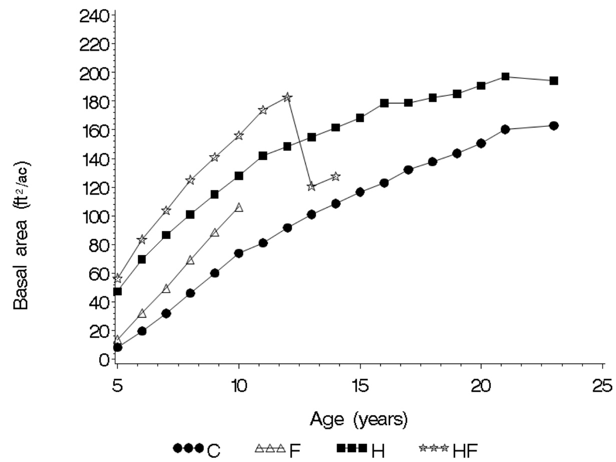
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	18.0	23.1	50.9	65.6	8.3	13.7	47.2	56.2
6	28.8	35.8	69.1	83.5	19.7	32.2	69.4	83.4
7	40.9	56.3	87.4	106.1	31.9	49.4	86.6	103.6
8	54.7	74.5	101.9	125.3	46.1	69.2	100.8	124.9
9	67.4	89.8	112.5	135.2	60.1	88.6	114.9	140.8
10	80.3	105.6	120.7	146.0	73.7	106.1	127.7	155.8
11	89.9	118.6	129.0	159.0	81.2	.	141.7	173.7
12	102.9	130.9	139.7	171.3	91.5	.	148.3	182.7
13	108.1	134.6	143.1	177.5	100.9	.	155.1	120.6
14	117.1	142.1	147.4	182.6	108.4	.	161.6	127.3
15	125.2	151.7	155.0	190.0	116.5	.	168.2	.
16	132.6	159.6	158.7	195.7	122.8	.	178.7	.
17	141.6	165.9	165.4	200.8	132.0	.	178.8	.
18	152.6	171.7	170.0	194.4	137.8	.	182.3	.
19	154.9	171.3	177.0	190.7	143.6	.	184.9	.
20	157.3	175.3	177.3	163.5	150.6	.	190.8	.
21	162.6	178.4	180.7	148.9	160.2	.	197.2	.
23	171.6	184.3	186.6	149.8	162.7	.	194.2	.
25	177.3	175.9	184.0	143.3	.	.	.	.

Table 3.39: Average basal area (ft^2/acre) at the Eatonton - Powerline site for the 1995 time replicate.

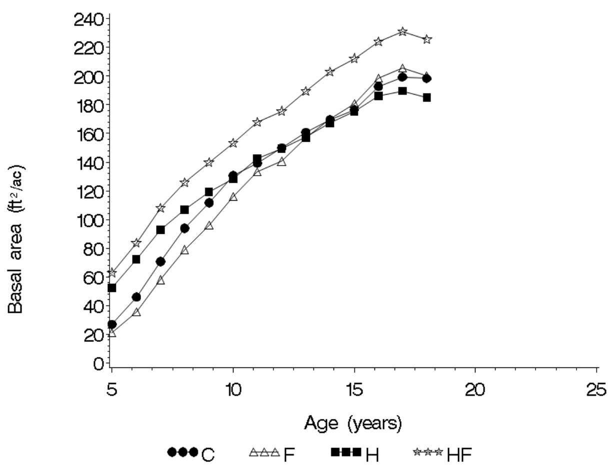
	1995			
Age	C	F	H	HF
5	26.8	21.0	52.2	62.8
6	46.0	35.7	72.2	83.5
7	70.7	58.1	92.8	108.0
8	93.9	78.9	106.9	125.6
9	111.7	96.1	119.4	139.6
10	130.5	116.0	128.5	153.1
11	139.5	133.2	142.7	167.7
12	149.9	140.7	149.5	175.5
13	160.6	157.0	157.5	189.4
14	169.7	170.0	167.1	202.8
15	176.6	180.8	175.4	212.2
16	192.8	198.6	186.3	223.9
17	199.4	205.6	189.6	230.8
18	198.3	200.3	185.1	225.6
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



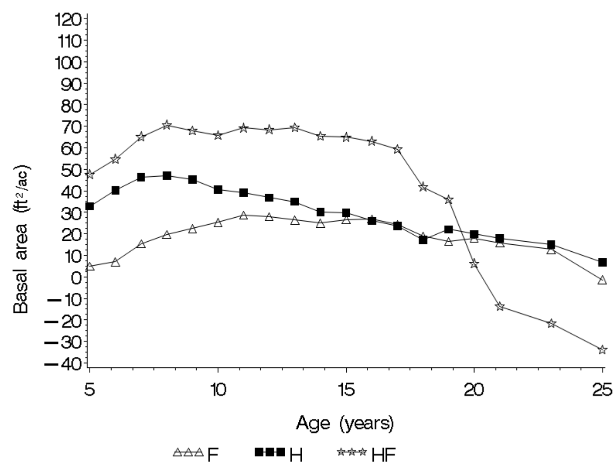
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

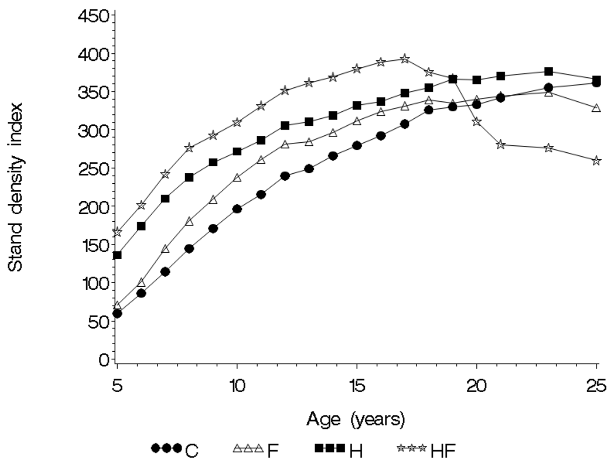
Figure 3.25: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures 3.25(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.40: Average stand density index development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

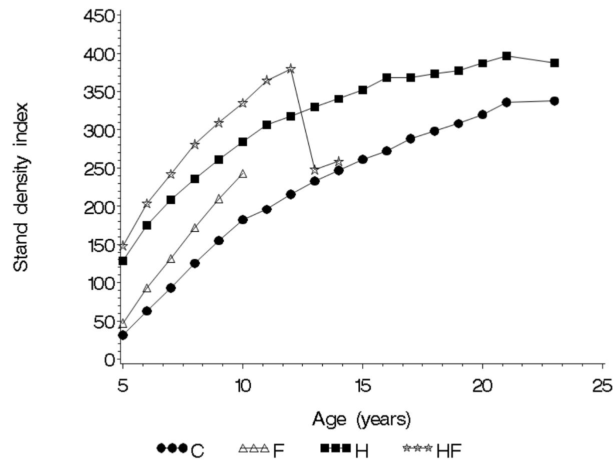
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	59.3	70.7	136.1	166.2	31.4	46.8	128.4	148.0
6	86.3	100.8	174.0	201.2	63.0	93.0	174.7	203.1
7	114.4	144.7	210.0	241.9	93.1	131.3	208.3	241.8
8	144.5	180.6	237.4	276.5	125.3	172.2	235.5	280.8
9	170.6	209.1	257.4	292.7	155.1	209.8	261.1	309.2
10	196.4	237.8	271.6	309.6	182.3	242.6	283.9	335.0
11	215.1	260.9	286.4	331.2	195.8	.	306.6	364.5
12	239.5	281.3	305.4	351.5	215.4	.	318.0	379.8
13	249.2	284.5	310.9	361.6	233.1	.	329.5	247.5
14	265.7	296.4	318.4	368.8	246.9	.	340.5	258.5
15	279.6	311.7	331.5	379.8	261.2	.	351.8	.
16	292.1	323.6	336.9	388.2	272.4	.	368.3	.
17	307.5	331.2	348.3	392.7	288.4	.	368.5	.
18	326.1	339.2	355.1	375.2	298.0	.	373.2	.
19	330.1	334.4	366.4	367.0	308.1	.	377.5	.
20	333.3	340.1	365.3	310.5	320.1	.	387.1	.
21	341.8	344.3	370.5	280.7	335.9	.	396.3	.
23	355.4	349.3	376.5	276.4	337.7	.	387.1	.
25	361.3	328.8	365.8	259.6	.	.	.	.

Table 3.41: Average stand density index development at the Eatonton - Powerline site for the 1995 time replicate.

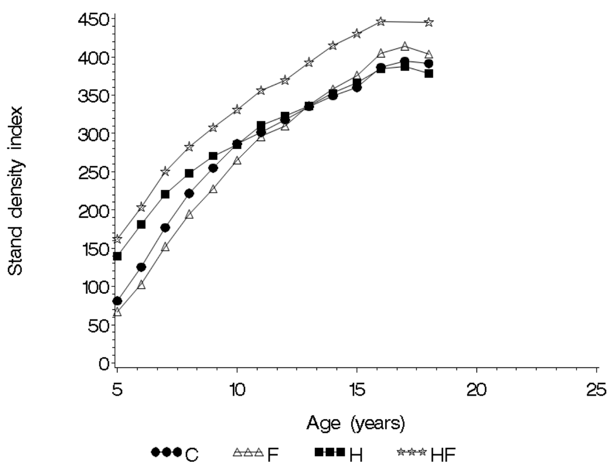
	1995			
Age	C	F	H	HF
5	81.1	67.2	139.6	162.0
6	125.3	102.9	181.1	203.6
7	176.8	152.2	220.9	250.3
8	221.4	194.6	247.6	282.5
9	254.6	227.8	270.5	307.6
10	286.2	265.0	285.5	331.1
11	301.0	296.2	310.6	356.3
12	318.0	309.4	322.5	369.5
13	335.2	337.0	336.2	392.7
14	349.4	358.3	352.6	414.9
15	359.8	375.6	366.6	430.3
16	386.0	405.0	384.8	445.9
17	394.2	414.2	387.2	454.6
18	391.4	403.5	378.8	445.1
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

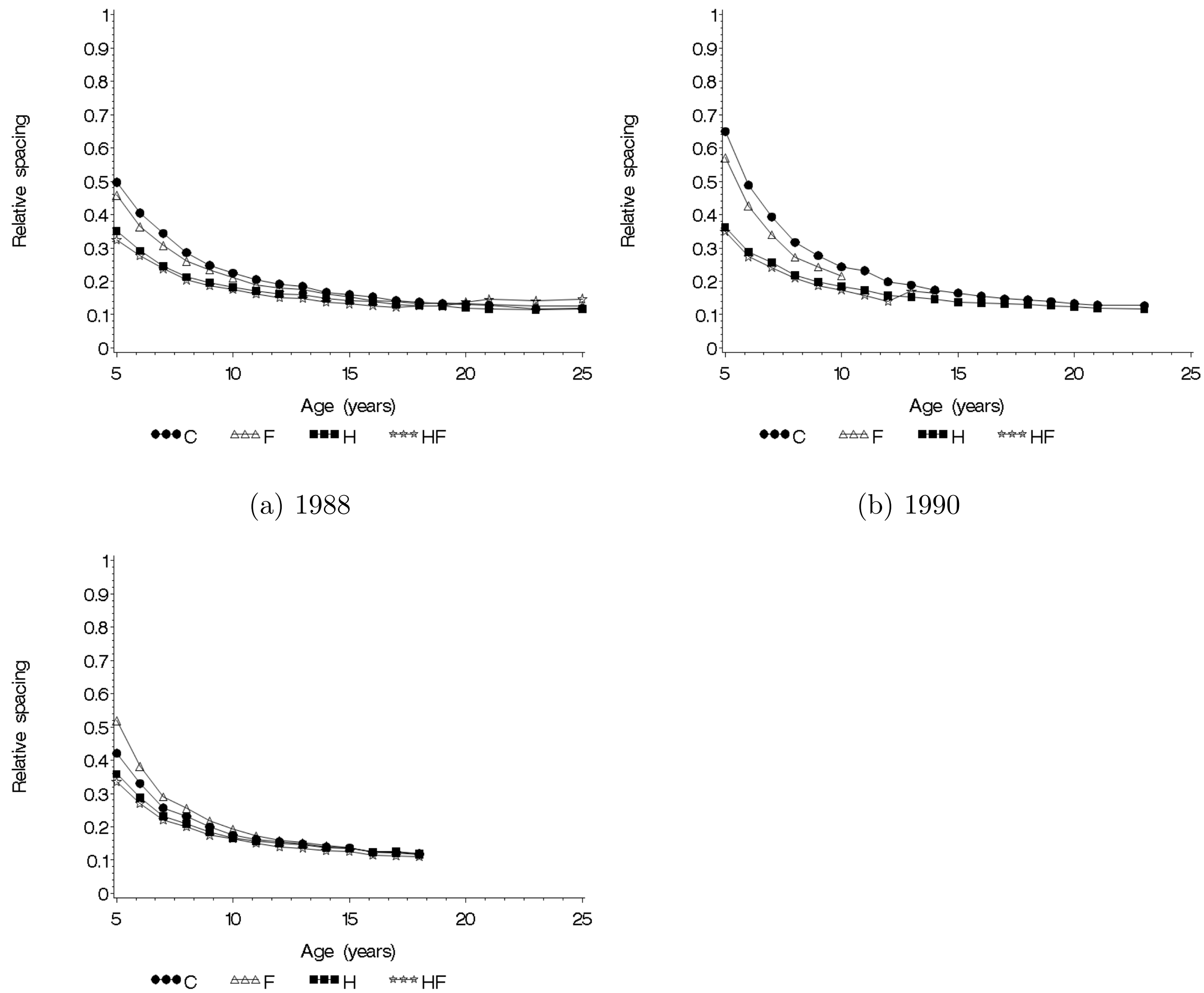
Figure 3.26: Average stand density index over the course of the study for the individual time replicates at the Eatonton - Powerline site are shown in subfigures (a)-(c).

Table 3.42: Average relative spacing development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	0.50	0.46	0.35	0.32	0.65	0.57	0.36	0.35
6	0.40	0.36	0.29	0.28	0.49	0.43	0.29	0.27
7	0.34	0.31	0.24	0.24	0.39	0.34	0.26	0.24
8	0.29	0.26	0.21	0.20	0.32	0.27	0.22	0.21
9	0.25	0.23	0.19	0.19	0.28	0.24	0.20	0.19
10	0.22	0.21	0.18	0.18	0.24	0.22	0.18	0.17
11	0.21	0.19	0.17	0.16	0.23	.	0.17	0.16
12	0.19	0.18	0.16	0.15	0.20	.	0.16	0.14
13	0.18	0.18	0.16	0.15	0.19	.	0.15	0.17
14	0.17	0.16	0.15	0.14	0.17	.	0.15	0.16
15	0.16	0.15	0.14	0.13	0.16	.	0.14	.
16	0.15	0.14	0.14	0.13	0.16	.	0.14	.
17	0.14	0.14	0.13	0.12	0.15	.	0.13	.
18	0.14	0.13	0.13	0.13	0.14	.	0.13	.
19	0.13	0.14	0.13	0.12	0.14	.	0.13	.
20	0.13	0.13	0.12	0.14	0.13	.	0.12	.
21	0.13	0.13	0.12	0.15	0.13	.	0.12	.
23	0.12	0.13	0.11	0.14	0.13	.	0.12	.
25	0.12	0.13	0.12	0.15	.	.	.	.

Table 3.43: Average relative spacing development at the Eatonton - Powerline site for the 1995 time replicate.

	1995			
Age	C	F	H	HF
5	0.42	0.52	0.36	0.34
6	0.33	0.38	0.29	0.27
7	0.26	0.29	0.23	0.22
8	0.23	0.26	0.21	0.20
9	0.20	0.22	0.18	0.17
10	0.17	0.19	0.17	0.16
11	0.16	0.17	0.16	0.15
12	0.15	0.16	0.15	0.14
13	0.15	0.15	0.15	0.14
14	0.14	0.14	0.14	0.13
15	0.14	0.14	0.13	0.13
16	0.12	0.12	0.12	0.11
17	0.12	0.12	0.13	0.11
18	0.12	0.12	0.12	0.11
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988

(b) 1990

(c) 1995

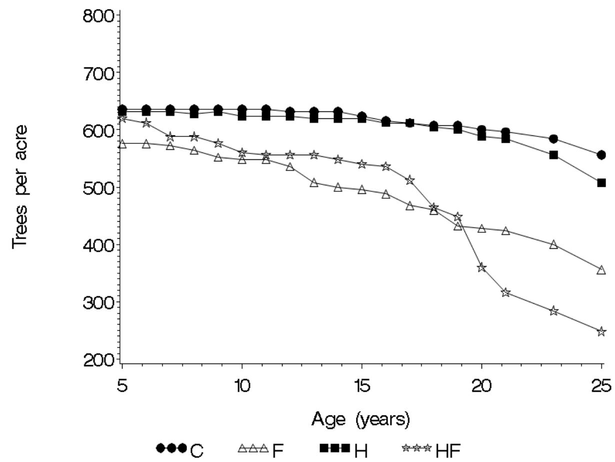
Figure 3.27: Average relative spacing development over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures (a)-(c).

Table 3.44: Average trees per acre development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

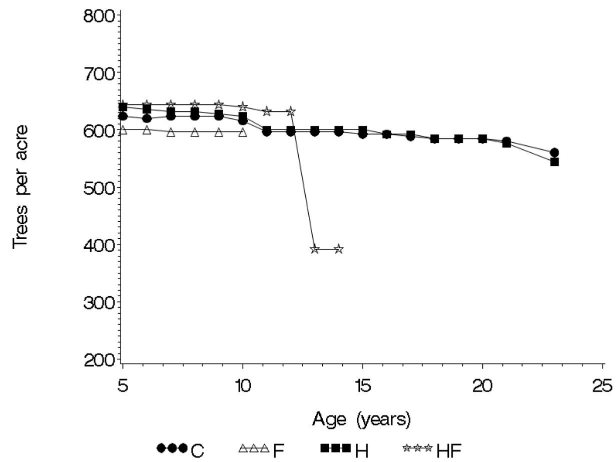
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	636	576	632	620	624	600	640	644
6	636	576	632	612	620	600	636	644
7	636	572	632	588	624	596	632	644
8	636	564	628	588	624	596	632	644
9	636	552	632	576	624	596	628	644
10	636	548	624	560	616	596	624	640
11	636	548	624	556	596	.	600	632
12	632	536	624	556	596	.	600	632
13	632	508	620	556	596	.	600	392
14	632	500	620	548	596	.	600	392
15	624	496	620	540	592	.	600	.
16	616	488	612	536	592	.	592	.
17	612	468	612	512	588	.	592	.
18	608	460	604	464	584	.	584	.
19	608	432	600	448	584	.	584	.
20	600	428	588	360	584	.	584	.
21	596	424	584	316	580	.	576	.
23	584	400	556	284	560	.	544	.
25	556	356	508	248	.	.	.	.

Table 3.45: Average trees per acre development at the Eatonton - Powerline site for the 1995 time replicates.

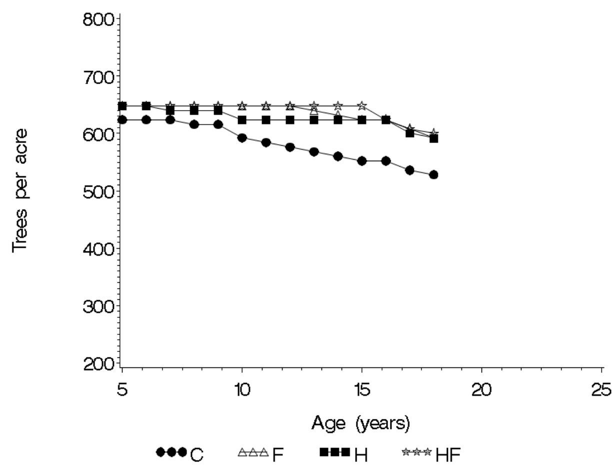
	1995			
Age	C	F	H	HF
5	624	648	648	648
6	624	648	648	648
7	624	648	640	648
8	616	648	640	648
9	616	648	640	648
10	592	648	624	648
11	584	648	624	648
12	576	648	624	648
13	568	640	624	648
14	560	632	624	648
15	552	624	624	648
16	552	624	624	624
17	536	608	600	608
18	528	592	592	600
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



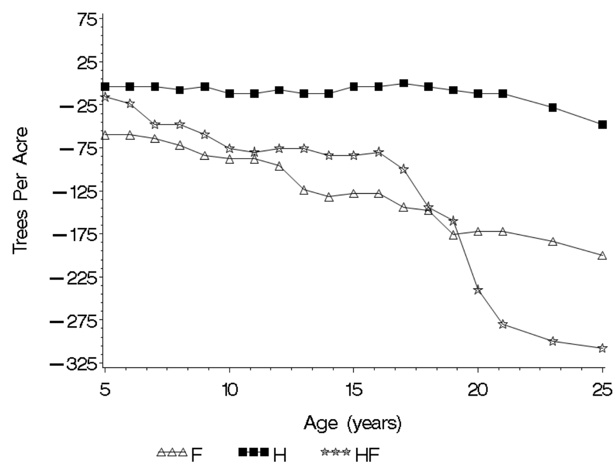
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

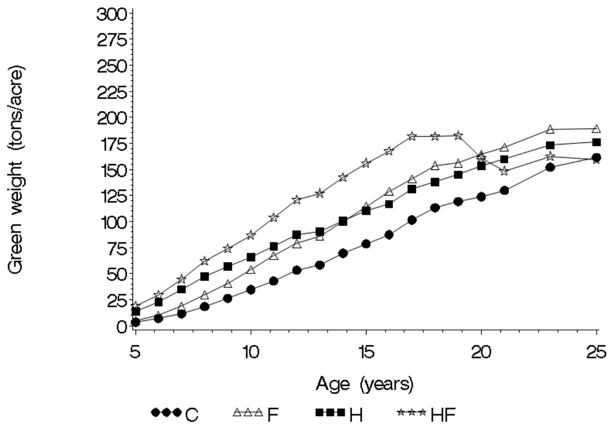
Figure 3.28: Average trees per acre development over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures 3.28(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.46: Average total green weight (tons/acre) development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

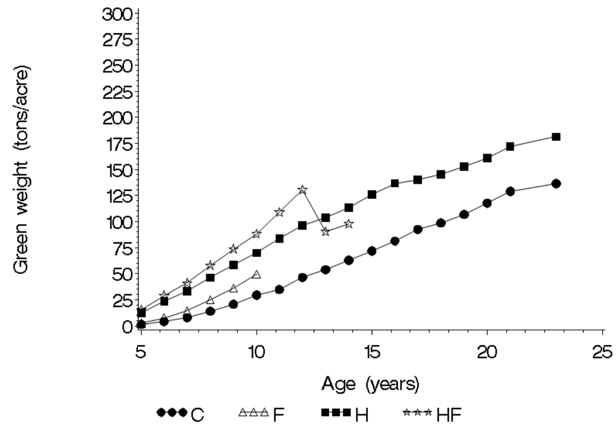
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	3.4	5.0	13.8	19.0	1.3	2.4	12.5	15.1
6	6.7	9.8	22.9	29.4	3.9	7.4	23.5	28.8
7	11.4	18.7	34.9	44.6	7.6	14.3	33.3	41.0
8	18.4	29.6	47.2	62.1	13.9	25.0	46.1	57.8
9	26.1	40.4	56.8	74.0	20.8	36.2	58.2	73.5
10	34.5	54.0	66.0	86.8	29.3	49.3	69.9	88.0
11	43.0	67.1	76.0	103.7	34.9	.	83.7	108.8
12	53.2	78.8	87.1	120.6	46.1	.	96.2	130.1
13	58.1	86.1	90.5	127.0	53.6	.	103.8	90.1
14	69.5	100.2	100.7	142.1	62.8	.	113.3	97.8
15	78.6	114.2	110.5	155.8	71.8	.	126.2	.
16	87.2	128.9	116.7	167.5	81.1	.	136.6	.
17	101.4	140.9	130.9	181.5	92.4	.	139.9	.
18	113.1	153.6	137.9	181.5	98.7	.	145.5	.
19	118.9	156.1	144.9	182.3	106.9	.	152.4	.
20	123.8	164.3	153.4	161.1	117.5	.	161.0	.
21	129.9	171.3	159.8	148.4	128.8	.	172.0	.
23	152.1	188.5	173.1	162.5	136.4	.	181.3	.
25	161.2	188.9	176.0	159.3	.	.	.	.

Table 3.47: Average total green weight (tons/acre) development at the Eatonton - Powerline site for the 1995 time replicate.

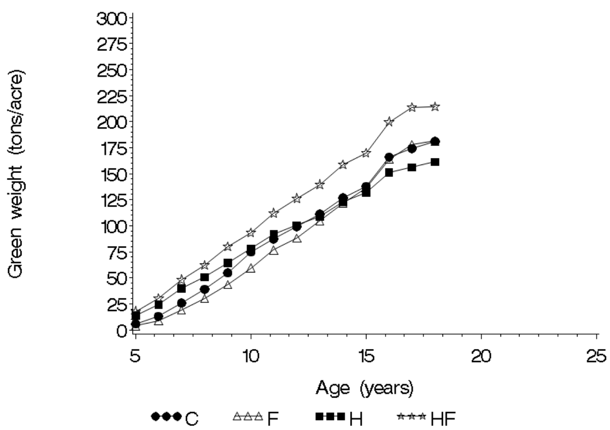
	1995			
Age	C	F	H	HF
5	5.9	3.9	14.0	17.8
6	12.9	8.8	24.4	30.0
7	25.9	19.1	39.6	48.2
8	38.7	30.0	50.6	61.8
9	54.9	43.3	64.6	79.9
10	74.8	59.4	78.0	93.2
11	87.3	76.5	91.5	112.0
12	99.2	88.0	100.3	126.0
13	111.2	104.8	108.9	139.5
14	126.8	121.5	122.8	158.3
15	137.5	136.2	132.1	169.5
16	165.8	163.8	150.9	199.7
17	173.9	178.1	156.0	213.6
18	181.1	181.3	161.2	214.2
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



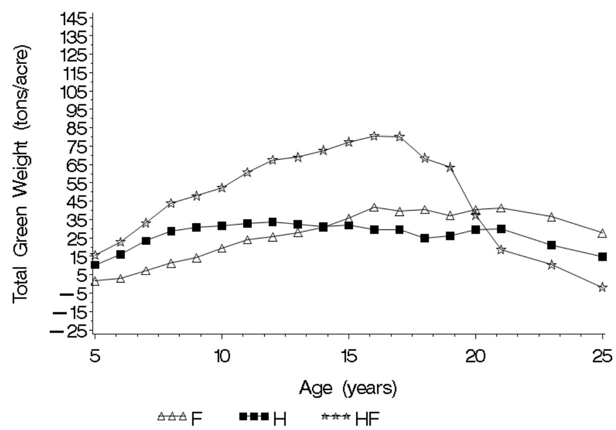
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

Figure 3.29: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures (a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.48: Mean annual increment (tons/acre/year) development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	0.7	1.0	2.8	3.8	0.3	0.5	2.5	3.0
6	1.1	1.6	3.8	4.9	0.7	1.2	3.9	4.8
7	1.6	2.7	5.0	6.4	1.1	2.0	4.8	5.9
8	2.3	3.7	5.9	7.8	1.7	3.1	5.8	7.2
9	2.9	4.5	6.3	8.2	2.3	4.0	6.5	8.2
10	3.5	5.4	6.6	8.7	2.9	4.9	7.0	8.8
11	3.9	6.1	6.9	9.4	3.2	.	7.6	9.9
12	4.4	6.6	7.3	10.1	3.8	.	8.0	10.8
13	4.5	6.6	7.0	9.8	4.1	.	8.0	6.9
14	5.0	7.2	7.2	10.2	4.5	.	8.1	7.0
15	5.2	7.6	7.4	10.4	4.8	.	8.4	.
16	5.5	8.1	7.3	10.5	5.1	.	8.5	.
17	6.0	8.3	7.7	10.7	5.4	.	8.2	.
18	6.3	8.5	7.7	10.1	5.5	.	8.1	.
19	6.3	8.2	7.6	9.6	5.6	.	8.0	.
20	6.2	8.2	7.7	8.1	5.9	.	8.1	.
21	6.2	8.2	7.6	7.1	6.1	.	8.2	.
23	6.6	8.2	7.5	7.1	5.9	.	7.9	.
25	6.5	7.6	7.0	6.4	.	.	.	.

Table 3.49: Mean annual increment (tons/acre/year) development at the Eatonton - Powerline site for the 1995 time replicate.

	1995			
Age	C	F	H	HF
5	1.2	0.8	2.8	3.6
6	2.1	1.5	4.1	5.0
7	3.7	2.7	5.7	6.9
8	4.8	3.8	6.3	7.7
9	6.1	4.8	7.2	8.9
10	7.5	5.9	7.8	9.3
11	7.9	7.0	8.3	10.2
12	8.3	7.3	8.4	10.5
13	8.6	8.1	8.4	10.7
14	9.1	8.7	8.8	11.3
15	9.2	9.1	8.8	11.3
16	10.4	10.2	9.4	12.5
17	10.2	10.5	9.2	12.6
18	10.1	10.1	9.0	11.9
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

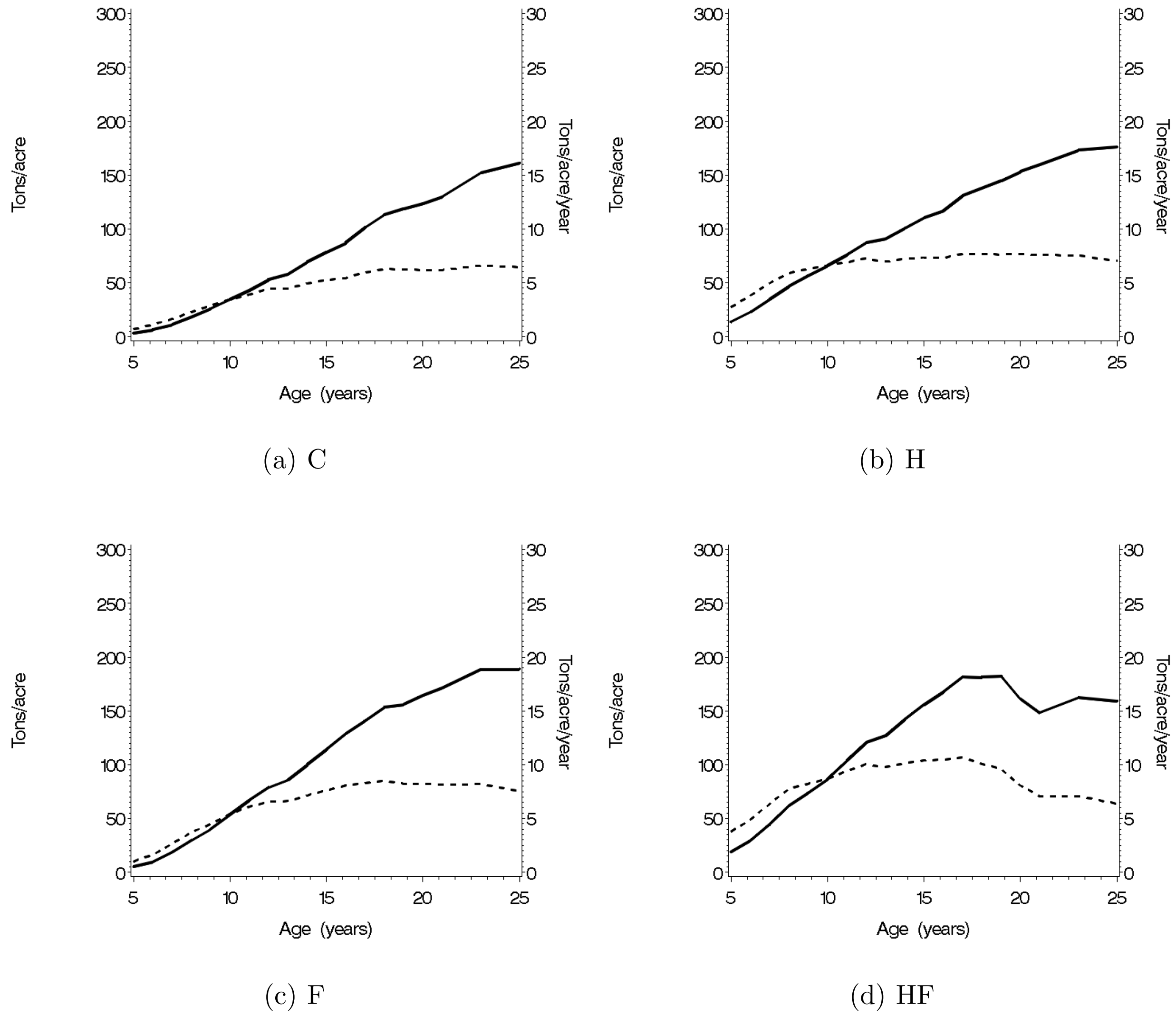
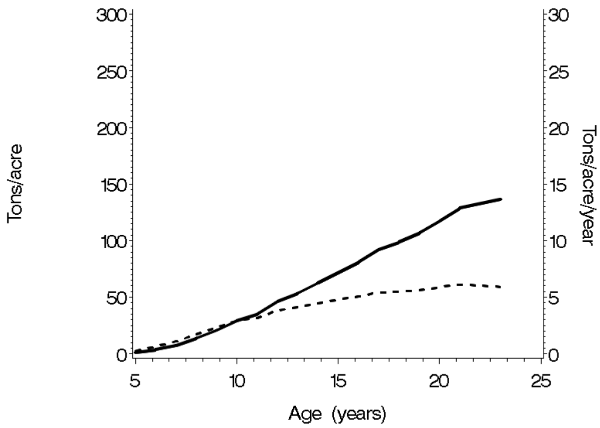
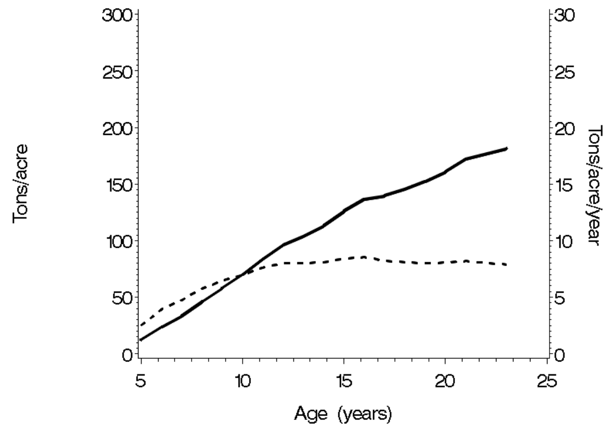


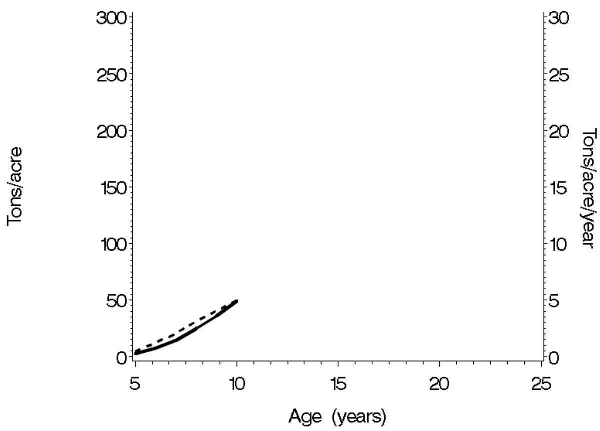
Figure 3.30: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Eatonton - Powerline 1988 time replicate.



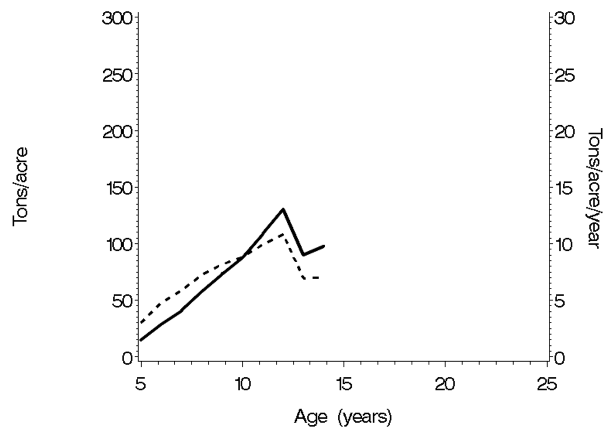
(a) C



(b) H

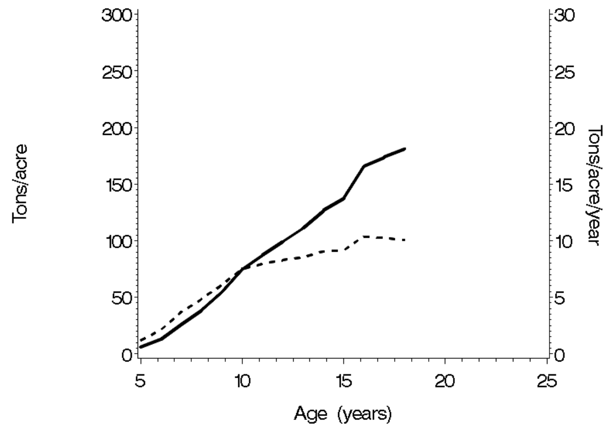


(c) F

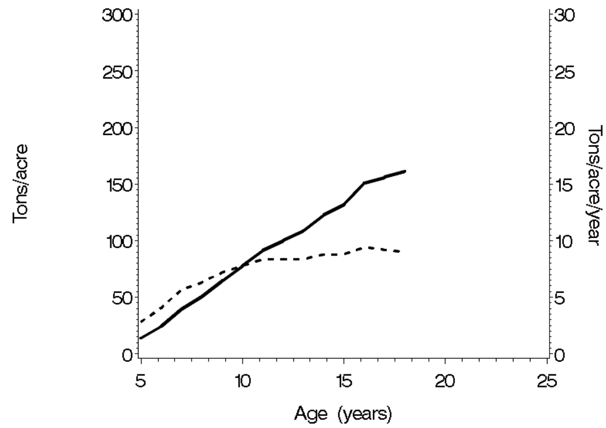


(d) HF

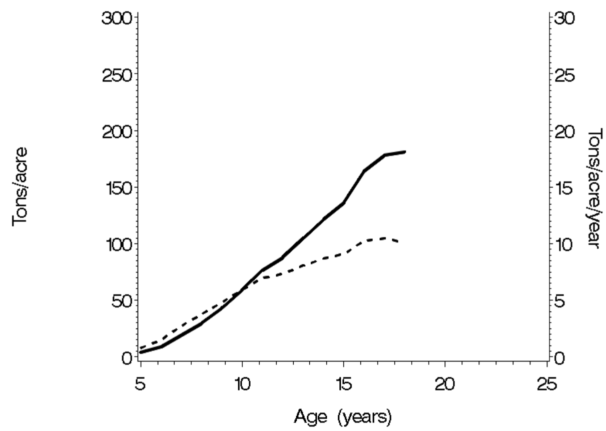
Figure 3.31: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Eatonton - Powerline 1990 time replicate.



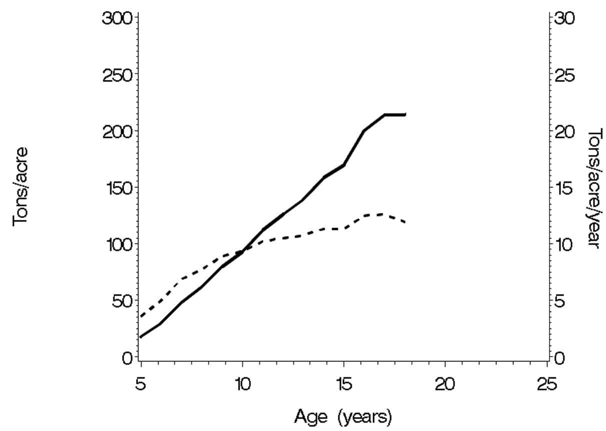
(a) C



(b) H



(c) F



(d) HF

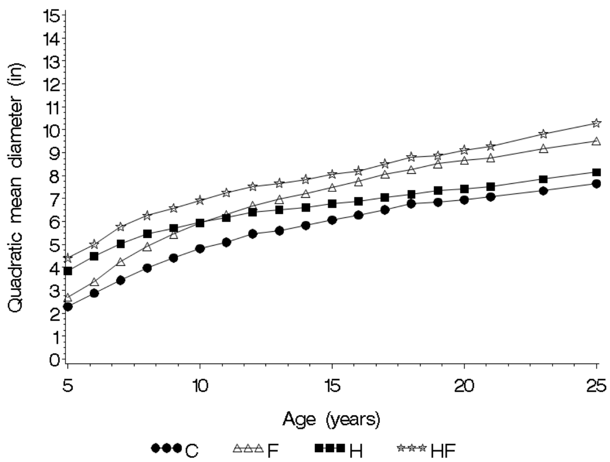
Figure 3.32: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (——–) by treatment for the Eatonton - Powerline 1995 time replicate.

Table 3.50: Average quadratic mean diameter (inches) development at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

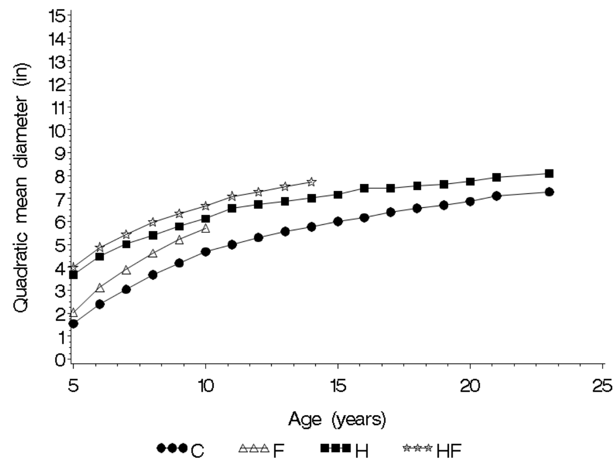
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	2.3	2.7	3.8	4.4	1.5	2.0	3.7	4.0
6	2.9	3.4	4.5	5.0	2.4	3.1	4.5	4.9
7	3.4	4.2	5.0	5.8	3.1	3.9	5.0	5.4
8	4.0	4.9	5.5	6.3	3.7	4.6	5.4	6.0
9	4.4	5.5	5.7	6.6	4.2	5.2	5.8	6.3
10	4.8	5.9	6.0	6.9	4.7	5.7	6.1	6.7
11	5.1	6.3	6.2	7.3	5.0	.	6.6	7.1
12	5.5	6.7	6.4	7.5	5.3	.	6.7	7.3
13	5.6	7.0	6.5	7.7	5.6	.	6.9	7.5
14	5.8	7.2	6.6	7.8	5.8	.	7.0	7.7
15	6.1	7.5	6.8	8.1	6.0	.	7.2	.
16	6.3	7.7	6.9	8.2	6.2	.	7.4	.
17	6.5	8.1	7.0	8.5	6.4	.	7.4	.
18	6.8	8.3	7.2	8.8	6.6	.	7.6	.
19	6.8	8.5	7.4	8.9	6.7	.	7.6	.
20	6.9	8.7	7.4	9.1	6.9	.	7.7	.
21	7.1	8.8	7.5	9.3	7.1	.	7.9	.
23	7.3	9.2	7.8	9.8	7.3	.	8.1	.
25	7.6	9.5	8.2	10.3	.	.	.	.

Table 3.51: Average quadratic mean diameter (inches) development at the Eatonton - Powerline site for the 1995 time replicate.

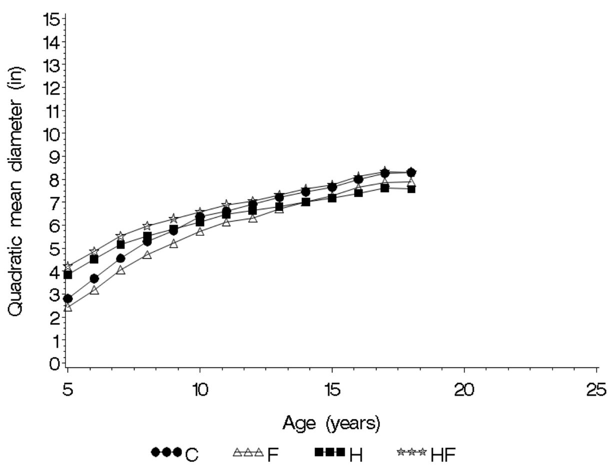
	1995			
Age	C	F	H	HF
5	2.8	2.4	3.8	4.2
6	3.7	3.2	4.5	4.9
7	4.6	4.1	5.2	5.5
8	5.3	4.7	5.5	6.0
9	5.8	5.2	5.9	6.3
10	6.4	5.7	6.1	6.6
11	6.6	6.1	6.5	6.9
12	6.9	6.3	6.6	7.1
13	7.2	6.7	6.8	7.3
14	7.5	7.0	7.0	7.6
15	7.7	7.3	7.2	7.8
16	8.0	7.6	7.4	8.1
17	8.3	7.9	7.6	8.3
18	8.3	7.9	7.6	8.3
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



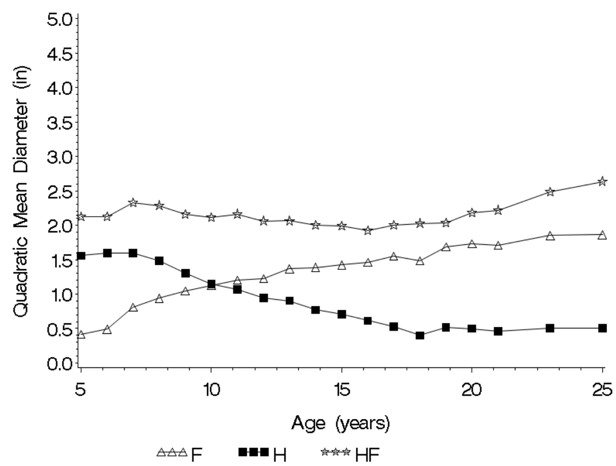
(a) 1988



(b) 1990



(c) 1995



(d) 1988 Treatment Effects

Figure 3.33: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Eatonton - Powerline site is shown in subfigures (a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.52: Average pulpwood development (tons/acre) at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	0.9	6.3	16.4	.	.	6.0	9.6
6	0.5	3.9	19.7	27.8	0.6	1.2	20.3	26.9
7	3.2	14.3	33.2	43.3	2.1	9.0	31.4	39.6
8	11.2	26.8	45.5	60.1	7.0	21.3	44.4	56.0
9	21.4	37.5	55.0	70.8	16.2	33.5	56.5	69.2
10	31.3	50.6	64.4	74.6	25.9	46.0	68.3	81.6
11	39.5	60.0	73.8	78.2	32.0	.	81.3	94.7
12	50.3	66.0	80.9	79.0	43.2	.	89.4	104.0
13	54.5	64.1	83.7	76.4	50.3	.	94.0	61.6
14	65.1	67.3	92.3	78.0	59.1	.	96.4	60.6
15	72.7	68.2	96.0	77.2	66.4	.	103.6	.
16	78.8	68.9	98.9	76.2	72.1	.	97.7	.
17	86.6	65.9	105.8	74.4	80.3	.	96.2	.
18	87.0	68.3	102.3	67.1	82.8	.	89.3	.
19	88.3	62.6	98.7	64.4	85.7	.	92.3	.
20	86.8	62.3	102.5	50.8	86.1	.	90.6	.
21	84.8	61.0	104.6	43.5	83.2	.	87.3	.
23	92.3	58.6	102.3	39.0	81.3	.	87.4	.
25	88.4	53.1	84.0	33.3	.	.	.	.

Table 3.53: Average pulpwood development (tons/acre) at the Eatonton - Powerline site for the 1995 time replicate.

	1995			
Age	C	F	H	HF
5	1.0	.	8.2	13.4
6	8.2	0.4	21.6	28.5
7	20.6	12.0	37.5	47.0
8	36.5	27.7	49.2	60.6
9	51.4	42.0	63.1	78.6
10	67.2	58.0	76.6	91.9
11	72.6	74.0	88.8	103.7
12	74.0	85.2	96.2	113.9
13	75.3	92.1	101.5	117.9
14	74.0	96.6	107.1	110.1
15	70.9	103.1	105.9	100.7
16	77.2	104.2	109.9	92.7
17	72.5	91.6	102.2	90.6
18	73.6	96.9	108.8	91.9
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.54: Average chip-n-saw development (tons/acre) at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

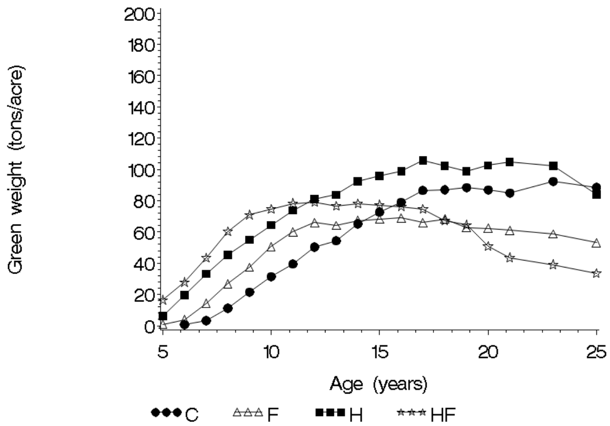
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	1.1	.	.	.	1.2
9	.	1.1	.	3.6	.	.	.	3.0
10	.	2.6	.	11.0	.	1.8	.	5.0
11	.	5.2	1.1	24.3	.	.	1.1	12.9
12	1.0	11.4	4.6	40.3	.	.	5.5	24.8
13	1.1	20.6	5.3	49.3	1.2	.	8.5	27.6
14	2.0	31.5	6.8	62.9	1.7	.	15.5	36.4
15	3.7	44.7	12.8	77.3	2.3	.	21.2	.
16	6.2	58.8	16.2	90.1	5.7	.	37.6	.
17	12.6	73.9	23.4	105.9	9.6	.	42.3	.
18	24.0	81.8	34.1	111.0	13.7	.	54.8	.
19	28.4	89.9	44.7	116.8	18.8	.	58.7	.
20	34.8	98.2	49.4	107.1	28.8	.	69.0	.
21	43.2	106.2	53.7	99.2	43.4	.	83.3	.
23	57.7	117.2	69.4	105.1	52.3	.	92.5	.
25	71.3	116.2	90.7	93.5	.	.	.	.

Table 3.55: Average chip-n-saw development (tons/acre) at the Eatonton - Powerline site for the 1995 time replicate.

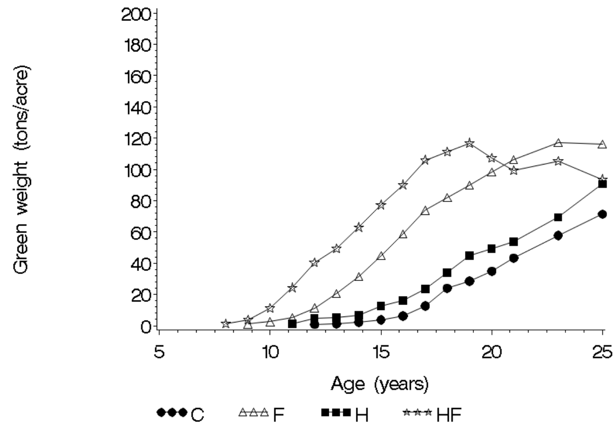
	1995			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	1.2	.	.	.
10	5.3	.	.	.
11	12.9	1.1	1.3	6.9
12	23.3	1.3	2.7	10.6
13	34.4	11.2	6.0	20.2
14	51.3	23.3	14.2	46.7
15	65.1	31.7	24.8	67.3
16	87.1	58.1	39.5	105.5
17	99.8	84.9	52.3	121.4
18	105.4	82.8	50.9	120.8
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.56: Average sawtimber development (tons/acre) at the Eatonton - Powerline site for the 1988 and 1990 time replicates.

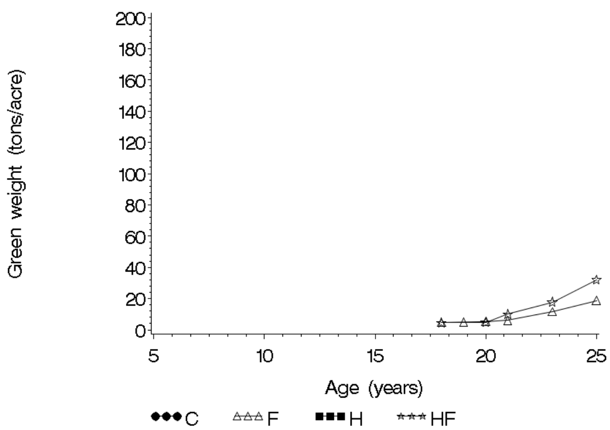
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.
17	.	.	.	.	.	.	.	.
18	.	4.7	.	4.5	.	.	.	.
19	.	5.1	.	.	.	.	.	.
20	.	5.4	.	4.7	.	.	.	.
21	.	6.1	.	10.0	.	.	.	.
23	.	11.7	.	17.7	.	.	.	.
25	.	18.8	.	32.0	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw



(c) Sawtimber

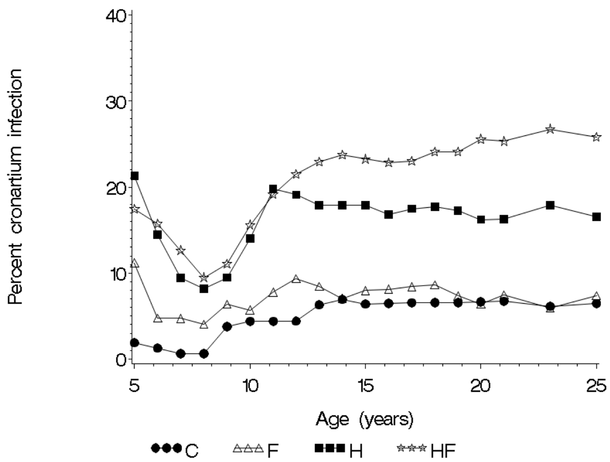
Figure 3.34: Average product distribution (tons/acre) over the course of the study for the Eatonton - Powerline 1988 time replicate. Pulpwood is shown in 3.34(a), Chip-N-Saw in 3.34(b), and sawtimber in 3.34(c).

Table 3.57: Average cronartium infection rates (%) at the Eatonton - Powerline site for the 1988 and 1995 time replicates.

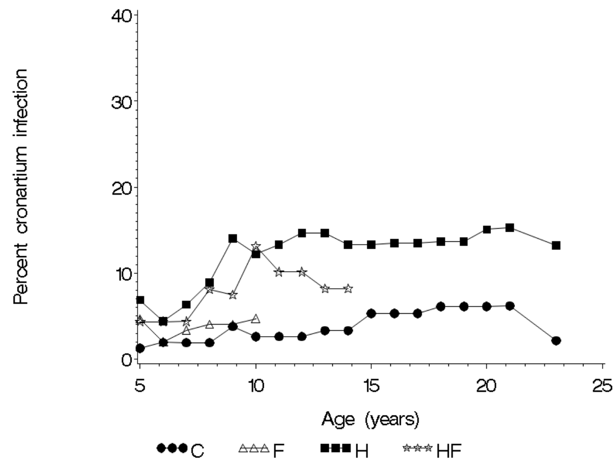
	1988				1990			
Age	C	F	H	HF	C	F	H	HF
5	1.9	11.2	21.3	17.4	1.3	4.7	6.9	4.4
6	1.3	4.8	14.5	15.7	1.9	2.0	4.4	4.3
7	0.6	4.7	9.4	12.6	1.9	3.4	6.3	4.4
8	0.6	4.1	8.2	9.5	1.9	4.0	8.9	8.1
9	3.8	6.4	9.5	11.1	3.8	4.0	14.0	7.5
10	4.4	5.7	14.1	15.6	2.6	4.7	12.2	13.1
11	4.4	7.8	19.8	19.2	2.6	.	13.3	10.1
12	4.4	9.3	19.1	21.5	2.6	.	14.7	10.1
13	6.3	8.5	17.9	22.9	3.3	.	14.7	8.2
14	7.0	7.1	17.9	23.7	3.3	.	13.3	8.2
15	6.4	8.0	17.9	23.3	5.3	.	13.3	.
16	6.5	8.1	16.9	22.9	5.3	.	13.5	.
17	6.5	8.4	17.5	23.0	5.3	.	13.5	.
18	6.6	8.7	17.7	24.1	6.1	.	13.7	.
19	6.6	7.3	17.3	24.1	6.1	.	13.7	.
20	6.7	6.4	16.2	25.6	6.1	.	15.1	.
21	6.7	7.4	16.3	25.3	6.2	.	15.3	.
23	6.2	5.9	17.9	26.8	2.1	.	13.2	.
25	6.5	7.4	16.5	25.8	.	.	.	.

Table 3.58: Average cronartium infection rates (%) at the Eatonton - Powerline site for the 1995 time replicate.

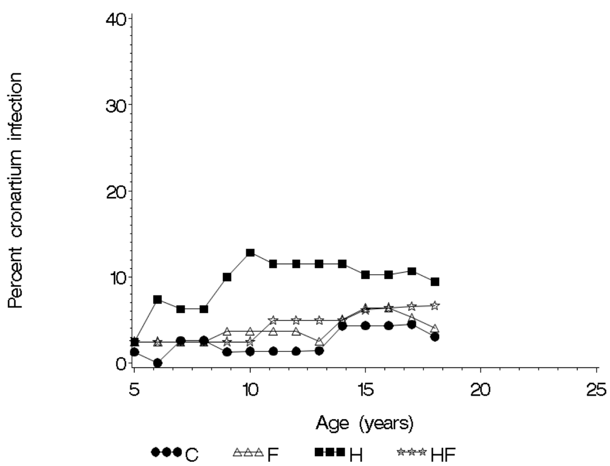
	1995			
Age	C	F	H	HF
5	1.3	2.5	2.5	2.5
6	0.0	2.5	7.4	2.5
7	2.6	2.5	6.3	2.5
8	2.6	2.5	6.3	2.5
9	1.3	3.7	10.0	2.5
10	1.4	3.7	12.8	2.5
11	1.4	3.7	11.5	4.9
12	1.4	3.7	11.5	4.9
13	1.4	2.5	11.5	4.9
14	4.3	5.1	11.5	4.9
15	4.4	6.4	10.3	6.2
16	4.4	6.4	10.3	6.4
17	4.5	5.3	10.7	6.6
18	3.0	4.1	9.5	6.7
19	.	.	.	.
20	.	.	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

Figure 3.35: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Eatonton - Powerline site are shown in subfigures (a)-(c).

3.4 Dawsonville - Bottom

The Dawsonville - Bottom site only had two time replicates established. There were four treatments that ended early due to poor survival and beaver damage early in the study. The two F treatments in the 1987 time replicate were ended after its sixth growing seasons due to 100% mortality resulting from excessive competition on the study site. Due to its location in the flood plain of the Etowah River, the Dawsonville - Bottom site was very fertile and promoted large levels of herbaceous competitors on treatments that did not receive vegetation control. One of the 1989 C treatments was ended after the 19^{th} growing season, and one 1989 HF treatment ended after the 10^{th} growing season. For the remainder of the the study, it should be noted that the 1989 C and HF treatments are based off of the one remaining plot. This site saw higher rates of mortality that occurred earlier in the development of the stands.

Inherent site quality, measured by site index, is very high on this site. The C treatment has a base site index of 93 feet at age 25 for the 1987 time replicate (Table 3.59; Figure 3.36). The 1989 time replicate showed similar site index. Dominant height-age development patterns are very similar for the two time replicates which showed the H and HF treatments following extremely close trajectories from age 5 to 20 (Table 3.59). The 1987 time replicate shows a slight decrease in dominant height for the H treatment compared with the HF treatment. The 1989 time replicate showed similar trends in respect to the HF and H treatments. The C and F treatments followed similar development trends until approximately age 13, when the C treatment began to develop faster (Table 3.59, Figure 3.36(b)). Maximum dominant height values for the C treatment were 93 and 90 feet for the 1987 and 1989 time replicates, respectively. The F treatment had a maximum of 83 feet in the 1989 time replicate, which is lower than the C due to excessive rates of competition due to site conditions. Maximum dominant heights for the H treatment were 96 and 89 feet and the HF treatment had maximum values of 98 and 85 feet for the 1987 and 1989 time replicates. This site showed no nutrient deficiency issues due to no differences in dominant heights. The F treatment did show lower dominant heights, but that was due to severe competition.

Comparing dominant height and basal area per acre (BA) development shows that stand development is occurring faster on the HF and H treatments (Tables 3.59, 3.60; Figures 3.36, 3.37). BA development shows rapid increases in the H and HF treatments for both time replicates until approximately age 10. The 1989 time replicate shows slightly greater development in the H treatment compared with the HF treatment. Excessive mortality on the F treatments, due to severe competition, changed development to not allow for comparisons to the other treatments. The early mortality seen in the F treatments The F treatment shows the slowest development on the 1989 time replicate (Figure 3.37(b)). No treatments experienced a BA crash on this site, although the H treatment experienced a slight decline at age 16 (Table 3.60). All treatments in the 1987 and 1989 time replicates seem to continue to increase in BA as the study ended except for the 1989 HF and H treatments, which are beginning to stabilize at $\sim$ 235 and 220 ft^2/acre, respectively (Table 3.60). The 1989 time replicate shows higher BA values compared with the same treatments at the same age after age 10 in the 1987 time replicate.

Stand density index (SDI) development is consistent with BA development on both time replicates for the Dawsonville - Bottom site (Figures 3.37, 3.38). SDI development follows the rapid increase seen in BA for the HF and F treatments on the 1987 and 1989 time replicates followed by a decrease in rates occurring after age 10. Slight increases for SDI are still occurring for all treatments on the 1987 time replicate while slight decreases are seen in SDI for the C and H treatments in the 1989 time replicate. The maximum SDI values for the C treatment reached were 282 and 401 for the 1987 and 1989 time replicates, respectively. The F treatment had a maximum of 266 in the 1989 time replicate, which is much lower due to the initial high rates of mortality. The C and F treatment maximums occur on the last measurement age (Table 3.61). The H treatment had maximum SDI values of 374 and 403 at ages 14 and 15 for the two time replicates, respectively. The maximum SDI values on the HF treatment were 368 and 423 at ages 25 and 21 in the 1987 and 1989 time replicates, respectively.

Relative spacing (RS) reached minimum values of .13 on the HF and H treatments on the 1987 time replicate and on the 1989 C treatment (Table 3.62). These low RS rates, indicating higher stand density, are dependent on large dominant heights and low rates of stem mortality. The higher RS values seen in treatments, such as the 1989 F, are due to high stem mortality that occurred (Tables 3.63, 3.62).

Trees per acre (TPA) development showed high rates of stem mortality in all treatments on both time replicates (Table 3.63). The 1989 F treatment had the highest overall rate of mortality, ending the study with 196 TPA, followed by the 1987 C treatment with an ending TPA of 212. These two treatments had lower overall BA, SDI, and total green tons per acre (GT) development rates, and higher rates of mortality early on compared with treatments within their individual time replicates (Tables 3.60, 3.61, 3.64, 3.63). Although the F treatments had very high rates of initial stem mortality which lead to a large difference between it and the three other treatments, TPA development over the remainder of the study followed very similar trends (Figure 3.40). These lower survival rates may suggest that mortality was an issue on these specific treatments due to the lower than expected development in the previously listed variables. Earlier mortality that was seen on this site proved to change development throughout the remainder of the study.

Total green tons per acre (GT) development patterns follow similar trends seen in BA development for the same treatments within time replicates (Tables 3.64, 3.60). Initial GT development showed the H and HF treatments follow similar trajectories for the first 12 years of development. Since no treatments suffered BA crashes on site, GT continued to increase and the maximum GT values were found at the end of the study (Figure 3.41). Maximum GT values for the HF treatment were 257 and 246 tons/acre for the 1987 and 1989 time replicates (Table 3.64). The H treatment, which showed a slight decrease in BA after age 15 in the 1987 time replicate, showed no declines in GT development, reaching maximum GT values of 230 and 241 tons/acre at age 25 and 23 for the 1987 and 1989 time replicates, respectively. This suggests that any mortality that occurred was concentrated on smaller trees with less individual GT. The F treatment GT maximum was 151 tons/acre for the 1989 time replicate. The C treatment reached maximum GT values of 190 and 252 tons/acre in the two time replicates. The high rates of mortality that affected this site changed the values seen, but development patterns of GT remained similar (Table 3.64). Mean annual increment (MAI), which is the average yearly GT growth at a given age, showed increased MAI rates at earlier ages for sites that have greater initial growth rates. The C treatment had maximum MAI rates of 7.6 and 11 tons/acre/year at age 25 and 23 for the 1987 and 1989 time replicates, respectively (Table 3.65; Figures 3.42-3.43). The F treatment reached a maximum MAI value of 6.6 tons/acre/year at age 23 for the 1989 time replicate. Maximum MAI values for the H treatment were 10.3 and 10.8 tons/acre/year occurring at age 15 and 21 for the two time replicates. HF maximum MAI values were 10.3 and 12.1 tons/acre/year at age 25 and 18 for the two time replicates.

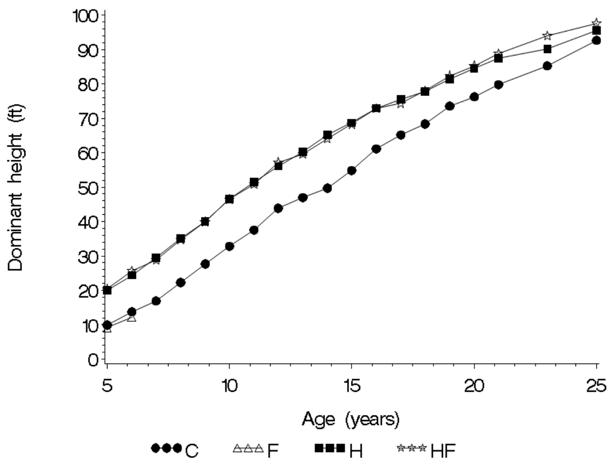
Quadratic mean diameter (DQ) development showed consistent patterns for the treatments between time replicates (Figure 3.44). Early growth patterns on this site showed the H and HF treatments with greater DQ development compared with the C and F treatments. The 1987 time replicate showed the C treatment with increasing growth rates and eventually catching up to the H treatment by approximately age 15 (Figure 3.44(a)). The 1989 time replicate showed a similar event, with the C and F treatments approaching the H development (Figure 3.44(b)). Maximum DQ values for the C treatment were 12.2 and 11.5 inches for the 1987 and 1989 time replicates. The H treatment maximums were 11.4 and 11.6 inches for the 1987 and 1989 time replicates and the F treatment had a maximum of 12.2 on the 1989 time replicate (Table 3.66). The HF treatment DQ maximums were 12.1 and 12.6 for the two time replicates. Throughout the study, there were no decreases in DQ, which can be attributed to only small trees being affected by stem mortality (Tables 3.63, 3.66). The F and C treatments can attribute higher DQs partially due to lower TPA. Overall, the DQs were high for all treatments. It is interesting to see that the C treatment on the 1987 time replicate following the similar development of the HF and H treatments, even barely exceeding the HF's ending DQ. This is due to the Dawsonville - Bottom site having very high inherent site quality (Table 3.59) and that the throughout the study, the C treatment had a much lower TPA, which promotes greater DQ.

Pulpwood is present on the HF and H treatments in both time replicates at age 5. the C and F treatments on the 1989 time replicate see pulpwood at age 6 and the 1987 time replicate has pulpwood on the C treatment beginning at age 7 (Table 3.67). In the 1987 time replicate, pulpwood development peaks earliest in the HF treatment at age 10, followed by the H treatment at age 14. The C treatment peaks at age 17. The 1989 has pulpwood development peak on the HF site first at age 11, followed by H at 13, F 21 and C at age 23. Total pulpwood rates are lower for the C and F treatments due to lower TPA rates, but development trajectories are similar between to the HF and H treatments. Chip-n-saw development first begins on the HF and H treatments for both time replicates (Table 3.68). The 1987 C treatment first develops pulpwood at age 10, and the 1989 time replicate has C chip-n-saw first start at age 9 and F at age 10. The order in which chip-n-saw first develops coincides with the treatments that first reach the average DQ of 8 inches, which is the minimum diameter for chip-n-saw classification. Chip-n-saw development peaks earliest in the HF treatment at age 20, followed by the H and C treatments at age 21 for the 1987 time replicate. The 1989 time replicate saw chip-n-saw development peak earliest on the HF treatment at age 16, followed by the H treatment at age 18, the F treatment at age 19, and the C treatment at age 20 (Table 3.68). TPA rates also showed to affect overall chip-n-saw totals, with the treatments that experienced high initial mortality rates also having lower overall chip-n-saw rates. Sawtimber development for the 1987 time replicate showed the earliest sawtimber on the HF treatment, occurring at age 11, followed by the H and C treatments at age 14 (Table 3.69). The 1989 time replicate showed similar developments, with the HF treatment first having sawtimber on the HF treatment at age 11, followed by the H and F treatments at age 14, and the C at age 15 (Table 3.69). For all treatments on all time replicates, sawtimber continued to develop as the study ended, with maximum values occurring at the final measurement age. Sites that experience high initial rates of stem mortality showed lesser differences in overall sawtimber production, due to greater DQ, which promoted more trees into the sawtimber classification (Table 3.66).

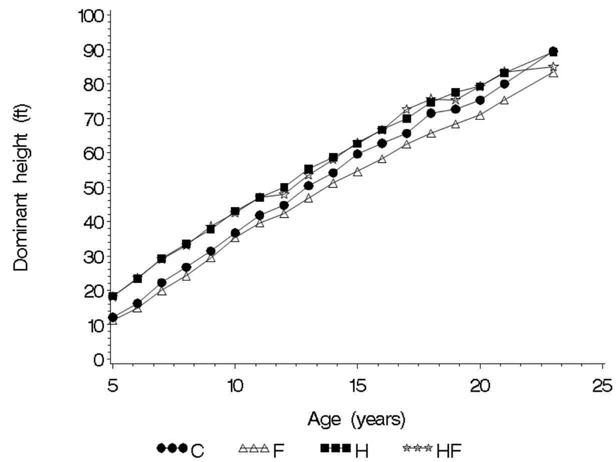
Cronartium infection for the Dawsonville - Bottom site showed very high initial infection rates on all treatments in the 1987 time replicate (Table 3.70, Figure 3.46). At age 5, the C treatment had an infection rate of 38.5%, F had 32.1%, H had 18.8%, and HF had 29.5% (Table 3.70). Infection rates stabilize around age 10, lasting until approximately age 15 for the 1987 time replicate (Figure 3.46(a)). High initial infection rates were also seen in the 1989 time replicate at age 5, but decreased by age 6 (Table 3.65). The 1989 time replicate showed lower rates for the F and C treatments, less than 5 and 10%, respectively, which coincides with lower initial growth rates (Table 3.65). The HF and H treatment follow this relationship, which both have greater growth rates and greater infection rates (Tables 3.65, 3.70).

Table 3.59: Average dominant height (feet) development at the Dawsonville - Bottom site for the 1987 and 1989 time replicates.

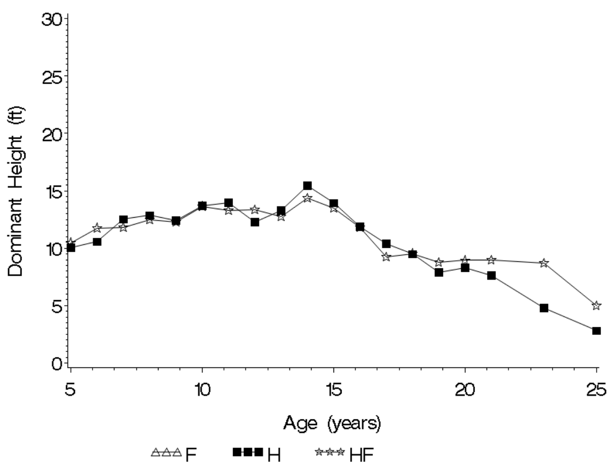
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	9.9	9.1	20.0	20.4	12.2	11.3	18.3	18.1
6	13.8	12.2	24.4	25.6	16.2	14.8	23.4	23.6
7	17.0	.	29.5	28.8	22.2	19.9	29.3	29.0
8	22.3	.	35.1	34.7	26.7	24.2	33.6	33.0
9	27.7	.	40.1	39.9	31.4	29.5	37.8	38.6
10	32.8	.	46.5	46.4	36.7	35.3	43.0	42.5
11	37.5	.	51.5	50.8	41.8	39.7	47.0	46.9
12	43.8	.	56.1	57.2	44.7	42.3	49.8	47.9
13	46.9	.	60.2	59.6	50.4	46.9	55.4	53.4
14	49.7	.	65.1	64.0	54.1	51.2	58.7	57.9
15	54.8	.	68.7	68.3	59.7	54.6	62.6	62.9
16	61.1	.	72.9	72.9	62.8	58.2	66.7	66.5
17	65.1	.	75.5	74.3	65.6	62.5	70.0	72.6
18	68.4	.	77.9	77.9	71.5	65.6	74.6	75.6
19	73.6	.	81.4	82.3	72.7	68.3	77.5	75.4
20	76.3	.	84.6	85.3	75.3	71.0	79.3	79.3
21	79.8	.	87.4	88.7	80.0	75.3	83.1	83.5
23	85.3	.	90.1	94.0	89.5	83.3	89.3	85.0
25	92.7	.	95.5	97.7	.	.	.	.



(a) 1987



(b) 1989

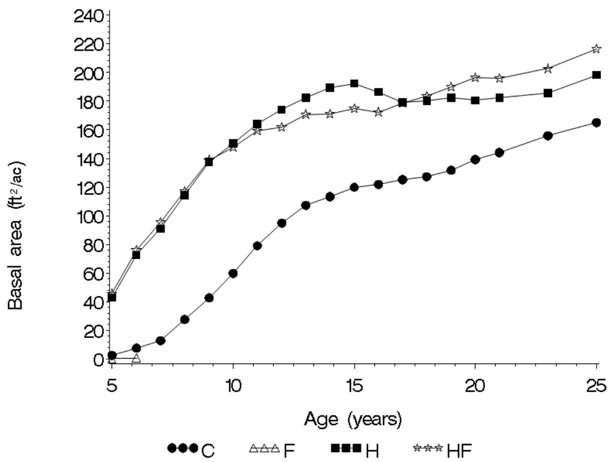


(c) 1987 Treatment Effects

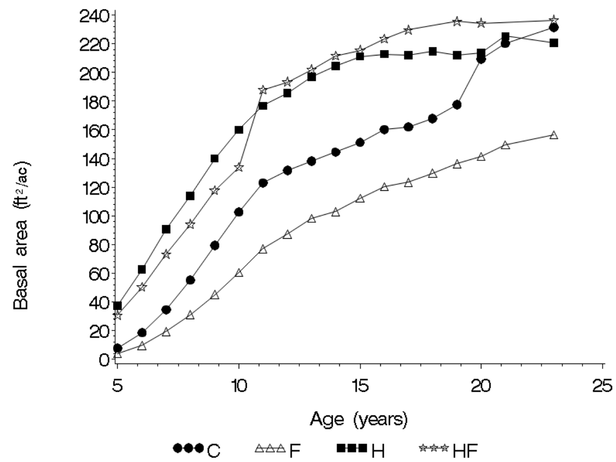
Figure 3.36: Average dominant height (feet) over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures 3.36(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.60: Average basal area (ft^2/acre) at the Dawsonville - Bottom site for the 1987 and 1989 time replicates.

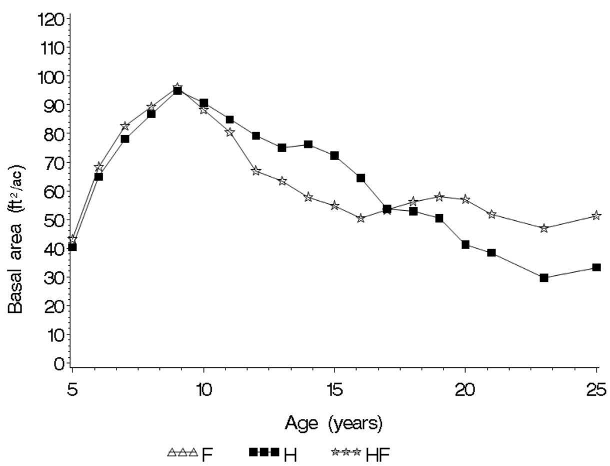
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	2.5	0.3	42.9	45.6	7.8	3.7	37.1	30.5
6	7.7	0.8	72.6	76.1	18.4	9.6	62.5	50.2
7	12.8	.	90.9	95.4	34.4	19.3	90.5	73.1
8	27.6	.	114.3	116.9	55.3	31.0	113.9	94.0
9	42.8	.	137.7	138.9	79.3	44.9	140.0	117.7
10	59.6	.	150.3	147.9	102.8	60.5	160.0	133.9
11	79.0	.	163.9	159.4	122.9	77.0	176.7	187.8
12	94.8	.	174.0	161.8	131.6	87.2	185.6	193.3
13	107.3	.	182.4	170.7	138.2	98.3	197.0	201.9
14	113.3	.	189.5	171.1	144.3	102.9	204.7	211.4
15	120.0	.	192.3	174.9	151.3	112.3	211.2	215.4
16	121.9	.	186.4	172.3	160.2	120.4	212.8	223.3
17	125.2	.	179.0	178.6	162.1	123.4	212.1	229.6
18	127.2	.	180.0	183.5	167.9	129.7	214.8	241.3
19	131.9	.	182.3	189.8	177.6	136.4	212.1	235.5
20	139.2	.	180.5	196.3	209.1	141.3	213.7	234.4
21	144.1	.	182.5	195.8	220.3	149.4	225.3	245.2
23	155.8	.	185.5	202.7	231.3	156.4	220.6	236.5
25	165.0	.	198.3	216.3	.	.	.	.



(a) 1987



(b) 1989

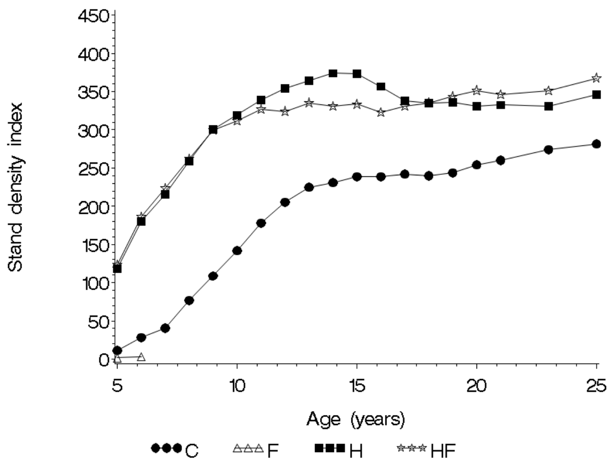


(c) 1987 Treatment Effects

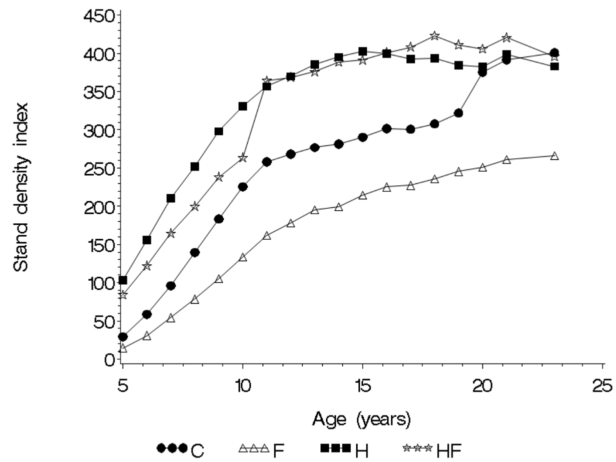
Figure 3.37: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.61: Average stand density index development at the Dawsonville - Bottom site by time replicate.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	11.4	1.6	118.0	123.5	29.1	14.4	103.3	84.1
6	28.0	3.0	180.1	186.3	58.3	30.8	156.2	122.0
7	40.4	.	215.8	223.4	95.9	54.1	210.1	164.5
8	76.6	.	259.0	262.0	139.3	78.5	252.1	199.7
9	108.7	.	300.3	299.1	183.5	105.4	297.9	238.1
10	141.8	.	319.3	311.6	225.1	133.5	330.7	263.5
11	177.8	.	338.8	326.5	258.0	162.1	356.6	363.9
12	205.0	.	354.0	323.9	268.2	178.1	369.8	368.6
13	225.0	.	364.3	335.3	276.7	195.5	385.6	375.9
14	231.0	.	373.9	331.0	281.2	199.1	395.1	388.4
15	238.6	.	373.5	333.4	290.1	214.3	402.5	391.2
16	238.6	.	356.6	322.5	301.5	225.2	399.3	400.9
17	242.0	.	337.8	331.1	300.8	227.3	392.2	408.1
18	239.7	.	335.0	335.3	307.7	235.8	393.9	422.9
19	243.7	.	336.1	343.6	322.0	245.5	384.5	411.0
20	254.4	.	331.1	351.3	375.3	250.8	382.4	405.4
21	259.9	.	332.5	346.1	391.3	261.2	398.9	420.4
23	274.0	.	330.9	351.0	401.1	265.9	382.8	395.5
25	281.6	.	346.1	367.7	.	.	.	.



(a) 1987

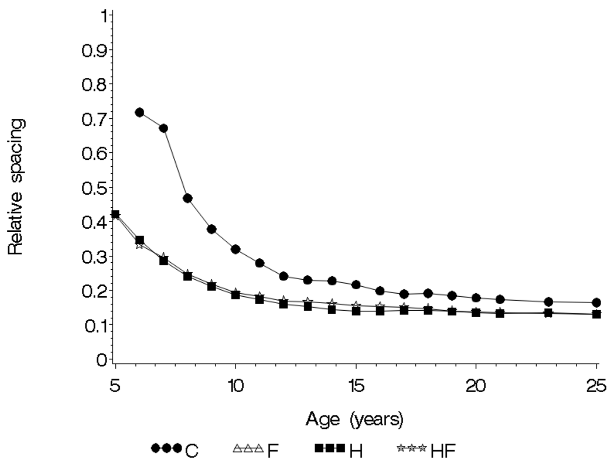


(b) 1989

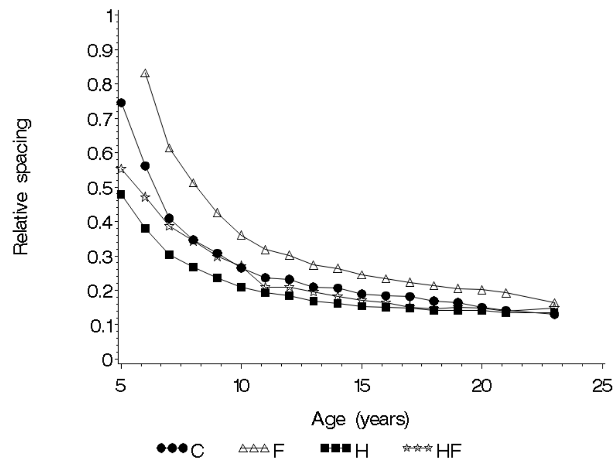
Figure 3.38: Average stand density index over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures (a)-(b).

Table 3.62: Average relative spacing development at the Dawsonville - Bottom site by time replicate.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	1.00	2.59	0.42	0.42	0.75	1.09	0.48	0.55
6	0.72	2.18	0.35	0.33	0.56	0.83	0.38	0.47
7	0.67	.	0.29	0.30	0.41	0.61	0.30	0.39
8	0.47	.	0.24	0.25	0.35	0.51	0.27	0.34
9	0.38	.	0.21	0.22	0.31	0.43	0.24	0.30
10	0.32	.	0.19	0.19	0.27	0.36	0.21	0.27
11	0.28	.	0.17	0.18	0.24	0.32	0.19	0.21
12	0.24	.	0.16	0.17	0.23	0.30	0.18	0.21
13	0.23	.	0.15	0.17	0.21	0.27	0.17	0.20
14	0.23	.	0.14	0.16	0.21	0.26	0.16	0.18
15	0.22	.	0.14	0.15	0.19	0.24	0.15	0.17
16	0.20	.	0.14	0.15	0.18	0.23	0.15	0.16
17	0.19	.	0.14	0.15	0.18	0.22	0.15	0.15
18	0.19	.	0.14	0.15	0.17	0.21	0.14	0.15
19	0.18	.	0.14	0.14	0.17	0.21	0.14	0.15
20	0.18	.	0.14	0.14	0.15	0.20	0.14	0.15
21	0.17	.	0.13	0.14	0.14	0.19	0.14	0.14
23	0.17	.	0.14	0.13	0.13	0.16	0.14	0.15
25	0.16	.	0.13	0.13	.	.	.	.



(a) 1987

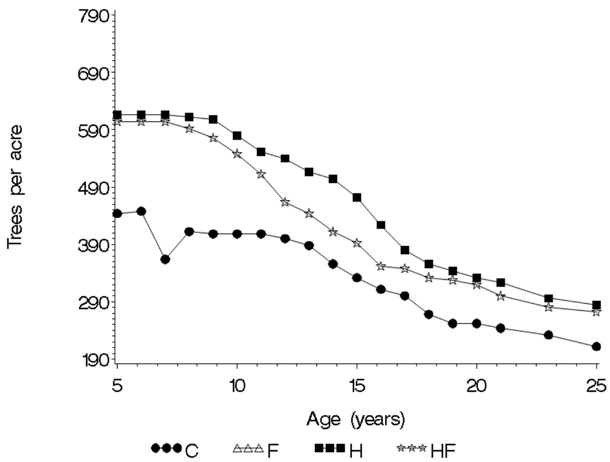


(b) 1989

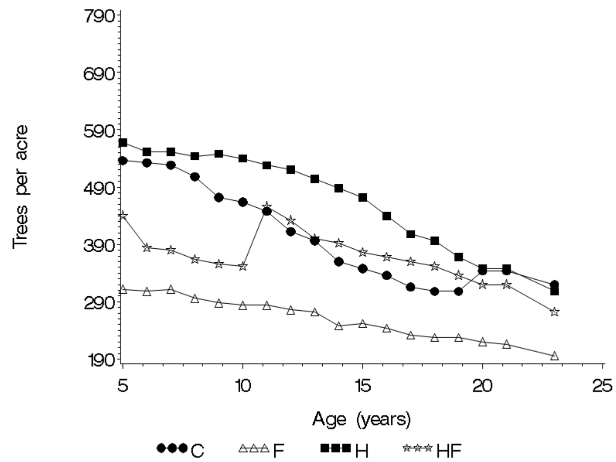
Figure 3.39: Average relative spacing development over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures (a)-(b).

Table 3.63: Average trees per acre development at the Dawsonville - Bottom site by time replicate.

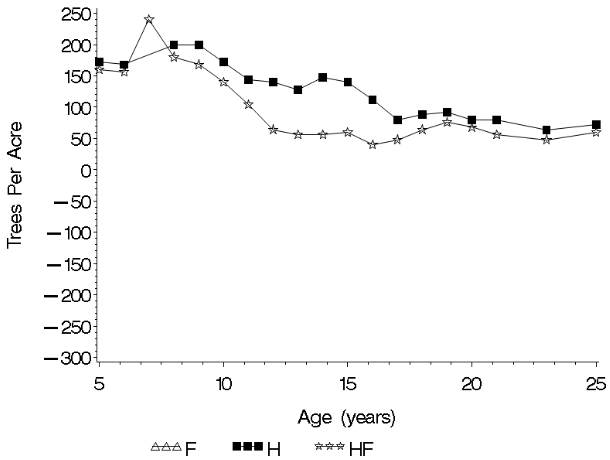
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	444	88	616	604	536	312	568	440
6	448	64	616	604	532	308	552	384
7	364	.	616	604	528	312	552	380
8	412	.	612	592	508	296	544	364
9	408	.	608	576	472	288	548	356
10	408	.	580	548	464	284	540	352
11	408	.	552	512	448	284	528	456
12	400	.	540	464	412	276	520	432
13	388	.	516	444	396	272	504	400
14	356	.	504	412	360	248	488	392
15	332	.	472	392	348	252	472	376
16	312	.	424	352	336	244	440	368
17	300	.	380	348	316	232	408	360
18	268	.	356	332	308	228	396	352
19	252	.	344	328	308	228	368	336
20	252	.	332	320	344	220	348	320
21	244	.	324	300	344	216	348	320
23	232	.	296	280	320	196	308	272
25	212	.	284	272	.	.	.	.



(a) 1987



(b) 1989

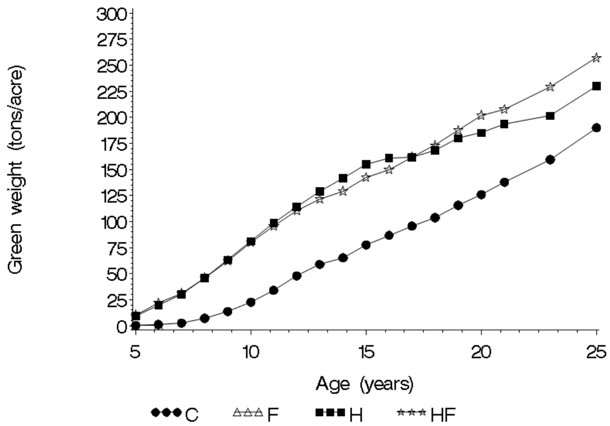


(c) 1987 Treatment Effects

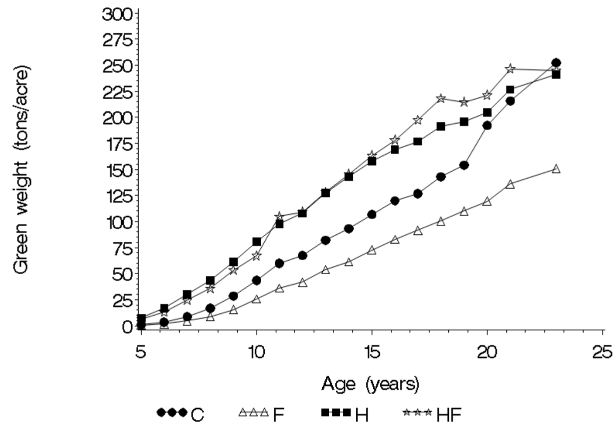
Figure 3.40: Average trees per acre development over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.64: Average total green weight (tons/acre) development at the Dawsonville - Bottom site by time replicate.

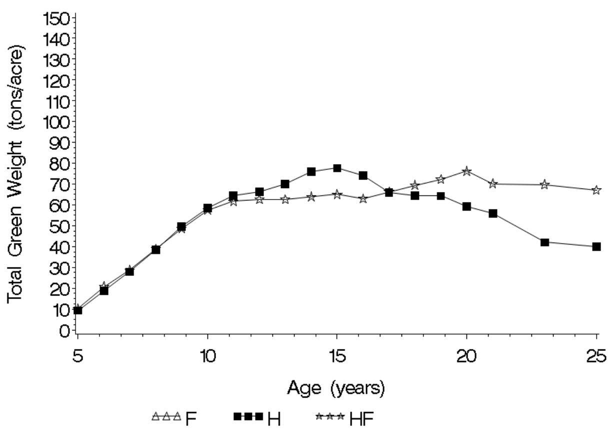
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.3	0.0	9.6	10.4	1.1	0.5	7.5	6.2
6	1.2	0.1	20.0	21.9	3.4	1.7	16.5	13.3
7	2.5	.	30.4	31.2	8.8	4.6	30.2	24.5
8	7.0	.	45.4	45.9	16.7	8.8	43.7	35.8
9	13.6	.	63.2	62.2	28.4	15.5	61.3	53.4
10	22.5	.	81.1	80.0	43.5	25.5	80.7	67.0
11	34.0	.	98.5	95.7	59.7	36.2	97.4	104.8
12	47.7	.	114.0	110.3	67.4	41.7	107.8	109.1
13	58.7	.	128.7	121.3	81.8	54.0	127.1	128.1
14	65.3	.	141.3	129.1	93.1	61.2	143.1	145.4
15	77.3	.	154.9	142.3	106.8	72.8	157.8	163.3
16	86.8	.	160.9	149.8	119.8	82.8	168.9	178.2
17	95.6	.	161.6	161.8	126.8	91.5	176.7	197.2
18	103.7	.	168.3	173.1	142.9	100.3	191.0	218.0
19	115.5	.	179.8	187.6	153.8	110.1	195.9	214.5
20	125.7	.	185.0	201.9	192.3	119.5	204.8	221.2
21	137.5	.	193.4	207.7	215.6	136.0	226.6	246.4
23	159.3	.	201.3	229.1	252.4	150.7	240.9	244.9
25	190.1	.	230.0	257.0	.	.	.	.



(a) 1987



(b) 1989

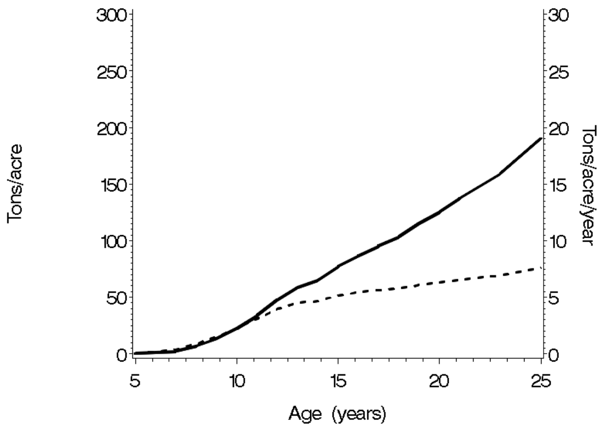


(c) 1987 Treatment Effects

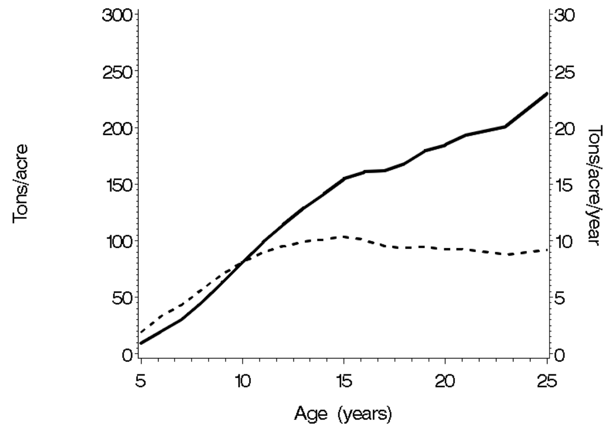
Figure 3.41: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures (a)-(a). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.65: Mean annual increment (tons/acre/year) development at the Dawsonville - Bottom site by time replicate.

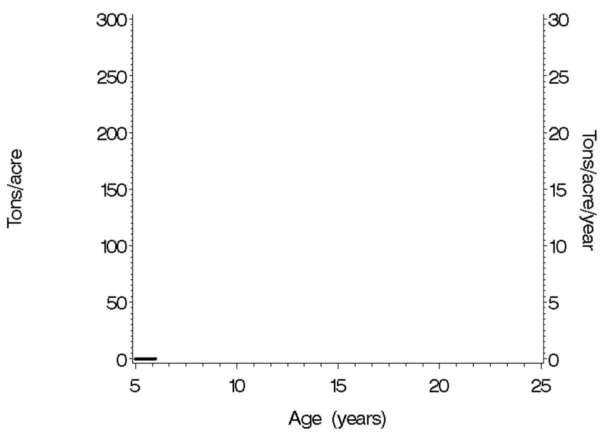
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.1	0.0	1.9	2.1	0.2	0.1	1.5	1.2
6	0.2	0.0	3.3	3.7	0.6	0.3	2.8	2.2
7	0.4	.	4.3	4.5	1.3	0.7	4.3	3.5
8	0.9	.	5.7	5.7	2.1	1.1	5.5	4.5
9	1.5	.	7.0	6.9	3.2	1.7	6.8	5.9
10	2.2	.	8.1	8.0	4.4	2.6	8.1	6.7
11	3.1	.	9.0	8.7	5.4	3.3	8.9	9.5
12	4.0	.	9.5	9.2	5.6	3.5	9.0	9.1
13	4.5	.	9.9	9.3	6.3	4.2	9.8	9.9
14	4.7	.	10.1	9.2	6.7	4.4	10.2	10.4
15	5.2	.	10.3	9.5	7.1	4.9	10.5	10.9
16	5.4	.	10.1	9.4	7.5	5.2	10.6	11.1
17	5.6	.	9.5	9.5	7.5	5.4	10.4	11.6
18	5.8	.	9.4	9.6	7.9	5.6	10.6	12.1
19	6.1	.	9.5	9.9	8.1	5.8	10.3	11.3
20	6.3	.	9.3	10.1	9.6	6.0	10.2	11.1
21	6.6	.	9.2	9.9	10.3	6.5	10.8	11.7
23	6.9	.	8.8	10.0	11.0	6.6	10.5	10.7
25	7.6	.	9.2	10.3	.	.	.	.



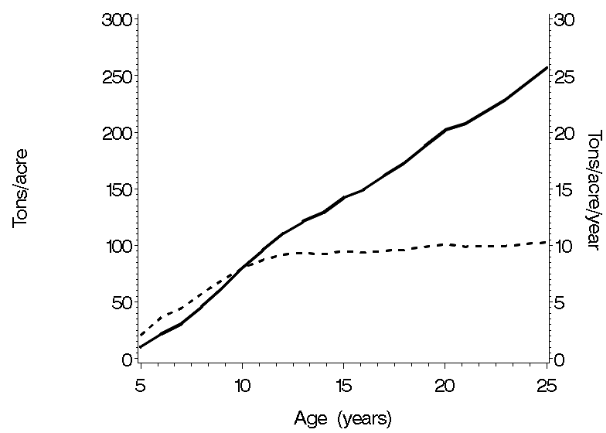
(a) C



(b) H

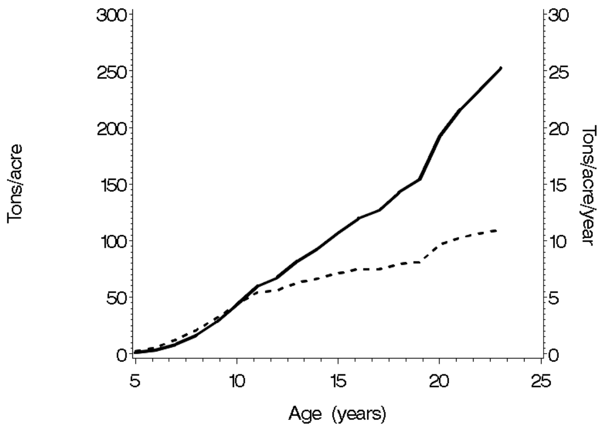


(c) F

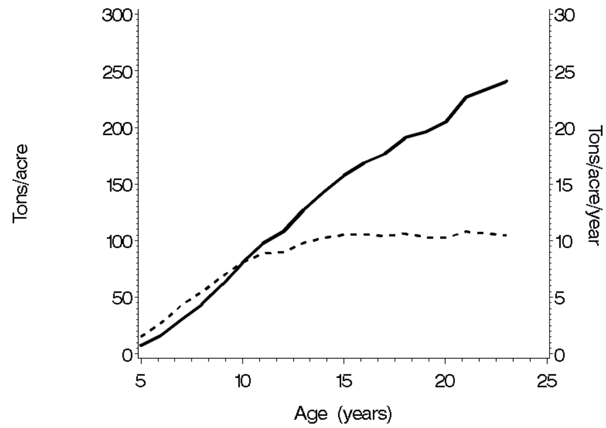


(d) HF

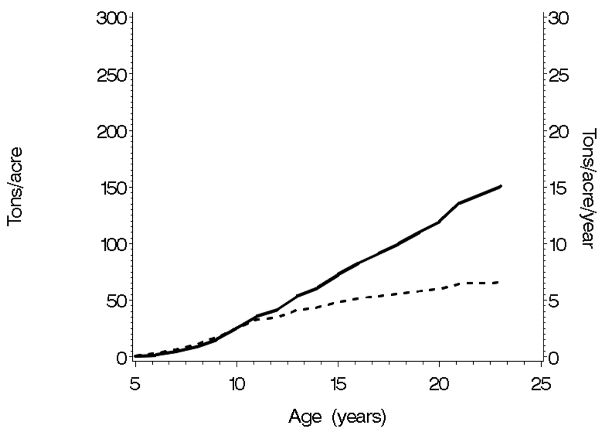
Figure 3.42: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Dawsonville - Bottom 1987 time replicate.



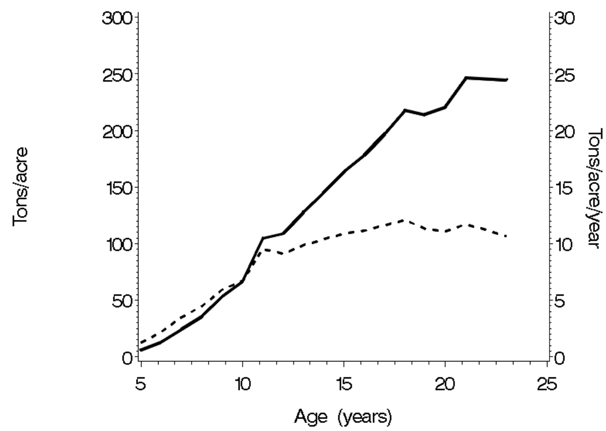
(a) C



(b) H



(c) F

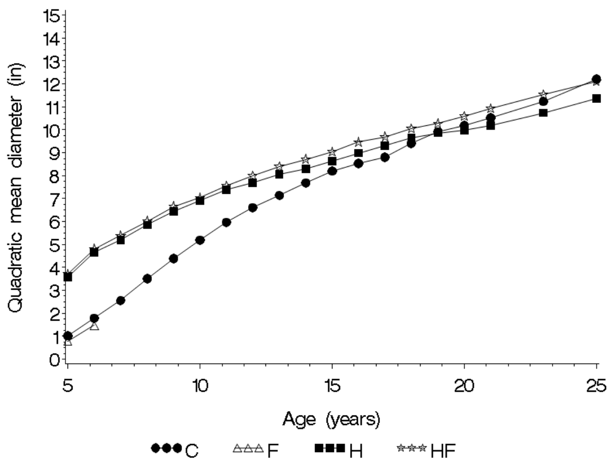


(d) HF

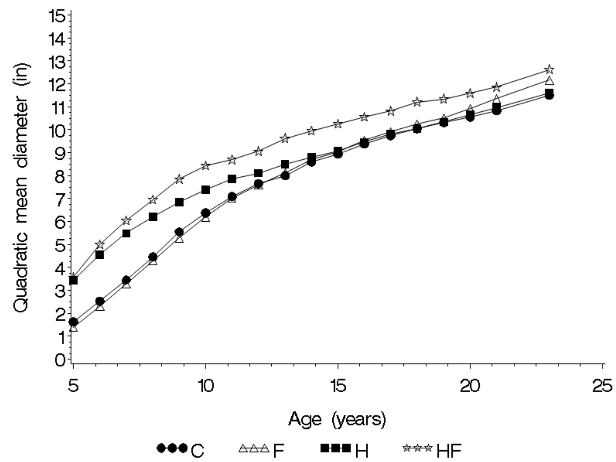
Figure 3.43: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Dawsonville - Bottom 1987 time replicate.

Table 3.66: Average quadratic mean diameter (inches) development at the Dawsonville - Bottom site by time replicate.

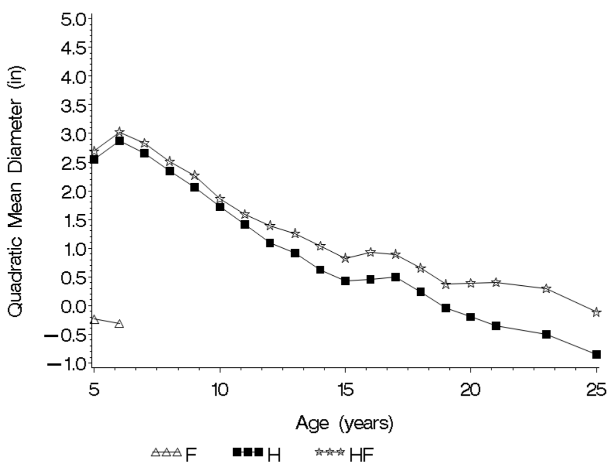
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	1.0	0.8	3.6	3.7	1.6	1.4	3.5	3.6
6	1.8	1.5	4.6	4.8	2.5	2.3	4.6	5.0
7	2.6	.	5.2	5.4	3.5	3.3	5.5	6.0
8	3.5	.	5.9	6.0	4.5	4.3	6.2	7.0
9	4.4	.	6.4	6.7	5.6	5.3	6.9	7.8
10	5.2	.	6.9	7.0	6.4	6.2	7.4	8.4
11	6.0	.	7.4	7.6	7.1	7.0	7.9	8.7
12	6.6	.	7.7	8.0	7.7	7.6	8.1	9.1
13	7.1	.	8.1	8.4	8.0	8.1	8.5	9.6
14	7.7	.	8.3	8.7	8.6	8.7	8.8	9.9
15	8.2	.	8.6	9.0	9.0	9.0	9.1	10.3
16	8.5	.	9.0	9.5	9.4	9.5	9.5	10.6
17	8.8	.	9.3	9.7	9.8	9.9	9.8	10.8
18	9.4	.	9.6	10.1	10.0	10.3	10.1	11.2
19	9.9	.	9.9	10.3	10.3	10.5	10.3	11.3
20	10.2	.	10.0	10.6	10.6	10.9	10.7	11.6
21	10.5	.	10.2	10.9	10.8	11.4	11.0	11.9
23	11.2	.	10.7	11.5	11.5	12.2	11.6	12.6
25	12.2	.	11.4	12.1	.	.	.	.



(a) 1987



(b) 1989



(c) 1987 Treatment Effects

Figure 3.44: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Dawsonville - Bottom site is shown in subfigures 3.44(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.67: Average pulpwood development (tons/acre) at the Dawsonville - Bottom site by time replicate.

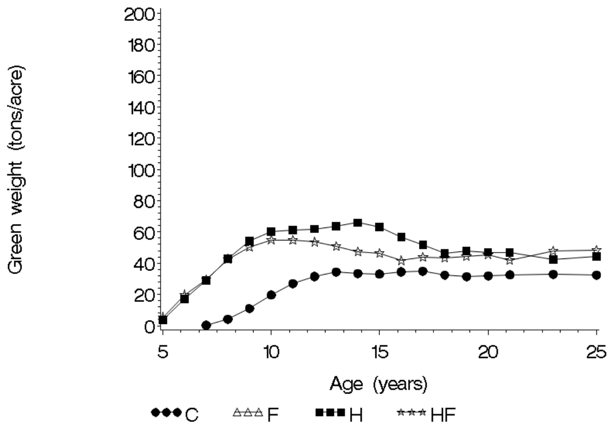
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	3.6	5.4	.	.	2.5	3.2
6	.	.	17.1	19.7	0.1	0.1	14.3	12.1
7	0.3	.	29.0	29.5	4.6	2.3	28.8	23.4
8	4.1	.	43.0	42.5	14.0	7.3	40.9	27.4
9	10.9	.	54.4	50.3	26.7	14.4	46.1	28.6
10	19.7	.	60.0	54.9	35.1	21.0	50.4	28.8
11	26.9	.	61.3	54.6	41.1	23.3	48.1	36.6
12	31.5	.	61.9	53.5	37.1	20.0	49.0	34.3
13	34.2	.	63.8	50.7	40.1	23.1	50.0	32.9
14	33.4	.	65.9	47.3	36.2	20.7	49.1	32.6
15	33.1	.	63.0	46.2	35.6	24.1	48.8	35.5
16	34.4	.	56.6	41.7	35.0	24.0	44.3	35.1
17	34.9	.	51.6	43.9	34.7	23.2	42.8	35.0
18	32.3	.	46.4	43.3	35.5	22.3	44.9	37.5
19	31.3	.	47.6	44.2	36.0	23.7	42.0	36.2
20	31.9	.	47.0	45.5	36.9	25.5	42.2	38.3
21	32.6	.	46.8	41.9	41.7	28.4	45.5	40.6
23	32.9	.	42.5	47.7	43.5	26.1	48.4	39.5
25	32.3	.	44.2	48.3	.	.	.	.

Table 3.68: Average chip-n-saw development (tons/acre) at the Dawsonville - Bottom site by time replicate.

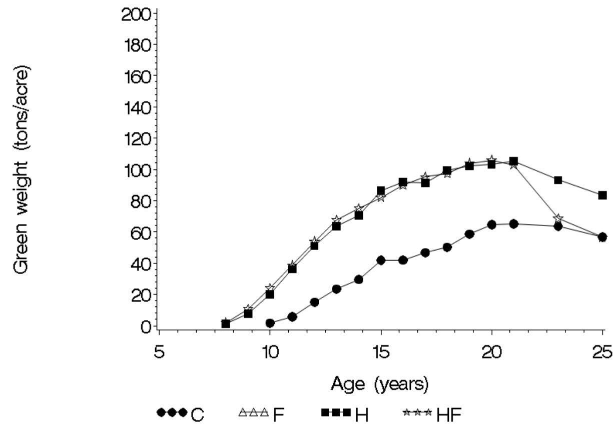
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	1.3	1.8	.	.	3.2	7.7
9	.	.	7.6	10.8	0.7	.	14.2	24.1
10	1.5	.	20.0	24.1	7.1	3.7	29.2	37.5
11	5.8	.	36.2	38.7	17.8	12.3	48.2	61.9
12	15.0	.	51.1	54.0	29.7	21.2	57.8	68.0
13	23.3	.	63.8	67.4	41.0	30.3	76.0	80.4
14	29.7	.	70.4	74.9	56.3	38.4	91.2	95.6
15	41.9	.	86.4	82.1	68.8	41.0	104.1	100.3
16	42.0	.	91.8	89.8	74.8	41.4	117.5	107.0
17	46.6	.	91.5	95.1	71.5	48.1	119.2	110.8
18	50.1	.	99.3	97.4	76.6	51.0	123.2	103.8
19	58.6	.	102.0	103.9	75.3	52.4	119.8	100.9
20	64.6	.	103.4	105.9	112.6	47.6	113.9	82.6
21	65.1	.	105.1	102.9	110.8	48.2	108.1	86.0
23	63.4	.	93.1	68.5	105.5	43.9	75.9	53.4
25	56.7	.	83.4	56.5	.	.	.	.

Table 3.69: Average sawtimber development (tons/acre) at the Dawsonville - Bottom site by time replicate.

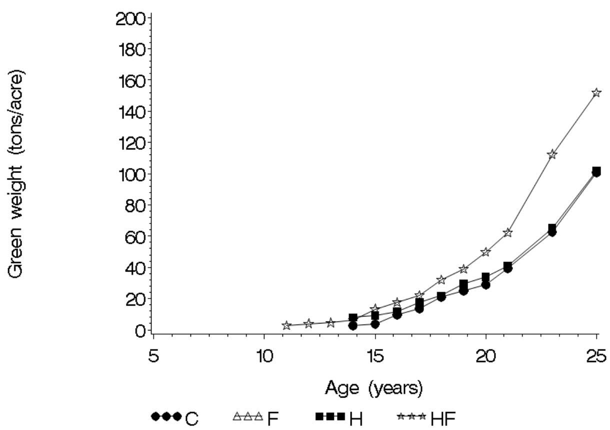
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.
11	.	.	.	2.7	.	.	.	5.2
12	.	.	.	3.9	.	.	.	5.9
13	.	.	.	4.5	.	.	.	14.1
14	2.6	.	8.0	6.1	.	3.5	3.6	16.6
15	3.5	.	9.2	13.2	3.7	7.3	8.0	26.9
16	9.7	.	11.6	17.6	9.5	17.0	6.3	35.5
17	13.6	.	17.6	22.1	20.0	19.8	13.9	50.8
18	20.8	.	21.8	31.8	30.2	26.6	22.2	76.1
19	25.1	.	29.4	38.9	42.1	33.6	33.4	76.9
20	28.7	.	33.8	49.7	42.1	46.1	47.9	99.7
21	39.2	.	40.7	62.2	62.4	59.0	72.4	119.2
23	62.6	.	65.0	112.3	102.9	80.4	115.9	151.5
25	100.7	.	101.8	151.7	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw

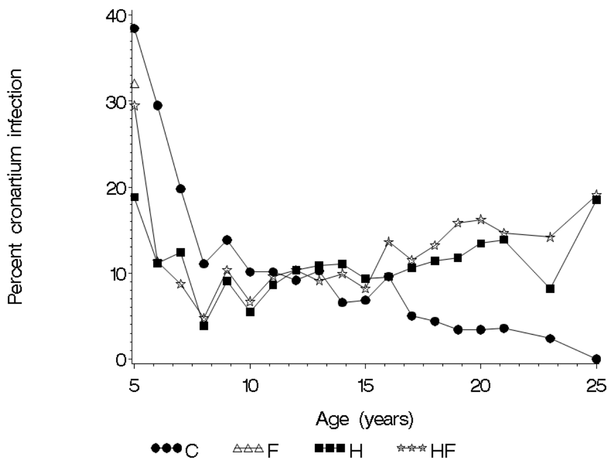


(c) Sawtimber

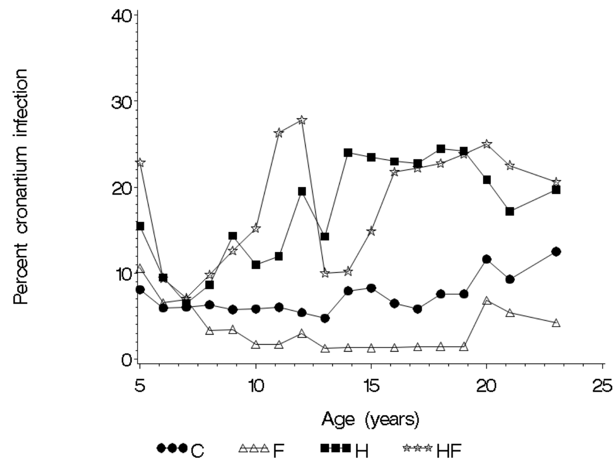
Figure 3.45: Average product distribution (tons/acre) over the course of the study for the Dawsonville - Bottom 1987 time replicate. Pulpwood is shown in 3.45(a), Chip-N-Saw in 3.45(b), and sawtimber in 3.45(c).

Table 3.70: Average cronartium infection rates (%) at the Dawsonville - Bottom site by time replicate.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	38.5	32.1	18.8	29.5	8.1	10.6	15.5	22.8
6	29.5	43.8	11.2	11.3	6.0	6.5	9.5	9.4
7	19.8	.	12.4	8.7	6.1	7.0	6.5	7.1
8	11.1	.	3.8	4.8	6.3	3.3	8.7	9.8
9	13.9	.	9.1	10.3	5.8	3.5	14.3	12.6
10	10.1	.	5.5	6.7	5.8	1.7	11.0	15.2
11	10.1	.	8.7	9.6	6.0	1.7	12.0	26.3
12	9.2	.	10.3	10.3	5.4	3.0	19.5	27.8
13	10.3	.	10.9	9.1	4.7	1.3	14.3	10.0
14	6.6	.	11.1	9.9	8.0	1.4	24.0	10.2
15	6.9	.	9.3	8.2	8.3	1.3	23.5	14.9
16	9.6	.	9.6	13.6	6.5	1.4	23.0	21.7
17	5.0	.	10.6	11.5	5.8	1.4	22.7	22.2
18	4.4	.	11.4	13.2	7.6	1.5	24.5	22.7
19	3.4	.	11.8	15.8	7.6	1.5	24.2	23.8
20	3.4	.	13.5	16.2	11.6	6.8	20.9	25.0
21	3.6	.	13.9	14.7	9.3	5.4	17.2	22.5
23	2.4	.	8.2	14.2	12.5	4.2	19.7	20.6
25	0.0	.	18.5	19.1	.	.	.	.



(a) 1987



(b) 1989

Figure 3.46: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Dawsonville - Bottom site are shown in subfigures (a)-(b).

3.5 Dawsonville - Top

The Dawsonville - Top site was established with only two time replicates with two treatments (C, H) due to space constraints. One of the 1987 H treatments and one of the 1987 C treatments were removed after the 14^{th} growing season due to insect infestations. For the remainder of the study, the 1987 H and C treatments were based off of only one plot. Both time replicates started this study with greater rates of stem mortality on the C treatments, which goes on to affect variables discussed in this report.

Site index for the Dawsonville - Top site, 77 feet for the 1987 time replicate, showed an overall good site quality (Table 3.71). The 1989 time replicate corroborates this with similar overall development of dominant height. The H treatment maintained a fairly consistent dominant height advantage over the C treatment on both treatments (Figure 3.36). The 1987 time replicate had maximum dominant heights of 77 and 81 feet at the end of the study, age 25 for C and H, respectively. The 1989 time replicate had maximum dominant heights of 72 and 79 feet at age 23 for these two treatments.

Basal area per acre (BA) development showed large, increasing gains for the H treatments on both time replicates until approximately age 10, when gains stabilized compared with the C treatment (Table 3.72; Figure 3.48). This is due to the greater mortality on the C treatments that occurred earlier in the stands. No treatments on the site exhibit a BA crash which signifies that the individual treatments have not yet reached carrying capacity. The maximum BA achieved for the 1987 time replicate are 171.3 ft^2/acre at age 25 and 252.1 ft^2/acre at age 25 for the C and H treatments, respectively (Table 3.72). The 1989 treatments also had maximum BA occur at the last measurement age for both treatments, reaching 160.5 and 219.2 ft^2/acre for the C and H treatments, respectively. Maximum BA rates are lower for the C treatments due to the high initial stem mortality rates. The 1989 H treatment begins to show BA increases slowing, which may indicate that carrying capacity is close to being met.

Stand density index (SDI) development followed comparable trends to BA for each treatment (Figures 3.49, 3.48). SDI continued to increase for the treatments for the 1987 time replicate. Maximum SDI values reached for this time replicate were 319.8 and 477.3 for the C and H treatments, respectively. The 1989 time replicate saw SDI values beginning to stabilize on the H treatment at ∼410 around age 18. The C treatment for this time replicate continued to display consistent increases through the most recent measurement at age 25, ending with a maximum SDI value of 304.9 (Table 3.73). Lower SDI values for the C treatments can be attributed to the fewer TPA on site throughout the study (Table 3.75).

The two time replicates showed very similar relative spacing (RS) development patterns for the C and H treatments (Figure 3.50). Both treatments on both time replicates decrease at similar rates, but not reaching the same minimum values (Table 3.74). The 1987 H treatment reached the overall minimum RS value seen on the entire site, .11, at the last measurement year of the study (age 25). The C treatment of the same time replicate reached a minimum of .15 at age 20 and remained at that value for the remainder of the study. The 1989 time replicates reached minimums of .16 and .13 for the C and H treatments, respectively (Table 3.74). The 1989 H treatment reached its minimum of .13 at age 18 and stayed constant until the end of the study. Higher RS values in both C treatments can be attributed to greater stem mortality rates (Table 3.75).

Initial trees per acre (TPA) values showed higher levels of stem mortality in both C treatments compared with starting densities (Table 3.75). The C treatments continued to have greater rates of mortality throughout the study compared with the H treatments of the same time replicates (Figure 3.51). In the 1987 time replicate, from the beginning of the study (age 5) to the end (age 25) the C treatment lost approximately 184 TPA compared with the H treatment, which lost 100 TPA (Table 3.75). The 1989 time replicate had less of an ending difference of losses between the two treatments, with the C treatment losing 176 TPA compared with 136 TPA for the H treatment. Trees per acre development showed similar rates of mortality between H treatments for the two time replicates (Figure 3.51). H treatment in the 1987 time replicate had the least overall stem mortality, ending the study with 544 trees per acre while the C treatment in the same time replicate ended with 344 trees per acre (Table 3.75). The H treatment in the 1989 time replicate had an ending TPA value of 444 and the C treatment had an ending value of 352 TPA. While TPA decreased through time due to stem mortality, it shows that, on this site, stem mortality is a result of stand crowding, not site quality.

Total green tons per acre (GT) showed continued increases as the stands continued to develop for all treatments in both time replicates (Figure 3.52). The GT trends follow similar development as BA and SDI (Figures 3.52, 3.48, 3.49). Maximum GT values occurred at the last measurement year for all treatments. The H treatment had maximum values of 242.9 and 211.0 tons/acre for the 1987 and 1989 time replicates, respectively. The C treatment had maximums of 158.4 and 139.5 tons/acre for both time replicates. All treatments show no signs of GT development beginning to slow, but treatment effects of the 1987 H treatment show signs of stabilization in gains over the C treatment (Figure 3.52). Mean annual increment (MAI) of GT showed greater initial rates on the H treatments for both time replicates (Table 3.77, Figures 3.53, 3.54). Maximum MAI values achieved for the H treatment were 10.4 and 9.8, occurring at age 18 and 17 for the 1987 and 1989 time replicates, respectively (Table 3.77). The C treatment reached maximum MAI values of 6.3 and 6.1 at the oldest time measurements for the 1987 and 1989 time replicates, respectively.

Quadratic mean diameter (DQ) showed similar development patterns for the two time replicates (Figure 3.55). The H treatment had an initial advantage over the C treatment, but by approximately 17, there is little difference between the two treatments. This initial advantage for the H treatment is due to higher TPA and BA seen in the treatment. DQ development showed continued increases for all treatments, suggesting that stem mortality was concentrated on the smaller individual diameter trees (Table 3.75). Maximum DQ values for the H treatment were 9.2 and 9.5 for the 1987 and 1989 time replicates (Table 3.78). The C treatment had maximum DQ values of 9.6 and 9.1 for the two time replicates. It is interesting to see that the C treatment on the 1987 time replicate surpassed the H treatment in DQ for the final four years (Table 3.78). One possible explanation for this result could be that the greater amounts of stem mortality in the C treatment removed many of the lower diameter trees, thus giving it a higher DQ (Table 3.75). It may also be explained by the fact that the C treatment grew at significantly lower TPA for its entire life, promoting greater DQ growth.

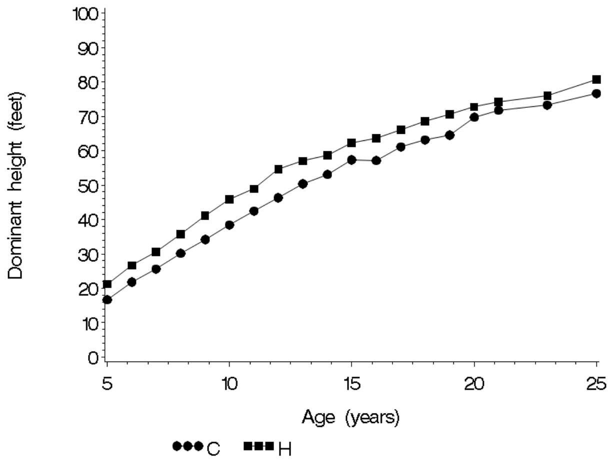
Product development is directly related to the individual diameter of trees. As diameter increases, products are placed into higher value classes. Pulpwood is on site for all treatments and time replicates at age 5, except for the 1989 C treatment (Table 3.79). The H treatment peaked first on both time replicates, occurring at age 12 and 13 for the 1987 and 1989 time replicates, respectively (Table 3.79). The C treatment had pulpwood peaks occur at age 15 for both time replicates. Chip-n-saw also saw its earliest development on the H treatments, occurring at age 10 and 9 for the 1987 and 1989 time replicates (Table 3.80). The C treatment first developed pulpwood at age 11 and 13 for the two time replicates. The H treatments both saw chip-n-saw amounts continue to increase as the study ended. The 1989 C treatment also saw chip-n-saw rates continue to increase as the study ended while the 1987 C treatment saw chip-n-saw begin to slow down, with the final two measurement years remaining around 90 tons/acre (Table 3.80). Sawtimber development first began in the 1989 time replicate on the H treatment at age 19 (Table 3.81). The 1987 H treatment saw sawtimber first develop four years later, at age 23 (Table 3.81). The C treatment first developed at age 23 on the 1987 time replicate and age 21 on the 1989 time replicate. The 1987 time replicate ended with greater sawtimber rates, which corresponds with greater DQ rates during that time (Table 3.78).

Initial cronartium rates for the 1987 treatment were very high for the C treatment (Table 3.82). After that initial spike, cronartium rates for that C treatment dropped to below 5% by age 7, and dropped to below 1% at age 13. While not having such a high initial infection rate, the 1987 H treatment also had rates drop below 5% at age 7, and remained below

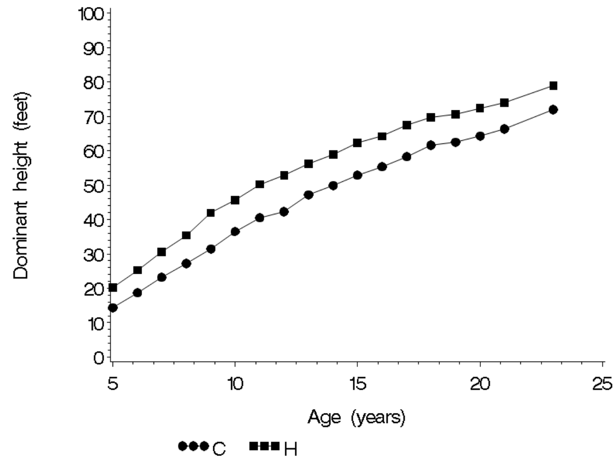
2% for a majority of the time from age 8 until the end of the study (Table 3.82). The 1989 time replicate showed higher initial rates in the H treatment, which remained fairly constant around 7% from age 6 to 16. The C treatment in that time replicate maintained a lower average infection rate, staying below 5% the entire study. Except for the first two years of the 1987 C treatment, cronartium infection followed typical trends, with the higher producing treatments having a greater infection rate.

Table 3.71: Average dominant height (feet) development at the Dawsonville - Top site by time replicate.

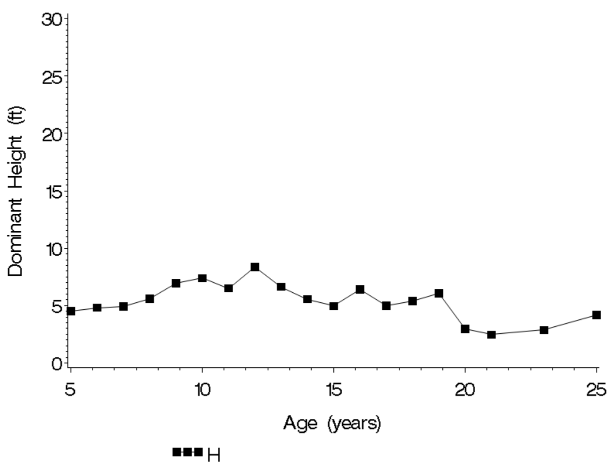
	1987		1989	
Age	C	H	C	H
5	16.7	21.2	14.3	20.3
6	21.8	26.7	18.7	25.3
7	25.6	30.5	23.2	30.5
8	30.2	35.8	27.2	35.4
9	34.2	41.1	31.4	41.9
10	38.4	45.8	36.5	45.6
11	42.4	48.9	40.6	50.2
12	46.3	54.7	42.3	52.8
13	50.4	57.0	47.2	56.3
14	53.2	58.7	49.8	58.8
15	57.4	62.3	52.9	62.3
16	57.2	63.6	55.4	64.2
17	61.1	66.1	58.3	67.5
18	63.1	68.5	61.6	69.7
19	64.5	70.6	62.4	70.7
20	69.8	72.7	64.2	72.3
21	71.8	74.3	66.3	74.0
23	73.2	76.1	72.0	78.9
25	76.6	80.7	.	.



(a) 1987



(b) 1989

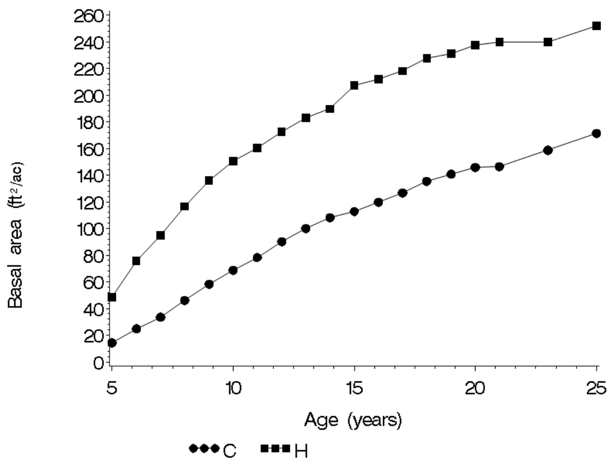


(c) 1987 Treatment Effects

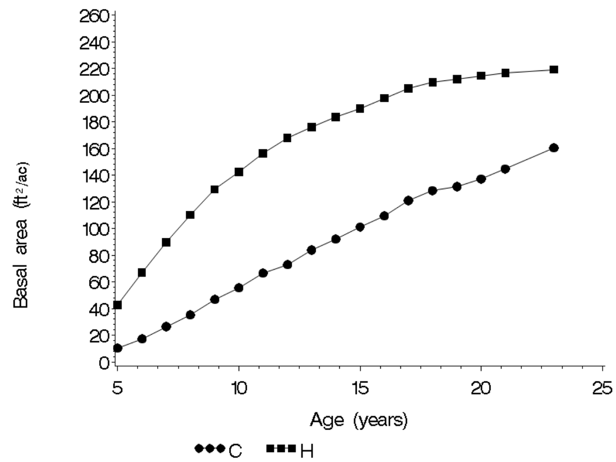
Figure 3.47: Average dominant height (feet) over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.72: Average basal area (ft^2/acre) at the Dawsonville - Top site by time replicate.

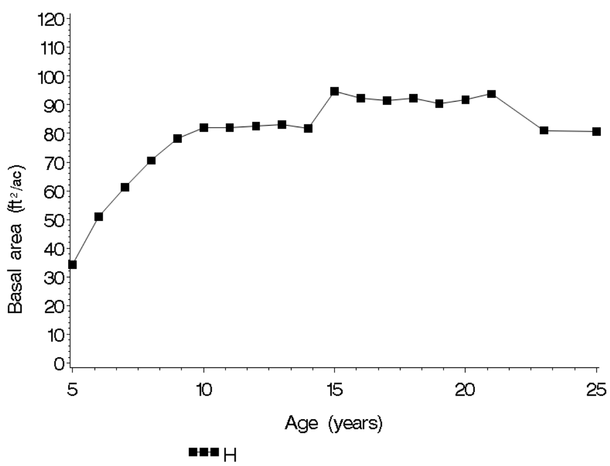
	1987		1989	
Age	C	H	C	H
5	14.3	48.5	10.4	42.7
6	24.9	75.9	17.3	67.0
7	33.6	94.9	26.4	89.5
8	46.0	116.6	35.4	110.2
9	58.1	136.2	46.8	129.4
10	68.5	150.5	55.6	142.4
11	78.3	160.2	66.7	156.4
12	90.0	172.5	73.0	167.9
13	100.0	183.1	83.8	176.0
14	107.9	189.7	92.1	183.6
15	112.7	207.5	101.1	190.0
16	119.6	212.0	109.5	197.7
17	126.6	218.1	120.9	205.2
18	135.2	227.5	128.4	209.6
19	140.9	231.2	131.3	211.9
20	145.6	237.4	137.0	214.6
21	146.3	240.0	144.5	216.7
23	158.7	239.7	160.5	219.2
25	171.3	252.1	.	.



(a) 1987



(b) 1989

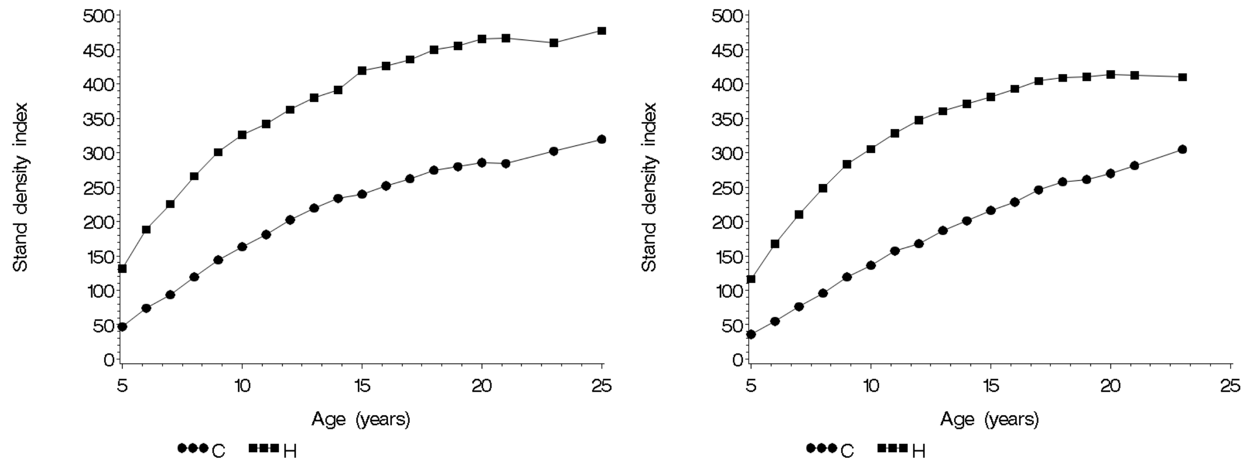


(c) 1987 Treatment Effects

Figure 3.48: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.73: Average stand density index development at the Dawsonville - Top site by time replicate.

	1987		1989	
Age	C	H	C	H
5	47.0	131.4	36.1	116.3
6	73.7	188.3	54.8	167.1
7	93.7	225.3	76.2	210.6
8	119.6	265.7	95.8	248.8
9	144.1	300.8	119.4	283.0
10	163.3	325.7	136.3	305.2
11	181.1	341.8	157.0	328.6
12	202.3	362.6	167.7	347.3
13	219.6	380.4	186.8	360.4
14	233.3	391.4	200.8	370.6
15	239.9	419.5	216.1	380.9
16	251.7	425.6	228.1	392.8
17	262.4	435.6	246.0	404.1
18	274.5	449.3	257.6	408.6
19	279.4	455.2	261.2	410.3
20	285.7	465.0	269.7	413.8
21	284.2	466.6	281.5	412.5
23	302.1	459.8	304.9	409.8
25	319.8	477.3	.	.



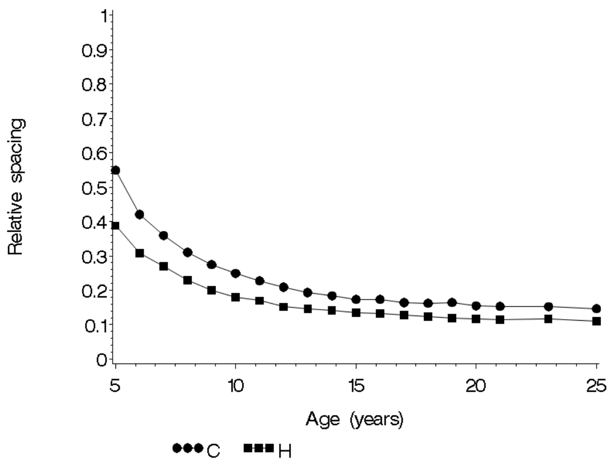
(a) 1987

(b) 1989

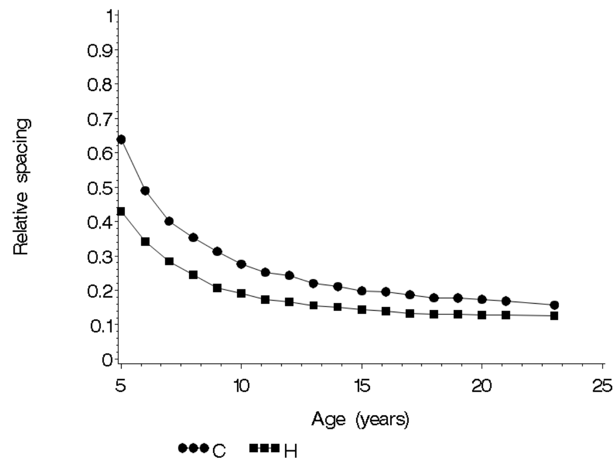
Figure 3.49: Average stand density index over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b).

Table 3.74: Average relative spacing development at the Dawsonville - Top site by time replicate.

	1987		1989	
Age	C	H	C	H
5	0.55	0.39	0.64	0.43
6	0.42	0.31	0.49	0.34
7	0.36	0.27	0.40	0.28
8	0.31	0.23	0.35	0.24
9	0.27	0.20	0.31	0.21
10	0.25	0.18	0.28	0.19
11	0.23	0.17	0.25	0.17
12	0.21	0.15	0.24	0.17
13	0.19	0.15	0.22	0.16
14	0.18	0.14	0.21	0.15
15	0.17	0.13	0.20	0.14
16	0.17	0.13	0.20	0.14
17	0.16	0.13	0.19	0.13
18	0.16	0.12	0.18	0.13
19	0.17	0.12	0.18	0.13
20	0.15	0.12	0.17	0.13
21	0.15	0.12	0.17	0.13
23	0.15	0.12	0.16	0.13
25	0.15	0.11	.	.



(a) 1987

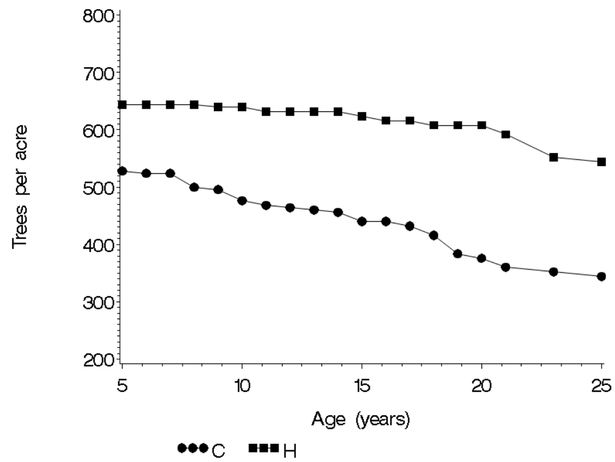


(b) 1989

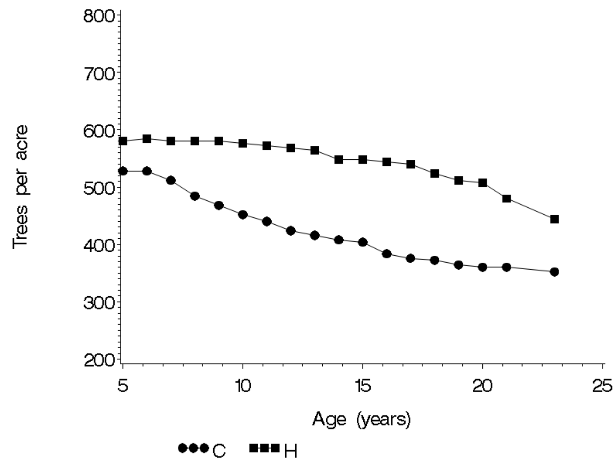
Figure 3.50: Average relative spacing development over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b).

Table 3.75: Average trees per acre development at the Dawsonville - Top site by time replicate.

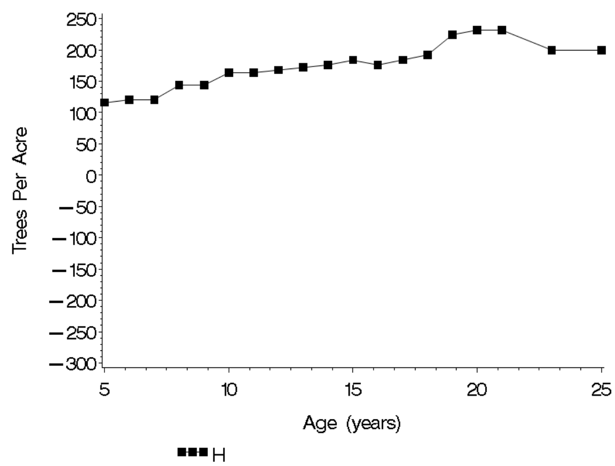
	1987		1989	
Age	C	H	C	H
5	528	644	528	580
6	524	644	528	584
7	524	644	512	580
8	500	644	484	580
9	496	640	468	580
10	476	640	452	576
11	468	632	440	572
12	464	632	424	568
13	460	632	416	564
14	456	632	408	548
15	440	624	404	548
16	440	616	384	544
17	432	616	376	540
18	416	608	372	524
19	384	608	364	512
20	376	608	360	508
21	360	592	360	480
23	352	552	352	444
25	344	544	.	.



(a) 1987



(b) 1989

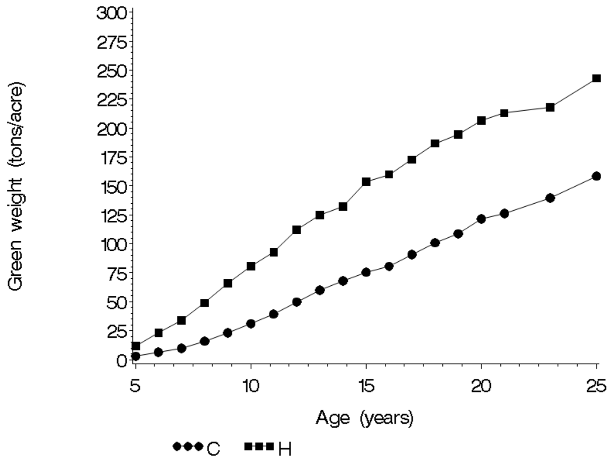


(c) 1987 Treatment Effects

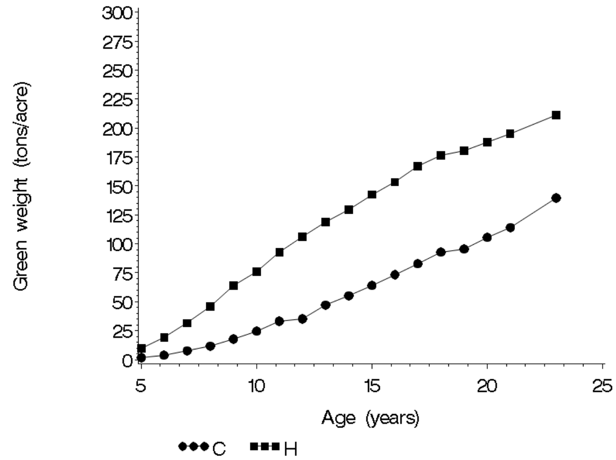
Figure 3.51: Average trees per acre development over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.76: Average total green weight (tons/acre) development at the Dawsonville - Top site by time replicate.

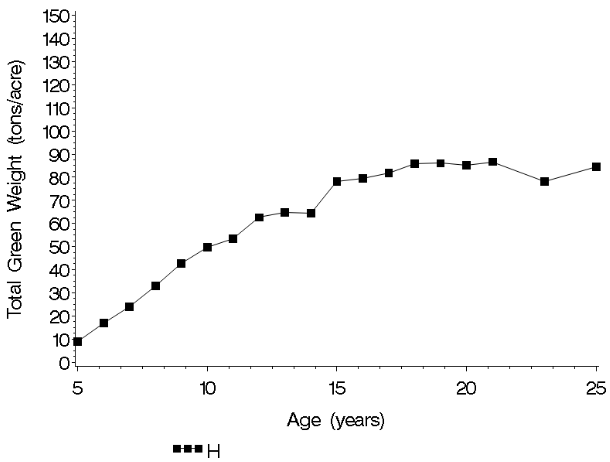
	1987		1989	
Age	C	H	C	H
5	2.8	11.8	1.8	9.6
6	6.4	23.3	3.9	19.3
7	9.8	33.8	7.4	31.5
8	16.0	48.9	11.5	45.6
9	23.0	65.7	17.7	63.9
10	31.0	80.7	24.6	76.1
11	39.5	92.9	33.2	92.7
12	49.6	112.2	35.2	106.0
13	59.9	124.6	47.0	118.9
14	67.9	132.4	54.9	129.3
15	75.5	153.7	64.2	142.5
16	80.5	159.9	73.3	153.3
17	90.7	172.7	82.8	167.1
18	100.9	186.7	92.8	176.1
19	108.6	194.7	95.7	180.6
20	121.6	206.7	105.7	187.6
21	126.2	212.9	113.8	195.1
23	139.5	217.7	139.5	211.0
25	158.4	242.9	.	.



(a) 1987



(b) 1989

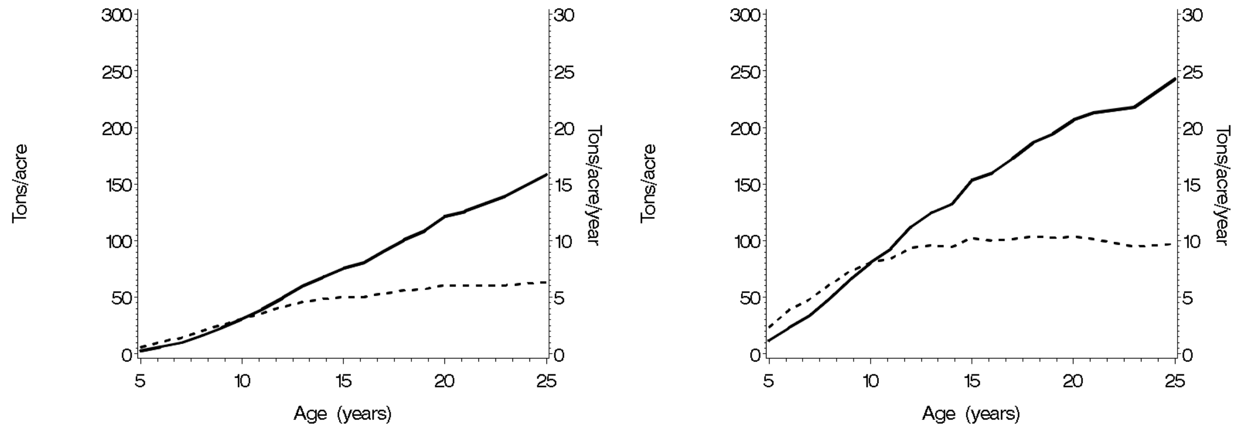


(c) 1987 Treatment Effects

Figure 3.52: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures 3.52(a)-(a). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.77: Mean annual increment (tons/acre/year) development at the Dawsonville - Top site by time replicate.

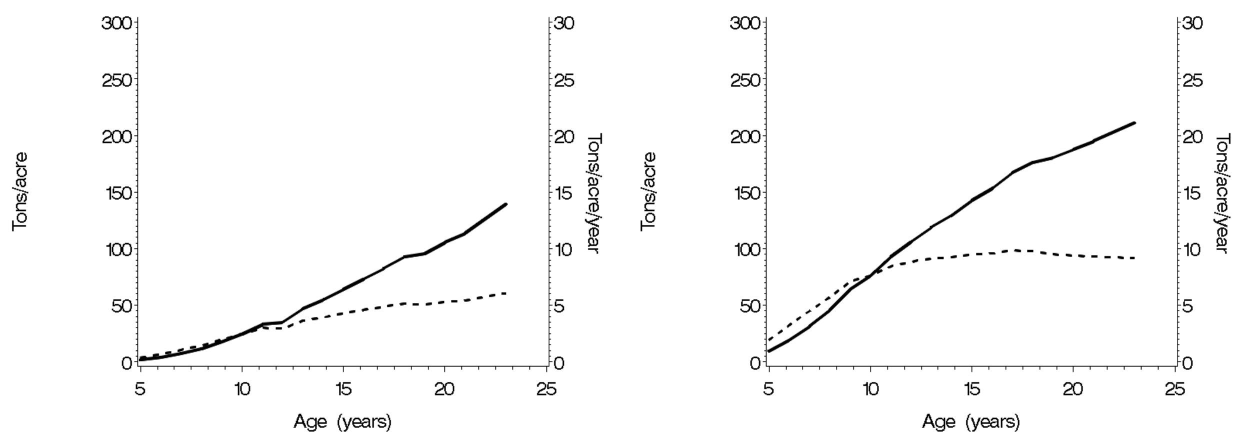
	1987		1989	
Age	C	H	C	H
5	0.6	2.4	0.4	1.9
6	1.1	3.9	0.7	3.2
7	1.4	4.8	1.1	4.5
8	2.0	6.1	1.4	5.7
9	2.6	7.3	2.0	7.1
10	3.1	8.1	2.5	7.6
11	3.6	8.4	3.0	8.4
12	4.1	9.4	2.9	8.8
13	4.6	9.6	3.6	9.2
14	4.9	9.5	3.9	9.2
15	5.0	10.2	4.3	9.5
16	5.0	10.0	4.6	9.6
17	5.3	10.2	4.9	9.8
18	5.6	10.4	5.2	9.8
19	5.7	10.2	5.0	9.5
20	6.1	10.3	5.3	9.4
21	6.0	10.1	5.4	9.3
23	6.1	9.5	6.1	9.2
25	6.3	9.7	.	.



(a) C

(b) H

Figure 3.53: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Dawsonville - Top 1987 time replicate.



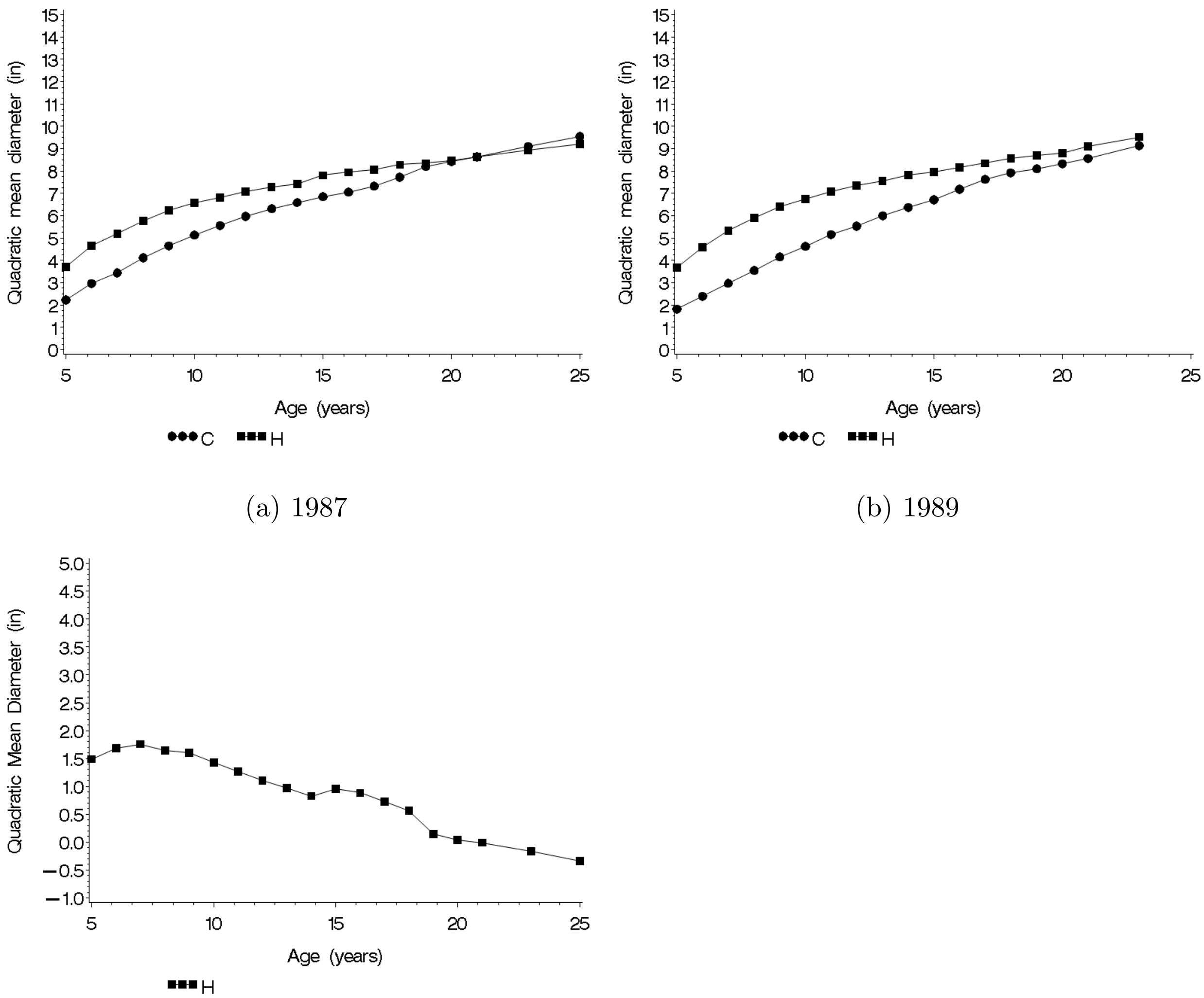
(a) C

(b) H

Figure 3.54: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Dawsonville - Top 1989 time replicate.

Table 3.78: Average quadratic mean diameter (inches) development at the Dawsonville - Top site by time replicate.

	1987		1989	
Age	C	H	C	H
5	2.2	3.7	1.8	3.7
6	3.0	4.7	2.4	4.6
7	3.4	5.2	3.0	5.3
8	4.1	5.8	3.6	5.9
9	4.6	6.3	4.2	6.4
10	5.1	6.6	4.6	6.7
11	5.6	6.8	5.2	7.1
12	6.0	7.1	5.5	7.4
13	6.3	7.3	6.0	7.6
14	6.6	7.4	6.4	7.8
15	6.9	7.8	6.7	8.0
16	7.1	7.9	7.2	8.2
17	7.3	8.1	7.6	8.4
18	7.7	8.3	7.9	8.6
19	8.2	8.4	8.1	8.7
20	8.4	8.5	8.3	8.8
21	8.6	8.6	8.6	9.1
23	9.1	8.9	9.1	9.5
25	9.6	9.2	.	.



(a) 1987

(b) 1989

(c) 1987 Treatment Effects

Figure 3.55: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Dawsonville - Top site is shown in subfigures (a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.79: Average pulpwood development (tons/acre) at the Dawsonville - Top site by time replicate.

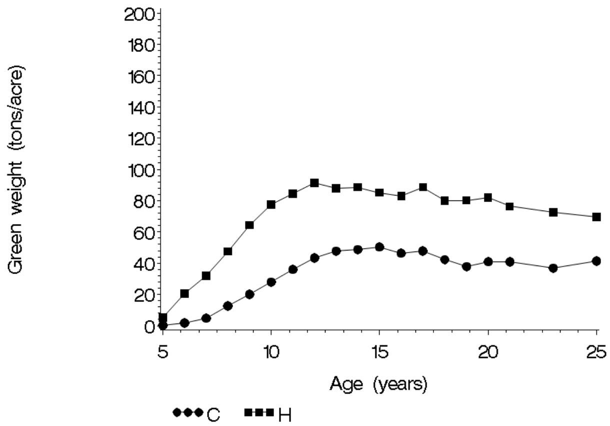
	1987		1989	
Age	C	H	C	H
5	0.2	5.1	.	3.8
6	1.7	20.6	0.2	17.2
7	4.9	32.1	2.3	30.1
8	12.6	47.5	7.8	44.2
9	20.1	64.4	14.6	59.5
10	27.8	77.7	22.1	66.4
11	36.2	84.3	31.0	73.7
12	43.3	91.5	33.5	74.8
13	47.6	88.1	43.1	78.4
14	48.6	88.6	48.7	73.9
15	50.4	85.1	53.3	77.5
16	46.5	83.0	50.6	72.1
17	47.9	88.6	45.5	72.1
18	42.3	80.2	44.4	68.7
19	37.8	80.2	40.0	67.5
20	41.0	81.9	39.5	66.9
21	40.8	76.3	37.2	61.3
23	36.7	72.5	38.0	59.3
25	41.4	69.8	.	.

Table 3.80: Average chip-n-saw development (tons/acre) at the Dawsonville - Top site by time replicate.

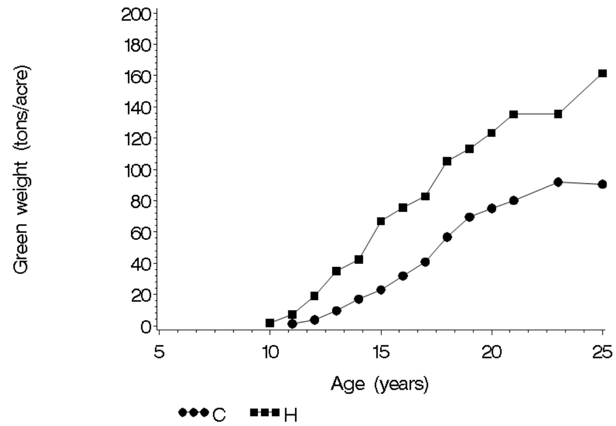
	1987		1989	
Age	C	H	C	H
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	.	.	.	3.2
10	.	1.6	.	8.4
11	1.2	7.3	.	17.9
12	3.7	19.3	.	30.1
13	9.5	35.0	2.4	39.4
14	17.0	42.3	4.8	54.3
15	22.9	66.9	9.4	63.9
16	31.8	75.7	21.6	80.1
17	40.8	82.7	36.3	93.9
18	56.8	105.2	47.5	106.3
19	69.5	113.1	54.6	109.8
20	75.1	123.4	65.2	115.4
21	80.2	135.2	73.6	125.8
23	91.9	135.4	93.2	123.1
25	90.5	161.4	.	.

Table 3.81: Average sawtimber development (tons/acre) at the Dawsonville - Top site by time replicate.

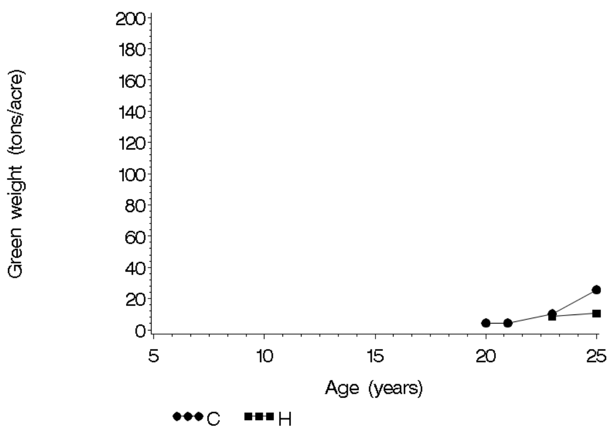
	1987		1989	
Age	C	H	C	H
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	.	.	.	.
10	.	.	.	.
11	.	.	.	.
12	.	.	.	.
13	.	.	.	.
14	.	.	.	.
15	.	.	.	.
16	.	.	.	.
17	.	.	.	.
18	.	.	.	.
19	.	.	.	4.2
20	4.4	.	.	4.2
21	4.4	.	4.1	6.9
23	10.2	8.6	7.2	27.6
25	25.7	10.4	.	.



(a) Pulpwood



(b) Chip-N-Saw

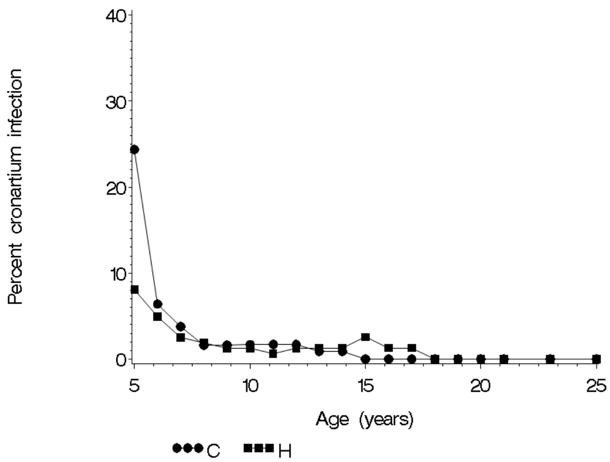


(c) Sawtimber

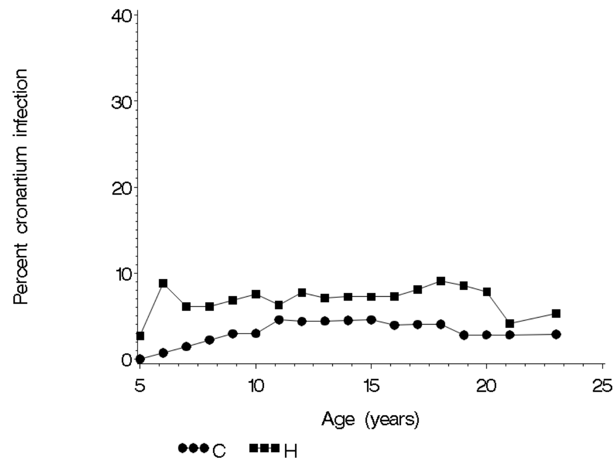
Figure 3.56: Average product distribution (tons/acre) over the course of the study for the Dawsonville - Top 1987 time replicate. Pulpwood is shown in (a), Chip-N-Saw in (b), and sawtimber in (c).

Table 3.82: Average cronartium infection rates (%) at the Dawsonville - Top site by time replicate.

	1987		1989	
Age	C	H	C	H
5	24.4	8.1	0.0	2.7
6	6.4	5.0	0.7	8.8
7	3.8	2.5	1.5	6.1
8	1.6	1.9	2.2	6.1
9	1.6	1.3	2.9	6.9
10	1.7	1.3	3.0	7.6
11	1.7	0.6	4.6	6.3
12	1.7	1.3	4.4	7.7
13	0.9	1.3	4.4	7.1
14	0.9	1.3	4.5	7.2
15	0.0	2.6	4.6	7.2
16	0.0	1.3	3.9	7.3
17	0.0	1.3	4.0	8.1
18	0.0	0.0	4.0	9.1
19	0.0	0.0	2.8	8.5
20	0.0	0.0	2.8	7.8
21	0.0	0.0	2.8	4.2
23	0.0	0.0	2.9	5.3
25	0.0	0.0	.	.



(a) 1987



(b) 1989

Figure 3.57: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Dawsonville - Top site are shown in subfigures (a)-(b).

3.6 Thompson

Due to a harvest that occurred on site, the Thompson site was abandoned in 2006. Final measurement were taken after the 18^{th}, 16^{th}, and 11^{th} growing seasons for the 1988, 1990, and 1995 time replicates, respectively.

Site quality, as measured by site index, is good on the Thompson site. On the 1988 time replicate, the C treatment shows a base site index of 61 feet at age 18, which can be predicted to be higher by base age 25 (Table 3.83). All time replicates showed similar trends between the treatments, with slightly higher dominant heights for the H treatments compared with the C treatments (Figure 3.58). The 1988 time replicate had an ending dominant height of 66 feet for the H treatment. The 1990 time replicate showed similar values at each age for treatments compared with the 1988 time replicate. The 1995 time replicate showed higher growth rates compared to the other time replicates for the first 11 years.

Basal area per acre (BA) development showed slightly higher rates for the H treatment in the 1988 and 1995 time replicates for the first few years of the study, eventually slowing down and matching the C treatment (Table 3.84; Figure 3.59). The 1988 H treatment also saw a slight decline in BA two years prior to the end of the study (Figure 3.59(a)). The 1990 time replicate showed the H and C treatments begin with very similar BA rates, but by age 7, the C treatment developed faster than the H and maintained that advantage until the study ended (Figure 3.59(b)). Maximum BA values for the C treatment, which all occurred at the last measurement year, were 169.8, 169.1, and 146.2 ft^2/acre for the 1988, 1990, and 1995 time replicates, respectively. The H treatment maximums were 162.9, 143.5, and 152.1 ft^2/acre at ages 16, 16, and 11 for the three time replicates.

Stand density index (SDI) development for the Thompson site is consistent with BA development (Tables 3.85, 3.84). SDI increased as the stand continued to develop, and in the case of the 1988 H treatment, declined where BA also declined (Figures 3.60, 3.84). On treatments that did not see BA declines, SDI continued to increase and reached maximum values at the last measurement age. Maximum SDI values for C were 357, 351, and 317 for the 1988, 1990, and 1995 time replicates. The H treatment maximums were 342, 303, and 326 for the three time replicates. Since SDI is used to measure maximum number of 10 inch trees a site can support given current stand characteristics, the C treatments on the 1988 and 1990 time replicates show that, for the ages covered in this study, it is considered to be more dense than the H treatment.

Relative spacing (RS) showed decreasing values as density increased. Minimum RS values reached for the C treatment were .14, .15, and .17 for the 1988, 1990, and 1995 time replicates (Table 3.86). While this site has fewer measurement years compared to other sites seen in this study, the lowest values on this site show stands that do not reach high density levels. The RS values seen on the 1988 time replicate reflect the BA decline seen at the end of the study with increases in RS (Table 3.86). Little difference is seen between treatments on the 1990 time replicate Table 3.86; Figure 3.61).

Trees per acre (TPA) development showed similar rates in stem mortality for the H and C treatments on all time replicates for the first 12-15 years (Figure 3.62). During this age 12-15 period, mortality rates increased for the H treatment. Final TPA values for the C treatment were 616, 584, and 624 trees per acre for the 1988, 1990, and 1995 time replicates, respectively (Table 3.87). The H treatment had final TPA values of 460, 540, and 620 trees per acre for the three time replicates.

Total green tons per acre (GT) developed very similarly to BA for treatments on all time replicates (Tables 3.88, 3.84; Figures 3.63, 3.59). Maximum GT occurred on the C treatments at the last measurement age. These maximums for the C treatment were 130, 125, and 92 tons/acre for the 1988, 1990, and 1995 time replicates, respectively (Table 3.88). The H treatment reached maximums of 128, 106, and 103 tons/acre at age 16, 16, and 11 for the three time replicates, respectively. The 1988 H treatment showed a decrease in GT after the 16^{th} growing season, which corresponds with the decline in BA. Mean annual increment (MAI) peaked for the C treatment at or near the last measurement age for all time replicates. The peak MAI rates for the C treatment were 7.3, 7.8, and 8.4 tons/acre/year for the 1988, 1990, and 1995 time replicates, respectively (Table 3.89;, Figures 3.64-3.66). MAI peaks for the H treatment were 8.0, 6.6, and 9.4 at age 16, 16, and 11 for the three time replicates. In the case of the 1990 and 1995 time replicates, the H MAI peaks occurred at the last measurement age. Comparison of MAI rates until age 11 showed faster development in both treatments in the 1995 time replicate, followed by the 1990 then 1988 time replicates (Table 3.89).

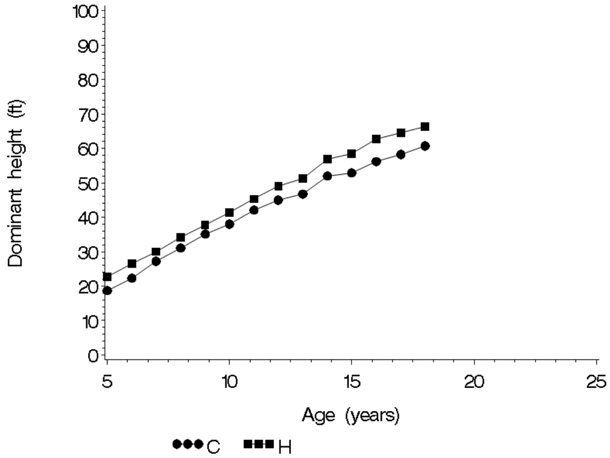
Quadratic mean diameter (DQ) development patterns showed different development for the treatments between time replicates (Figure 3.67). The 1988 time replicate showed little differences between the H and C treatments for the duration of the study, until the final measurement year when the H treatment had a slight advantage (Figure 3.67(a)). The 1990 time replicate showed increased rates on the C treatment from ages 6 to 14, after which the H treatment caught up (Figure 3.67(b)). The 1995 time replicate showed early increased rates on the H treatment until age 10 (Figure 3.67(c)). DQ development patterns reflect their individual qualities, with the 1995 treatment, the higher quality site, showing greater responses on the H treatment while the lowest quality time replicate, 1988, showed little to no response in the H treatment. Ending DQ values for the C treatment, which were the maximum for all time replicates, were 7.1, 7.3, and 6.6 inches on the 1988, 1990, and 1995 time replicates, respectively (Table 3.90).. The H treatment had maximum DQ values of 7.6, 7.0, and 6.7 for the three time replicates.

Product development on the Thompson site showed pulpwood present for all treatments at age 5 (Table 3.91). Pulpwood peaks occurred at or near the last measurement age for the C treatments. Pulpwood peaks for the H treatment occurred at age 14, 16, and 11 for the 1988, 1990, and 1995 time replicates (Table 3.91). Chip-n-saw development first occurred on the C treatment at age 12, 9, and 10 for the 1988, 1990, and 1995 time replicates, respectively (Table 3.92). The H treatment first occurred at age 11, 10, and 10 for the three time replicates. Chip-n-saw development continued to increase on all treatments on all time replicates. No sawtimber development occurred on the Thompson site. As DQ development continued to increase, higher classes of products became more prevalent. Low amounts of chip-n-saw and no sawtimber on site occurred due to lower DQ rates (Table 3.90).

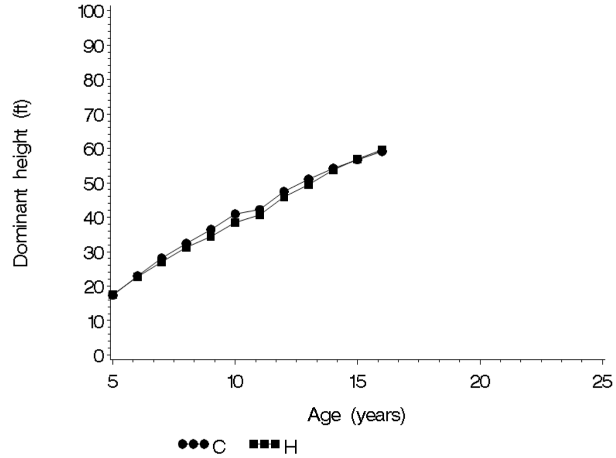
Cronartium infection rates for the first 10 years of development were the highest in the H treatments for the 1988 and 1995 time replicates (Table 3.93; Figure 3.69). The 1990 time replicate saw similar rates between the two treatments for the duration of the study. The 1995 time replicate exhibited the standard relationship between growth rates and infection rates, with the more intensive treatment, H, having higher rates of infection (Figure 3.69(b)). This was also seen in the 1988 time replicate, where MAI rates were slightly higher for the H treatment. The 1988 and 1990 time replicates saw similar overall rates of infection, while the 1995 time replicate started at lower rates.

Table 3.83: Average dominant height (feet) development at the Thompson site by time replicate.

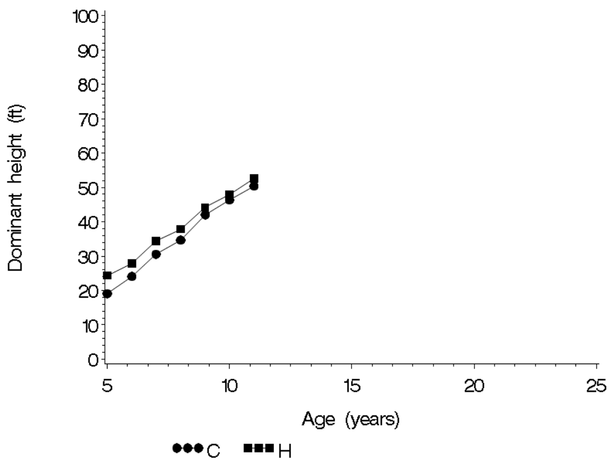
	1988		1990		1995	
Age	C	H	C	H	C	H
5	18.7	22.7	17.4	17.5	19.0	24.4
6	22.4	26.6	23.0	22.7	24.1	27.9
7	27.2	30.0	28.2	27.0	30.5	34.5
8	31.1	34.2	32.4	31.2	34.7	37.9
9	35.1	37.8	36.5	34.4	42.0	44.2
10	38.0	41.4	41.0	38.5	46.4	48.0
11	42.1	45.3	42.2	40.6	50.4	52.6
12	45.0	49.0	47.5	45.8	.	.
13	46.7	51.2	51.1	49.4	.	.
14	52.0	56.9	54.2	53.8	.	.
15	52.9	58.5	56.7	57.0	.	.
16	56.1	62.8	59.1	59.7	.	.
17	58.2	64.6	.	.	.	.
18	60.7	66.3	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



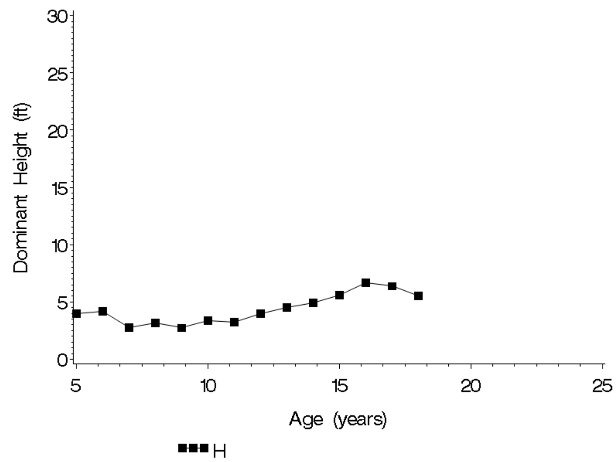
(a) 1988



(b) 1990



(c) 1995

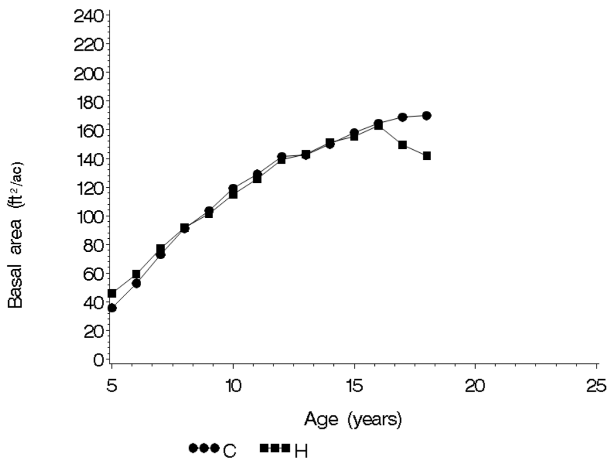


(d) 1988 Treatment Effects

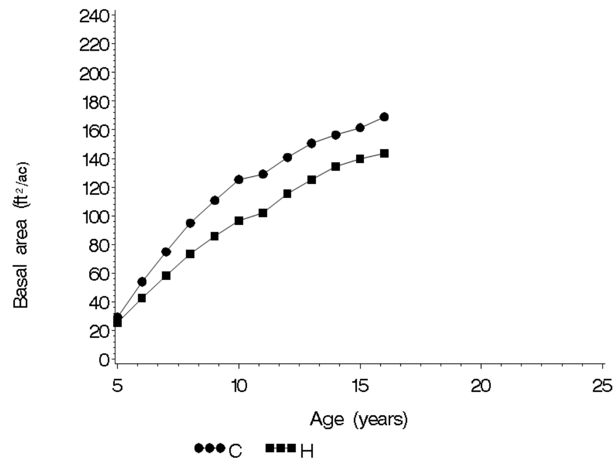
Figure 3.58: Average dominant height (feet) over the course of the study for the individual time replicates at the Thompson site is shown in subfigures (a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.84: Average basal area (ft^2/acre) at the Thompson site by time replicate.

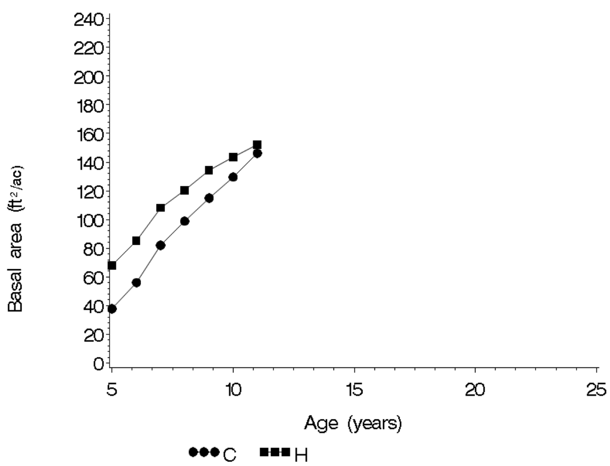
	1988		1990		1995	
Age	C	H	C	H	C	H
5	35.7	46.1	29.2	25.4	37.8	67.9
6	52.9	59.4	53.9	42.5	55.9	85.3
7	73.1	77.0	74.7	58.2	82.0	108.1
8	91.1	91.6	94.8	73.4	98.8	120.5
9	103.5	101.5	110.8	85.9	114.9	134.3
10	119.1	115.0	125.3	96.8	129.7	143.6
11	129.1	125.7	129.2	102.0	146.2	152.1
12	141.2	139.2	140.6	115.3	.	.
13	142.3	143.1	150.6	125.1	.	.
14	149.9	151.0	156.4	134.4	.	.
15	157.8	155.3	161.6	139.8	.	.
16	164.4	162.9	169.1	143.5	.	.
17	168.7	149.6	.	.	.	.
18	169.8	142.1	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



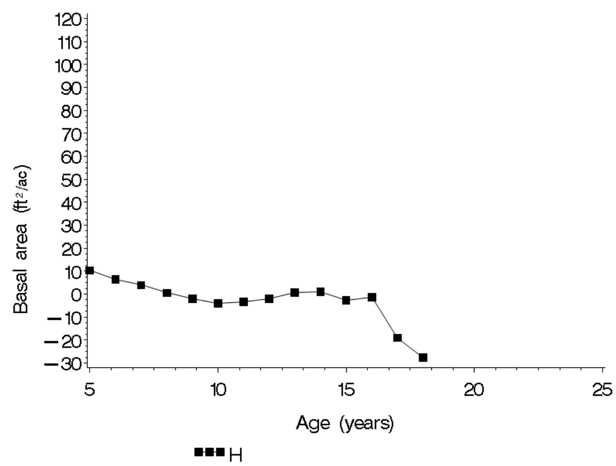
(a) 1988



(b) 1990



(c) 1995

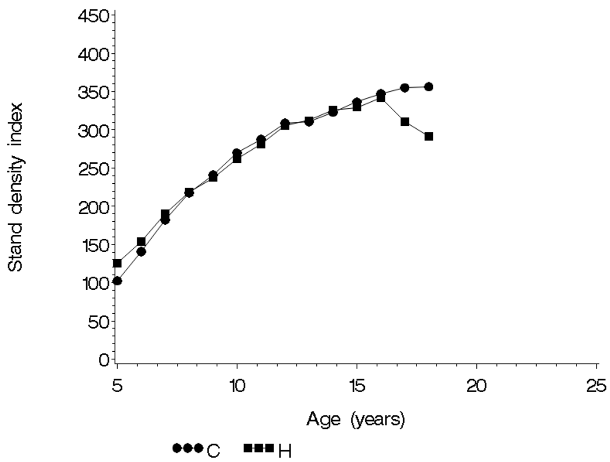


(d) 1988 Treatment Effects

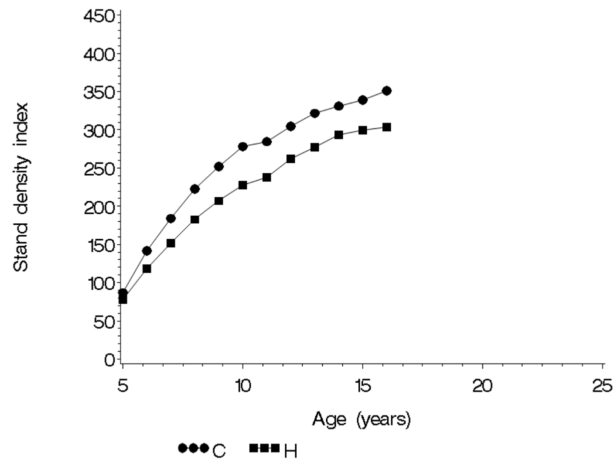
Figure 3.59: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Thompson site is shown in subfigures (a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.85: Average stand density index development at the Thompson site by time replicate.

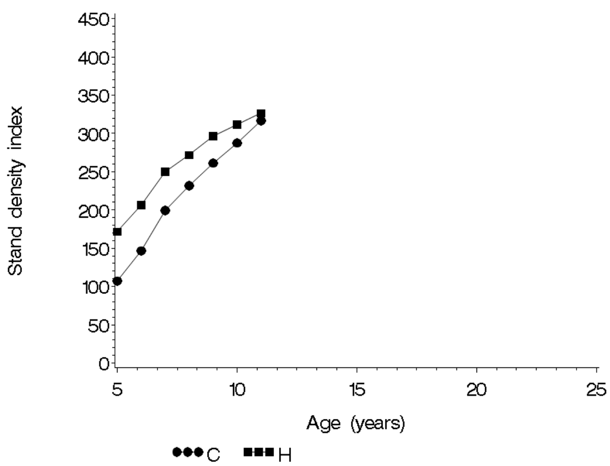
	1988		1990		1995	
Age	C	H	C	H	C	H
5	102.5	125.4	86.6	78.1	107.0	171.5
6	140.6	154.0	141.6	118.1	146.5	206.3
7	182.2	190.0	183.9	151.7	199.4	249.7
8	217.4	218.4	222.6	182.7	231.6	271.7
9	240.9	237.2	251.9	207.0	261.4	296.4
10	269.6	262.2	277.9	227.8	287.8	311.7
11	287.7	281.5	284.5	237.5	316.6	326.3
12	308.8	305.6	304.4	262.2	.	.
13	310.4	312.2	321.3	277.4	.	.
14	323.1	325.5	331.2	293.7	.	.
15	336.4	329.2	338.9	299.5	.	.
16	347.5	342.1	351.0	303.2	.	.
17	354.8	310.3	.	.	.	.
18	356.3	291.4	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) 1988



(b) 1990

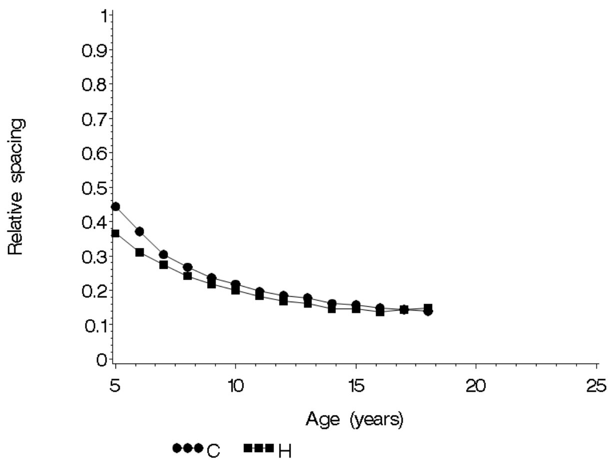


(c) 1995

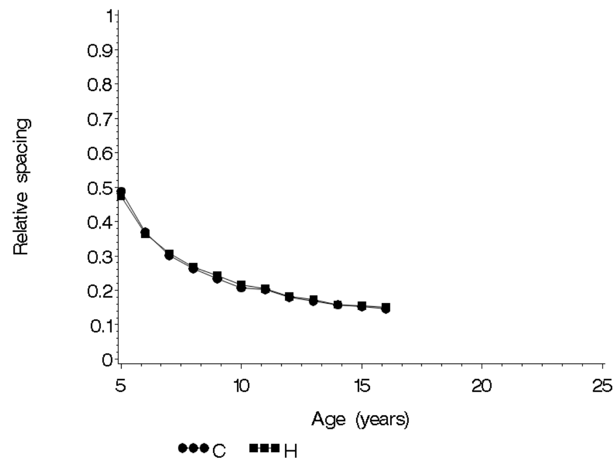
Figure 3.60: Average stand density index over the course of the study for the individual time replicates at the Thompson site is shown in subfigures 3.60(a)-(c).

Table 3.86: Average relative spacing development at the Thompson site by time replicate.

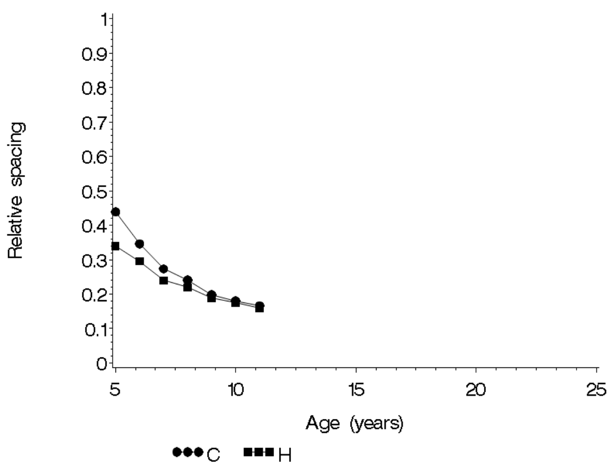
	1988		1990		1995	
Age	C	H	C	H	C	H
5	0.44	0.37	0.49	0.47	0.44	0.34
6	0.37	0.31	0.37	0.36	0.35	0.30
7	0.30	0.28	0.30	0.31	0.27	0.24
8	0.27	0.24	0.26	0.27	0.24	0.22
9	0.24	0.22	0.23	0.24	0.20	0.19
10	0.22	0.20	0.21	0.22	0.18	0.17
11	0.20	0.18	0.20	0.21	0.17	0.16
12	0.18	0.17	0.18	0.18	.	.
13	0.18	0.16	0.17	0.17	.	.
14	0.16	0.15	0.16	0.16	.	.
15	0.16	0.15	0.15	0.15	.	.
16	0.15	0.14	0.15	0.15	.	.
17	0.14	0.14	.	.	.	.
18	0.14	0.15	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) 1988



(b) 1990

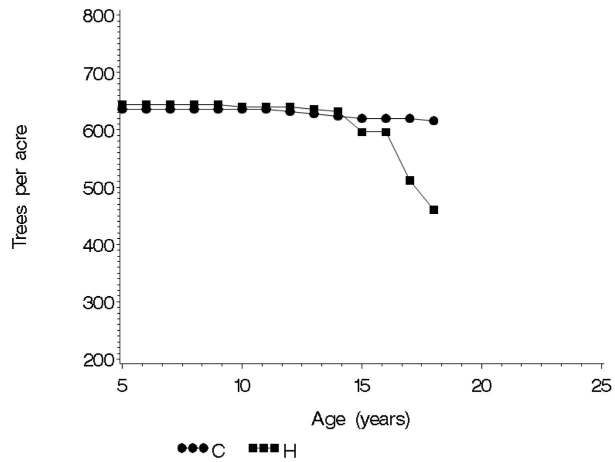


(c) 1995

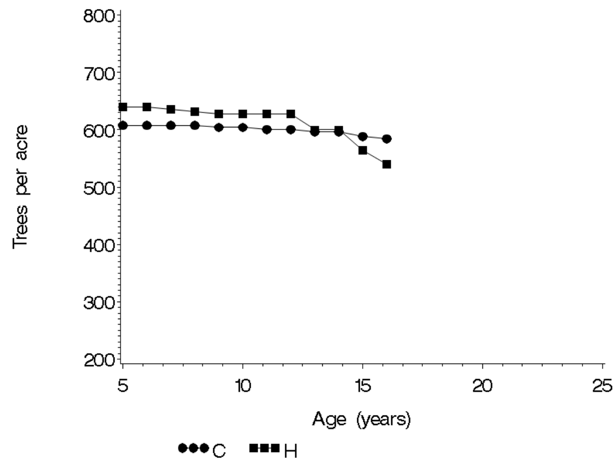
Figure 3.61: Average relative spacing development over the course of the study for the individual time replicates at the Thompson site is shown in subfigures 3.61(a)-(c).

Table 3.87: Average trees per acre development at the Thompson site by time replicate.

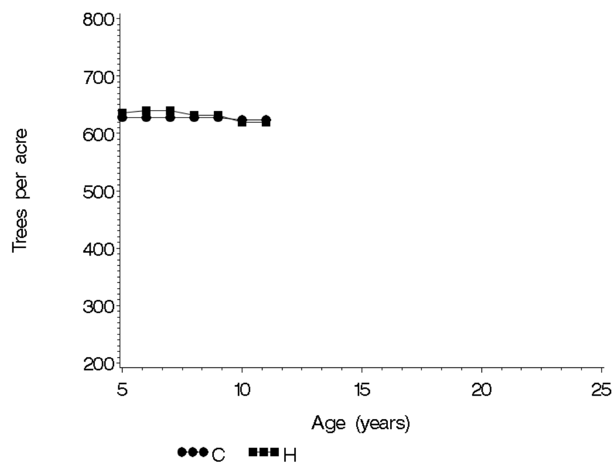
	1988		1990		1995	
Age	C	H	C	H	C	H
5	636	644	608	640	628	636
6	636	644	608	640	628	640
7	636	644	608	636	628	640
8	636	644	608	632	628	632
9	636	644	604	628	628	632
10	636	640	604	628	624	620
11	636	640	600	628	624	620
12	632	640	600	628	.	.
13	628	636	596	600	.	.
14	624	632	596	600	.	.
15	620	596	588	564	.	.
16	620	596	584	540	.	.
17	620	512	.	.	.	.
18	616	460	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



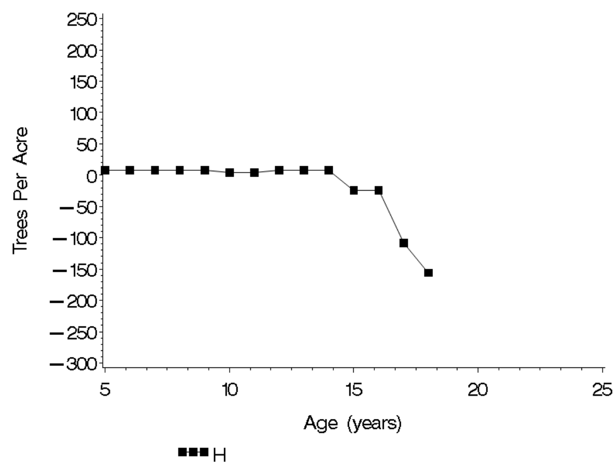
(a) 1988



(b) 1990



(c) 1995

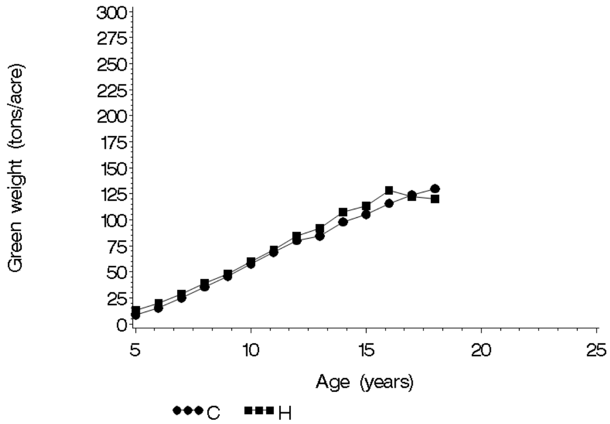


(d) 1988 Treatment Effects

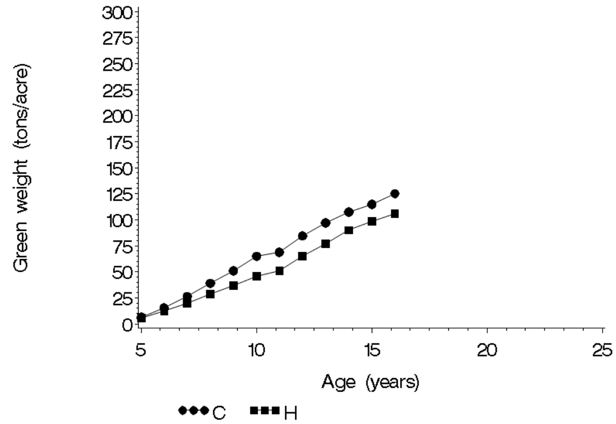
Figure 3.62: Average trees per acre development over the course of the study for the individual time replicates at the Thompson site is shown in subfigures (a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.88: Average total green weight (tons/acre) development at the Thompson site by time replicate.

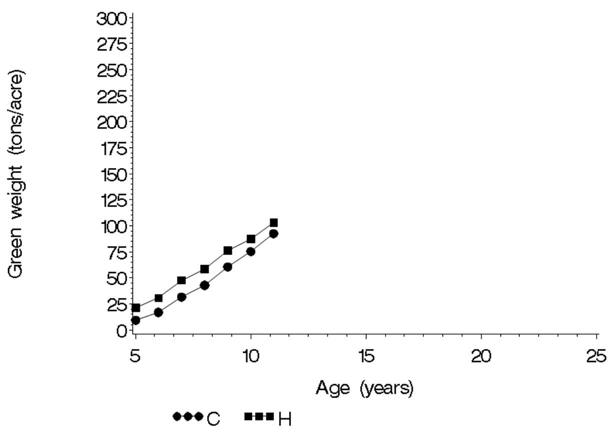
	1988		1990		1995	
Age	C	H	C	H	C	H
5	8.5	13.3	6.4	5.6	9.1	21.1
6	14.9	19.9	15.4	12.1	16.8	30.5
7	24.7	28.9	26.2	19.5	31.4	47.5
8	35.6	39.4	38.7	28.4	42.7	58.2
9	45.4	48.0	50.8	36.5	60.3	75.9
10	57.3	59.6	64.7	45.9	75.0	87.2
11	68.4	71.0	68.7	51.1	92.3	102.8
12	80.0	84.4	84.7	65.3	.	.
13	84.1	91.6	97.0	76.7	.	.
14	97.8	107.3	107.3	89.9	.	.
15	105.1	113.1	114.9	98.4	.	.
16	115.7	128.1	125.0	105.9	.	.
17	123.7	122.1	.	.	.	.
18	129.8	120.1	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



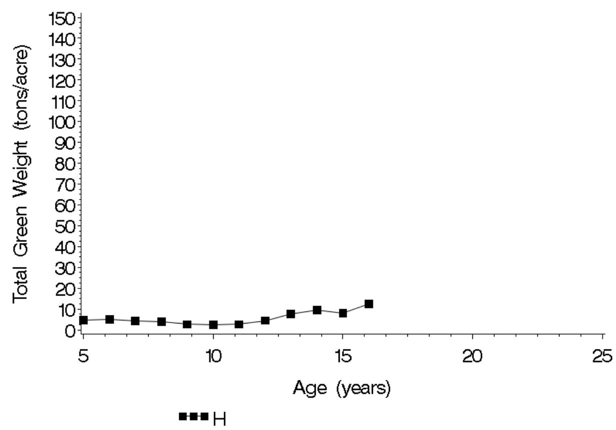
(a) 1988



(b) 1990



(c) 1995

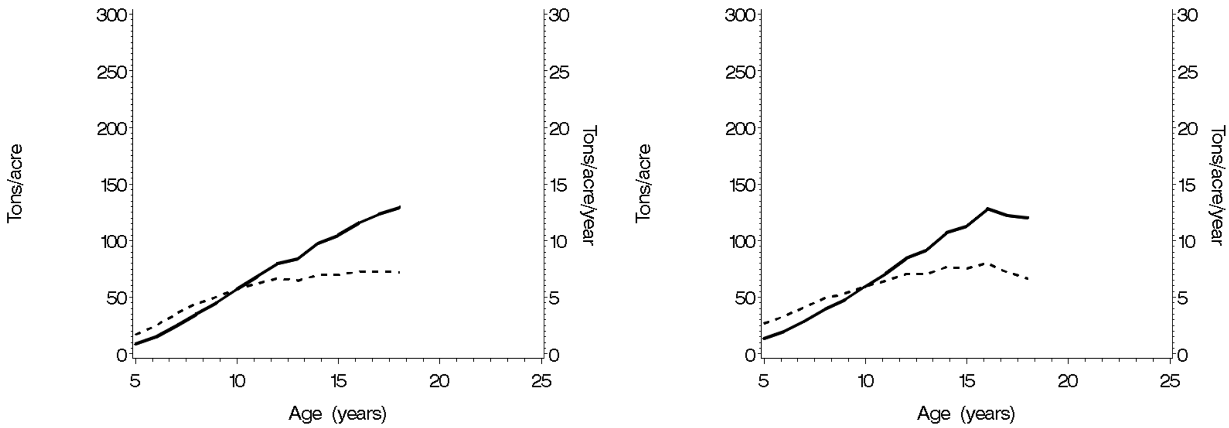


(d) 1988 Treatment Effects

Figure 3.63: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Thompson site is shown in subfigures 3.63(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

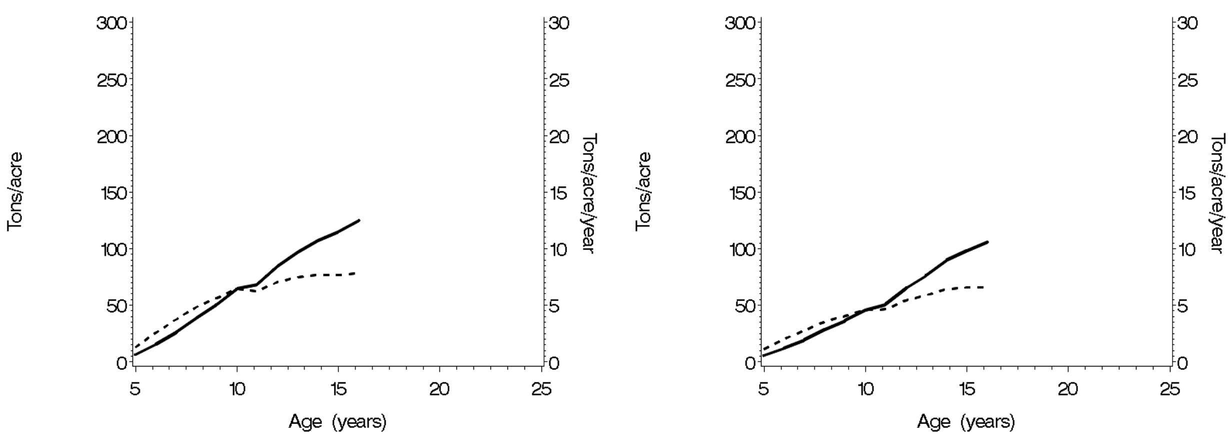
Table 3.89: Mean annual increment (tons/acre/year) development at the Thompson site by time replicate.

	1988		1990		1995	
Age	C	H	C	H	C	H
5	1.7	2.7	1.3	1.1	1.8	4.2
6	2.5	3.3	2.6	2.0	2.8	5.1
7	3.5	4.1	3.8	2.8	4.5	6.8
8	4.4	4.9	4.8	3.6	5.3	7.3
9	5.0	5.3	5.7	4.1	6.7	8.4
10	5.7	6.0	6.5	4.6	7.5	8.7
11	6.2	6.5	6.2	4.7	8.4	9.4
12	6.7	7.0	7.1	5.4	.	.
13	6.5	7.1	7.5	5.9	.	.
14	7.0	7.7	7.7	6.4	.	.
15	7.0	7.5	7.7	6.6	.	.
16	7.2	8.0	7.8	6.6	.	.
17	7.3	7.2	.	.	.	.
18	7.2	6.7	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) C (b) H

Figure 3.64: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Thompson 1988 time replicate.



(a) C (b) H

Figure 3.65: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Thompson 1990 time replicate.

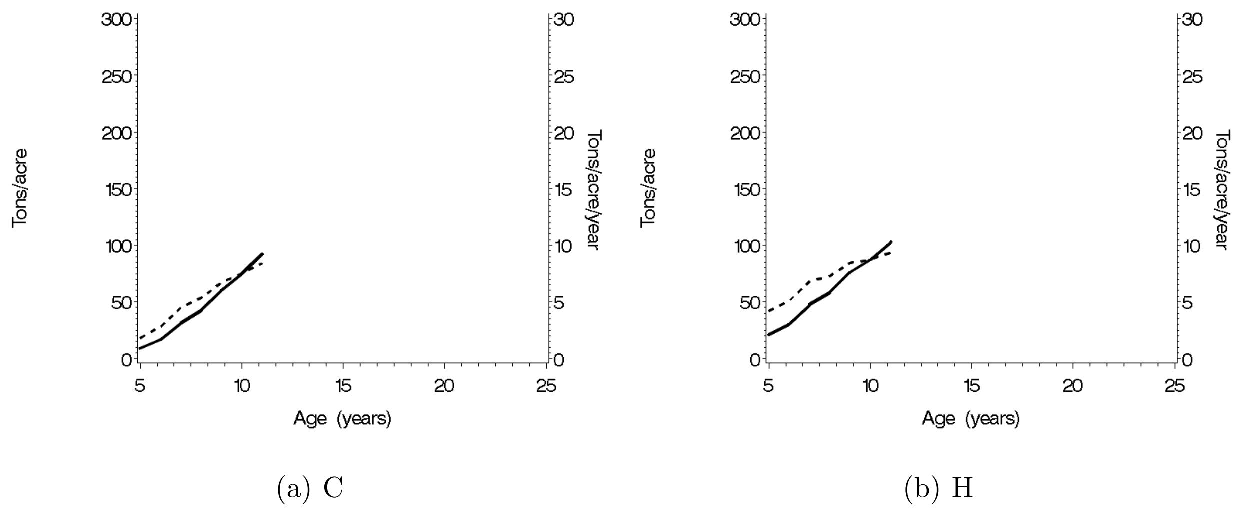
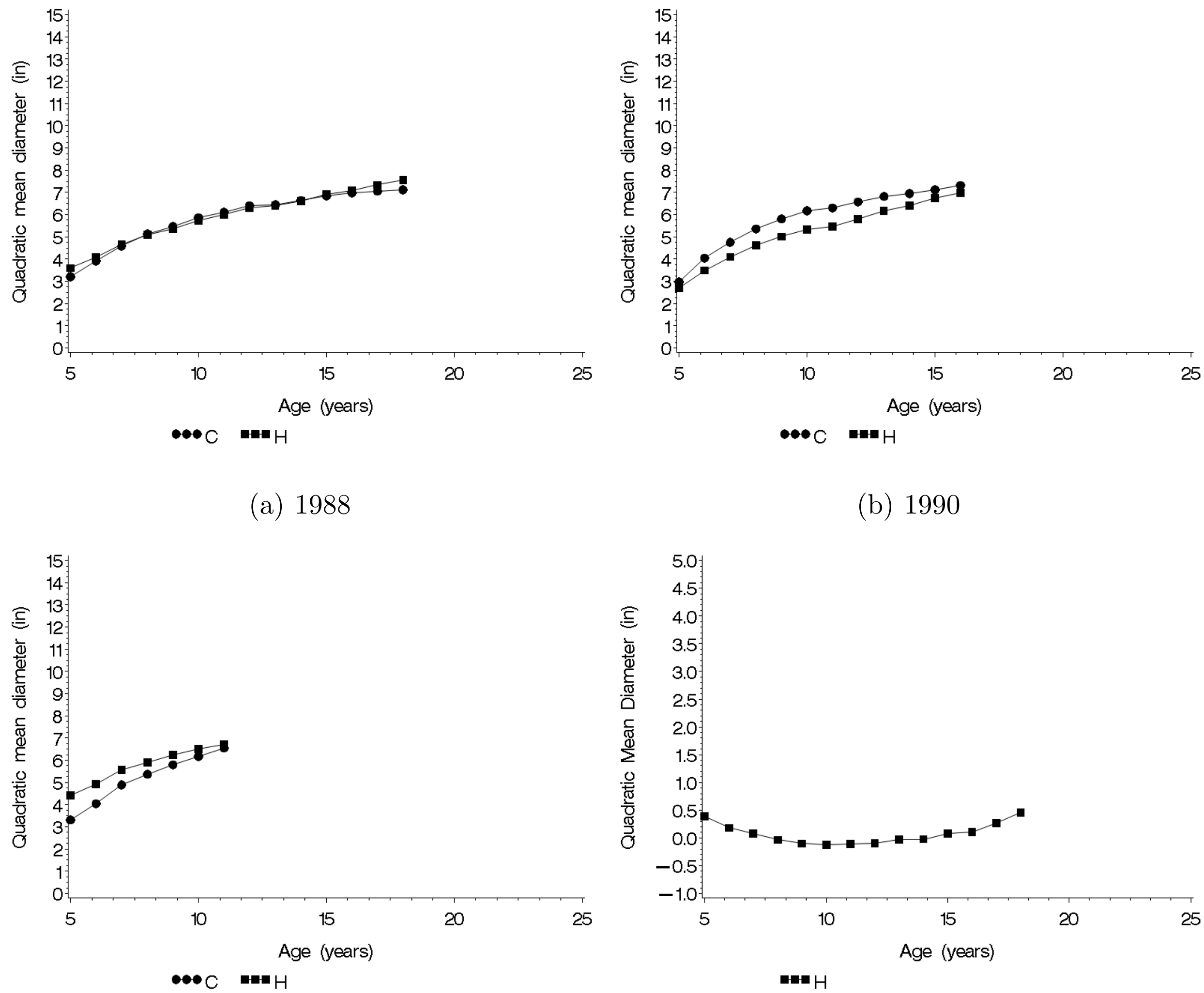


Figure 3.66: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (——) by treatment for the Thompson 1995 time replicate.

Table 3.90: Average quadratic mean diameter (inches) development at the Thompson site by time replicate.

	1988		1990		1995	
Age	C	H	C	H	C	H
5	3.2	3.6	3.0	2.7	3.3	4.4
6	3.9	4.1	4.0	3.5	4.0	4.9
7	4.6	4.7	4.8	4.1	4.9	5.6
8	5.1	5.1	5.4	4.6	5.4	5.9
9	5.5	5.4	5.8	5.0	5.8	6.2
10	5.9	5.7	6.2	5.3	6.2	6.5
11	6.1	6.0	6.3	5.5	6.6	6.7
12	6.4	6.3	6.6	5.8	.	.
13	6.5	6.4	6.8	6.2	.	.
14	6.6	6.6	7.0	6.4	.	.
15	6.8	6.9	7.1	6.7	.	.
16	7.0	7.1	7.3	7.0	.	.
17	7.1	7.3	.	.	.	.
18	7.1	7.6	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) 1988

(b) 1990

(c) 1995

(d) 1988 Treatment Effects

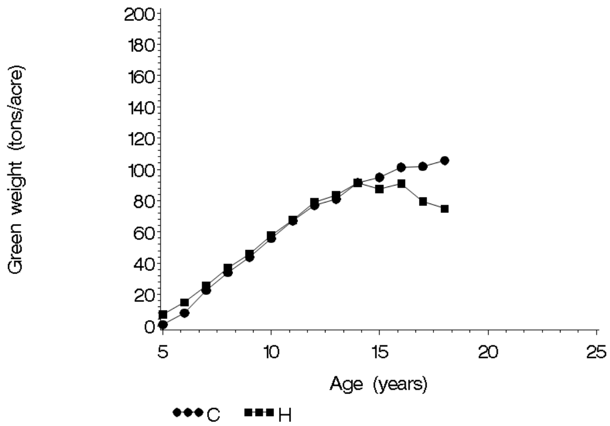
Figure 3.67: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Thompson site is show in subfigures 3.67(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.91: Average pulpwood development (tons/acre) at the Thompson site by time replicate.

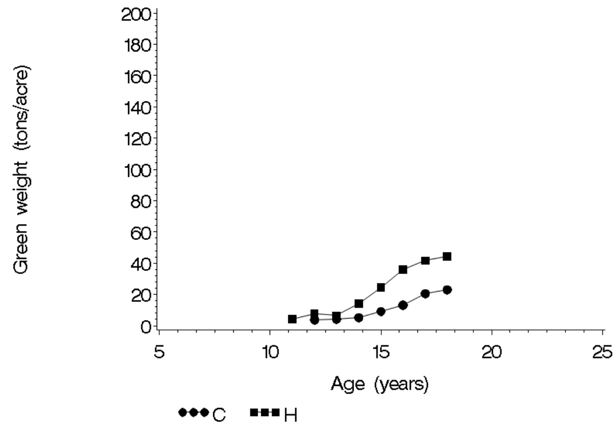
	1988		1990		1995	
Age	C	H	C	H	C	H
5	0.7	7.1	0.6	0.4	1.9	18.5
6	8.1	14.9	10.1	6.1	10.9	29.2
7	22.7	25.3	23.8	13.8	29.8	46.4
8	34.1	37.0	37.5	24.8	41.5	57.1
9	43.7	45.7	49.4	33.8	59.2	74.9
10	55.9	57.9	61.3	43.1	73.4	84.9
11	67.0	67.4	64.1	48.0	86.2	98.0
12	76.8	78.9	73.8	61.7	.	.
13	80.8	83.5	80.0	72.5	.	.
14	91.5	91.5	87.9	81.9	.	.
15	94.9	87.3	87.0	81.9	.	.
16	101.3	91.0	87.7	82.4	.	.
17	102.0	79.4	.	.	.	.
18	105.6	74.8	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.

Table 3.92: Average chip-n-saw development (tons/acre) at the Thompson site by time replicate.

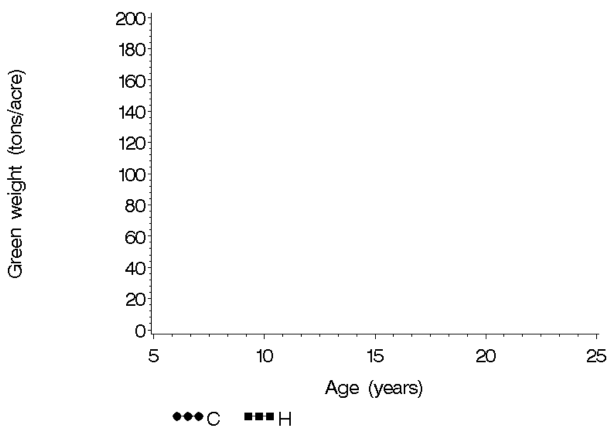
	1988		1990		1995	
Age	C	H	C	H	C	H
5	.	.	.	.	.	.
6	.	.	.	.	.	.
7	.	.	.	.	.	.
8	.	.	.	.	.	.
9	.	.	1.0	.	.	.
10	.	.	4.7	1.2	1.2	2.5
11	.	4.2	3.6	1.3	5.0	3.7
12	3.6	7.8	9.8	1.5	.	.
13	4.0	6.5	15.9	2.6	.	.
14	5.0	14.1	18.3	6.3	.	.
15	9.1	24.5	26.8	15.2	.	.
16	13.2	35.7	36.2	22.3	.	.
17	20.5	41.6	.	.	.	.
18	22.9	44.3	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw

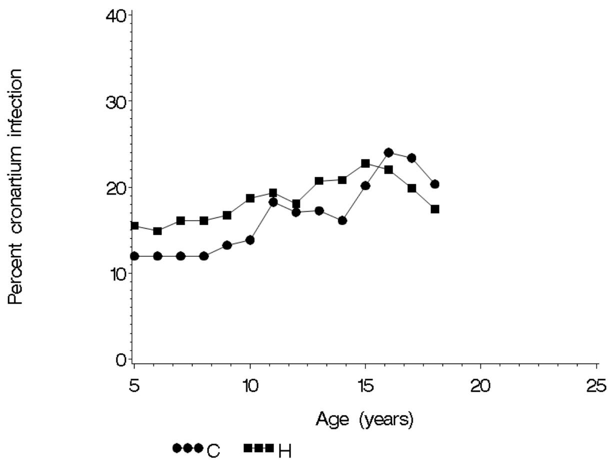


(c) Sawtimber

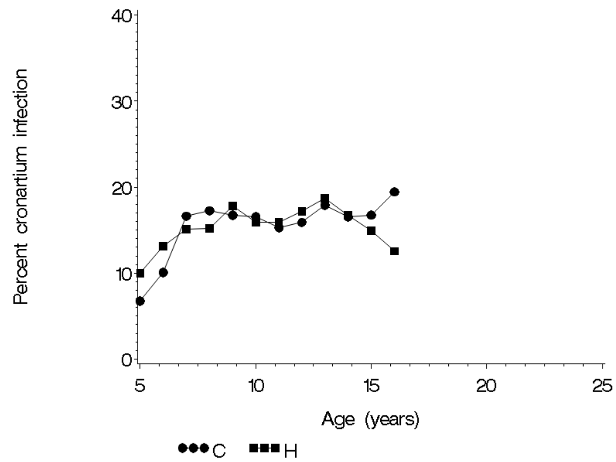
Figure 3.68: Average product distribution (tons/acre) over the course of the study for the Thompson 1988 time replicate. Pulpwood is shown in 3.68(a), Chip-N-Saw in 3.68(b), and sawtimber in 3.68(c).

Table 3.93: Average cronartium infection rates (%) at the Thompson site by time replicate.

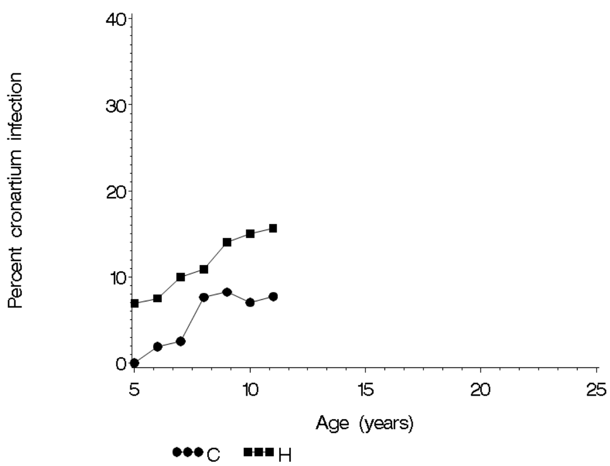
	1988		1990		1995	
Age	C	H	C	H	C	H
5	12.0	15.5	6.7	10.0	0.0	6.9
6	12.0	14.9	10.1	13.1	1.9	7.5
7	12.0	16.1	16.6	15.1	2.5	10.0
8	12.0	16.1	17.2	15.2	7.6	10.9
9	13.2	16.7	16.7	17.8	8.2	14.0
10	13.9	18.7	16.6	15.9	7.0	15.0
11	18.3	19.3	15.3	15.9	7.7	15.7
12	17.1	18.1	15.9	17.2	.	.
13	17.3	20.7	17.9	18.7	.	.
14	16.1	20.8	16.5	16.7	.	.
15	20.2	22.7	16.7	14.9	.	.
16	24.0	22.1	19.4	12.6	.	.
17	23.4	19.9	.	.	.	.
18	20.4	17.4	.	.	.	.
19	.	.	.	.	.	.
20	.	.	.	.	.	.
21	.	.	.	.	.	.
23	.	.	.	.	.	.
25	.	.	.	.	.	.



(a) 1988



(b) 1990



(c) 1995

Figure 3.69: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Thompson site are shown in subfigures 3.69(a)-(c).

3.7 Tifton

The Tifton site had two time replicates. The 1988 time replicate had all four treatments while the 1990 time replicate only had the C and H treatments. The 1988 F treatment experienced high rates of mortality prior to age 5, which affected many variables.

Site quality on the Tifton site is very high as measured by site index. The base site index for the C treatment on the 1988 time replicate is 84 feet at age 25 (Table 3.94). The 1990 time replicate showed slightly higher implied site index values. Dominant height development on the 1988 time replicate showed higher rates for the H and HF treatments for the first 10 years of development, after which little difference was seen between all four treatments (Figure 3.70). The 1990 time replicate showed similar development patterns for H and C treatments. The C treatment had maximum dominant height values of 84 and 83 feet for the 1988 and 1990 time replicates for the last measurement years. The H treatment had maximums of 85 feet for both time replicates. The F and HF treatments had maximums of 85 and 88 feet in the 1988 time replicate, respectively (Table 3.94). This high quality site showed little to no difference in dominant height for all treatments by the end of the study, showing that nutrition is not limited. For a Coastal Plain site to see these results, it may be due to past history which could have included agricultural operations. The most previous use was a pine stand, but records did not say what was on site prior to the stand.

Early stand development was shown to be slightly faster in dominant height growth for the HF treatment, which also expands to faster development of basal area per acre (BA) for this treatment (Figure 3.71). The HF treatment commanded the greatest development of BA until age 10, where it slowed and the H treatment took over as the fastest developing treatment. The C and H treatments in both time replicates developed in very similar trends, with the H treatment maintaining an advantage over the course of the study (Table 3.95; Figure 3.71). The 1988 F treatment displayed development beginning to slow at an earlier age, 14, with a noticeable decrease in BA after age 23. The 1988 F treatment started the study with greater mortality rates due to excessive rates of vegetation that out competed the pine, which lead to high mortality rates. BA rates for the F treatment were able keep up with the other treatments due to comparatively higher quadratic mean diameters, but slowed due to a lower number of total trees. The 1990 H treatment also displayed a decrease in BA in the last measurement year. Maximum BA values for the C treatments, all which occurred at or near the last measurement age, were 211 and 190 ft^2/acre for the 1988 and 1990 time replicates (Table 3.95). The H treatment maximums were 228 and 231 ft^2/acre at age 23 and 21 for the two time replicates, respectively. The F maximum was 175 ft^2/acre at age 23 and the HF treatment maximum was 205 ft^2/acre at age 23 for the 1988 time replicate. Development trends in BA suggest that on the Tifton site, competition is the biggest issue limiting stand development.

Development trends in stand density index (SDI), support this notion. The H sites achieve overall greater SDI values on both time replicates, with 443 and 441 for the 1988 and 1990 time replicates, respectively (Table 3.96). Initial development patterns showed the HF and H treatments in the 1988 time replicate with the faster development, but after age 10, the HF treatment began to slow (Figure 3.72). Development in SDI for the Tifton site follow very similarly to BA (Figure 3.72, 3.71). Maximum SDI values for the HF and F treatments were 373 at age 19 and 300 at age 23, respectively. The C treatments had the second highest overall SDI values within time replicates, which reached 411 and 350 for the 1988 and 1990 time replicates. Greater SDI rates on the H treatments show how SDI is affected by understory competition.

Relative spacing (RS), which also measures stand density, reaches minimum values of .11 on the 1988 C and H treatments and on the 1990 H treatment. These lower values indicate greater stand density. RS, which is a function of dominant height and trees per acre, showed stabilization on the 1988 H treatment starting at age 19 (Table 3.97). This stabilization is provided by low mortality rates proportion increases in dominant height (Tables 3.98, 3.94). The 1988 HF and F treatments see greater RS values (lower stand density) due to greater rates of stem mortality (Figure 3.74). The 1988 F treatment, which reached a minimum RS value of .18, had an overall greater RS due to the high initial mortality that occurred on the site.

Trees per acre (TPA) development showed the greatest mortality that occurred within the study in the HF treatment. Mortality rates for the HF treatment were very similar to the C treatment, until age 10 where the HF treatment suffered greater losses (Figure 3.74). TPA rates for the F, H, and C treatments remained consistent from the beginning of the study until approximately age 20 in the 1988 time replicate. The 1990 time replicate also saw consistent TPA rates for the first 20 years of the C treatment. The H treatment saw mortality rates begin to increase after the 15^{th} year (Figure 3.74). The F treatment, which suffered excessive mortality prior to age 5, saw a decrease in BA towards the end of the study which coincided with a decline of approximately 40 TPA between ages 23 and 25. It is interesting to note that while the F treatment ended the study with 180 trees per acre due to the high initial mortality rates, overall mortality rates between ages 5 and 25 were very similar when compared with the C and H treatments (Table 3.98, Figure 3.74(c)). The HF treatment also saw large amounts of stem mortality, ending the study with 336 trees per acre. Higher mortality rates in the 1990 HF treatment can be attributed to the higher density achieved, seen by greater SDI and BA (Tables 3.96, 3.95). The H treatment, which had the least amount of mortality on both treatments, ended with 523 and 464 trees per acre for the 1988 and 1990 time replicates, respectively. The C treatment had ending values of 472 and 356 trees per acre for both time replicates.

Total green tons per acre (GT) development patterns showed very similar trends with BA development (Figures 3.75, 3.71). Where the F treatment started to experience lesser BA development and more stem mortality, there were also declines in GT rates (Figures 3.74, 3.71, 3.75). Maximum GT values for the C treatment were 221 and 196 tons/acre for the 1988 and 1990 time replicates, respectively. The H treatment maximums were 241 and 232 tons/acre for the two time replicates. Both the H and C treatments had maximum values occur at the end of the study, relating to no BA declines. The HF treatment maximum was

217 tons/acre occurring at age 23 and the F treatment maximum was 175, also occurring at age 23 (Table 3.99). Mean annual increment (MAI) of GT showed greater initial values occur in the HF and H treatments (Figures 3.76, 3.77). Peak MAI values for the H treatment were 11.0 and 11.9 tons/acre for the 1988 and 1990 time replicates at ages 19 and 15, respectively. The C treatment had peak MAI values of 9.4 and 8.9 at ages 23 and 21 for the two time replicates, respectively. The 1988 F treatment had a peak MAI value of 10.8 at age 18 and the HF treatment reached 10.3 at age 16 (Table 3.100). The highest rates for this site were on treatments receiving competition control.

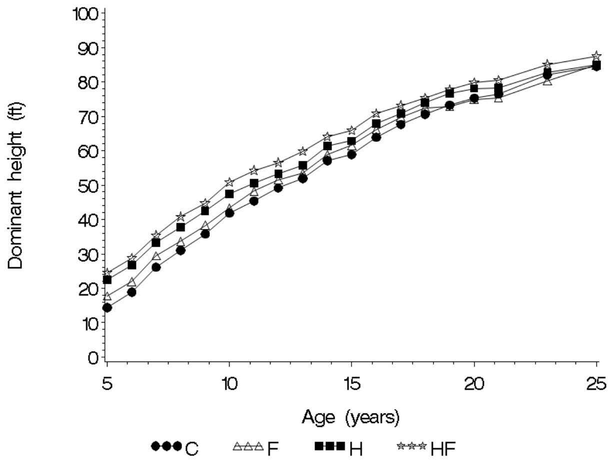
Quadratic mean diameter (DQ) saw similar development patterns for the H and C treatments between time replicates (Figure 3.78). The 1988 time replicate showed that initial rates were higher for the H and HF treatments, but the F treatment quickly superseded the HF and H treatments and maintained a sizable advantage for the remainder of the study (Table 3.101). Greater DQ for the 1988 F treatment is purely a result of the high mortality rates prior to age 5. While this treatment did have the greatest overall DQ, it also experienced lower overall rates in BA and SDI (Tables 3.98, 3.95, 3.96). DQs showed no decline on any of the treatments, which shows that stem mortality only affected the smaller diameter trees (Table 3.98). Maximum DQ value achieved by the C treatment were 9.0 and 10.0 inches for the 1988 and 1990 time replicates, respectively. The H treatment had maximum DQ values of 8.9 and 9.3 inches for the two time replicates. The 1988 F treatment reached a maximum of 12.1 inches and the HF treatment reached 10.4 inches.

Product development on the Tifton site showed pulpwood on all treatments and time replicates at the beginning of the study except for the 1988 C treatment (Table 3.102). Pulpwood rates peak on the C treatment at age 17 and 13 for the 1988 and 1990 time replicates, respectively. The H treatment saw pulpwood values peak at age 14 and 13 for the two time replicates. The 1988 F treatment had pulpwood peak at age 11 and the HF treatment peaked at age 10. Chip-n-saw first developed on the 1988 time replicate in the HF and F treatments, both at age 8 (Table 3.103). Both the C and H treatments first had pulpwood develop at age 11 in the 1988 time replicate while the 1990 time replicate had both treatments first develop chip-n-saw at age 8. The earlier development of chip-n-saw is driven by faster development of tree diameter. Sites with greater DQs see faster development of higher products (Table 3.101). Chip-n-saw development peaks first in the F and HF treatments, occurring at age 17 and 19 respectively. The H and C treatments saw chip-n-saw development peak at or near the last measurement age for both time replicates (Table 3.101). Sawtimber first develops in the F treatment at age 12, followed by the HF treatment at age 15 for the 1988 time replicate (Table 3.104). Sawtimber is seen earliest in the F treatment due to the lower stand density it maintained over the course of the study (Table 3.96). The C treatment had sawtimber first develop at age 23 in the 1988 time replicate and 15 in the 1990 time replicate. The H treatment had no sawtimber development in the 1988 time replicate but did have sawtimber develop at age 20 in the 1990 time replicate (Table 3.104). Earlier sawtimber production followed the development of DQ. Sites with faster increases of DQ saw earlier production of higher value products (Table 3.101). It is interesting to see that the 1988 F treatment reached a sawtimber peak at age 23 within the time frame of the project. Of note is that the following year, DQ for the 1988 F treatment surpassed 12 inches, which is the minimum diameter for sawtimber trees.

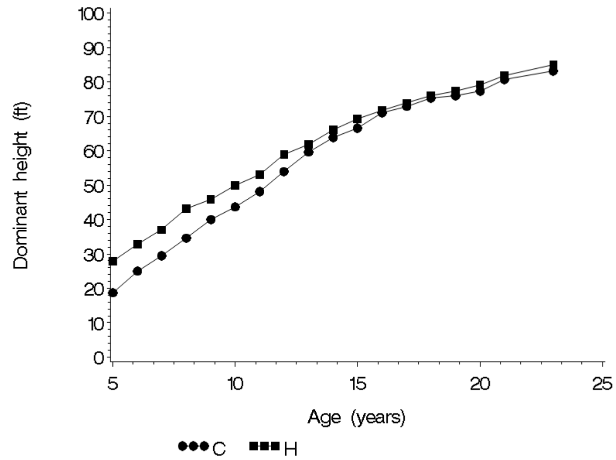
Cronartium infection rates remained fairly low for the 1988 time replicate prior to age 10, remaining less than 5% on average (Table 3.105; Figure 3.80). After age 10, the HF and F treatments had slightly higher infection rates, around 10%, which corresponds to the greater MAI values seen (Table 3.100). The cronartium infection rates stabilized on the F and C treatments after age 10, remaining below 5% (Table 3.105). The 1990 time replicate showed very similar trends compared with the 1988 time replicate. The higher infection rates that occur after the 10 year mark correspond with the higher MAI values seen on the H treatments (Table 3.100).

Table 3.94: Average dominant height (feet) development at the Tifton site by time replicate.

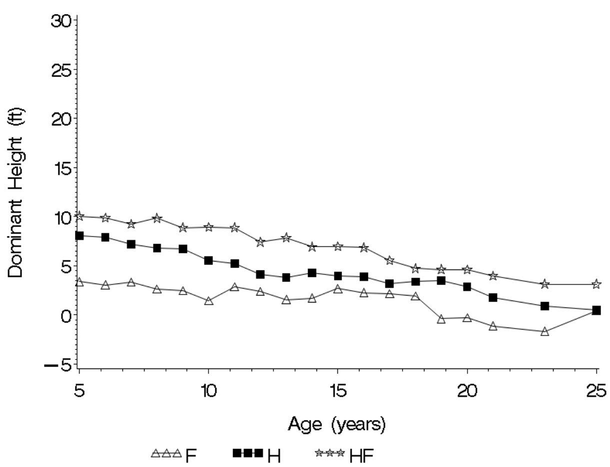
	1988				1990	
Age	C	F	H	HF	C	H
5	14.4	17.8	22.4	24.4	18.7	27.8
6	18.9	22.0	26.8	28.8	25.0	32.8
7	26.1	29.5	33.3	35.4	29.4	37.0
8	31.0	33.6	37.8	40.8	34.6	43.2
9	35.8	38.3	42.6	44.7	40.0	45.9
10	41.9	43.3	47.4	50.8	43.7	49.9
11	45.4	48.2	50.6	54.3	48.1	53.1
12	49.1	51.5	53.2	56.5	53.9	58.8
13	51.9	53.5	55.7	59.8	59.7	61.9
14	57.1	58.8	61.4	64.0	63.9	66.1
15	58.9	61.5	62.9	65.8	66.6	69.2
16	63.9	66.2	67.8	70.8	71.1	71.7
17	67.6	69.8	70.8	73.2	72.9	73.9
18	70.6	72.5	74.0	75.3	75.3	76.1
19	73.2	72.8	76.7	77.8	76.0	77.4
20	75.2	75.0	78.1	79.8	77.3	79.2
21	76.5	75.4	78.3	80.4	80.6	81.9
23	82.0	80.3	82.8	85.1	83.2	85.1
25	84.4	84.9	85.0	87.5	.	.



(a) 1988



(b) 1990

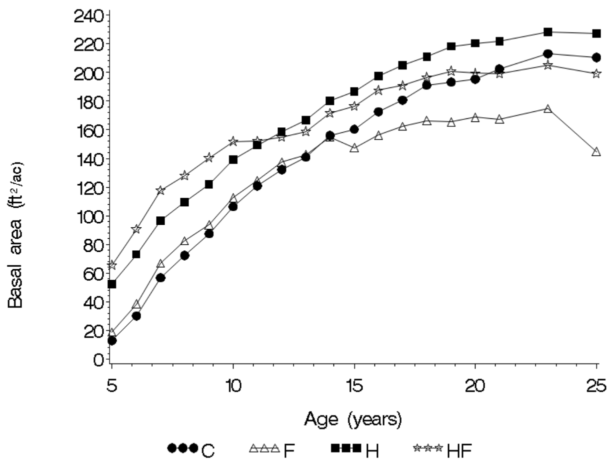


(c) 1988 Treatment Effects

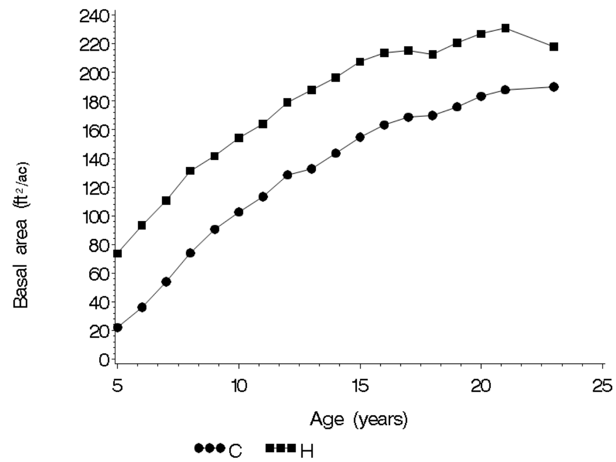
Figure 3.70: Average dominant height (feet) over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.70(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.95: Average basal area (ft^2/acre) at the Tifton site by time replicate.

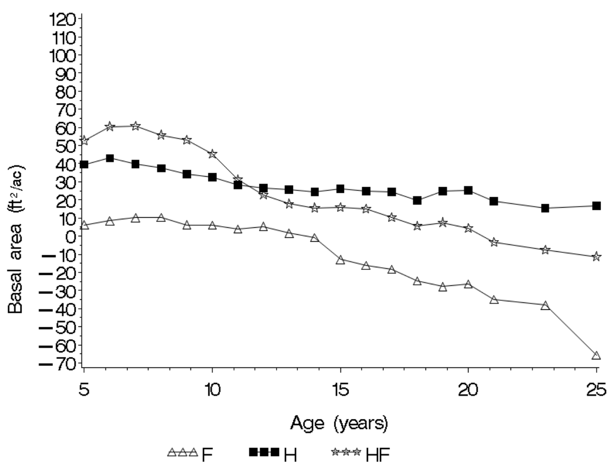
	1988				1990	
Age	C	F	H	HF	C	H
5	12.8	19.0	52.3	65.5	21.9	73.7
6	30.1	38.5	73.1	90.5	36.2	93.3
7	56.8	67.0	96.7	117.5	54.0	110.4
8	72.2	82.7	109.7	128.0	74.1	131.3
9	87.5	93.7	121.9	140.5	90.6	141.6
10	106.5	112.6	139.1	151.8	102.6	154.4
11	120.9	124.8	149.2	152.1	113.3	163.8
12	132.2	137.5	158.5	155.0	128.7	179.3
13	141.0	142.6	166.7	158.8	132.7	187.6
14	155.9	155.0	180.2	171.4	143.6	196.4
15	160.5	147.5	186.7	176.3	154.9	207.5
16	172.6	156.3	197.4	187.6	163.3	213.8
17	180.6	162.3	204.9	190.8	168.7	215.1
18	191.1	166.4	210.9	196.6	170.0	212.4
19	193.4	165.5	218.2	200.9	176.1	220.6
20	195.2	168.7	220.4	199.4	183.2	226.9
21	202.4	167.4	221.8	199.0	187.9	230.9
23	212.9	174.8	228.4	205.2	189.9	217.9
25	210.5	144.8	227.1	199.1	.	.



(a) 1988



(b) 1990



(c) 1988 Treatment Effects

Figure 3.71: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.71(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.96: Average stand density index development at the Tifton site by time replicate.

	1988				1990	
Age	C	F	H	HF	C	H
5	44.1	54.1	138.8	163.7	63.4	183.5
6	87.4	96.1	181.4	212.2	95.0	221.7
7	145.7	150.0	227.3	261.7	131.1	253.2
8	176.6	177.2	251.4	279.0	169.2	290.7
9	205.7	192.7	273.7	299.9	198.7	307.3
10	240.4	222.7	304.2	315.4	219.9	329.2
11	265.8	241.2	321.4	309.8	238.1	344.9
12	285.1	260.1	337.1	311.4	263.7	370.2
13	300.2	267.2	351.0	314.7	268.8	383.4
14	325.5	284.9	373.6	334.6	285.9	397.9
15	331.7	268.3	384.3	341.7	302.5	415.2
16	351.7	281.1	401.9	359.1	315.4	423.0
17	363.6	288.9	414.1	361.9	322.8	422.7
18	379.9	292.9	421.7	368.7	323.3	415.4
19	381.8	289.6	433.3	372.9	331.9	427.0
20	383.5	294.2	435.6	368.4	342.7	436.7
21	394.3	290.4	434.4	364.6	349.7	441.0
23	410.5	299.7	443.3	372.0	348.9	411.4
25	401.5	245.8	437.0	359.1	.	.

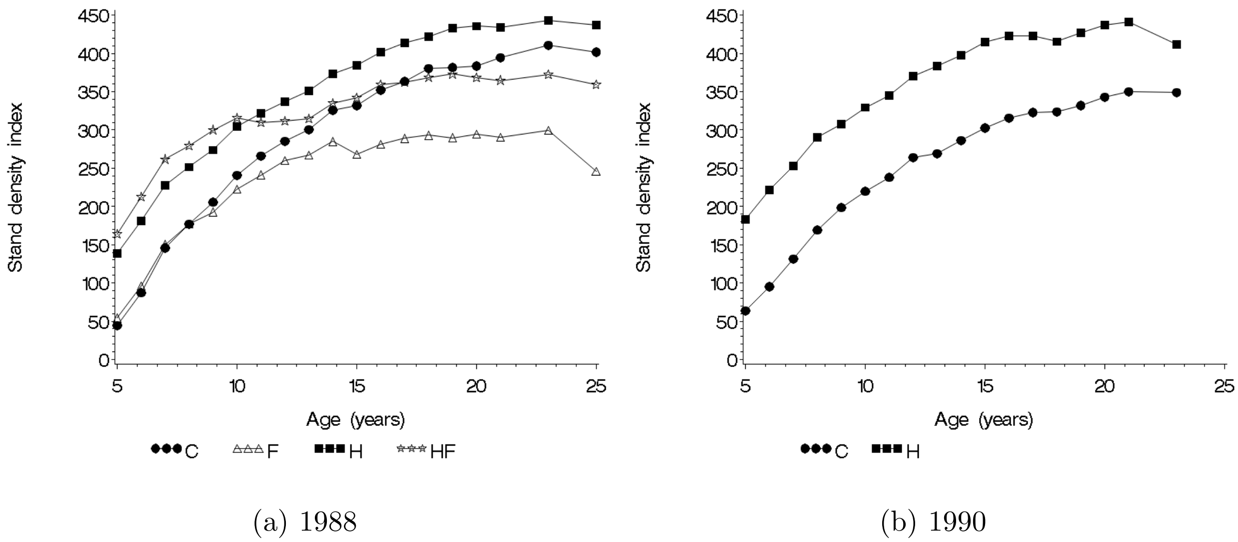
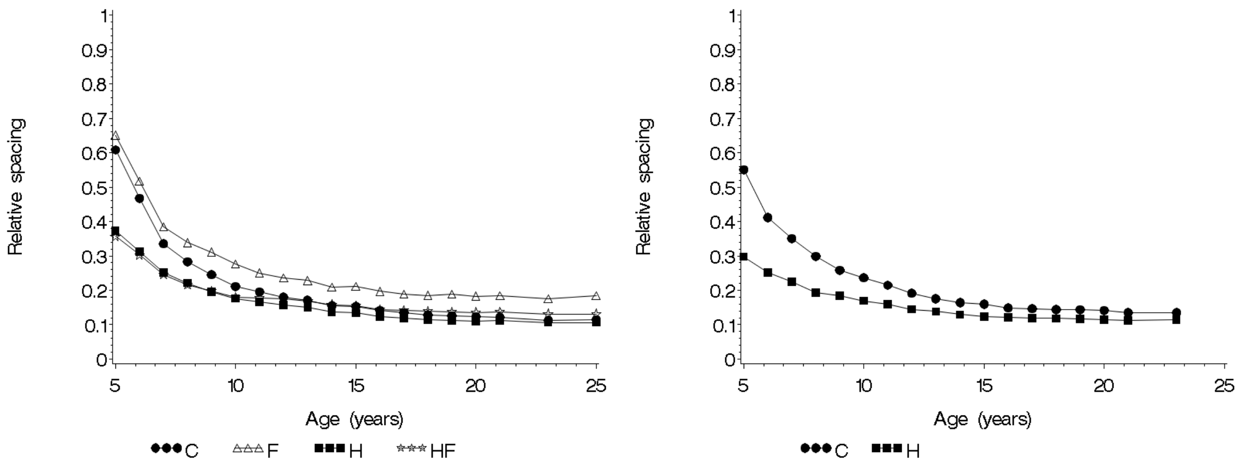


Figure 3.72: Average stand density index over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.72(a)-(b).

Table 3.97: Average relative spacing development at the Tifton site by time replicate.

	1988				1990	
Age	C	F	H	HF	C	H
5	0.61	0.65	0.37	0.36	0.55	0.30
6	0.47	0.52	0.31	0.30	0.41	0.25
7	0.34	0.38	0.25	0.25	0.35	0.23
8	0.28	0.34	0.22	0.22	0.30	0.19
9	0.25	0.31	0.20	0.20	0.26	0.18
10	0.21	0.28	0.18	0.18	0.24	0.17
11	0.20	0.25	0.17	0.18	0.21	0.16
12	0.18	0.24	0.16	0.17	0.19	0.14
13	0.17	0.23	0.15	0.17	0.18	0.14
14	0.16	0.21	0.14	0.16	0.16	0.13
15	0.15	0.21	0.13	0.15	0.16	0.12
16	0.14	0.20	0.12	0.14	0.15	0.12
17	0.13	0.19	0.12	0.14	0.15	0.12
18	0.13	0.19	0.12	0.14	0.14	0.12
19	0.13	0.19	0.11	0.14	0.14	0.12
20	0.12	0.18	0.11	0.14	0.14	0.11
21	0.12	0.18	0.11	0.14	0.14	0.11
23	0.11	0.18	0.11	0.13	0.13	0.11
25	0.11	0.18	0.11	0.13	.	.

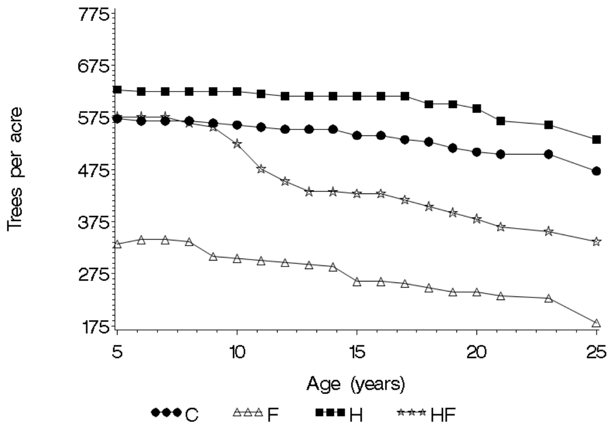


(a) 1988 (b) 1990

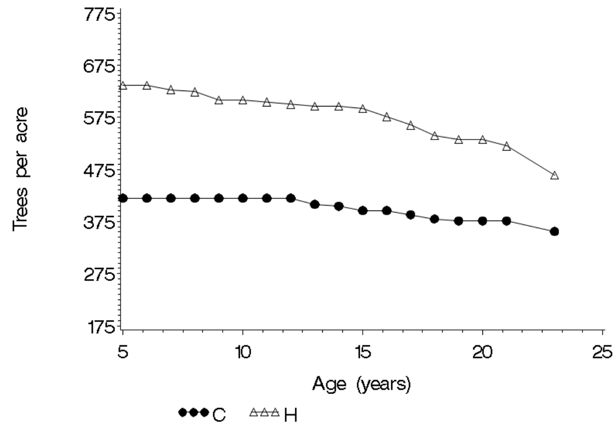
Figure 3.73: Average relative spacing development over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.73(a)-(b).

Table 3.98: Average trees per acre development at the Tifton site by time replicate.

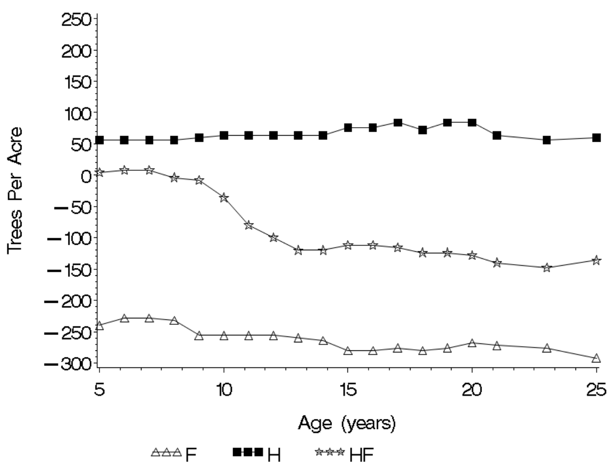
	1988				1990	
Age	C	F	H	HF	C	H
5	572	332	628	576	420	636
6	568	340	624	576	420	636
7	568	340	624	576	420	628
8	568	336	624	564	420	624
9	564	308	624	556	420	608
10	560	304	624	524	420	608
11	556	300	620	476	420	604
12	552	296	616	452	420	600
13	552	292	616	432	408	596
14	552	288	616	432	404	596
15	540	260	616	428	396	592
16	540	260	616	428	396	576
17	532	256	616	416	388	560
18	528	248	600	404	380	540
19	516	240	600	392	376	532
20	508	240	592	380	376	532
21	504	232	568	364	376	520
23	504	228	560	356	356	464
25	472	180	532	336	.	.



(a) 1988



(b) 1990

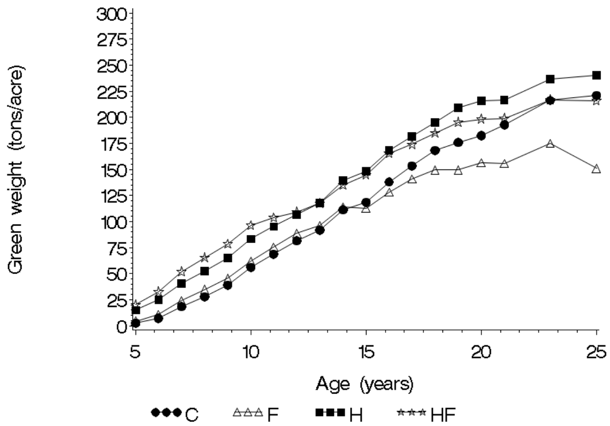


(c) 1988 Treatment Effects

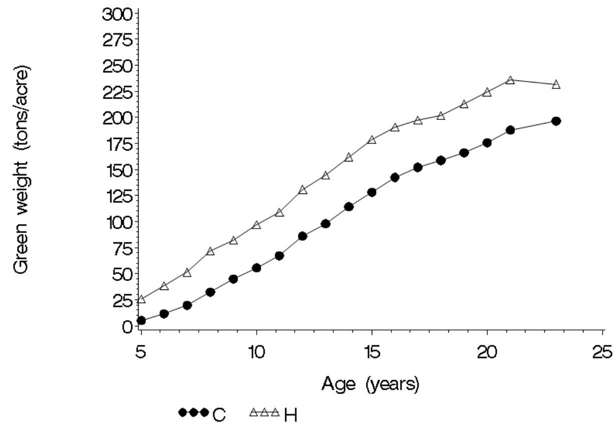
Figure 3.74: Average trees per acre development over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.74(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.99: Average total green weight (tons/acre) development at the Tifton site by time replicate.

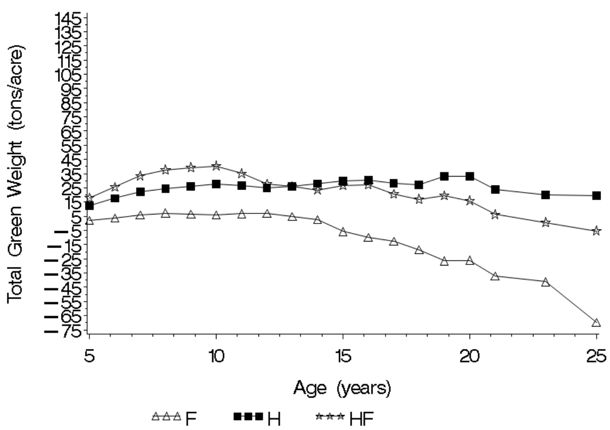
	1988				1990	
Age	C	F	H	HF	C	H
5	2.4	4.3	14.9	20.1	5.1	25.7
6	7.1	10.8	24.7	32.6	11.3	38.1
7	18.4	24.2	40.6	51.9	19.5	51.3
8	27.8	34.9	52.2	65.3	32.1	71.6
9	38.9	45.4	65.1	78.1	44.7	82.3
10	55.8	61.7	83.2	96.2	55.5	97.0
11	68.5	75.3	95.1	103.5	67.1	108.8
12	81.6	88.6	106.5	109.1	86.0	130.7
13	91.5	96.4	117.6	117.4	97.9	144.6
14	111.4	114.1	139.3	134.9	114.2	161.8
15	118.4	112.7	148.2	144.8	127.9	178.8
16	138.1	128.1	168.3	165.1	142.2	190.4
17	153.2	140.7	181.4	173.9	151.9	197.4
18	168.0	149.3	194.9	184.9	158.6	201.8
19	175.8	149.3	208.9	195.2	165.8	212.8
20	182.3	156.2	215.6	198.2	175.4	224.4
21	192.7	155.5	216.6	198.9	187.7	236.0
23	216.1	174.9	236.4	216.7	196.3	231.7
25	220.8	151.0	240.5	215.5	.	.



(a) 1988



(b) 1990



(c) 1988 Treatment Effects

Figure 3.75: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.75(a)-(a). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.100: Mean annual increment (tons/acre/year) development at the Tifton site by time replicate.

	1988				1990	
Age	C	F	H	HF	C	H
5	0.5	0.9	3.0	4.0	1.0	5.1
6	1.2	1.8	4.1	5.4	1.9	6.4
7	2.6	3.5	5.8	7.4	2.8	7.3
8	3.5	4.4	6.5	8.2	4.0	9.0
9	4.3	5.0	7.2	8.7	5.0	9.1
10	5.6	6.2	8.3	9.6	5.6	9.7
11	6.2	6.8	8.7	9.4	6.1	9.9
12	6.8	7.4	8.9	9.1	7.2	10.9
13	7.0	7.4	9.0	9.0	7.5	11.1
14	8.0	8.2	10.0	9.6	8.2	11.6
15	7.9	7.5	9.9	9.7	8.5	11.9
16	8.6	8.0	10.5	10.3	8.9	11.9
17	9.0	8.3	10.7	10.2	8.9	11.6
18	9.3	8.3	10.8	10.3	8.8	11.2
19	9.3	7.9	11.0	10.3	8.7	11.2
20	9.1	7.8	10.8	9.9	8.8	11.2
21	9.2	7.4	10.3	9.5	8.9	11.2
23	9.4	7.6	10.3	9.4	8.5	10.1
25	8.8	6.0	9.6	8.6	.	.

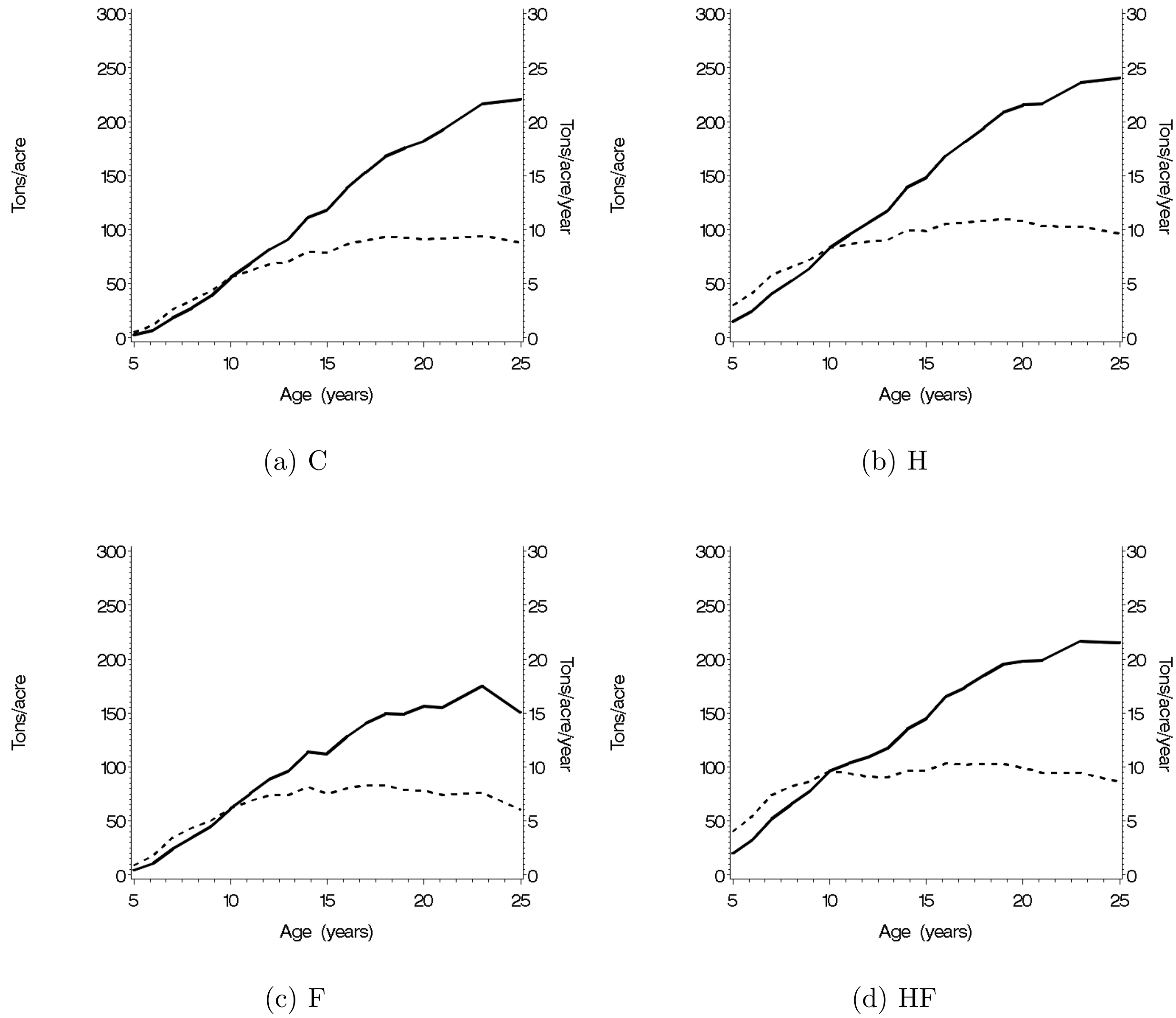
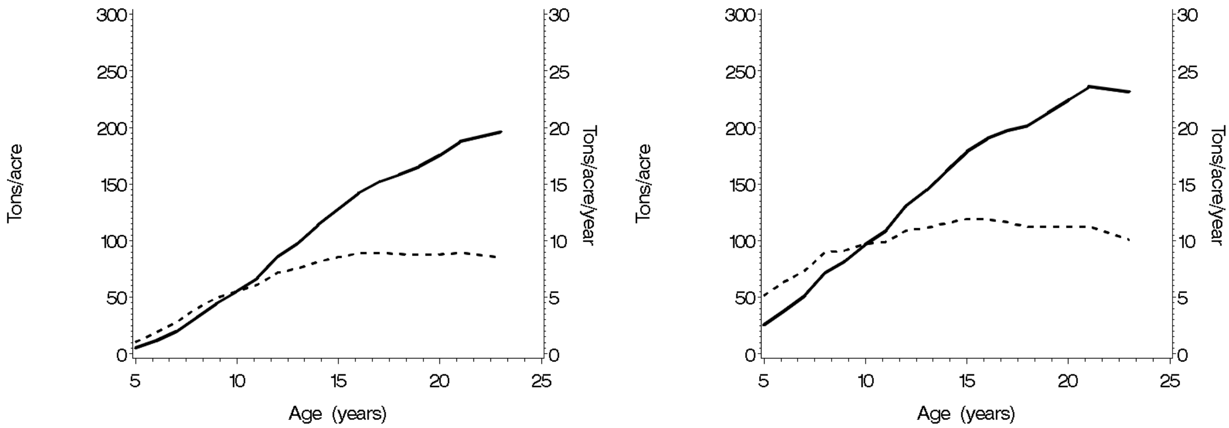


Figure 3.76: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (——–) by treatment for the Tifton 1988 time replicate.



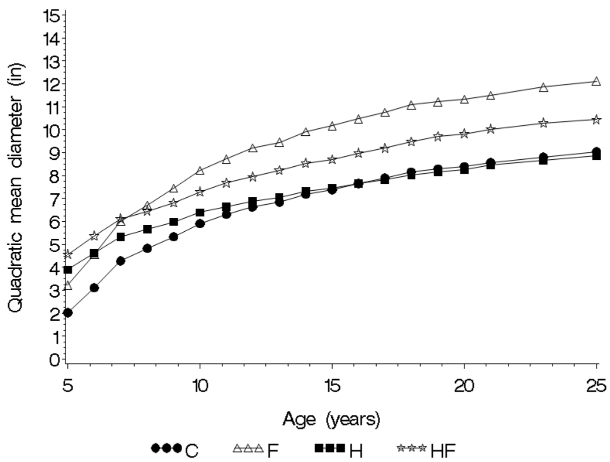
(a) C

(b) H

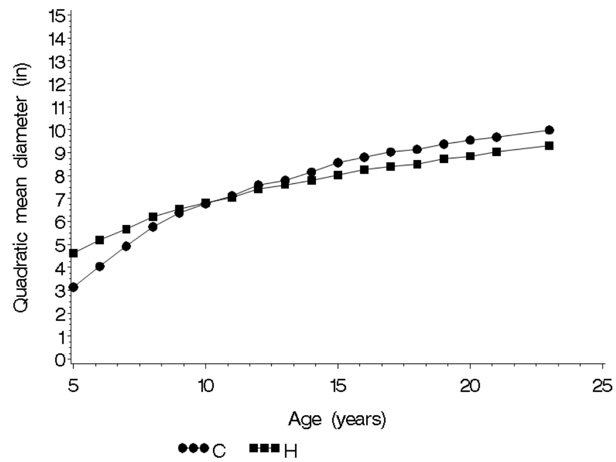
Figure 3.77: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Tifton 1990 time replicate.

Table 3.101: Average quadratic mean diameter (inches) development at the Tifton site by time replicate.

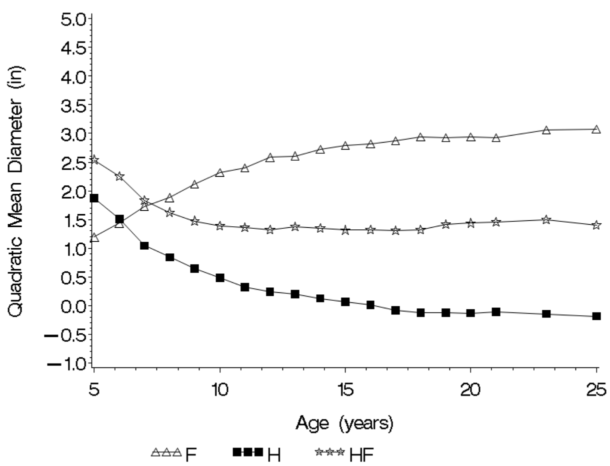
	1988				1990	
Age	C	F	H	HF	C	H
5	2.0	3.2	3.9	4.6	3.1	4.6
6	3.1	4.6	4.6	5.4	4.0	5.2
7	4.3	6.0	5.3	6.1	4.9	5.7
8	4.8	6.7	5.7	6.5	5.8	6.2
9	5.3	7.5	6.0	6.8	6.4	6.5
10	5.9	8.2	6.4	7.3	6.8	6.8
11	6.3	8.7	6.6	7.7	7.1	7.1
12	6.6	9.2	6.9	7.9	7.6	7.4
13	6.8	9.5	7.0	8.2	7.8	7.6
14	7.2	9.9	7.3	8.5	8.1	7.8
15	7.4	10.2	7.5	8.7	8.6	8.0
16	7.7	10.5	7.7	9.0	8.8	8.3
17	7.9	10.8	7.8	9.2	9.0	8.4
18	8.2	11.1	8.0	9.5	9.2	8.5
19	8.3	11.2	8.2	9.7	9.4	8.7
20	8.4	11.3	8.3	9.8	9.6	8.9
21	8.6	11.5	8.5	10.0	9.7	9.0
23	8.8	11.9	8.7	10.3	10.0	9.3
25	9.0	12.1	8.9	10.4	.	.



(a) 1988



(b) 1990



(c) 1988 Treatment Effects

Figure 3.78: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Tifton site is shown in subfigures 3.78(a)-(b). Subfigure (c) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.102: Average pulpwood development (tons/acre) at the Tifton site by time replicate.

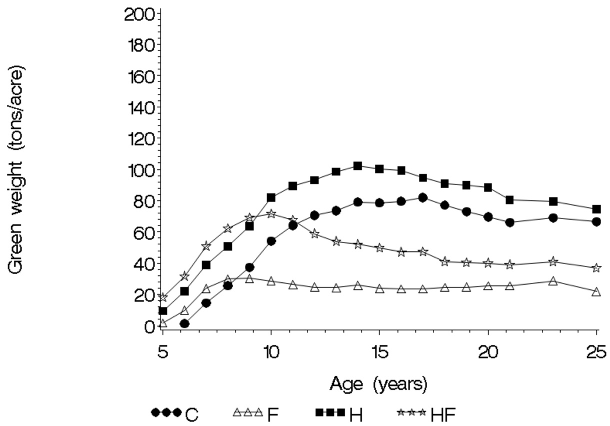
	1988				1990	
Age	C	F	H	HF	C	H
5	.	1.7	9.4	18.2	1.5	23.3
6	1.4	9.8	22.2	31.6	6.9	35.8
7	14.4	23.8	39.0	50.9	17.2	49.6
8	25.7	30.1	50.9	62.1	29.0	68.9
9	37.2	30.3	63.6	69.0	37.3	75.0
10	54.0	28.6	81.8	71.5	43.7	84.4
11	64.2	26.3	89.5	67.5	50.0	85.5
12	70.6	24.7	93.1	58.8	56.9	86.6
13	73.6	24.3	98.5	53.9	58.7	86.9
14	79.1	25.9	102.4	52.1	56.8	88.3
15	78.7	23.8	100.2	49.7	53.7	84.1
16	79.6	23.7	99.2	47.1	54.6	81.0
17	81.9	23.4	94.6	47.3	52.6	77.4
18	77.1	24.6	90.9	41.0	51.8	76.7
19	72.9	24.7	89.9	40.4	52.4	72.4
20	69.5	25.6	88.3	40.0	51.9	69.7
21	66.0	25.6	80.7	39.0	52.7	69.4
23	68.9	28.7	79.6	41.0	52.8	62.6
25	66.5	21.9	74.5	36.9	.	.

Table 3.103: Average chip-n-saw development (tons/acre) at the Tifton site by time replicate.

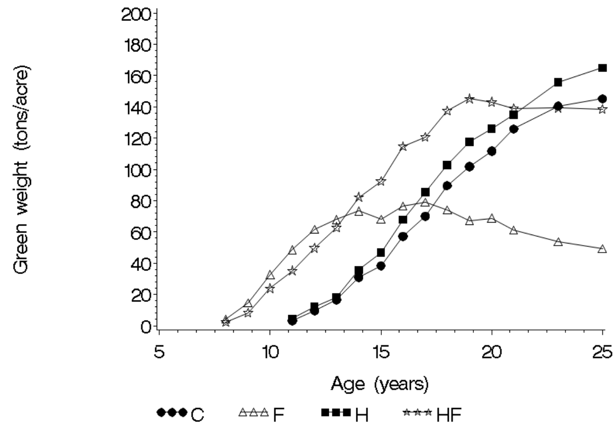
	1988				1990	
Age	C	F	H	HF	C	H
5	.	.	.	.	.	.
6	.	.	.	.	.	.
7	.	.	.	.	.	.
8	.	4.4	.	2.3	4.2	1.1
9	.	14.7	.	8.2	13.1	5.6
10	.	32.7	.	23.8	22.0	11.0
11	3.1	48.6	4.5	35.1	16.2	21.7
12	9.5	61.6	12.3	49.6	28.3	42.8
13	16.4	67.9	17.9	62.8	38.5	56.4
14	30.8	73.3	35.7	82.2	56.4	72.2
15	38.2	68.2	46.8	92.2	71.4	93.3
16	57.0	76.5	67.8	114.6	77.4	108.1
17	69.9	79.1	85.5	120.5	86.5	118.8
18	89.6	74.1	102.8	137.4	90.7	124.1
19	101.7	67.3	117.8	145.1	89.2	139.4
20	111.6	68.8	126.1	143.0	97.8	151.1
21	125.8	61.1	134.8	138.7	104.9	159.7
23	140.6	53.8	155.6	139.2	100.9	159.2
25	145.1	49.3	164.9	138.4	.	.

Table 3.104: Average sawtimber development (tons/acre) at the Tifton site by time replicate.

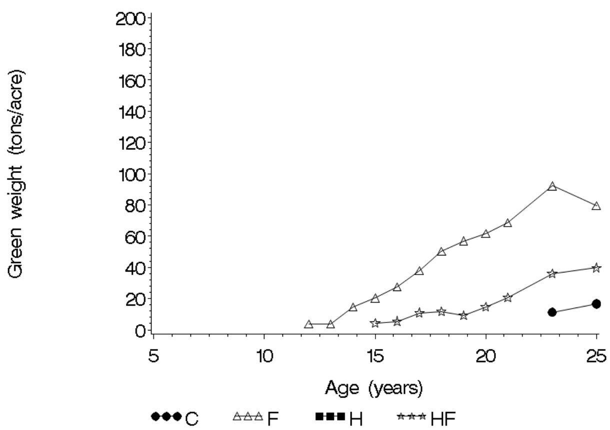
	1988				1990	
Age	C	F	H	HF	C	H
5	.	.	.	.	.	.
6	.	.	.	.	.	.
7	.	.	.	.	.	.
8	.	.	.	.	.	.
9	.	.	.	.	.	.
10	.	.	.	.	.	.
11	.	.	.	.	.	.
12	.	3.8	.	.	.	.
13	.	3.8	.	.	.	.
14	.	14.6	.	.	.	.
15	.	20.4	.	4.3	4.3	.
16	.	27.6	.	5.4	18.9	.
17	.	37.8	.	10.8	24.1	.
18	.	50.3	.	11.7	30.9	.
19	.	56.9	.	9.0	47.1	.
20	.	61.6	.	14.6	50.0	5.3
21	.	68.5	.	20.6	58.8	11.7
23	11.4	92.1	.	36.0	42.0	18.0
25	16.7	79.5	.	39.7	.	.



(a) Pulpwood



(b) Chip-N-Saw

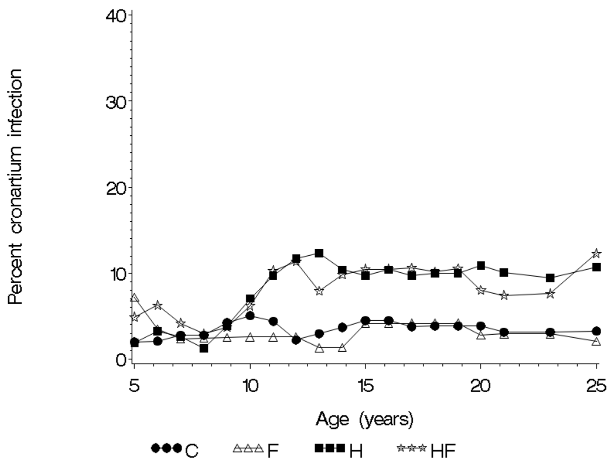


(c) Sawtimber

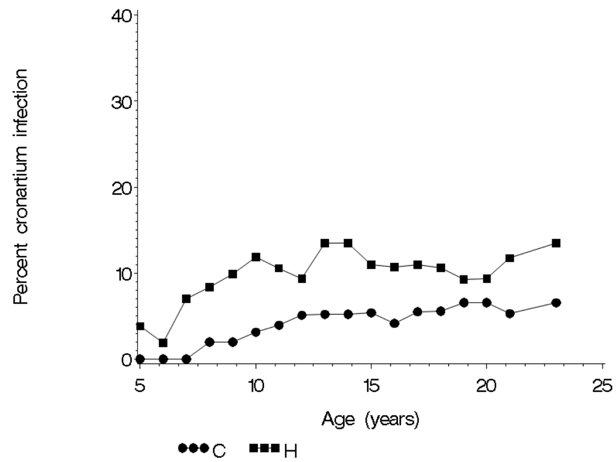
Figure 3.79: Average product distribution (tons/acre) over the course of the study for the Tifton 1988 time replicate. Pulpwood is shown in 3.79(a), Chip-N-Saw in 3.79(b), and sawtimber in 3.79(c).

Table 3.105: Average cronartium infection rates (%) at the Tifton site by time replicate.

	1988				1990	
Age	C	F	H	HF	C	H
5	2.0	7.2	1.9	4.9	0.0	3.8
6	2.1	3.5	3.2	6.3	0.0	1.9
7	2.8	2.4	2.6	4.2	0.0	7.1
8	2.8	2.4	1.3	2.9	2.0	8.4
9	4.3	2.5	3.9	3.7	2.0	9.9
10	5.1	2.6	7.1	6.2	3.1	11.9
11	4.4	2.6	9.7	10.3	3.9	10.6
12	2.2	2.6	11.7	11.4	5.1	9.4
13	2.9	1.3	12.3	7.9	5.2	13.5
14	3.7	1.4	10.4	9.8	5.2	13.5
15	4.5	4.2	9.7	10.5	5.4	11.0
16	4.5	4.2	10.4	10.5	4.2	10.7
17	3.8	4.2	9.7	10.6	5.5	11.0
18	3.9	4.2	10.0	10.2	5.6	10.6
19	3.9	4.2	10.0	10.5	6.6	9.3
20	3.9	2.8	10.9	8.0	6.6	9.4
21	3.1	2.9	10.1	7.4	5.3	11.7
23	3.1	2.9	9.5	7.6	6.6	13.5
25	3.3	2.1	10.7	12.3	.	.



(a) 1988



(b) 1990

Figure 3.80: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Tifton site are shown in subfigures 3.80(a)-(b).

3.8 Waycross - Dry

The Waycross - Dry site had three plots removed due to midrotation thinning treatments after the 10th growing season. These treatments were not a part of this study and information displayed in the remainder of the study only include one plot. The removed plots were F, H, and HF treatments in the 1989 time replicate.

Inherent site quality (as measured by site index) is very good on the Waycross - Dry site. The control treatment shows base age site index of approximately 78 feet for the oldest time replication and slightly higher implied site index values for the two younger time replicates (Tables 3.106, 3.107; Figure 3.81). Prior to age 7 to 10 years, H and HF treatments had significantly greater dominant height than treatments without vegetation control (e.g. C and F). However, within this range of ages the F treatment surpassed the H treatment dominant height. As the stands developed through time, the F and HF treatments surpassed the C and H treatments, and at age 25, F and HF show site index values of 95 and 93 feet compared to 78 and 82 for the C and H treatments. Clearly, nutrition was a limiting growth factor at this location.

With these patterns, it can be said that stand development is proceeding most quickly for the F and HF treatments. Early on, basal area per acre (BA) develops most quickly on H and HF treatments. Sometime between age 7 and 10, BA development on the F treatment approaches the H treatment. However, BA crashes on the F and HF treatments for the 1987 and 1989 time replicates sometime just after age 15, whereas on the 1993 time replicate, BA crashes on the F treatment at this age. It should be noted that while the HF treatment crashed on the 1987 and 1989 time replicates, it maintained higher levels of BA in the 1987 time replicate ($\sim$ 190 ft^2/acre) than it did in the 1989 time replicate ($\sim$ 150 ft^2/acre) (Table 3.108; Figures 3.82(a), 3.82(b)). It is interesting that the BA in the HF treatment of the 1993 time replicate did not crash at age 15, but stabilized at about 230 ft^2/acre (Table 3.108; Figure 3.82(c)).

Stand density index (SDI) is often used as a measure of stand crowding. SDI development is consistent with BA development for all treatments. SDI increased through time and kept increasing until the BA crash. Since neither the C nor H treatments experienced BA crashes, SDI continued to increase throughout the life of each time replicate. Maximum SDI values for C are 333, 384, and 422 and for the H are 430, 439, and 469 for the 1987, 1989, and 1993 time replicates, respectively (Tables 3.110, 3.111). For the HF treatment, SDI maximized at 369, 304, and 394 just prior to BA crashes for the 1987, 1989, and 1993 time replicates. It is interesting to speculate that the increased stand density on the HF treatment relative to the F treatment prior to crashing is related to the fact that a significant understory was present on F plots but not on HF plots. Thus maximum SDI for loblolly pine may not be simply a function of the stand itself, but also should account for carrying capacity occupied by understory biomass.

Relative spacing (RS) is another measure of stand density. Unlike SDI, RS has large values when stand density is low and small values when stand density is high. On this site, RS reached minimum values of 0.11 just prior to BA crashes and maintained minimum values of 0.11 when BA did not crash (Tables 3.112, 3.113; Figure 3.84). Sites that experienced a BA crash showed RS values increase as the stand continued to develop. Relative spacing values in sites that maintain the minimum values show how RS is a function of distance between trees and height, as trees per acre (TPA) continues to diminish (Tables 3.114, 3.115), average dominant height continues to increase (Tables 3.106, 3.107).

Trees per acre (TPA) development showed similar decreases from age 5 through the age at which BA crashes were observed for all treatments. While F and HF treatments had the fewest surviving trees at the oldest ages for the 1987 and 1989 time replicates, this does not imply survival was poor throughout the life of the plots (Tables 3.114, 3.115; Figure 3.85). The relatively low survival at older ages for the H and HF plots is simply a result of excessive crowding in these stands, which ultimately lead to crashes (i.e. large tree mortality events).

Total green tons per acre (GT) development patterns are very similar to BA development patterns. When F and HF treatments experienced BA crashes, they also experienced GT crashes. Maximum GT for the C and H treatments occurs at the oldest age of each time replicate. For C, these maximums are 176, 205, and 229 tons/acre for the 1987, 1989, and 1993 time replicates, respectively (Tables 3.116, 3.117). For H, these maximums are 233, 222, and 256 tons/acre. For the F treatment, a maximum of 192 tons/acre was reached at age 17 prior to crashing for the 1987 time replicate, a maximum of 141 tons/acre was reached at age 15 prior to crashing for the 1989 time replicate, and a maximum of 177 tons/acre was reached at age 14 for the 1993 time replicate. Maximum tons/acre for the HF treatment were 244, 201, and 278 for the three time replicates. Close study of GT development patterns indicates that the crashes in tons/acre were not as severe as crashes in BA likely due to the taller trees that remained on the site. Mean annual increment (MAI) of GT shows that the C treatment maximized at 7.2, 8.9, and 11.5 tons/acre/year for the three time replicates at or near their oldest age measurements (Tables 3.118, 3.119; Figures 3.87-3.89). For the H treatment, maximum MAI was 10.1, 9.7, and 12.8 tons/acre/year for the three time replicates at ages 19, 23, and 20, respectively. For the F treatment that experienced BA and GT crashes, maximum MAI was 12, 9.9, and 12.9 for the tree time replicates at ages 15, 14, and 13, respectively. Maximum MAI for HF was greater than the other treatments at 14.4, 14.0, and 15.5 tons/acre/year for the three time replicates at ages 15, 14, and 13, respectively.

Quadratic mean diameter (DQ) development patterns remained consistent for the treatments across the three time replicates. The patterns seen in DQ are very similar to what was seen in the dominant height development. Until age 10, the H and HF treatments had higher DQ values than the C and F treatments, which was eventually overtaken by the HF and F treatments. DQ continued to increase in every time replicate and had the maximum values occur at the end of the study. This continued increase of DQ showed that it was the smaller trees that were affected by stem mortality. The treatments that experienced the BA crashes, F and HF, showed the greatest DQ values throughout the study. These higher DQ values correspond with the higher BA values experience on these sites, leading to the crashes. Maximum DQ values for the HF treatment were 10.1, 9.2, and 9.2 inches for the 1987, 1989, and 1993 time replicates, respectively. For the F treatment, the maximum values reached were 10.5, 9.7, and 9.5 inches for the time replicates. The H treatment maximum DQ values were 8.2, 7.9, and 8.4 and for the C treatment are 7.5, 8.1, and 8.2 for the time replicates. Lower DQs on the sites not receiving nutrient amendments (C, H) show that, once again, nutrients were a limiting factor on this site.

Product development is a function of diameter. As diameter increases in individual trees, the product classification shifts to the higher levels. Pulpwood is present on the HF, F, and H treatments at the beginning of the study on all the time replicates. The C treatment didn't develop pulpwood until age 6 on the 1987 and 1989 time replicates, but it did have pulpwood on site at age 5 on the 1993 time replicate. Pulpwood development peaks the earliest in the HF and F treatments, which corresponds with the earlier development of chip-n-saw on site. Chip-n-saw development starts the earliest in the HF and F treatments starting in both treatments at age 8 in the 1987 time replicate, ages 8 and 9 for the HF and F treatments in the 1989 time replicate, and ages 8 and 7 for the HF and F treatments in the 1993 time replicate, respectively. It is interesting to see that immediately after the peak of pulpwood development, total chip-n-saw tons/acre on each treatment is higher than the pulpwood tons/acre. This change in dominance of product also corresponds with the average DQ on site, which crosses the 8 inch minimum for chip-n-saw classification during these pulpwood peaks. Sawtimber development started the earliest on the 1987 time replicate for the F and HF treatments at ages 14 and 18, respectively, followed by the H treatment at age 23 and C at 25. The 1989 time replicate saw earliest sawtimber development on the HF treatment at age 18, followed by C at age 20, and F at age 23. The H treatment for this time replicate did not see any sawtimber development within the time frame of the project. The 1993 time replicate had a different development pattern, with the C treatment first having sawtimber on site at 17, followed by the F treatment at age 18. The H and HF treatments saw no sawtimber development during the time frame of the project for the 1993 time replicate. The 1987 time replicate sees the chip-n-saw development starting to plateau towards the end of the study, which leaves room for speculation that, if following the product development seen from pulpwood to chip-n-saw, sawtimber will soon replace chip-n-saw as the product with the greatest tons/acre on site. This will also correspond with the average DQ, which will need to cross the 12 inch minimum for sawtimber classification.

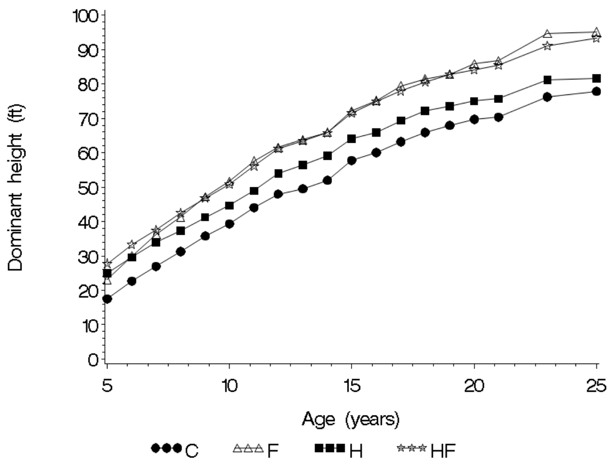
Cronartium infection rates for the first ten years of growth are highest in the HF stand, which also exhibited greatest growth rates in terms of MAI, BA, and dominant height (Tables 3.128, 3.129, 3.118, 3.119, 3.108, 3.109, 3.106, 3.107). It is interesting to see that, while the F treatment had greater overall MAI peaks than the H treatment, fast early development in the H treatment lead to greater cronartium infection rates on the sites. The C treatment maintained an average infection rate of less than 1% on the oldest time replicate and close to 2% on the 1993 time replicate compared with a much higher rate on the 1989 treatment. This higher rate may be a result of climatic differences between the planting years that favored higher rates of cronartium infection.

Table 3.106: Average dominant height (feet) development at the Waycross - Dry site for the 1987 and 1989 time replicates.

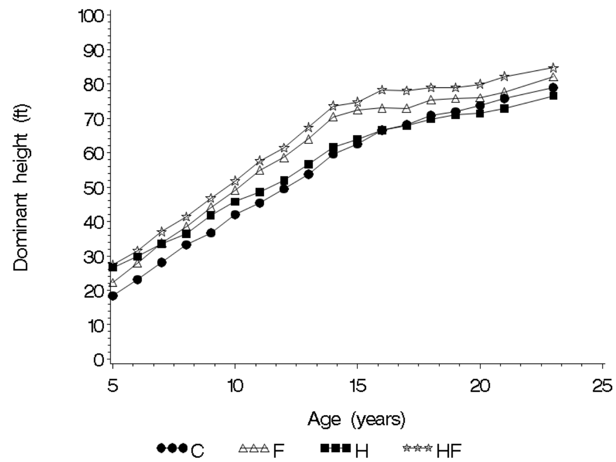
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	17.5	23.1	25.0	27.8	18.3	22.2	26.6	27.4
6	22.6	30.0	29.6	33.3	23.1	27.9	29.8	31.4
7	26.9	36.3	33.9	37.5	28.1	33.8	33.5	37.0
8	31.2	41.3	37.3	42.5	33.2	38.5	36.4	41.4
9	35.8	47.3	41.2	46.9	36.8	44.2	41.8	46.8
10	39.3	51.8	44.6	50.8	41.9	49.1	45.8	51.8
11	44.0	57.6	48.9	56.1	45.4	54.9	48.6	57.6
12	48.0	61.5	53.9	61.2	49.5	58.6	51.9	61.3
13	49.6	63.8	56.5	63.5	53.7	64.0	56.7	67.4
14	52.0	65.9	59.2	65.8	59.6	70.5	61.6	73.6
15	57.7	72.2	64.0	71.4	62.6	72.4	63.9	74.7
16	60.0	75.2	65.8	74.9	66.5	73.0	66.5	78.2
17	63.2	79.5	69.3	77.9	68.1	72.9	67.8	78.0
18	65.9	81.5	72.2	80.6	70.9	75.4	69.8	78.9
19	68.0	82.8	73.6	82.7	71.9	75.8	71.0	78.9
20	69.7	85.9	75.0	84.1	73.7	75.9	71.4	79.9
21	70.3	86.8	75.7	85.4	75.8	77.6	72.9	82.2
23	76.2	94.6	81.2	91.0	78.9	82.1	76.5	84.7
25	77.9	95.2	81.7	93.3	.	.	.	.

Table 3.107: Average dominant height (feet) development at the Waycross - Dry site for the 1993 time replicate.

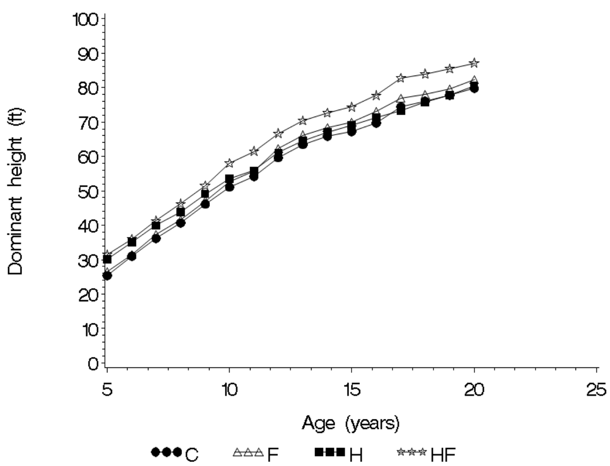
	1993			
Age	C	F	H	HF
5	25.3	26.6	30.1	31.4
6	31.1	31.4	35.1	35.9
7	36.1	37.4	39.9	41.3
8	40.6	41.6	43.9	46.2
9	46.2	47.1	49.1	51.5
10	51.1	52.5	53.6	58.0
11	54.2	55.8	55.9	61.5
12	59.7	62.2	61.0	66.6
13	63.5	66.2	64.6	70.4
14	65.8	68.3	67.0	72.6
15	67.2	69.9	69.0	74.3
16	69.6	73.1	71.3	77.7
17	74.4	76.9	73.2	82.7
18	76.0	77.9	75.7	83.9
19	77.7	79.6	77.9	85.4
20	79.7	82.3	80.6	87.1
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



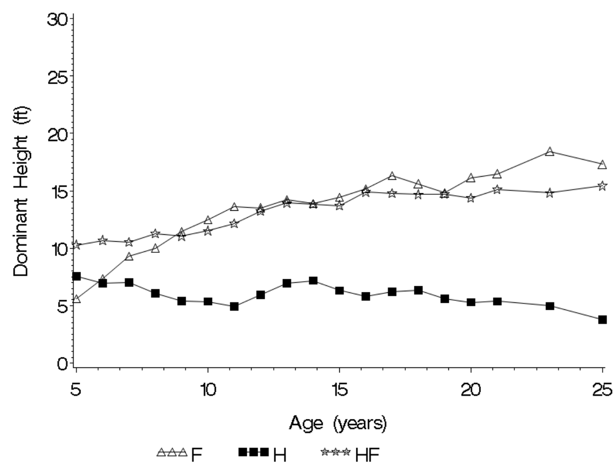
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

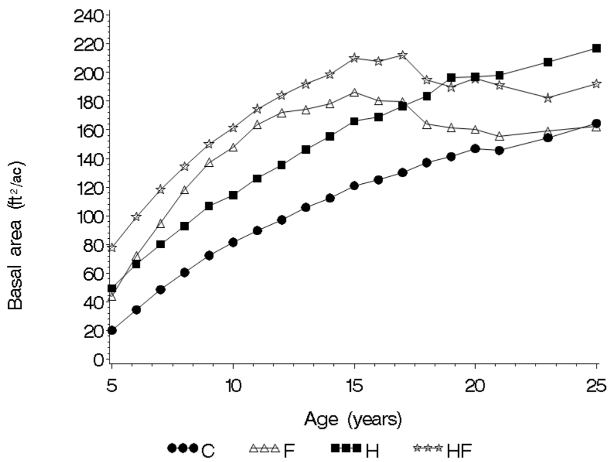
Figure 3.81: Average dominant height (feet) over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.81(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.108: Average basal area (ft^2/acre) at the Waycross - Dry site for the 1987 and 1989 time replicates.

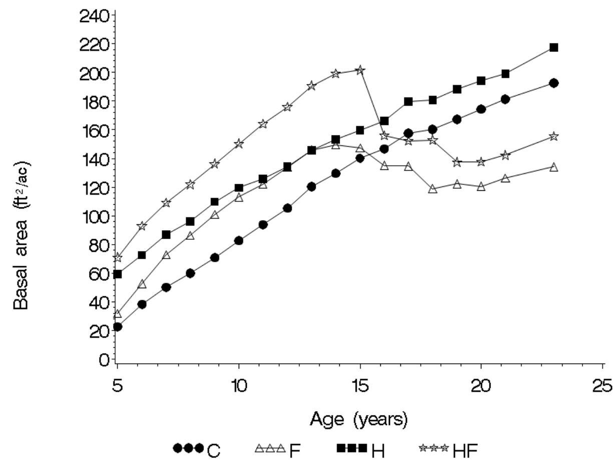
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	20.1	43.7	49.4	77.7	22.5	31.9	59.4	70.9
6	34.4	72.1	66.4	99.2	38.1	52.7	72.6	92.9
7	48.4	94.7	80.1	118.3	50.1	72.9	86.7	108.9
8	60.4	118.1	92.9	134.2	59.8	86.4	96.0	121.8
9	72.3	137.2	106.8	150.0	70.8	100.8	109.8	136.1
10	81.5	147.8	114.5	161.2	82.8	113.1	119.5	150.2
11	89.7	163.6	126.0	174.5	93.8	122.2	125.7	163.9
12	97.1	171.9	135.5	184.1	105.4	133.9	134.5	175.9
13	105.9	174.1	146.1	191.9	120.4	145.9	145.5	190.7
14	112.5	178.3	155.2	198.6	129.6	149.5	153.1	198.9
15	121.1	186.1	166.0	210.1	140.0	147.3	159.8	201.5
16	125.1	180.1	169.0	207.7	146.6	135.0	166.2	156.0
17	130.2	179.6	176.6	212.0	157.5	134.6	179.7	152.1
18	137.0	163.9	183.4	194.8	160.3	118.9	180.8	152.8
19	141.2	161.5	196.5	189.7	167.3	122.4	188.2	137.3
20	147.0	160.2	196.9	195.7	174.5	120.5	194.2	137.5
21	145.5	155.5	198.0	191.1	181.3	126.4	199.0	142.2
23	154.5	159.2	207.1	182.1	192.6	134.2	217.6	155.2
25	164.5	162.2	217.1	192.0	.	.	.	.

Table 3.109: Average basal area (ft^2/acre) at the Waycross - Dry site for the 1993 time replicate.

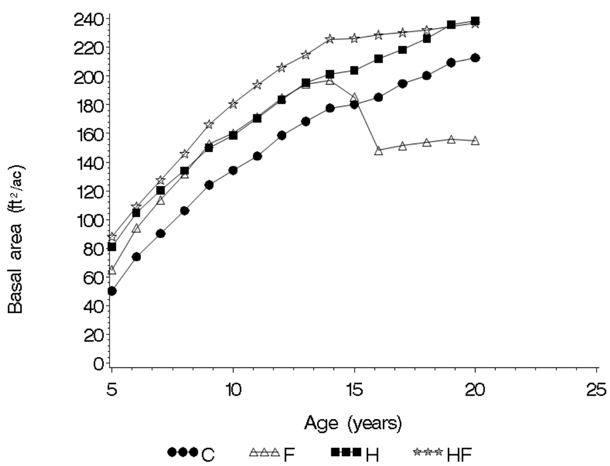
	1993			
Age	C	F	H	HF
5	50.2	64.9	81.1	87.8
6	74.0	94.0	104.6	108.9
7	90.3	113.6	120.2	127.3
8	106.0	131.6	134.1	145.6
9	124.2	152.6	150.1	166.0
10	134.1	160.1	158.7	180.5
11	144.3	171.4	170.7	193.9
12	158.6	184.7	183.4	205.9
13	168.4	194.2	195.4	214.8
14	177.7	197.0	201.4	225.8
15	180.1	185.2	203.9	226.2
16	185.2	148.2	212.2	228.5
17	194.6	151.5	218.3	230.2
18	200.4	153.8	226.3	231.8
19	209.3	156.0	236.0	240.1
20	212.7	155.1	238.4	236.6
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



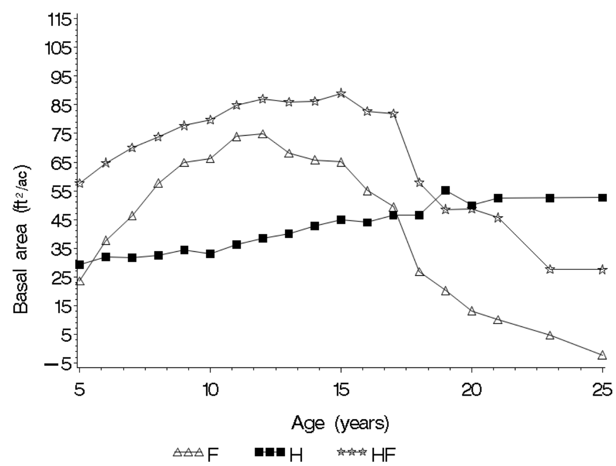
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

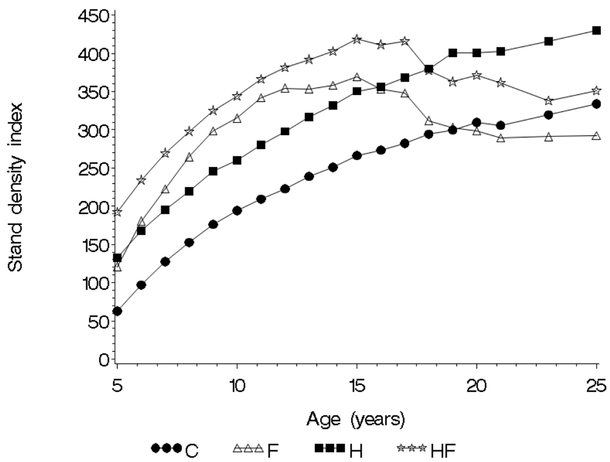
Figure 3.82: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.82(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.110: Average stand density index development at the Waycross - Dry site for the 1987 and 1989 time replicates.

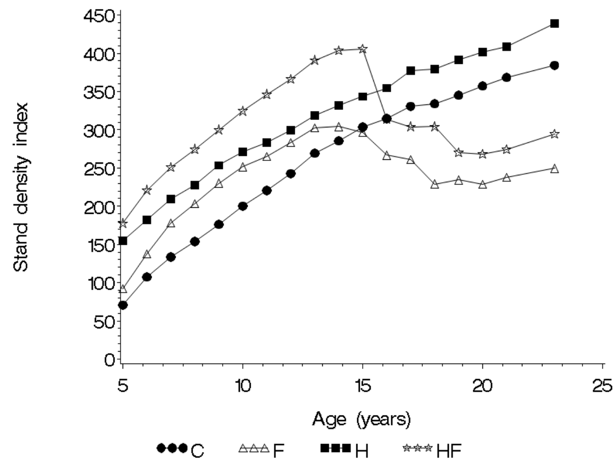
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	62.8	120.7	132.3	192.3	70.6	92.0	154.9	177.7
6	96.9	180.5	167.9	234.1	107.6	137.8	182.0	220.9
7	127.6	222.7	195.1	269.4	133.7	177.8	209.8	250.9
8	152.5	264.8	219.8	297.9	153.9	203.2	227.6	274.4
9	176.3	298.2	245.7	325.1	176.2	230.0	253.5	299.8
10	194.3	315.3	260.2	343.8	199.8	251.6	271.4	324.4
11	209.3	342.2	280.5	366.4	220.7	265.3	283.3	346.2
12	222.9	354.5	297.9	381.1	242.5	283.0	299.2	366.4
13	239.2	353.6	316.4	392.0	269.5	302.3	318.7	391.0
14	251.0	358.2	332.1	402.5	285.7	304.2	331.9	403.5
15	266.4	369.1	350.5	418.3	303.6	296.4	343.5	405.6
16	273.4	353.2	355.7	411.2	314.5	266.6	354.5	313.6
17	282.2	348.0	368.6	415.7	330.5	261.1	377.5	304.0
18	294.0	312.0	379.9	377.0	334.2	229.1	379.2	304.1
19	299.9	302.8	400.9	362.8	345.4	234.4	391.7	270.2
20	309.6	298.6	400.5	371.2	357.4	228.8	401.7	268.0
21	305.8	289.5	402.3	361.5	368.4	237.7	408.7	274.2
23	319.3	291.1	415.4	337.9	384.0	249.5	439.1	294.1
25	333.8	292.2	430.4	351.0	.	.	.	.

Table 3.111: Average stand density index development at the Waycross - Dry site for the 1993 time replicate.

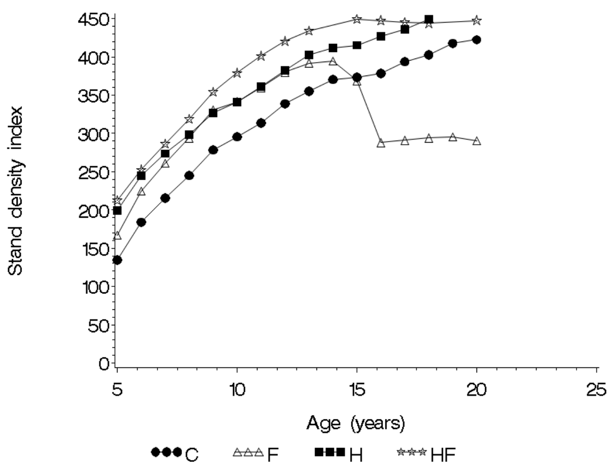
	1993			
Age	C	F	H	HF
5	134.6	166.8	199.5	212.4
6	183.9	224.4	244.6	252.6
7	215.5	261.2	273.7	286.2
8	245.2	294.0	298.4	318.8
9	278.4	330.9	326.7	354.3
10	295.9	341.4	341.1	378.9
11	313.7	359.8	361.3	401.3
12	338.5	380.0	382.7	420.4
13	355.2	392.0	402.8	434.0
14	370.4	394.4	411.6	451.1
15	373.4	368.8	415.2	449.0
16	378.4	287.9	427.1	447.4
17	393.7	291.0	436.3	445.0
18	402.6	293.9	449.1	443.7
19	417.5	295.3	463.9	455.6
20	422.4	290.3	469.0	447.6
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

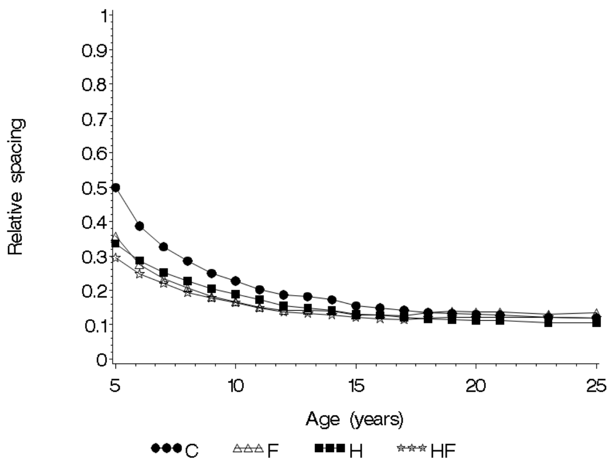
Figure 3.83: Average stand density index over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.83(a)-(c).

Table 3.112: Average relative spacing development at the Waycross - Dry site for the 1987 and 1989 time replicates.

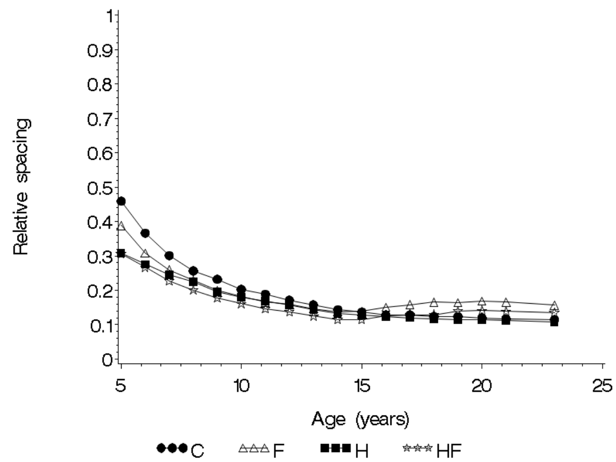
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.50	0.36	0.34	0.29	0.46	0.39	0.31	0.31
6	0.39	0.28	0.29	0.25	0.37	0.31	0.28	0.27
7	0.33	0.23	0.25	0.22	0.30	0.26	0.25	0.23
8	0.28	0.21	0.23	0.19	0.26	0.23	0.23	0.20
9	0.25	0.18	0.20	0.18	0.23	0.20	0.20	0.18
10	0.23	0.17	0.19	0.16	0.20	0.18	0.18	0.16
11	0.20	0.15	0.17	0.15	0.19	0.17	0.17	0.15
12	0.19	0.14	0.16	0.14	0.17	0.16	0.16	0.14
13	0.18	0.14	0.15	0.13	0.16	0.15	0.14	0.12
14	0.17	0.14	0.14	0.13	0.14	0.14	0.13	0.12
15	0.15	0.13	0.13	0.12	0.14	0.14	0.13	0.11
16	0.15	0.13	0.13	0.12	0.13	0.15	0.12	0.13
17	0.14	0.13	0.12	0.11	0.13	0.16	0.12	0.13
18	0.14	0.13	0.12	0.12	0.12	0.17	0.12	0.13
19	0.13	0.14	0.11	0.12	0.12	0.16	0.11	0.14
20	0.13	0.14	0.11	0.12	0.12	0.17	0.11	0.14
21	0.13	0.14	0.11	0.12	0.12	0.17	0.11	0.14
23	0.12	0.13	0.11	0.12	0.11	0.16	0.11	0.13
25	0.12	0.13	0.11	0.12	.	.	.	.

Table 3.113: Average relative spacing development at the Waycross - Dry site for the 1993 time replicate.

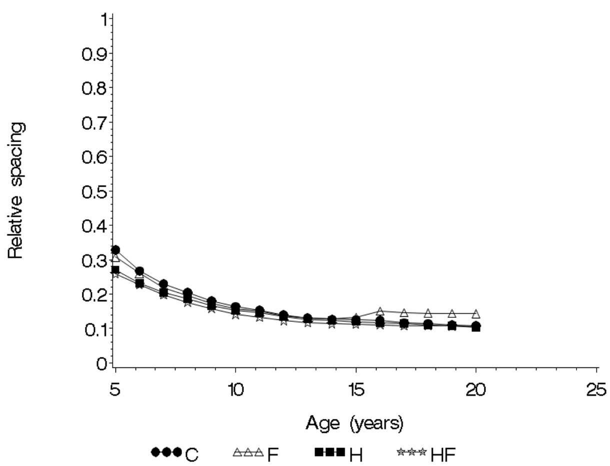
	1993			
Age	C	F	H	HF
5	0.33	0.31	0.27	0.26
6	0.27	0.26	0.23	0.23
7	0.23	0.22	0.20	0.20
8	0.20	0.20	0.19	0.18
9	0.18	0.17	0.17	0.16
10	0.16	0.16	0.15	0.14
11	0.15	0.15	0.15	0.13
12	0.14	0.14	0.13	0.12
13	0.13	0.13	0.13	0.12
14	0.13	0.13	0.12	0.11
15	0.13	0.13	0.12	0.11
16	0.12	0.15	0.12	0.11
17	0.12	0.15	0.11	0.11
18	0.11	0.14	0.11	0.11
19	0.11	0.14	0.11	0.11
20	0.11	0.14	0.10	0.11
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

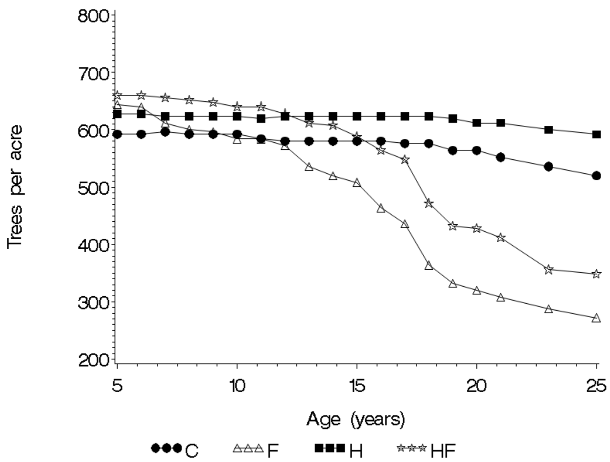
Figure 3.84: Average relative spacing development over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.84(a)-(c).

Table 3.114: Average trees per acre development at the Waycross - Dry site for the 1987 and 1989 time replicates.

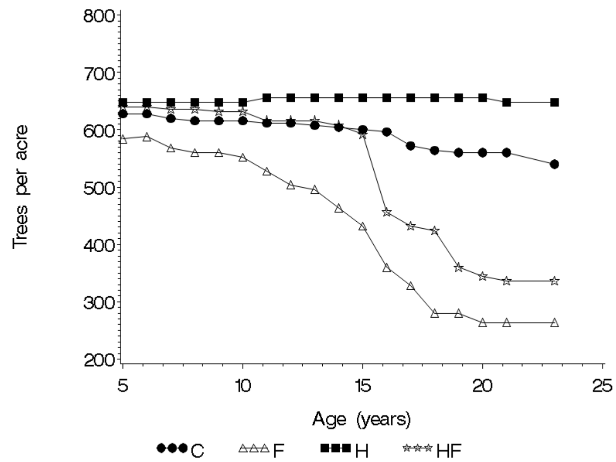
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	592	644	628	660	628	584	648	640
6	592	640	628	660	628	588	648	640
7	596	612	624	656	620	568	648	636
8	592	600	624	652	616	560	648	636
9	592	596	624	648	616	560	648	632
10	592	584	624	640	616	552	648	632
11	584	584	620	640	612	528	656	616
12	580	572	624	628	612	504	656	616
13	580	536	624	612	608	496	656	616
14	580	520	624	608	604	464	656	608
15	580	508	624	588	600	432	656	592
16	580	464	624	564	596	360	656	456
17	576	436	624	548	572	328	656	432
18	576	364	624	472	564	280	656	424
19	564	332	620	432	560	280	656	360
20	564	320	612	428	560	264	656	344
21	552	308	612	412	560	264	648	336
23	536	288	600	356	540	264	648	336
25	520	272	592	348	.	.	.	.

Table 3.115: Average trees per acre development at the Waycross - Dry site for the 1993 time replicate.

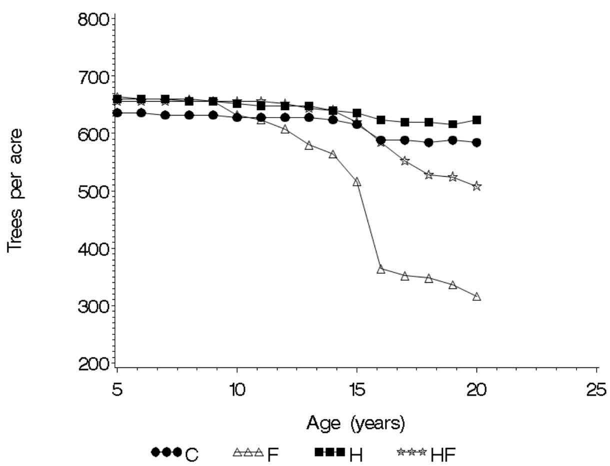
	1993			
Age	C	F	H	HF
5	636	664	660	656
6	636	660	660	656
7	632	660	660	656
8	632	660	656	656
9	632	656	656	656
10	628	632	652	656
11	628	624	648	656
12	628	608	648	652
13	628	580	648	644
14	624	564	640	640
15	616	516	636	620
16	588	364	624	584
17	588	352	620	552
18	584	348	620	528
19	588	336	616	524
20	584	316	624	508
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



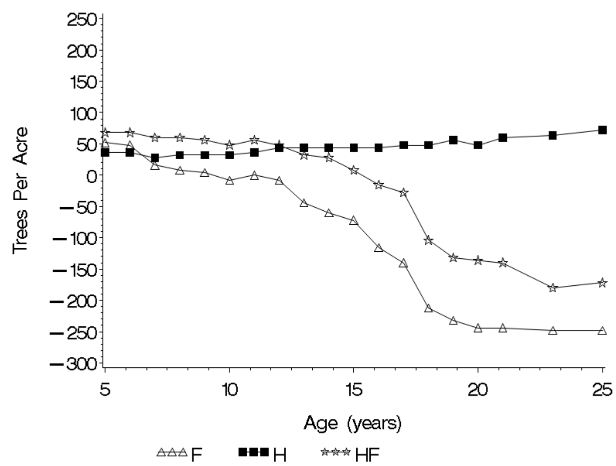
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

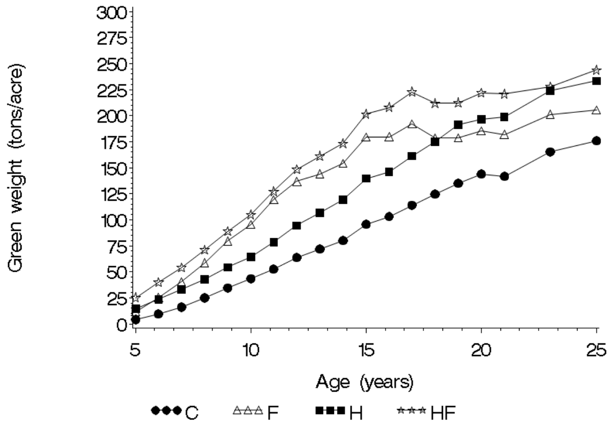
Figure 3.85: Average trees per acre development over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.85(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.116: Average total green weight (tons/acre) development at the Waycross - Dry site for the 1987 and 1989 time replicates.

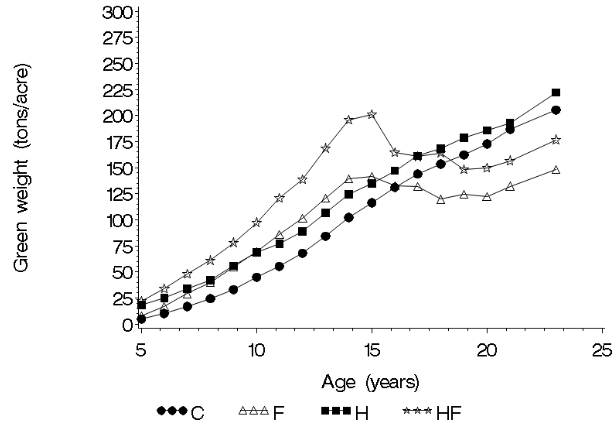
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	4.2	11.4	14.5	25.1	4.7	7.8	18.0	21.9
6	9.5	25.2	23.7	39.5	10.1	16.8	24.7	33.8
7	16.1	40.7	32.9	53.7	16.7	29.1	33.7	47.8
8	24.8	58.5	42.5	70.8	24.4	40.0	41.8	61.0
9	34.3	79.5	54.3	88.7	33.0	54.7	55.8	78.0
10	43.1	95.6	64.5	104.8	44.8	69.4	68.6	97.2
11	52.6	119.1	78.6	127.1	55.2	85.7	76.9	120.8
12	63.8	136.8	94.4	148.0	67.7	101.2	88.9	138.5
13	72.0	144.0	106.5	161.0	84.2	120.6	106.7	168.5
14	80.2	154.3	119.1	173.2	102.1	139.1	124.3	195.7
15	95.8	179.3	139.6	201.4	116.3	141.2	134.8	201.0
16	103.1	179.6	146.2	207.9	131.1	132.6	147.0	164.6
17	113.9	192.0	161.1	222.6	144.0	132.0	161.2	160.4
18	124.7	178.5	175.1	211.8	153.4	119.6	168.3	164.1
19	135.1	178.8	191.0	212.2	162.0	124.3	178.6	148.2
20	143.9	185.2	196.3	221.5	172.8	122.1	185.7	149.6
21	141.8	181.9	198.7	220.7	186.6	132.0	192.9	156.6
23	165.2	201.3	223.9	227.7	205.0	148.3	222.0	176.6
25	176.0	205.4	233.2	243.7	.	.	.	.

Table 3.117: Average total green weight (tons/acre) development at the Waycross - Dry site for the 1993 time replicates.

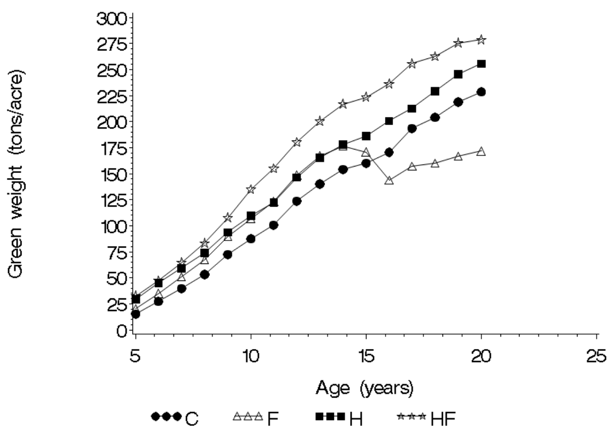
	1993			
Age	C	F	H	HF
5	14.9	20.2	29.2	32.6
6	27.3	34.8	44.9	47.0
7	39.7	51.0	59.2	64.6
8	53.2	67.4	73.7	83.2
9	72.1	89.7	93.7	107.7
10	87.5	106.9	109.6	134.8
11	100.5	123.1	122.5	154.8
12	123.3	148.4	146.3	180.2
13	140.0	167.1	165.3	200.3
14	154.0	176.7	178.0	216.9
15	159.8	170.8	186.0	223.5
16	170.4	143.8	200.6	236.3
17	193.2	157.1	212.5	255.5
18	204.2	160.0	229.1	262.6
19	218.8	166.8	245.5	275.5
20	228.7	171.6	255.6	278.5
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



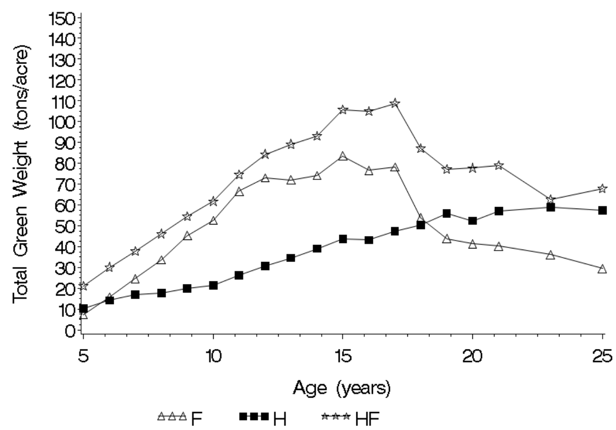
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

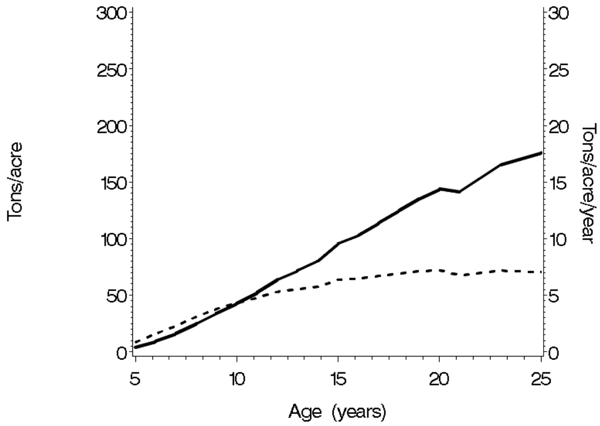
Figure 3.86: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.86(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.118: Mean annual increment (tons/acre/year) development at the Waycross - Dry site for the 1987 and 1989 time replicates.

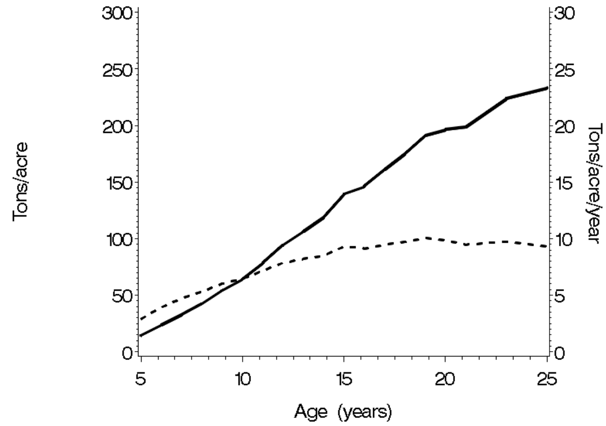
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.8	2.3	2.9	5.0	0.9	1.6	3.6	4.4
6	1.6	4.2	3.9	6.6	1.7	2.8	4.1	5.6
7	2.3	5.8	4.7	7.7	2.4	4.2	4.8	6.8
8	3.1	7.3	5.3	8.9	3.1	5.0	5.2	7.6
9	3.8	8.8	6.0	9.9	3.7	6.1	6.2	8.7
10	4.3	9.6	6.5	10.5	4.5	6.9	6.9	9.7
11	4.8	10.8	7.2	11.6	5.0	7.8	7.0	11.0
12	5.3	11.4	7.9	12.3	5.6	8.4	7.4	11.5
13	5.5	11.1	8.2	12.4	6.5	9.3	8.2	13.0
14	5.7	11.0	8.5	12.4	7.3	9.9	8.9	14.0
15	6.4	12.0	9.3	13.4	7.8	9.4	9.0	13.4
16	6.4	11.2	9.1	13.0	8.2	8.3	9.2	10.3
17	6.7	11.3	9.5	13.1	8.5	7.8	9.5	9.4
18	6.9	9.9	9.7	11.8	8.5	6.7	9.4	9.1
19	7.1	9.4	10.1	11.2	8.5	6.5	9.4	7.8
20	7.2	9.3	9.8	11.1	8.6	6.1	9.3	7.5
21	6.8	8.7	9.5	10.5	8.9	6.3	9.2	7.5
23	7.2	8.8	9.7	9.9	8.9	6.5	9.7	7.7
25	7.0	8.2	9.3	9.8	.	.	.	.

Table 3.119: Mean annual increment (tons/acre/year) development at the Waycross - Dry site for the 1993 time replicate.

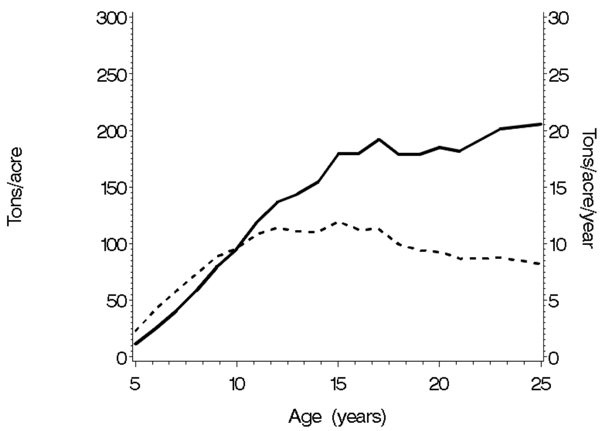
	1993			
Age	C	F	H	HF
5	3.0	4.0	5.8	6.5
6	4.6	5.8	7.5	7.8
7	5.7	7.3	8.5	9.2
8	6.7	8.4	9.2	10.4
9	8.0	10.0	10.4	12.0
10	8.8	10.7	11.0	13.5
11	9.1	11.2	11.1	14.1
12	10.3	12.4	12.2	15.0
13	10.8	12.9	12.7	15.4
14	11.0	12.6	12.7	15.5
15	10.7	11.4	12.4	14.9
16	10.7	9.0	12.5	14.8
17	11.4	9.2	12.5	15.0
18	11.3	8.9	12.7	14.6
19	11.5	8.8	12.9	14.5
20	11.4	8.6	12.8	13.9
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



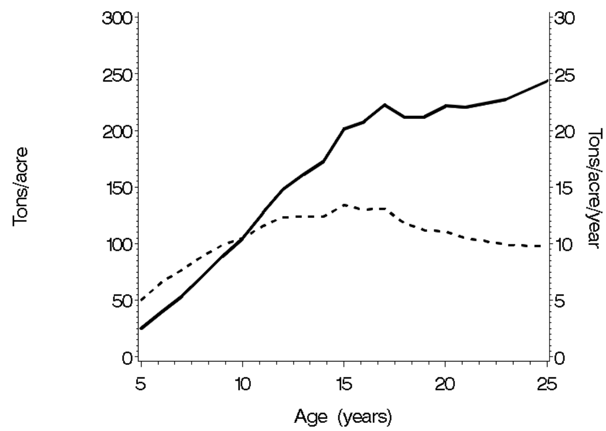
(a) C



(b) H

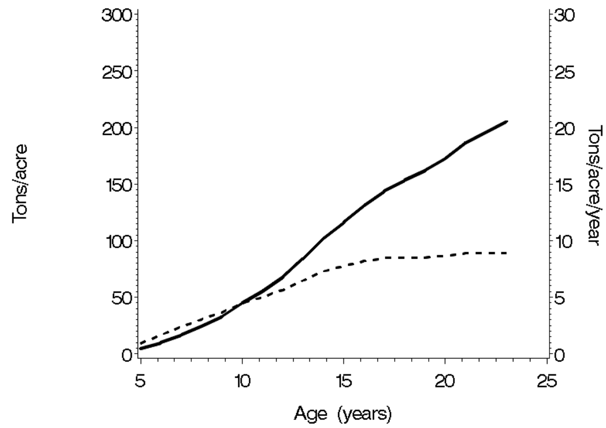


(c) F

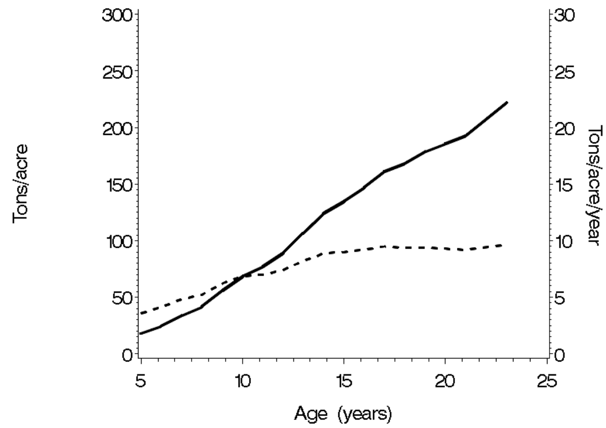


(d) HF

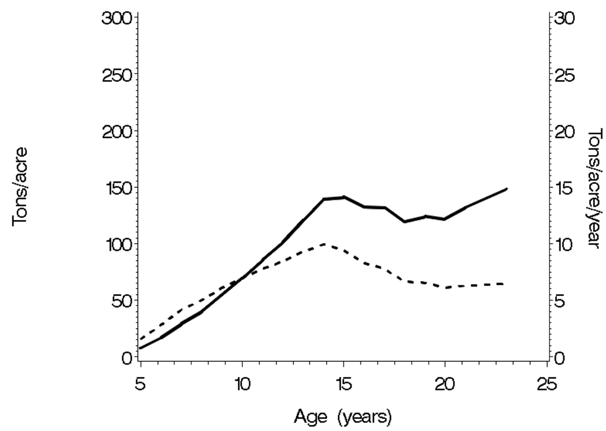
Figure 3.87: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Waycross - Dry 1987 time replicate.



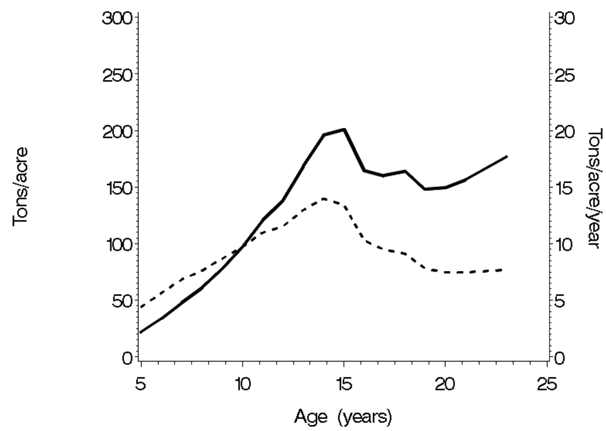
(a) C



(b) H



(c) F



(d) HF

Figure 3.88: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Waycross - Dry 1989 time replicate.

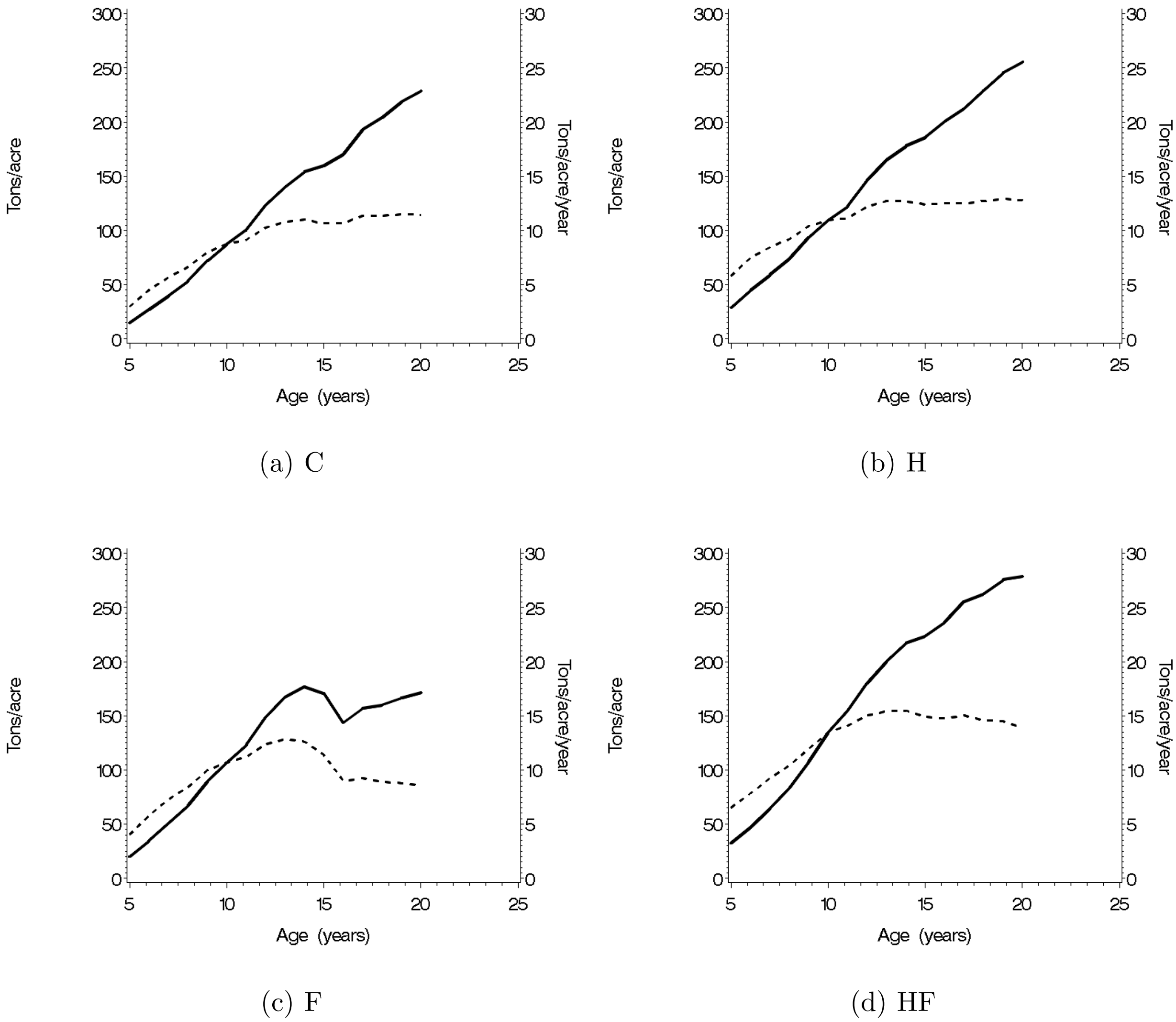


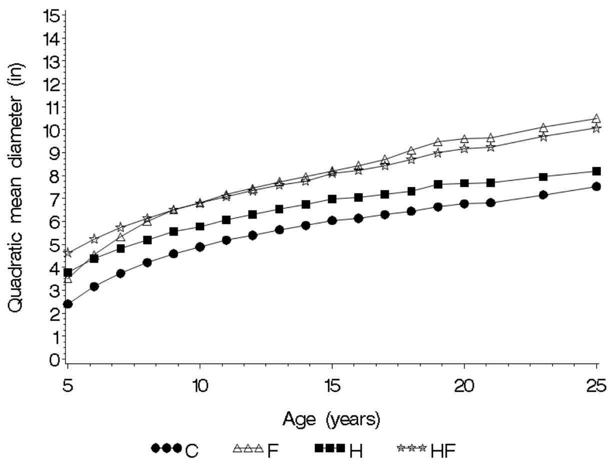
Figure 3.89: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Waycross - Dry 1993 time replicate.

Table 3.120: Average quadratic mean diameter (inches) development at the Waycross - Dry site for the 1987 and 1989 time replicates.

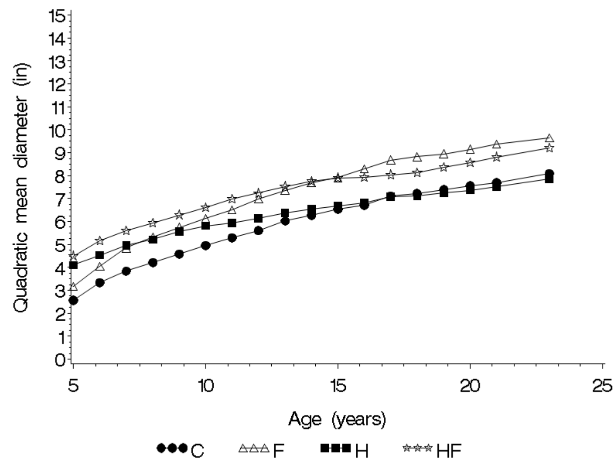
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	2.4	3.5	3.8	4.6	2.6	3.2	4.1	4.5
6	3.2	4.5	4.4	5.2	3.3	4.1	4.5	5.2
7	3.7	5.3	4.8	5.7	3.8	4.9	5.0	5.6
8	4.2	6.0	5.2	6.1	4.2	5.3	5.2	5.9
9	4.6	6.5	5.6	6.5	4.6	5.7	5.6	6.3
10	4.9	6.8	5.8	6.8	5.0	6.1	5.8	6.6
11	5.2	7.2	6.1	7.1	5.3	6.5	5.9	7.0
12	5.4	7.4	6.3	7.3	5.6	7.0	6.1	7.2
13	5.6	7.7	6.5	7.6	6.0	7.3	6.4	7.5
14	5.8	8.0	6.7	7.8	6.3	7.7	6.5	7.8
15	6.0	8.2	7.0	8.1	6.5	7.9	6.7	7.9
16	6.1	8.5	7.0	8.2	6.7	8.3	6.8	7.9
17	6.3	8.7	7.2	8.4	7.1	8.7	7.1	8.0
18	6.5	9.1	7.3	8.7	7.2	8.8	7.1	8.1
19	6.6	9.5	7.6	9.0	7.4	9.0	7.3	8.4
20	6.8	9.6	7.7	9.2	7.6	9.2	7.4	8.6
21	6.8	9.7	7.7	9.2	7.7	9.4	7.5	8.8
23	7.2	10.1	7.9	9.7	8.1	9.7	7.9	9.2
25	7.5	10.5	8.2	10.1	.	.	.	.

Table 3.121: Average quadratic mean diameter (inches) development at the Waycross - Dry site for the 1993 time replicate.

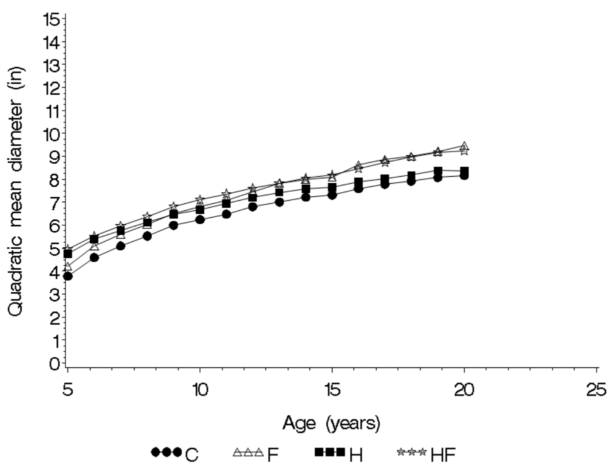
	1993			
Age	C	F	H	HF
5	3.8	4.2	4.7	5.0
6	4.6	5.1	5.4	5.5
7	5.1	5.6	5.8	6.0
8	5.5	6.0	6.1	6.4
9	6.0	6.5	6.5	6.8
10	6.3	6.8	6.7	7.1
11	6.5	7.1	7.0	7.4
12	6.8	7.5	7.2	7.6
13	7.0	7.8	7.4	7.8
14	7.2	8.0	7.6	8.0
15	7.3	8.1	7.7	8.2
16	7.6	8.6	7.9	8.5
17	7.8	8.9	8.0	8.7
18	7.9	9.0	8.2	9.0
19	8.1	9.2	8.4	9.2
20	8.2	9.5	8.4	9.2
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



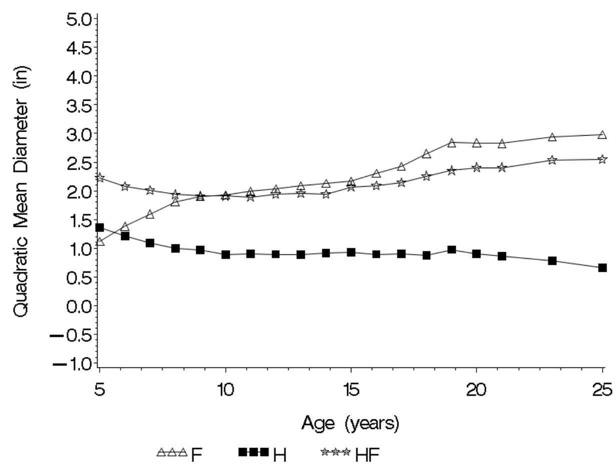
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

Figure 3.90: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Waycross - Dry site is shown in subfigures 3.90(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.122: Average pulpwood development (tons/acre) at the Waycross - Dry site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	4.6	7.9	22.0	.	2.5	13.4	19.2
6	4.3	21.8	19.2	37.6	3.3	12.7	21.5	32.3
7	11.2	39.0	28.9	52.3	10.9	26.0	31.1	46.5
8	20.4	55.5	40.6	69.0	19.6	37.7	39.5	58.5
9	29.5	69.2	52.5	79.1	28.2	51.2	53.6	73.6
10	38.8	77.9	61.8	87.5	40.5	62.4	66.0	88.6
11	48.4	84.7	76.1	98.6	51.6	67.4	74.0	105.7
12	56.5	87.2	87.1	103.6	63.7	70.8	86.5	107.4
13	61.0	81.5	91.8	103.0	74.3	72.6	101.3	111.4
14	67.5	79.8	95.3	102.0	86.9	67.1	113.0	110.7
15	73.0	79.2	104.9	96.7	93.5	62.6	118.9	107.2
16	76.6	71.7	106.2	93.7	99.7	45.5	122.0	84.6
17	79.6	68.4	107.1	91.4	94.7	41.9	118.0	79.4
18	83.2	55.4	105.9	74.4	94.1	35.4	122.6	78.3
19	85.3	47.7	106.0	63.1	95.0	33.8	119.7	63.3
20	84.0	47.2	104.8	60.6	97.8	31.9	117.1	61.4
21	83.1	45.3	104.8	55.8	99.1	32.3	109.5	56.5
23	79.1	42.4	107.8	50.2	94.7	35.4	97.4	51.1
25	78.0	38.8	99.6	47.6	.	.	.	.

Table 3.123: Average pulpwood development (tons/acre) at the Waycross - Dry site for the 1993 time replicate.

	1993			
Age	C	F	H	HF
5	8.2	15.7	26.6	30.9
6	24.2	32.1	43.2	45.4
7	37.6	47.9	57.6	62.9
8	51.2	63.4	72.0	81.1
9	69.2	78.9	90.1	102.2
10	81.8	88.5	102.9	116.1
11	93.0	93.7	107.2	116.9
12	105.8	100.4	116.0	124.4
13	114.9	90.3	118.0	114.3
14	118.3	87.8	118.8	106.9
15	118.3	80.1	119.8	101.3
16	107.2	52.3	110.3	93.0
17	105.9	49.3	109.3	86.0
18	107.7	47.0	108.1	78.4
19	102.4	44.3	103.2	70.3
20	103.5	40.5	104.2	69.7
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.124: Average chip-n-saw development (tons/acre) at the Waycross - Dry site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	1.6	.	1.2	.	.	.	2.3
9	.	8.9	.	16.7	.	1.1	.	2.8
10	.	16.4	1.2	32.0	.	4.5	.	7.0
11	.	33.0	1.7	27.1	.	15.2	.	13.7
12	6.1	48.3	5.4	43.0	1.2	28.5	.	29.7
13	7.4	61.3	13.1	56.7	6.6	46.3	3.0	55.6
14	9.4	71.3	22.3	69.8	12.2	70.4	8.8	83.5
15	19.3	94.3	33.0	103.3	20.1	77.0	13.8	92.3
16	23.2	101.4	38.3	112.9	28.6	85.7	22.9	78.8
17	31.1	113.8	52.4	129.9	46.7	89.3	41.2	80.0
18	38.3	112.7	67.5	133.2	56.9	83.6	43.6	79.3
19	46.9	117.1	83.4	142.1	64.4	89.9	56.7	78.6
20	57.1	123.6	89.8	149.7	70.1	89.7	66.5	81.7
21	56.2	121.7	92.3	156.9	82.2	99.1	81.4	93.2
23	83.5	127.6	110.9	150.9	102.1	101.2	122.7	111.5
25	92.5	118.9	128.0	159.0	.	.	.	.

Table 3.125: Average chip-n-saw development (tons/acre) at the Waycross - Dry site for the 1993 time replicate.

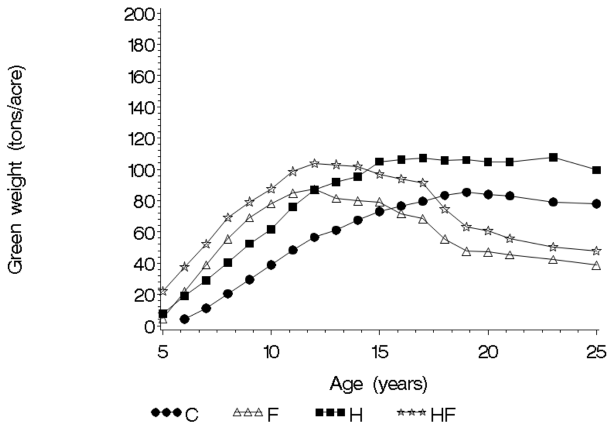
	1993			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	1.9	.	.
8	.	3.7	.	1.2
9	2.4	9.1	1.8	4.0
10	4.0	16.6	5.0	17.2
11	5.8	27.6	13.7	36.3
12	15.8	46.2	28.6	54.1
13	23.3	75.3	45.8	84.4
14	33.9	87.4	57.7	108.4
15	39.6	89.3	64.7	120.7
16	61.5	90.7	88.8	141.9
17	83.2	107.0	101.5	168.2
18	92.2	109.6	119.3	183.0
19	111.4	113.4	140.8	204.0
20	114.7	112.9	149.8	207.7
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.126: Average sawtimber development (tons/acre) at the Waycross - Dry site for the 1987 and 1989 time replicates.

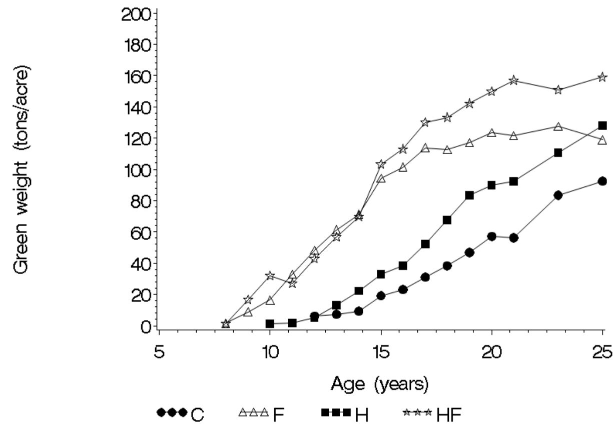
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.
14	.	4.0	.	.	.	.	.	.
15	.	4.6	.	.	.	.	.	.
16	.	5.4	.	.	.	.	.	.
17	.	8.7	.	.	.	.	.	.
18	.	9.6	.	6.1	.	.	.	5.4
19	.	13.4	.	11.9	.	.	.	5.4
20	.	13.8	.	20.6	4.9	.	.	5.6
21	.	14.3	.	14.2	5.9	.	.	6.1
23	.	30.6	7.1	25.9	12.6	11.1	.	13.3
25	6.0	47.1	8.3	36.3	.	.	.	.

Table 3.127: Average sawtimber development (tons/acre) at the Waycross - Dry site for the 1993 time replicate.

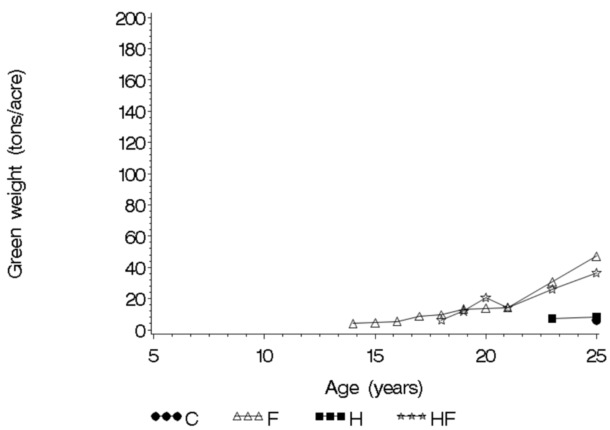
	1993			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	.	.	.	.
10	.	.	.	.
11	.	.	.	.
12	.	.	.	.
13	.	.	.	.
14	.	.	.	.
15	.	.	.	.
16	.	.	.	.
17	4.8	.	.	.
18	5.4	5.3	.	.
19	6.2	8.4	.	.
20	8.8	17.6	.	.
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw



(c) Sawtimber

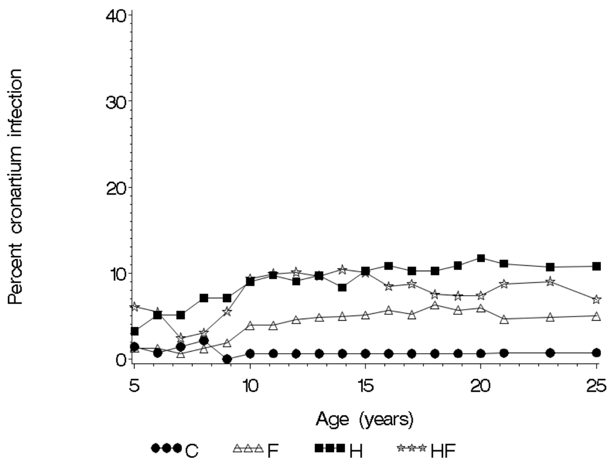
Figure 3.91: Average product distribution (tons/acre) over the course of the study for the Waycross - Dry 1987 time replicate. Pulpwood is shown in 3.91(a), Chip-N-Saw in 3.91(b), and sawtimber in 3.91(c).

Table 3.128: Average cronartium infection rates (%) at the Waycross - Dry site for the 1987 and 1989 time replicates.

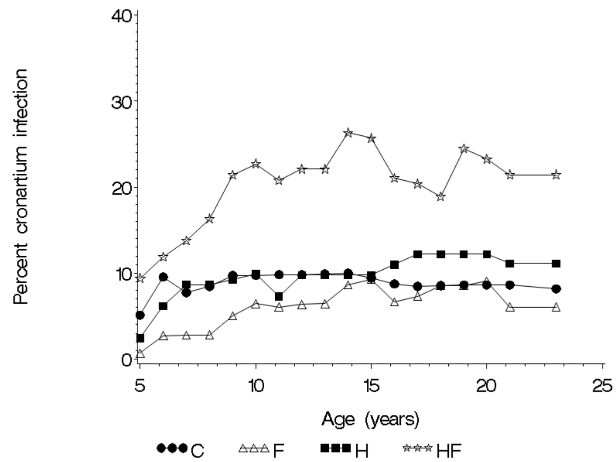
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	1.5	1.2	3.2	6.1	5.1	0.7	2.5	9.4
6	0.7	1.3	5.1	5.5	9.6	2.7	6.2	11.9
7	1.4	0.6	5.1	2.5	7.7	2.8	8.7	13.8
8	2.1	1.2	7.1	3.1	8.4	2.8	8.7	16.3
9	0.0	1.9	7.1	5.5	9.7	5.0	9.3	21.4
10	0.6	3.9	9.0	9.4	9.7	6.4	9.9	22.7
11	0.7	3.9	9.8	9.9	9.8	6.1	7.3	20.8
12	0.6	4.6	9.0	10.1	9.8	6.4	9.8	22.1
13	0.6	4.9	9.7	9.7	9.9	6.5	9.8	22.1
14	0.6	5.0	8.3	10.4	10.0	8.6	9.8	26.3
15	0.6	5.1	10.2	10.0	9.4	9.3	9.8	25.7
16	0.6	5.7	10.8	8.5	8.8	6.7	11.0	21.1
17	0.6	5.2	10.2	8.7	8.5	7.3	12.2	20.4
18	0.6	6.3	10.2	7.5	8.5	8.6	12.2	18.9
19	0.7	5.7	10.9	7.3	8.6	8.6	12.2	24.4
20	0.7	5.9	11.7	7.4	8.6	9.1	12.2	23.3
21	0.7	4.7	11.1	8.7	8.6	6.1	11.1	21.4
23	0.7	4.9	10.7	9.0	8.1	6.1	11.1	21.4
25	0.8	5.0	10.8	6.9	.	.	.	.

Table 3.129: Average cronartium infection rates (%) at the Waycross - Dry site for the 1993 time replicate.

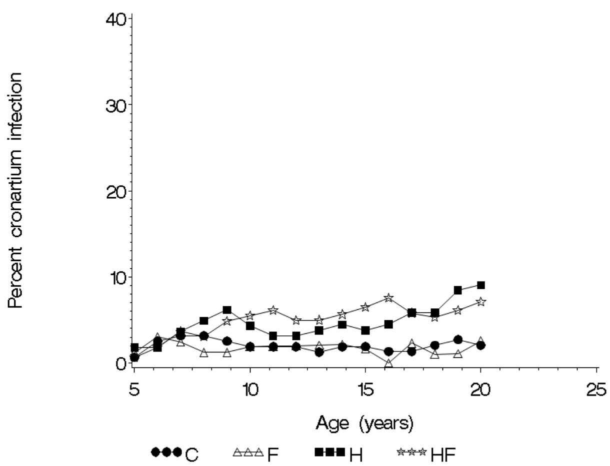
	1993			
Age	C	F	H	HF
5	0.7	1.2	1.8	0.6
6	2.5	3.0	1.8	1.8
7	3.2	2.4	3.6	3.6
8	3.2	1.2	4.9	3.0
9	2.5	1.2	6.2	4.9
10	1.9	1.9	4.3	5.5
11	1.9	1.9	3.1	6.1
12	1.9	2.0	3.1	4.9
13	1.3	2.1	3.8	5.0
14	1.9	2.1	4.5	5.6
15	1.9	1.6	3.8	6.5
16	1.3	0.0	4.5	7.5
17	1.3	2.3	5.8	5.8
18	2.0	1.0	5.8	5.3
19	2.7	1.1	8.4	6.1
20	2.0	2.5	9.0	7.1
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

Figure 3.92: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Waycross - Dry site are shown in subfigures 3.92(a)-(c).

3.9 Waycross - Wet

They Waycross - Wet site had midrotation thinning treatments applied to three individual treatment plots after the 10th growing season. These three treatment plots, F, H, and HF on block 3 were a part of the 1989 time replicate. All information provided on the 1989 time replicate after the 10th growing season reflects only one plot.

The Waycross - Wet site showed high inherent site quality in respect to the site index. The C treatment showed a base age 25 site index of 73 feet on the 1987 time replicate (Table 3.130). The two younger time replicates showed even better quality sites, with the 1993 time replicate reaching 84 feet in the 20th growing season (Tables 3.130, 3.131). The 1987 time replicate showed the HF and F treatments with significantly greater heights than the C and H treatments from age 15 until age 23. Little difference was seen between the H and F treatments early on in the study until age 10, where the F treatment's growth rate was faster. The treatment effects on dominant height for the 1987 time replicate showed the F treatment with the highest site index, 92 feet at age 25, followed by HF with 90 feet, H with 76 feet, and C with 73 feet (Table 3.130). These large gains in site index for the HF and F treatments show that nutrition was a limiting factor on this Coastal Plain site.

Basal area (BA) development showed the HF and F treatments with the quickest development on all three time replicates. These quicker developments for the HF and F treatments show that stand level development on the site is occurring at the greatest rate for these treatments. Only in the initial study year, the 5th growing season, did the H and F treatments have similar BA values until the last measurement year, the 25th growing season for the 1987 time replicate. Similar trends were seen in the 1989 and 1993 time replicates. An interesting trend on this site for the HF and F treatments was that no BA crash was present on any of the time replicates. The 1987 time replicate saw the HF treatment with an early peak at age 13 followed by the BA values remaining fairly constant in the 190 ft^2/ac for the remainder of the study. Slight declines in BA occur during this stretch of time for the HF treatment, but no more than a loss of 8 ft^2/acre within a year (Table 3.132). The 1993 time replicate had similar development in the HF treatment, with the treatment stabilizing towards the end of the study with around 210 ft^2/acre. The 1989 time replicate saw the HF treatment BA development begin to slow after age 15, reaching a small peak of 228.7 ft^2/acre at age 18, followed by a slight decline. This treatment began to increase at the end of the study, reaching 234.2 ft^2/acre at age 23. The F treatments on all time replicates followed extremely similar development patterns compared with the HF treatments of the same time replicates. The H and C treatments on the 1987 and 1989 time replicates had fairly consistent increases throughout the study, reaching their max at the oldest measurement age. Maximum BA reached for the C treatments were 174.9, 173.2 and 209.9 ft^2/acre for the 1987, 1989, and 1993 time replicates, respectively. The H treatment maximum BA reached was 198.7, 198.4, and 200.3 ft^2/acre for the three time replicates. The 1987 and 1989 time replicates showed the H treatment maintaining a $\sim$25 ft^2/acre advantage over the C.

Stand density index (SDI) development was consistent with BA development on all sites. On the time replicates where BA continues to increase over the course of the study for the H and C treatments, so does SDI (Table 3.134). For these treatments, the C had maximum SDI values at the last measurement age of 369.0, 354.4, and 416.7 on the 1987, 1989, and 1993 time replicates, respectively (Tables 3.134, 3.135). The H treatment reached maximum SDI values of 405.4, 404.7, and 404.5, each at the last measurement age, for the three time replicates. On the HF and F treatments, where BA peaked and began to stabilize, SDI also began to stabilize (Table 3.134). The HF treatment saw SDI peak at age 13 with a value of 402.2 in the 1987 treatment. By the end of the study, SDI had decreased to and stabilized around 360. The 1989 HF treatment saw HF peak at 441.5 at age 18, and 394.9 at age 19 in the 1993 time replicate.

Relative spacing (RS) reached minimum values of .11 by the end of the study for the C and H treatments on the 1987 time replicate (Table 3.136) An interesting note is that the F treatment on this time replicate maintained an RS value of .12 from age 14 to 25. While BA and SDI stabilized on this treatment, the average height continued to increase while trees per acre decreased at a rate to keep the RS constant. The 1993 time replicate saw the C, F, and H treatments all reach the .11 minimum (Table 3.137). With the exception of one year in the 1989 HF treatment, none of the other treatments on any of the time replicates saw an increase in RS. The increase in RS for the 1989 HF treatment can be attributed to a large decrease in TPA, 32, between years 19 and 20 (Table 3.138). Overall, for all three time replicates and treatments, RS follows similar trends as the stand develops. The RS values for these treatments eventually reach a minimum value and maintain it for the rest of the development phase (Figure 3.96).

Trees per acre development showed similar mortality rates for all treatments on all time replicates from age 5 to 10 (Tables 3.138, 3.139; Figure 3.97). After age 10, greater stem mortality is seen in the HF and F treatments across all time replicates. These increased rates of stem mortality in the HF and F treatments coincide with the advent of crown closure. Prior to crown closure, the mortality rates stayed constant, as noted above, in all treatments, but faster development rates in the HF and F treatments meant that crown closure was happening earlier. Stem mortality rates are shown to decrease in the in the 1987 time replicate after age 17, which corresponds with the stabilization of BA and SDI. While stem mortality is greater in the HF and F treatments, this does not represent a poor stand due to the larger dominant height and quadratic mean diameter expressed by the trees. These variables show that it is the smaller trees that are affected by stem mortality.

Total green tons per acre (GT) development patterns show continued increases as the stand developed for all treatments on all time replicates (Figure 3.98). For all treatments, the maximum GT occurred at the oldest age on each time replicate (Tables 3.140, 3.141). The maximums achieved for C were 165.8, 172.3 and 238.9 tons/acre for the 1987, 1989, and 1993 time replicates, respectively. The maximums for the F treatment were 254.7, 241.6, and 252.4 tons/acre. H maximums were 199.7, 190.1, and 211.9 tons/acre and the HF maximums were 244.3, 275.0, and 242.6 tons/acre for the three time replicates. While the F treatment had the most GT on the 1989 and 1993 time replicates, the max set by the HF treatment on the 1989 time replicate was the most seen on the Waycross - Wet site. While dominant height, basal area, and quadratic mean diameter values were very similar between the HF and F treatments, what allowed for the F treatment to have greater GT maximums on the two time replicates was slightly less mortality (Tables 3.138, 3.139). Mean annual increment (MAI) values showed the C and H treatments reach maximum values at or near the last measurement year (Tables 3.140, 3.141). The C treatment reached maximums of 6.6, 7.5, and 12.0 tons/acre/year for the 1987, 1989, and 1993 time replicates, respectively (Figures 3.99(a), 3.100(a), 3.101(a)). The H treatment had maximums of 8.0, 8.3, and 10.8 tons/acre/year for the three time replicates. For the F and HF treatments, MAI reached maximums right as BA began to stabilize. The F treatment had maximums of 12.9, 12.7, and 13.6 tons/acre/year at ages 12, 13, and 12 for the three time replicates, respectively (Figures 3.99(c), 3.100(c), 3.101(c)). The HF treatment had the highest MAI values achieved on all time replicates, reaching 13.9, 13.7, and 14.3 tons/acre/year were reached at ages 13, 18, and 12, respectively.

Quadratic mean diameter (DQ) had similar growth patterns for the treatments across the three time replicates. On all treatments, DQ continued to increase throughout the study, having the highest values on the final measurement age. The HF and F treatments saw faster development in the early ages of the study, except for the very beginning where the F and H treatments had similar DQ values (Tables 3.144, 3.145; Figure 3.102). Because DQ never decreases on the study, it can be inferred that stem mortality only affects the smaller diameter trees. On all three sites, the HF and F treatments followed similar trajectories, with minimal differences between them at the end of the study (Tables 3.144, 3.144). The H and C treatments followed similar trajectories starting between ages 13 and 15 (Figure 3.102). Maximum DQ values that the HF treatment saw were 10.1, 9.5, and 9.4 inches for the 1987, 1989, and 1993 time replicates. The F treatment had similar maximum values, with 10.1, 9.6, and 9.2 inches for the three time replicates. The H treatment had maximums of 7.6, 7.6, and 7.8 inches and the C treatment had maximums of 7.0, 7.5, and 8.2 inches for the three time replicates.

Pulpwood was present on all time replicates and treatments at the beginning of the study, except for the C treatment in the 1987 time replicate (Tables 3.146, 3.147). Pulpwood weights peaked earliest on the HF treatments in all time replicates, occurring at ages 10, 13, and 10 for the 1987, 1989, and 1993 time replicates, respectively. The F treatments had the second earliest peaks, occurring at age 12 on all time replicates. These earlier peaks for pulpwood development for the HF and F treatments are consistent with the larger DQs seen on these treatments. While peaks occurred earlier on the sites receiving fertilizer, the H and C treatments were able to maintain higher total pulpwood on the sites as the study went on. Chip-n-saw development first occurred on the HF and F treatments for all three time replicates (Tables 3.148, 3.148). Chip-n-saw growth rates were also the highest throughout this study for the HF and F treatments. These product class growth rates for the HF and F treatments develop similarly to the dominant height and DQ. Since the product classes are defined by diameter, treatments increasing DQ experienced greater development in the higher product classes. Increased heights also provided greater product development, which can be seen for the HF and F treatments. Sawtimber also first developed on the HF and F treatments for the time replicates (Tables 3.150, 3.151). As the stand continues to develop, it can be predicted that sawtimber rates will continue to increases as DQ approaches the 12 inch average on the treatments. Under the current stand development patterns, HF and F will continue to develop faster, having greater DQ values thus having greater sawtimber rates.

Cronartium infection rates showed two different development patterns between the three time replicates (Figure 3.104). The 1987 and 1993 time replicates showed low overall infection rates for all treatments (Tables 3.152, 3.153). The first ten years showed the highest infection rates occur in the HF and C treatments for the 1987 time replicate and HF and F treatments on the 1993 time replicate. As the stands continued to develop, the F treatment in the

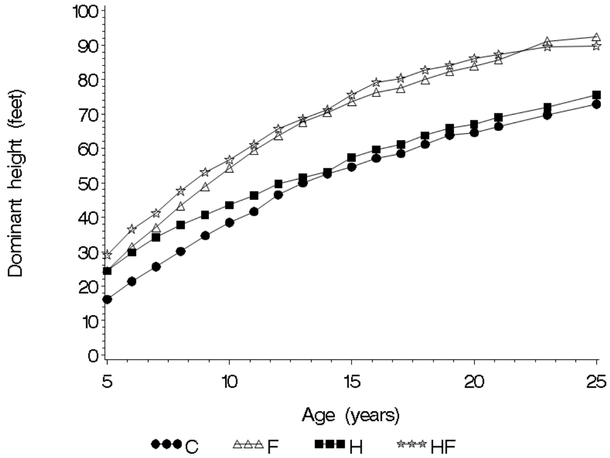
1987 time replicate and the H treatment in the 1993 time replicate had the highest overall infection rate within their time replicates (Tables 3.152, 3.104(c)). It is interesting to see the higher C infection rates in the 1987 time replicate because the C treatment has much lower overall growth rates than the other treatments (Tables 3.142). The 1989 time replicate had comparatively higher rates on all treatments than the two other time replicates. All treatments receiving cultural treatments (H, F, HF) have greater infection rates than the C treatment for this time replicate. Until age 10, infection rates were very similar among the H, F, and HF treatments. These higher rates on this time replicate may be due to climatic differences that favored the spread and infection of cronartium on the site.

Table 3.130: Average dominant height (feet) development at the Waycross - Wet site for the 1987 and 1989 time replicates.

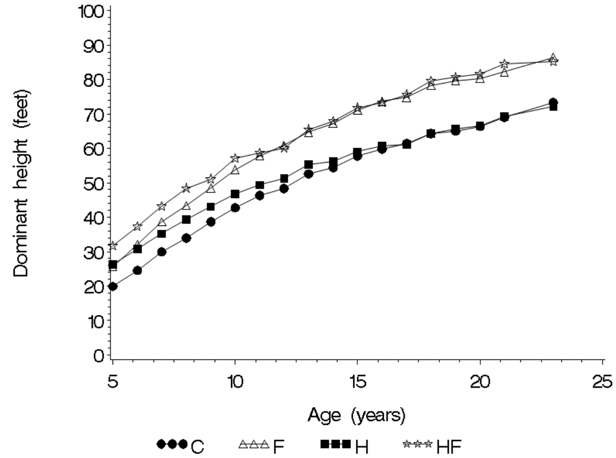
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	16.1	24.5	24.4	29.0	19.9	25.6	26.3	31.7
6	21.4	31.5	29.8	36.5	24.6	32.1	30.7	37.3
7	25.6	37.0	34.1	41.1	30.0	38.6	35.2	43.2
8	30.1	43.3	37.7	47.6	34.0	43.4	39.4	48.4
9	34.7	48.9	40.6	53.0	38.7	48.5	43.1	51.1
10	38.5	54.3	43.5	56.6	42.8	53.8	46.8	57.1
11	41.6	59.4	46.2	61.0	46.3	57.7	49.4	58.6
12	46.5	63.6	49.6	65.6	48.4	60.9	51.3	60.1
13	50.0	67.6	51.6	68.5	52.5	64.7	55.4	65.5
14	52.6	70.4	53.2	71.2	54.4	67.3	56.1	67.9
15	54.5	73.5	57.4	75.5	57.7	71.2	59.0	71.8
16	57.2	76.3	59.7	79.1	59.8	73.7	60.7	73.3
17	58.5	77.5	61.1	80.4	61.4	74.8	61.2	75.6
18	61.2	80.0	63.8	82.7	64.3	78.2	64.4	79.6
19	63.8	82.3	65.9	84.0	65.1	79.7	65.6	80.7
20	64.6	83.8	67.0	86.1	66.4	80.3	66.6	81.6
21	66.4	85.7	69.0	87.2	69.0	82.2	69.2	84.6
23	69.7	91.1	71.9	89.4	73.3	86.4	72.1	85.2
25	72.8	92.4	75.6	89.7	.	.	.	.

Table 3.131: Average dominant height (feet) development at the Waycross - Wet site for the 1993 time replicate.

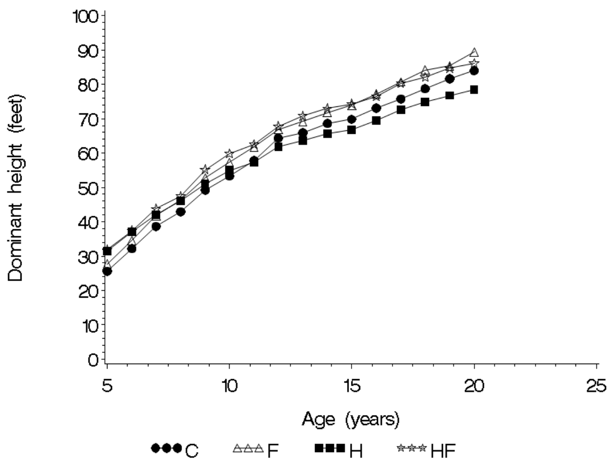
	1993			
Age	C	F	H	HF
5	25.6	27.7	31.5	31.8
6	32.2	34.5	37.1	37.4
7	38.6	41.8	42.1	43.8
8	42.9	46.3	46.1	47.4
9	49.2	52.8	51.1	55.2
10	53.3	57.4	54.9	59.8
11	57.8	61.7	57.4	62.4
12	64.4	66.7	61.8	67.7
13	65.9	69.1	63.7	70.7
14	68.7	71.8	65.6	73.0
15	69.8	73.9	66.8	74.3
16	73.1	77.2	69.5	76.5
17	75.7	80.7	72.7	80.2
18	78.8	84.2	74.8	82.0
19	81.6	85.3	76.8	84.7
20	84.0	89.4	78.5	86.1
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



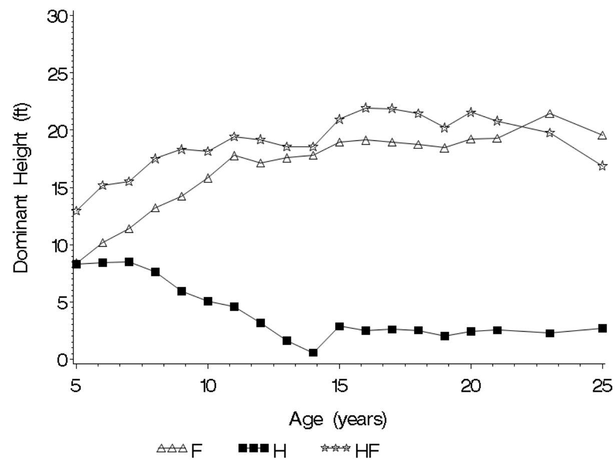
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

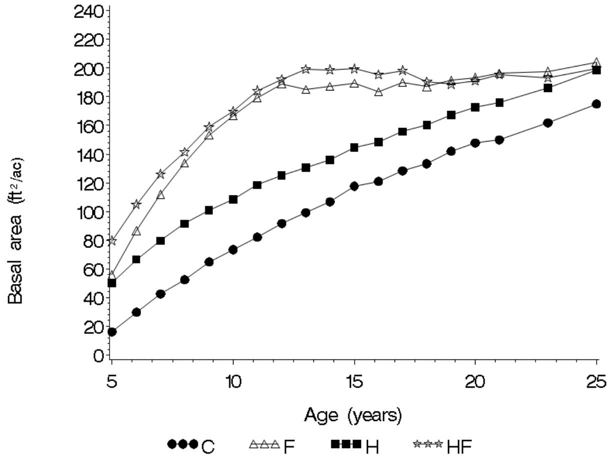
Figure 3.93: Average dominant height (feet) over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.93(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.132: Average basal area (ft^2/acre) at the Waycross - Wet site for the 1987 and 1989 time replicates.

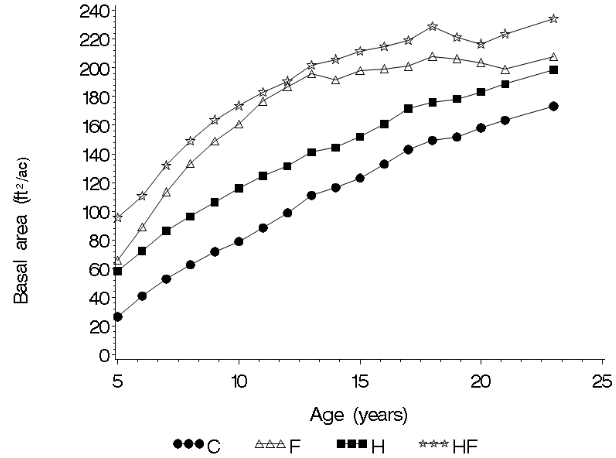
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	16.1	55.9	50.1	79.5	26.5	65.8	58.3	95.4
6	29.8	86.6	66.6	104.9	40.9	89.0	72.2	110.6
7	42.4	112.1	79.6	126.0	52.8	113.5	86.4	131.9
8	52.4	133.8	91.5	141.4	62.8	133.3	96.4	148.8
9	65.0	153.3	101.0	158.9	71.8	148.9	106.3	163.6
10	73.5	166.8	108.5	169.8	78.9	160.7	116.1	173.5
11	82.2	179.3	118.5	184.1	88.3	176.8	124.5	182.9
12	91.7	189.0	125.0	192.1	98.9	186.8	131.4	190.6
13	99.2	185.0	130.6	199.1	111.0	195.8	141.1	201.7
14	106.6	187.3	135.9	198.7	116.4	191.7	144.4	205.8
15	117.6	189.3	144.7	199.4	123.3	198.1	151.9	211.4
16	121.0	183.5	148.4	195.3	132.9	199.4	160.8	214.7
17	128.3	190.0	155.7	198.2	143.0	201.1	171.8	219.0
18	133.3	187.0	160.1	190.3	149.2	207.9	176.0	228.7
19	142.0	191.3	167.4	188.6	151.8	206.4	178.3	221.1
20	147.7	193.4	172.6	191.0	158.1	203.6	183.1	216.5
21	149.8	196.5	175.8	195.3	163.3	199.0	188.6	223.6
23	161.7	197.6	186.0	193.3	173.2	207.8	198.4	234.2
25	174.9	204.2	198.7	199.9	.	.	.	.

Table 3.133: Average basal area (ft^2/acre) at the Waycross - Wet site for the 1993 time replicate.

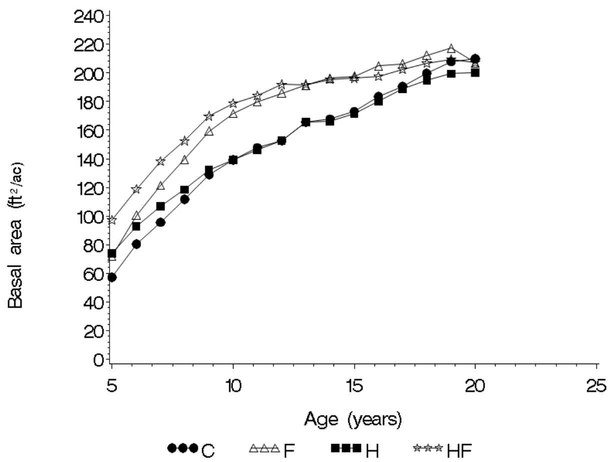
	1993			
Age	C	F	H	HF
5	57.2	71.9	74.1	97.1
6	80.4	100.6	92.9	118.6
7	95.7	121.3	107.0	138.0
8	111.6	139.5	118.5	152.5
9	128.7	159.4	132.0	169.7
10	139.3	171.6	139.2	178.6
11	147.8	179.7	146.0	184.0
12	152.5	185.9	152.8	191.8
13	165.5	191.4	165.8	191.8
14	167.7	196.2	166.2	195.5
15	173.1	197.7	171.4	196.2
16	183.4	204.8	180.2	197.4
17	190.5	206.3	188.7	202.5
18	199.6	212.3	194.6	206.5
19	207.9	217.3	199.4	209.3
20	209.9	207.0	200.3	207.0
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



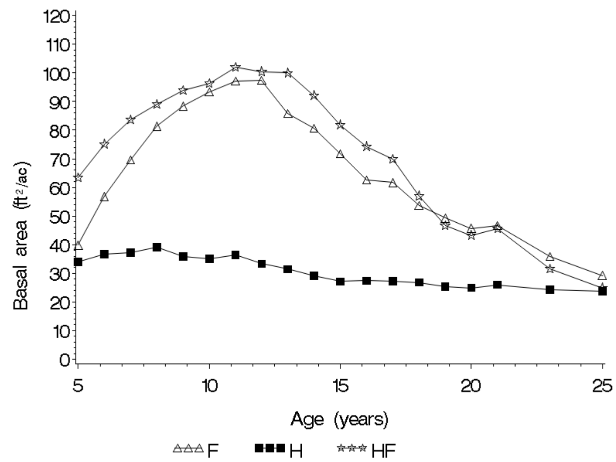
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

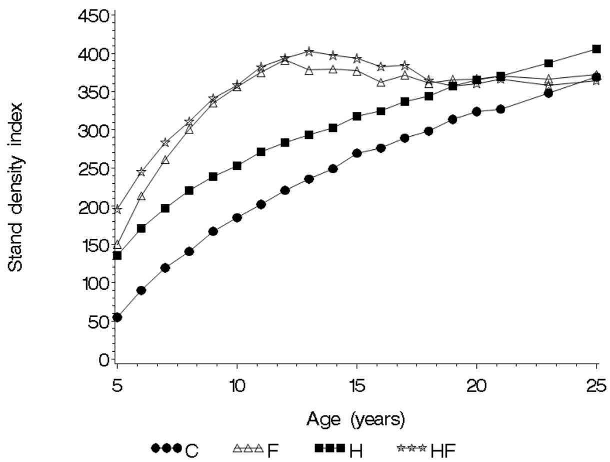
Figure 3.94: Average basal area (ft^2/acre) development over the course of the study for the individual time replicates at the Waycross - Wet site are shown in subfigures 3.94(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.134: Average stand density index development at the Waycross - Wet site for the 1987 and 1989 time replicates.

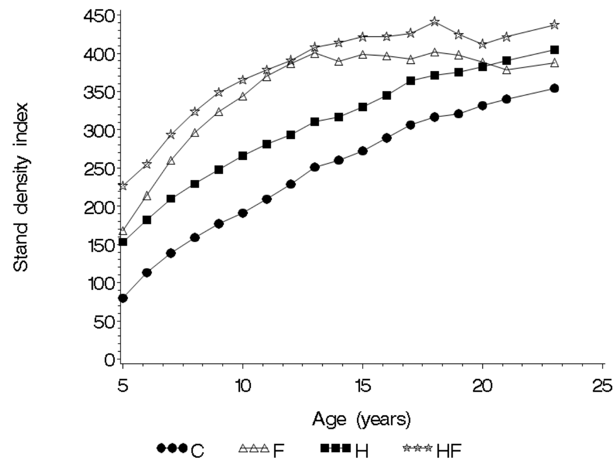
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	54.5	150.2	135.8	195.9	79.6	168.2	153.2	226.5
6	89.7	213.4	170.8	244.8	113.0	214.2	181.8	255.0
7	119.3	260.9	197.3	283.3	138.5	260.1	209.9	293.8
8	140.8	300.8	220.5	310.6	159.0	296.3	229.2	323.7
9	167.3	335.1	238.5	341.1	176.9	323.9	247.9	348.8
10	185.0	356.0	252.7	358.4	190.7	343.8	266.2	365.2
11	202.4	374.9	271.2	382.0	209.1	369.8	281.1	378.1
12	220.8	391.1	283.0	393.3	229.1	386.6	293.6	390.9
13	235.3	378.1	293.0	402.2	251.2	400.4	310.9	408.0
14	249.1	379.2	302.1	397.2	260.5	389.6	316.7	413.5
15	269.5	377.0	317.8	393.1	272.6	398.9	329.8	421.5
16	275.7	362.1	324.3	382.4	289.4	396.5	345.3	421.9
17	289.1	371.7	336.6	383.9	306.3	392.2	364.1	426.3
18	298.1	360.8	344.3	364.6	316.7	401.5	371.3	441.5
19	313.6	365.5	356.8	357.3	321.0	397.9	375.1	424.5
20	323.6	366.6	365.3	360.1	331.5	388.4	382.3	412.1
21	327.0	370.0	370.3	366.0	340.2	378.6	390.5	421.5
23	347.7	366.5	387.0	357.7	354.4	387.7	404.7	437.5
25	369.0	372.3	405.4	364.4	.	.	.	.

Table 3.135: Average stand density index development at the Waycross - Wet site for the 1993 time replicate.

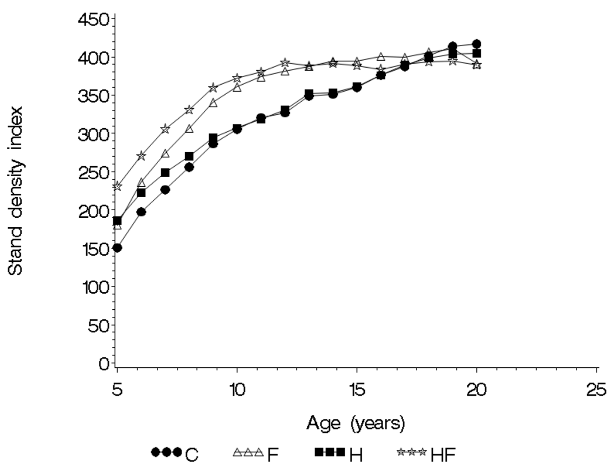
	1993			
Age	C	F	H	HF
5	150.4	180.6	185.9	230.9
6	197.6	236.2	222.7	270.7
7	226.2	274.0	248.9	305.8
8	256.1	306.5	270.1	330.9
9	286.7	340.7	294.6	359.7
10	305.5	360.9	307.1	372.4
11	320.4	374.0	319.0	380.4
12	327.0	381.5	330.5	392.3
13	349.0	387.8	352.5	388.1
14	351.3	394.6	352.7	391.5
15	359.8	394.2	361.6	388.6
16	375.9	400.7	375.9	383.8
17	387.0	399.3	389.6	390.5
18	401.3	406.1	398.3	393.5
19	414.2	411.1	403.5	394.9
20	416.7	391.2	404.5	389.4
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

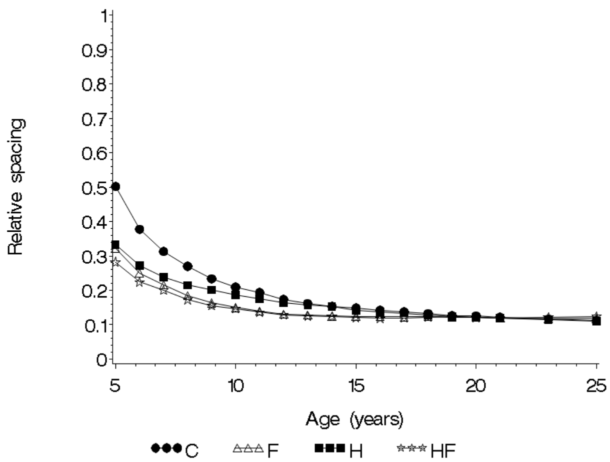
Figure 3.95: Average stand density index over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.95(a)-(c).

Table 3.136: Average relative spacing development at the Waycross - Wet site for the 1987 and 1989 time replicates.

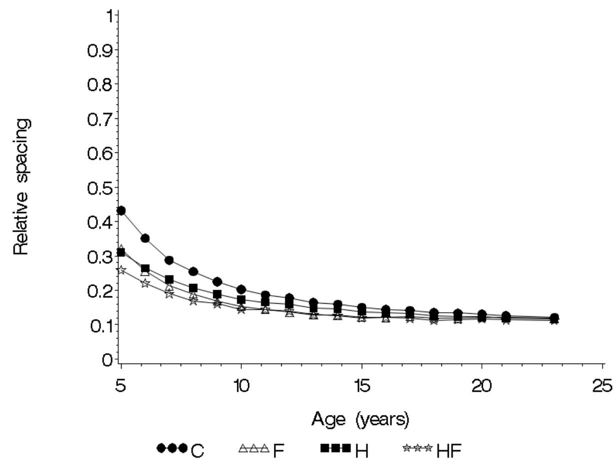
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.50	0.32	0.33	0.28	0.43	0.32	0.31	0.26
6	0.38	0.25	0.27	0.22	0.35	0.26	0.26	0.22
7	0.31	0.22	0.24	0.20	0.29	0.21	0.23	0.19
8	0.27	0.18	0.21	0.17	0.25	0.19	0.21	0.17
9	0.23	0.16	0.20	0.15	0.22	0.17	0.19	0.16
10	0.21	0.15	0.19	0.15	0.20	0.15	0.17	0.14
11	0.19	0.14	0.18	0.14	0.19	0.14	0.17	0.14
12	0.17	0.13	0.16	0.13	0.18	0.14	0.16	0.14
13	0.16	0.13	0.16	0.12	0.16	0.13	0.15	0.13
14	0.15	0.12	0.15	0.12	0.16	0.13	0.15	0.13
15	0.15	0.12	0.14	0.12	0.15	0.12	0.14	0.12
16	0.14	0.12	0.14	0.12	0.14	0.12	0.13	0.12
17	0.14	0.12	0.13	0.12	0.14	0.12	0.13	0.12
18	0.13	0.12	0.13	0.12	0.14	0.12	0.13	0.11
19	0.13	0.12	0.12	0.12	0.13	0.12	0.12	0.11
20	0.13	0.12	0.12	0.12	0.13	0.12	0.12	0.12
21	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.11
23	0.12	0.12	0.11	0.12	0.12	0.12	0.12	0.11
25	0.11	0.12	0.11	0.12	.	.	.	.

Table 3.137: Average relative spacing development at the Waycross - Wet site for the 1993 time replicate.

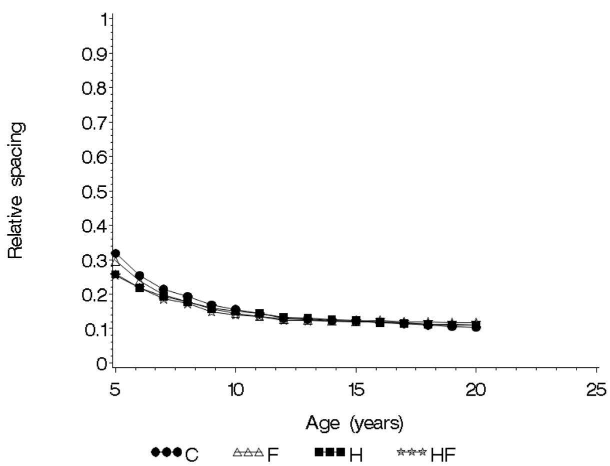
	1993			
Age	C	F	H	HF
5	0.32	0.30	0.26	0.25
6	0.25	0.24	0.22	0.22
7	0.21	0.20	0.19	0.19
8	0.19	0.18	0.18	0.17
9	0.17	0.16	0.16	0.15
10	0.16	0.14	0.15	0.14
11	0.14	0.14	0.14	0.13
12	0.13	0.13	0.13	0.12
13	0.13	0.13	0.13	0.12
14	0.12	0.12	0.13	0.12
15	0.12	0.12	0.12	0.12
16	0.12	0.12	0.12	0.12
17	0.11	0.12	0.11	0.12
18	0.11	0.11	0.11	0.12
19	0.11	0.11	0.11	0.12
20	0.10	0.11	0.11	0.12
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

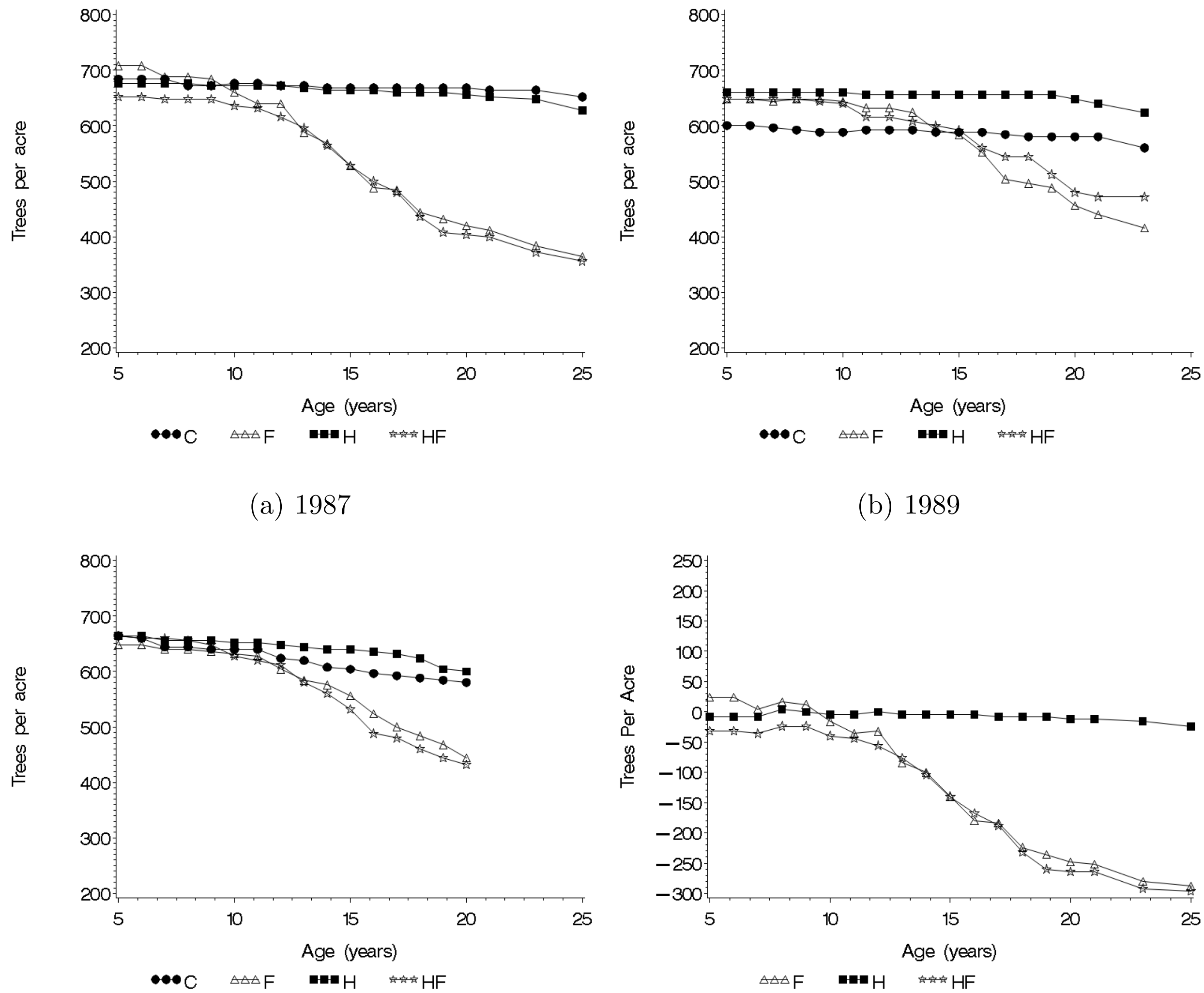
Figure 3.96: Average relative spacing development over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.96(a)-(c).

Table 3.138: Average trees per acre development at the Waycross - Wet site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	684	708	676	652	600	648	660	648
6	684	708	676	652	600	648	660	648 .0
7	684	688	676	648	596	644	660	648
8	672	688	676	648	592	648	660	648
9	672	684	672	648	588	648	660	644
10	676	660	672	636	588	644	660	640
11	676	640	672	632	592	632	656	616
12	672	640	672	616	592	632	656	616
13	672	588	668	596	592	624	656	608
14	668	568	664	564	588	592	656	600
15	668	528	664	528	588	584	656	592
16	668	488	664	500	588	552	656	560
17	668	484	660	480	584	504	656	544
18	668	444	660	436	580	496	656	544
19	668	432	660	408	580	488	656	512
20	668	420	656	404	580	456	648	480
21	664	412	652	400	580	440	640	472
23	664	384	648	372	560	416	624	472
25	652	364	628	356	.	.	.	.

Table 3.139: Average trees per acre development at the Waycross - Wet site for the 1993 time replicate.

	1993			
Age	C	F	H	HF
5	664	648	664	664
6	660	648	664	660
7	644	640	656	660
8	644	640	656	656
9	640	636	656	648
10	640	632	652	628
11	640	628	652	620
12	624	604	648	612
13	620	584	644	580
14	608	576	640	560
15	604	556	640	532
16	596	524	636	488
17	592	500	632	480
18	588	484	624	460
19	584	468	604	444
20	580	444	600	432
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987

(b) 1989

(c) 1993

(d) 1987 Treatment Effects

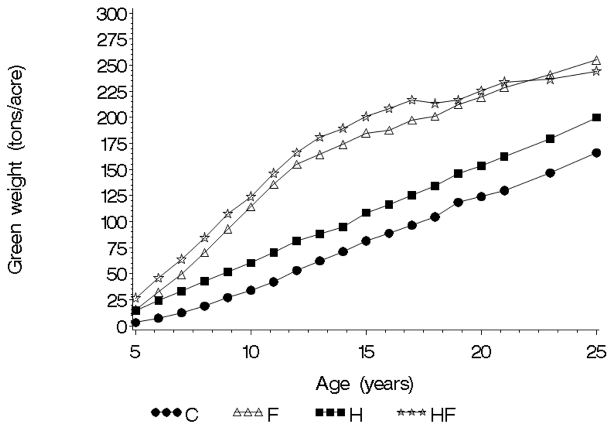
Figure 3.97: Average trees per acre development over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.97(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.140: Average total green weight (tons/acre) development at the Waycross - Wet site for the 1987 and 1989 time replicates.

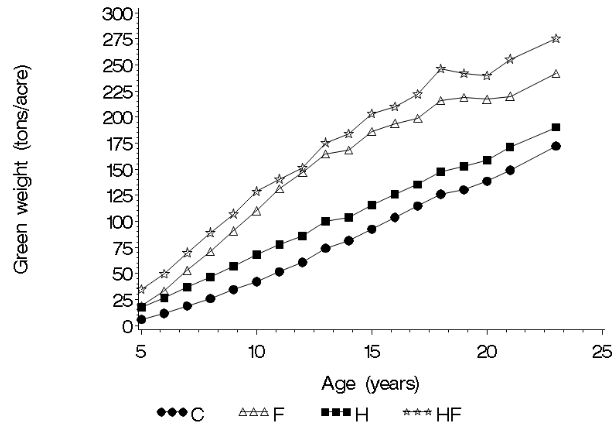
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	3.0	15.5	14.4	26.6	5.9	18.9	17.7	34.5
6	7.3	32.0	24.0	45.6	11.6	33.0	26.2	49.5
7	12.4	49.2	33.0	63.7	18.6	52.8	36.6	69.6
8	18.6	70.4	42.7	84.6	25.8	70.9	46.4	89.0
9	26.8	92.8	51.5	107.3	34.4	90.6	56.6	106.8
10	34.1	114.1	60.2	123.8	42.0	110.1	67.9	128.6
11	42.1	135.4	70.0	146.1	51.4	131.2	77.4	140.3
12	52.8	154.8	81.1	166.0	60.5	146.9	85.9	150.9
13	62.3	164.3	87.8	180.9	74.0	164.7	99.9	175.2
14	71.1	173.8	94.5	189.3	81.3	168.1	103.5	184.0
15	81.4	184.8	108.4	200.6	92.3	185.9	115.7	203.2
16	88.4	187.4	116.3	208.3	103.6	193.7	126.0	209.8
17	96.4	197.3	125.0	216.3	114.5	198.9	135.2	221.6
18	104.4	200.8	134.4	213.3	125.9	215.7	147.6	246.3
19	118.2	212.0	145.8	216.5	130.0	218.6	152.9	241.9
20	124.0	219.1	153.4	225.3	138.3	216.9	158.7	239.6
21	129.7	228.7	162.2	233.9	148.9	219.8	171.3	255.4
23	146.5	241.1	179.1	236.2	172.3	241.6	190.1	275.0
25	165.8	254.7	199.7	244.3	.	.	.	.

Table 3.141: Average total green weight (tons/acre) development at the Waycross - Wet site for the 1993 time replicate.

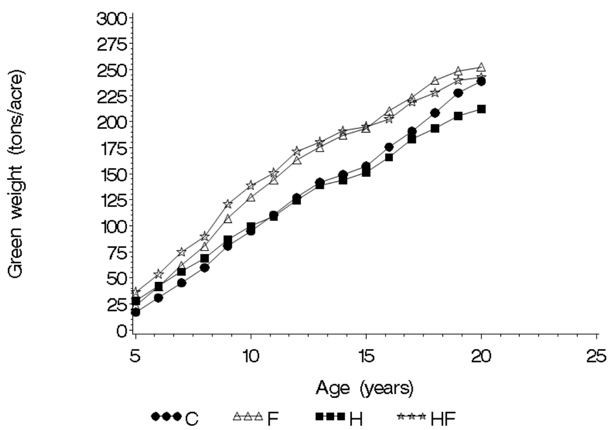
	1993			
Age	C	F	H	HF
5	17.0	23.2	27.8	36.4
6	30.6	41.4	42.2	53.4
7	45.3	61.9	55.8	74.5
8	59.5	80.4	68.8	89.7
9	80.6	107.0	86.5	120.5
10	95.1	127.5	99.6	138.7
11	110.1	143.8	109.1	150.7
12	127.0	162.9	124.3	171.5
13	141.7	175.5	138.8	180.4
14	149.0	187.0	143.6	191.0
15	157.3	193.7	151.0	195.3
16	175.4	210.2	165.6	202.7
17	190.7	222.9	182.9	218.8
18	208.4	239.7	193.6	227.7
19	227.4	248.7	205.2	239.7
20	238.9	252.4	211.9	242.6
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



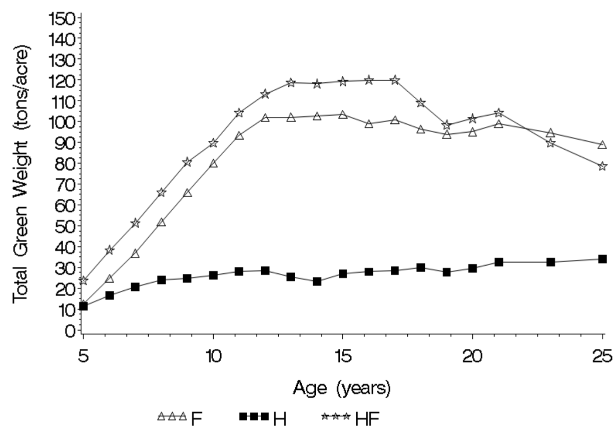
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

Figure 3.98: Average total green weight (tons/acre) over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.98(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.142: Mean annual increment (tons/acre/year) development at the Waycross - Wet site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	0.6	3.1	2.9	5.3	1.2	3.8	3.6	6.9
6	1.2	5.3	4.0	7.6	1.9	5.5	4.4	8.3
7	1.8	7.0	4.7	9.1	2.7	7.5	5.2	9.9
8	2.3	8.8	5.3	10.6	3.2	8.9	5.8	11.1
9	3.0	10.3	5.7	11.9	3.8	10.1	6.3	11.9
10	3.4	11.4	6.0	12.4	4.2	11.0	6.8	12.9
11	3.8	12.3	6.4	13.3	4.7	11.9	7.0	12.8
12	4.4	12.9	6.8	13.8	5.0	12.2	7.2	12.6
13	4.8	12.6	6.8	13.9	5.7	12.7	7.7	13.5
14	5.1	12.4	6.8	13.5	5.8	12.0	7.4	13.1
15	5.4	12.3	7.2	13.4	6.2	12.4	7.7	13.6
16	5.5	11.7	7.3	13.0	6.5	12.1	7.9	13.1
17	5.7	11.6	7.4	12.7	6.7	11.7	8.0	13.0
18	5.8	11.2	7.5	11.9	7.0	12.0	8.2	13.7
19	6.2	11.2	7.7	11.4	6.8	11.5	8.0	12.7
20	6.2	11.0	7.7	11.3	6.9	10.8	7.9	12.0
21	6.2	10.9	7.7	11.1	7.1	10.5	8.2	12.2
23	6.4	10.5	7.8	10.3	7.5	10.5	8.3	12.0
25	6.6	10.2	8.0	9.8	.	.	.	.

Table 3.143: Mean annual increment (tons/acre/year) development at the Waycross - Wet site for the 1993 time replicate.

	1993			
Age	C	F	H	HF
5	3.4	4.6	5.6	7.3
6	5.1	6.9	7.0	8.9
7	6.5	8.9	8.0	10.6
8	7.4	10.1	8.6	11.2
9	9.0	11.9	9.6	13.4
10	9.5	12.8	10.0	13.9
11	10.0	13.1	9.9	13.7
12	10.6	13.6	10.4	14.3
13	10.9	13.5	10.7	13.9
14	10.6	13.4	10.3	13.6
15	10.5	12.9	10.1	13.0
16	11.0	13.1	10.4	12.7
17	11.2	13.1	10.8	12.9
18	11.6	13.3	10.8	12.7
19	12.0	13.1	10.8	12.6
20	11.9	12.6	10.6	12.1
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

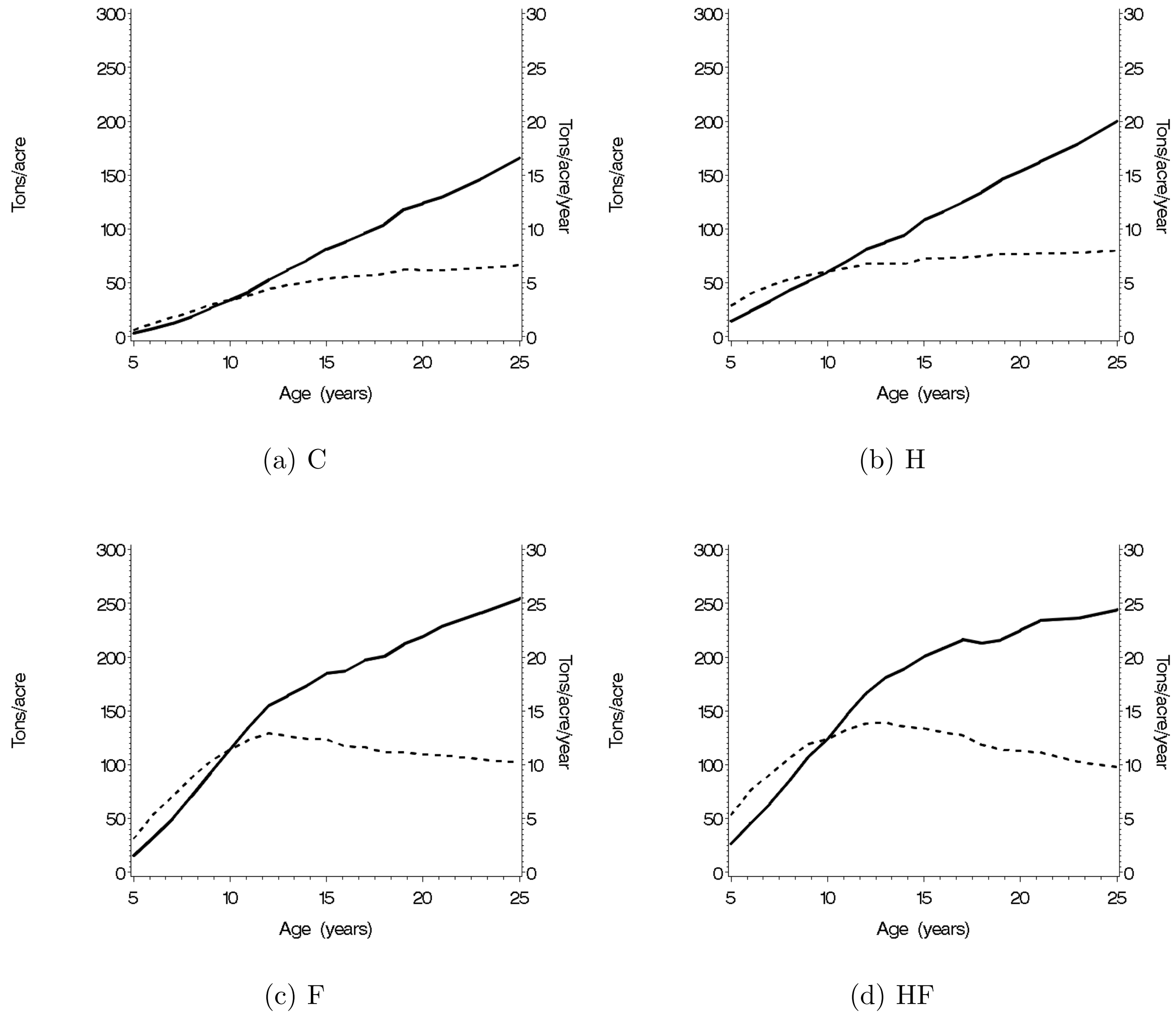
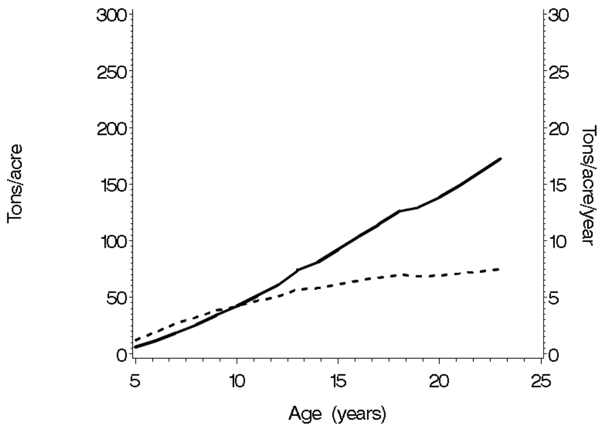
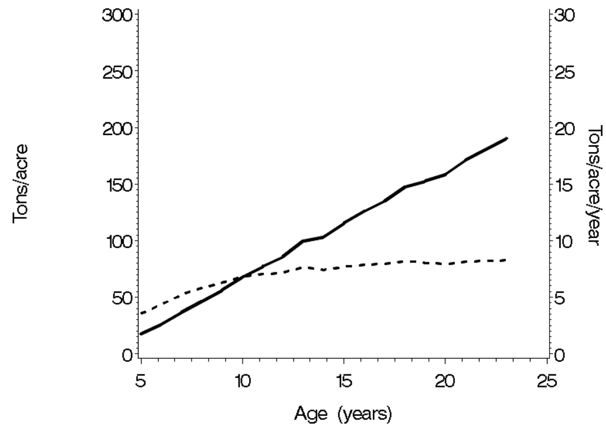


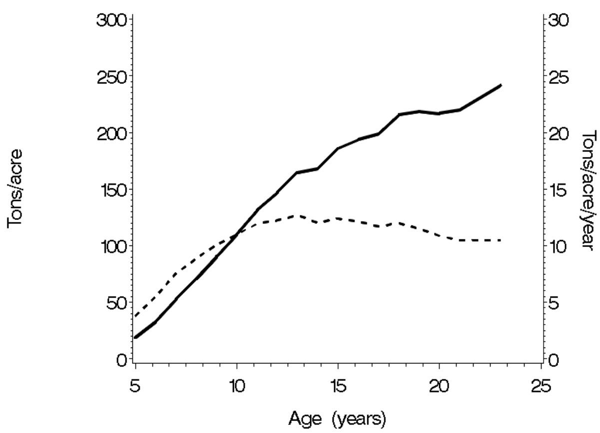
Figure 3.99: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Waycross - Wet 1987 time replicate.



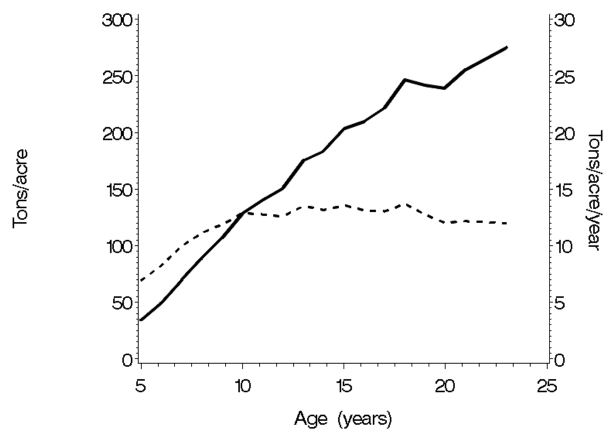
(a) C



(b) H

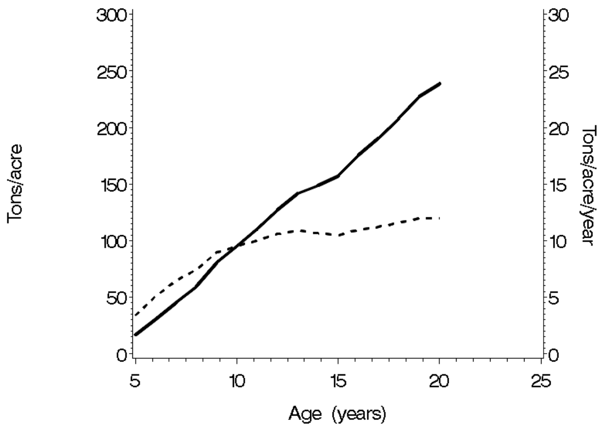


(c) F

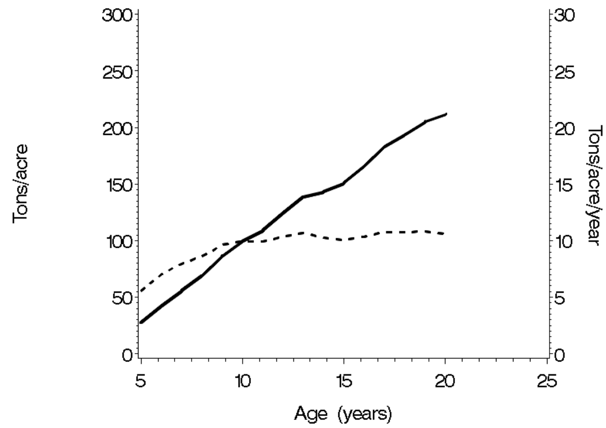


(d) HF

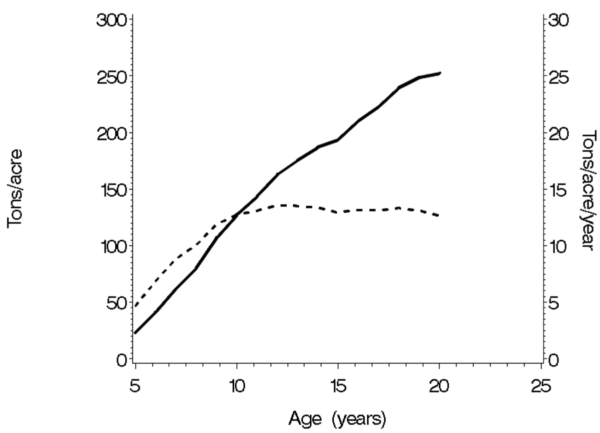
Figure 3.100: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (——–) by treatment for the Waycross - Wet 1989 time replicate.



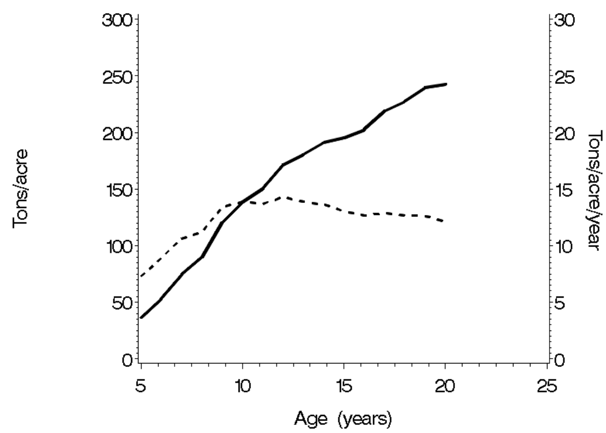
(a) C



(b) H



(c) F



(d) HF

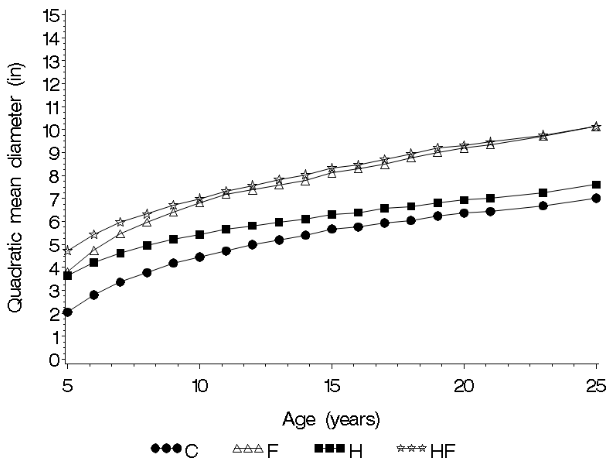
Figure 3.101: Mean annual increment (tons/acre/year) (– – –) and total green weight (tons/acre) (———) by treatment for the Waycross - Wet 1993 time replicate.

Table 3.144: Average quadratic mean diameter (inches) development at the Waycross - Wet site for the 1987 and 1989 time replicates.

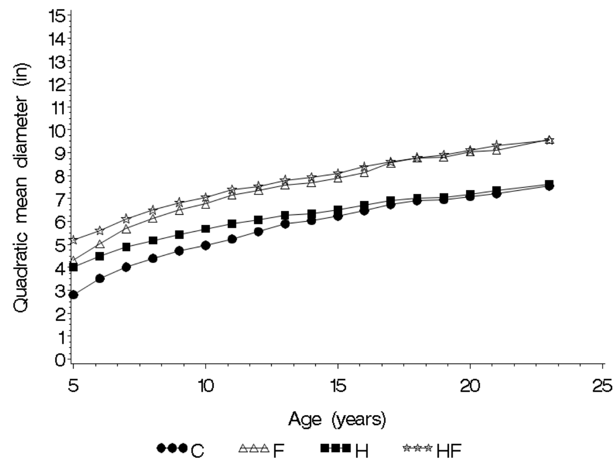
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	2.1	3.8	3.7	4.7	2.8	4.3	4.0	5.2
6	2.8	4.7	4.2	5.4	3.5	5.0	4.5	5.6
7	3.4	5.5	4.6	6.0	4.0	5.7	4.9	6.1
8	3.8	6.0	5.0	6.3	4.4	6.1	5.2	6.5
9	4.2	6.4	5.2	6.7	4.7	6.5	5.4	6.8
10	4.5	6.8	5.4	7.0	5.0	6.8	5.7	7.1
11	4.7	7.2	5.7	7.3	5.2	7.2	5.9	7.4
12	5.0	7.4	5.8	7.6	5.6	7.4	6.1	7.5
13	5.2	7.6	6.0	7.8	5.9	7.6	6.3	7.8
14	5.4	7.8	6.1	8.0	6.1	7.7	6.4	7.9
15	5.7	8.1	6.3	8.3	6.2	7.9	6.5	8.1
16	5.8	8.3	6.4	8.5	6.5	8.1	6.7	8.4
17	5.9	8.5	6.6	8.7	6.7	8.6	6.9	8.6
18	6.1	8.8	6.7	8.9	6.9	8.8	7.0	8.8
19	6.2	9.0	6.8	9.2	7.0	8.8	7.1	8.9
20	6.4	9.2	6.9	9.3	7.1	9.1	7.2	9.1
21	6.4	9.4	7.0	9.5	7.2	9.1	7.4	9.3
23	6.7	9.7	7.2	9.8	7.5	9.6	7.6	9.5
25	7.0	10.1	7.6	10.1	.	.	.	.

Table 3.145: Average quadratic mean diameter (inches) development at the Waycross - Wet site for the 1993 time replicate.

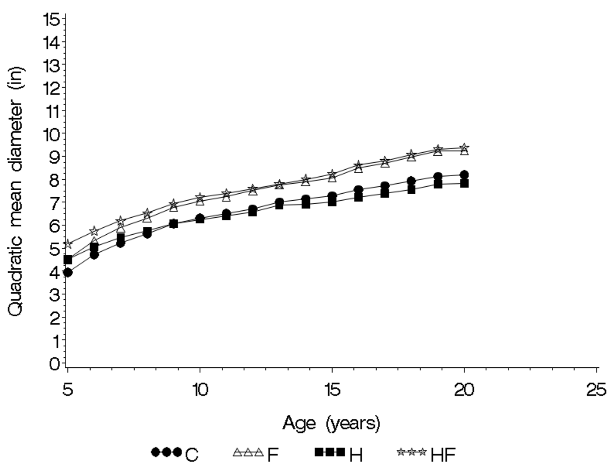
	1993			
Age	C	F	H	HF
5	4.0	4.5	4.5	5.2
6	4.7	5.3	5.1	5.7
7	5.2	5.9	5.5	6.2
8	5.6	6.3	5.8	6.5
9	6.1	6.8	6.1	6.9
10	6.3	7.1	6.3	7.2
11	6.5	7.2	6.4	7.4
12	6.7	7.5	6.6	7.6
13	7.0	7.8	6.9	7.8
14	7.1	7.9	6.9	8.0
15	7.3	8.1	7.0	8.2
16	7.5	8.5	7.2	8.6
17	7.7	8.7	7.4	8.8
18	7.9	9.0	7.6	9.1
19	8.1	9.2	7.8	9.3
20	8.2	9.2	7.8	9.4
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



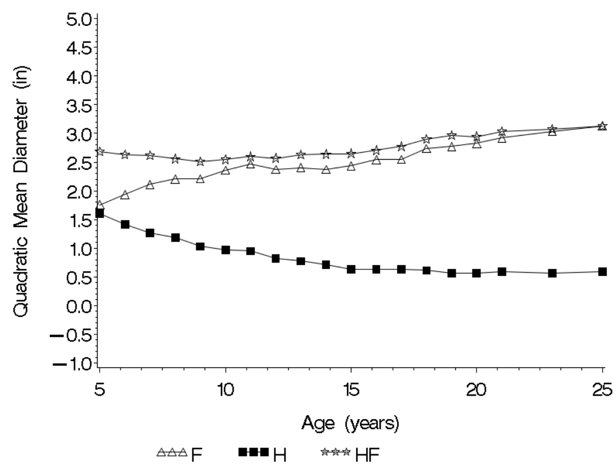
(a) 1987



(b) 1989



(c) 1993



(d) 1987 Treatment Effects

Figure 3.102: Average quadratic mean diameter (inches) over the course of the study for the individual time replicates at the Waycross - Wet site is shown in subfigures 3.102(a)-(c). Subfigure (d) shows the treatment effects by subtracting the control treatment from each of the individual treatments.

Table 3.146: Average pulpwood development (tons/acre) at the Waycross - Wet site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	8.6	6.8	24.2	0.3	15.0	11.8	32.7
6	1.5	28.6	19.3	43.4	4.1	30.7	22.0	47.9
7	5.3	47.1	29.4	61.7	12.4	49.3	34.4	66.8
8	12.0	66.0	39.4	80.4	21.4	66.8	44.3	81.0
9	20.6	81.9	48.9	94.1	30.1	80.5	54.7	92.6
10	27.5	92.5	57.9	99.6	38.8	91.4	66.0	104.0
11	35.9	96.6	67.9	98.5	49.0	94.5	74.2	101.2
12	47.2	100.7	78.6	98.5	58.0	96.9	81.2	104.9
13	56.6	95.6	85.3	98.1	70.9	95.3	90.1	106.7
14	64.0	94.8	91.2	84.8	72.2	91.2	93.1	99.3
15	72.2	85.7	101.7	78.8	78.9	88.5	99.4	99.6
16	78.1	77.9	107.6	74.8	82.7	82.8	102.5	90.8
17	81.3	75.3	111.7	71.9	87.6	70.4	104.8	85.3
18	85.5	66.7	116.0	64.6	94.3	72.4	104.6	86.4
19	87.6	65.1	117.3	58.3	94.0	73.0	107.9	84.7
20	86.5	63.7	116.7	59.3	95.1	65.0	103.3	72.9
21	86.9	61.0	119.1	57.4	98.8	59.0	102.3	70.2
23	82.5	52.0	110.1	52.4	103.2	58.9	101.9	72.3
25	81.6	50.3	103.3	50.3	.	.	.	.

Table 3.147: Average pulpwood development (tons/acre) at the Waycross - Wet site for the 1993 time replicate.

	1993			
Age	C	F	H	HF
5	11.2	20.2	24.6	34.8
6	27.1	39.4	40.4	51.8
7	43.2	60.4	54.1	72.3
8	57.3	77.5	67.3	85.1
9	74.9	94.0	84.2	105.2
10	87.3	104.3	94.1	110.4
11	96.9	106.1	97.3	109.7
12	109.2	107.8	107.7	109.1
13	111.4	104.0	111.4	104.7
14	108.3	100.9	113.1	98.2
15	108.7	96.7	114.3	85.8
16	105.2	81.8	114.6	73.5
17	104.0	73.7	114.0	70.5
18	106.0	69.7	109.9	69.1
19	104.7	66.8	104.5	65.3
20	107.6	67.2	107.9	67.0
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.148: Average chip-n-saw development (tons/acre) at the Waycross - Wet site for the 1987 and 1989 time replicates.

	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	1.4	.	1.1
8	.	2.1	.	2.4	.	2.1	.	6.3
9	.	8.4	.	11.5	.	8.1	.	12.7
10	.	19.3	.	22.7	.	16.7	.	22.9
11	.	37.0	.	46.0	.	35.0	1.2	37.8
12	.	52.3	.	66.0	.	48.2	2.7	44.7
13	1.3	67.4	.	81.4	1.7	67.6	7.7	67.1
14	2.1	77.6	1.6	103.2	13.7	75.2	8.4	83.3
15	4.1	97.9	9.1	120.6	11.1	95.7	14.2	102.3
16	5.2	108.4	6.5	132.3	18.4	109.6	21.4	117.7
17	10.1	120.9	11.2	143.3	24.7	122.0	28.3	135.1
18	13.8	133.1	16.2	147.6	29.4	136.4	40.8	152.7
19	25.9	140.5	26.4	151.1	33.7	138.3	42.7	149.4
20	33.0	142.7	34.5	158.7	40.9	138.6	53.4	153.2
21	38.4	148.2	41.2	168.4	47.8	151.5	67.1	164.6
23	59.6	155.3	66.7	167.9	64.1	159.4	86.2	175.1
25	80.3	151.1	91.4	156.4	.	.	.	.

Table 3.149: Average chip-n-saw development (tons/acre) at the Waycross - Wet site for the 1993 time replicate.

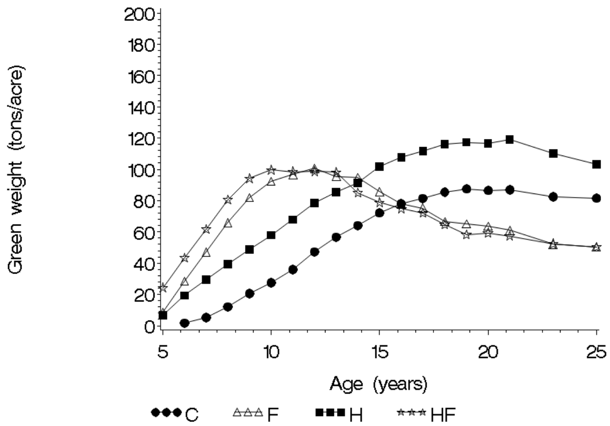
	1993			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	.	.	1.1
8	.	2.5	.	2.8
9	7.8	11.4	1.4	13.5
10	11.5	21.6	3.9	26.7
11	11.3	36.1	10.1	39.6
12	16.1	53.6	14.9	60.9
13	28.6	70.1	25.8	74.3
14	39.0	84.7	28.9	91.5
15	46.9	95.7	35.0	108.3
16	68.8	124.3	49.4	128.1
17	85.2	144.7	67.2	147.2
18	100.9	162.0	82.1	149.0
19	117.9	170.7	99.1	163.9
20	122.7	166.2	102.4	164.5
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.

Table 3.150: Average sawtimber development (tons/acre) at the Waycross - Wet site for the 1987 and 1989 time replicates.

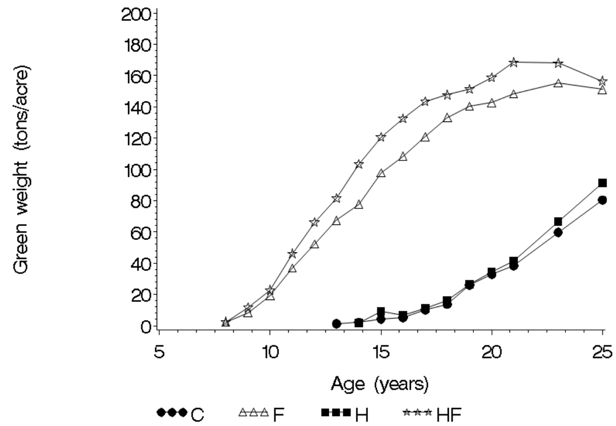
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	.	.	.	.	.	.	.	.
6	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
8	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.
10	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.
17	.	.	.	.	.	5.3	.	.
18	.	.	.	.	.	5.8	.	5.9
19	.	10.8	.	12.4	.	6.2	.	6.6
20	.	11.7	.	12.8	.	12.3	.	12.5
21	.	18.5	.	14.3	.	8.3	.	19.5
23	.	32.9	.	15.1	5.5	22.3	.	26.6
25	.	52.5	6.4	36.9	.	.	.	.

Table 3.151: Average sawtimber development (tons/acre) at the Waycross - Wet site for the 1993 time replicate.

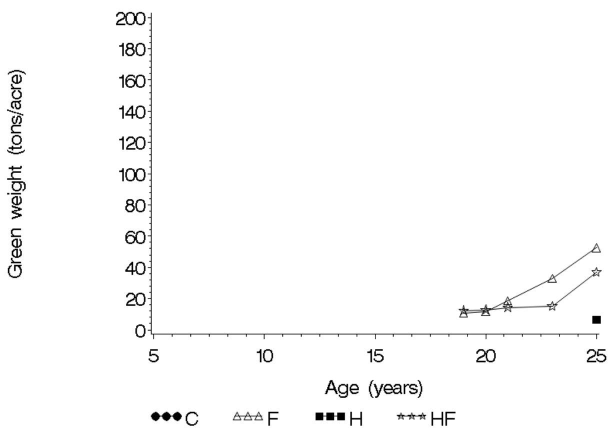
	1993			
Age	C	F	H	HF
5	.	.	.	.
6	.	.	.	.
7	.	.	.	.
8	.	.	.	.
9	.	.	.	.
10	.	.	.	.
11	.	.	.	.
12	.	.	.	.
13	.	.	.	.
14	.	.	.	.
15	.	.	.	.
16	.	5.7	.	.
17	.	6.6	.	.
18	.	13.7	.	17.1
19	6.5	20.4	.	19.1
20	14.0	36.0	.	20.2
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) Pulpwood



(b) Chip-N-Saw



(c) Sawtimber

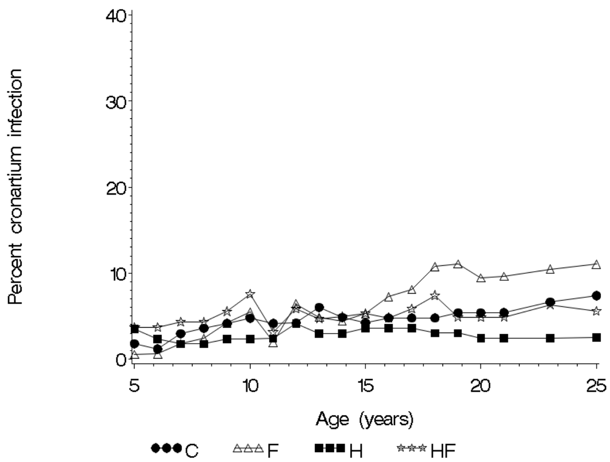
Figure 3.103: Average product distribution (tons/acre) over the course of the study for the Waycross - Wet 1987 time replicate. Pulpwood is shown in 3.103(a), Chip-N-Saw in 3.103(b), and sawtimber in 3.103(c).

Table 3.152: Average cronartium infection rates (%) at the Waycross - Wet site for the 1987 and 1989 time replicates.

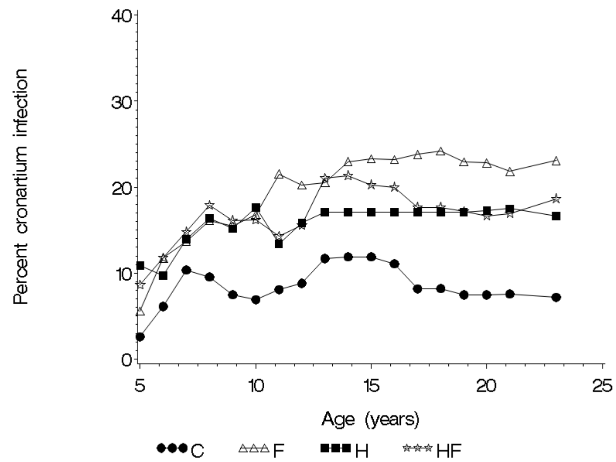
	1987				1989			
Age	C	F	H	HF	C	F	H	HF
5	1.8	0.5	3.5	3.7	2.6	5.6	10.9	8.7
6	1.2	0.6	2.3	3.7	6.1	11.8	9.7	11.8
7	2.9	1.8	1.8	4.3	10.4	13.7	13.9	14.8
8	3.6	2.4	1.8	4.3	9.6	16.1	16.4	17.9
9	4.2	4.2	2.3	5.5	7.5	15.5	15.2	16.1
10	4.7	5.4	2.3	7.5	6.9	16.8	17.6	16.2
11	4.2	1.9	2.4	3.2	8.1	21.5	13.4	14.3
12	4.2	6.4	4.1	5.9	8.8	20.3	15.9	15.6
13	6.0	4.8	3.0	4.7	11.7	20.5	17.1	21.1
14	4.8	4.4	3.0	5.0	11.9	23.0	17.1	21.3
15	4.2	5.3	3.6	5.3	11.9	23.3	17.1	20.3
16	4.8	7.3	3.6	4.8	11.1	23.2	17.1	20.0
17	4.8	8.1	3.6	5.8	8.2	23.8	17.1	17.7
18	4.8	10.8	3.0	7.4	8.2	24.2	17.1	17.7
19	5.4	11.1	3.0	4.9	7.5	23.0	17.1	17.2
20	5.4	9.4	2.4	4.9	7.5	22.8	17.3	16.7
21	5.4	9.6	2.4	4.9	7.6	21.8	17.5	17.0
23	6.6	10.5	2.4	6.3	7.2	23.1	16.7	18.6
25	7.4	11.0	2.6	5.6	.	.	.	.

Table 3.153: Average cronartium infection rates (%) at the Waycross - Wet site for the 1993 time replicate.

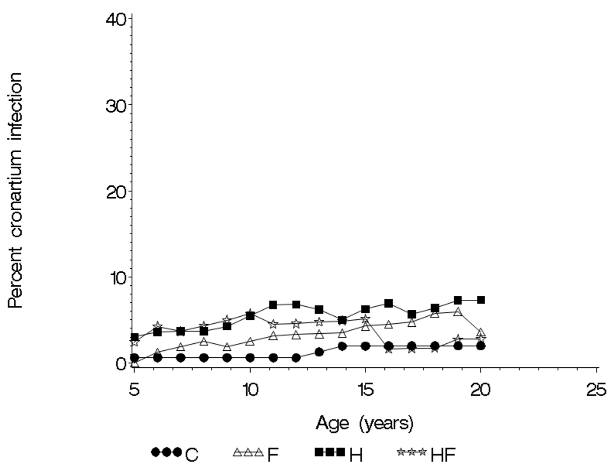
	1993			
Age	C	F	H	HF
5	0.6	0.0	3.0	2.4
6	0.6	1.2	3.6	4.3
7	0.6	1.9	3.7	3.7
8	0.6	2.5	3.7	4.3
9	0.6	1.9	4.3	5.0
10	0.6	2.5	5.5	5.7
11	0.6	3.2	6.7	4.5
12	0.6	3.3	6.8	4.6
13	1.3	3.4	6.2	4.7
14	1.9	3.5	5.0	4.9
15	1.9	4.3	6.3	5.1
16	2.0	4.5	6.9	1.6
17	2.0	4.7	5.7	1.7
18	2.0	5.8	6.4	1.7
19	2.0	6.0	7.3	2.8
20	2.0	3.6	7.3	2.8
21	.	.	.	.
23	.	.	.	.
25	.	.	.	.



(a) 1987



(b) 1989



(c) 1993

Figure 3.104: Average cronartium infection rates (%) over the course of the study for the individual time replicates at the Waycross - Wet site are shown in subfigures 3.104(a)-(c).

Chapter 4

Discussion and Conclusion

Inherent site quality is a very important aspect for forest managers when preparing management plans for current and future stands. Knowing the site index for a given stand, along with geography and management goals, provides a forester with necessary information to choose species, specific genetics, site preparation methods, mid-rotation stand treatments, rotation length, harvest schedules, and other planning activities. While it was not the goal of the initial researchers of this study to choose only high quality sites, it was shown that with proper site preparation techniques, sites can be manipulated to have higher base site indices for loblolly pine. Base site indices for C treatments seen in this study ranged from the lowest of 73 feet at age 25 on the Waycross - Wet site to the highest of 93 feet at age 25 on the Dawsonville - Bottom site (Tables 3.130, 3.59). This range of base site indices seen in this study are much higher than what is reported for "average" sites across the southeastern United States for loblolly pine. It can be seen that good mechanical site preparation, which was applied to all sites, can ameliorate low site quality on typically nutrient deficient Coastal Plain sites. Appropriate mechanical site preparation coupled with suitable genetics provided high base site index for all locations throughout Georgia.

Cultural treatments applied (H, F, and HF) were shown to increase site quality, measured through increases in site index, at varying rates on different sites. Due to differences in nutrient deficiencies and competition rates, sites responded differently. Sites in the Coastal Plain typically saw the greatest treatment effects in the HF or F treatments compared with the C treatment. The Waycross - Wet site had all three time replicates have the greatest dominant height occur in the F treatments in the last measurement year (Table 3.130, 3.131).

The Waycross - Dry site had two out of its three time replicates end with a greater dominant height in the HF treatment at the last measurement year (Tables 3.106, 3.107). Piedmont sites showed different treatment effects between sites and time replicates. The Athens site showed little difference between the C, F, and H treatments in the 1989 time replicates, which all were approximately 80 feet at age 25, while the HF treatment reached 91 feet. The Eatonton - Monitor and Powerline sites showed distinct differences between treatments, with the HF having the greatest response, followed by the F then H treatments for the 1988 and 1990 time replicates. The Dawsonville - Bottom site had the greatest dominant height growth in the C and H treatments for the 1989 time replicate, followed by the HF then F treatments (Table 3.59). While the Dawsonville - Bottom 1987 F treatment was abandoned at an early age due to excessive mortality caused by competition, the remaining treatments showed little differences between the HF and H treatments (Table 3.71). The Dawsonville - Bottom site was a special case due to its location in a river bottom, leading to excessive competition (still adding stuff). Across this study, Coastal Plain sites showed greater nutrient deficiencies, seen by varying levels of height growth in response to H and F treatments. Overall, on nutrient deficient sites, providing nutrient amendments sustained the greatest increase in site quality in the HF and F treatments. On Piedmont sites that were not nutrient deficient, H treatments were adequate to provide the greatest height growth response for the first 10-15 years of development. During that time period, which coincided with crown closure, growth response became greater for sites that received fertilization treatments. Cultural treatments were shown to increase site quality, but they did not affect site carrying capacity. Through the increases in site quality, stands were able to reach the site carrying capacity faster. The Waycross - Wet site showed the HF and F treatments peaking between approximately 190-200 ft^2/acre around age 13, where the C and H treatments reach their peaks around age 25 (Figure 3.94).

Stand density can be evaluated through examination of several variables, including trees per acre, stand density index, relative spacing, and basal area per acre. Stand density in this study was measured by stand density index (SDI) and relative spacing (RS). Reineke reported that the maximum stand density index for loblolly pine is 450 (1933). This study observed several sites exceed that maximum. Stand density index showed the greatest rates on the Dawsonville - Top site, where SDI in the 1987 H treatment reached 455.2 at age 19 and persisted above 450 for the remainder of the study, even reaching as high as 477.3 at age 25 (Table 3.73). At its greatest SDI, basal area was 252.1 ft^2/acre and trees per acre was 544. Low rates of mortality on this treatment along with relatively large quadratic mean diameter provided the high levels of basal area that ultimately lead to the high SDI. Other sites that exceeded the previously reported maximum SDI of 450 include the Eatonton - Powerline, which reached an SDI of 454.6 at age 17 in the 1995 HF treatment and the Waycross - Dry 1993 H and HF treatments, which both surpassed 450 at age 19 (Tables 3.41, 3.111). It is interesting to see that all treatments that surpassed the 450 SDI mark were all receiving complete competition control. Woody and herbaceous competition are factors that need to be considered when determining SDI for stands. Higher rates of understory competition reduce the density levels that can be achieved on any given site by loblolly pines.

Relative spacing (RS) is another important measure of stand density. RS uses the average distance between trees and their dominant heights to quantify stand density. Because stem mortality rates are fairly low for sites until crown closure, relative spacing is affected more by dominant height development rather than tree number prior to crown closure. Once mortality rates increase post crown closure for the different treatments, relative spacing was affected more by trees per acre values. Treatments with greater trees per acre values showed lower relative spacing values, indicating a greater stand density for a given dominant height. This can be seen in the Eatonton - Powerline 1988 time replicate, where initial dominant heights are greater for the HF and H treatments and it is reflected by the HF and H treatments having lower relative spacing values. After approximately age 12, mortality rates begin to increase of the HF and F treatments while the C and H treatments remain stabilized (Table 3.44). Due to higher trees per acre values, relative spacing values began to decline for the C and H treatments, indicating higher stand densities (Table 3.42). Relative spacing is another tool that can be used for density management. Land managers can use relative spacing as a guide for stand management activities, such as thinnings (Beekhuis, 1966).

Basal area development followed similar trends as to what was seen in SDI for each treatment. Whereas SDI used average stand diameter, basal area is calculated at the individual tree level and then summed at the per acre level. Maximum basal area per acre rates achieved in the study occurred on the Dawsonville - Top site, where the 1987 H treatment reached 252.1 ft^2/acre at age 25 (Table 3.72). At the treatment level, basal area developed most quickly for the HF treatment. Increased mortality rates, seen in the HF and F treatments, limited the total basal area achieved, and in several cases, basal area crashes occurred. These crashes, seen in treatments like the Athens 1989 HF treatment and the Eatonton - Powerline 1988 HF treatment, saw decreased basal area due to high stem mortality (Tables 3.2, 3.38). These large mortality events were likely caused by the increased densities, which the stand could not support. Basal area crashes also affected total green weight on site, which also saw overall decreases in growth rates, but not as severe as basal area. This suggests that it was the smaller trees that were affected. Understanding how and when sites reach carrying capacity and begin to self thin due to higher stand densities will allow for better density management. Thinning a stand prior to these basal area crashes will allow managers to capture value in the smaller trees that would normally be lost to mortality. Sites that experienced these basal area crashes experienced greater diameter growth following the crash because of lower densities. Density management through thinning also promotes greater diameters, which also promotes higher value products.

Stem mortality, measured by trees per acre (TPA), showed lasting impacts on sites that exhibited high initial mortality rates. The Dawsonville - Bottom and Tifton sites both had treatments that resulted in high mortality prior to age 5 due to excessive herbaceous competition. With much lower TPA numbers at the beginning of the study, direct comparisons of the affected treatments with the others was limited. These high initial mortality events affected many variables. Stand density (SDI and RS), BA, and GT were all lower throughout the study in these sites due to excessive early mortality. One benefit was that DQ was increased on sites that experienced the initial high mortality. Stands that were not affected by these initial mortality events saw low mortality rates until crown closure. The Waycross - Wet site, for example, showed very similar TPA rates for the 1993 time replicate, until approximately age 12 where mortality rates increased on the F and HF treatments (Figure 3.97(c)). The point at which mortality rates began to increase started earlier on the HF and F treatments for majority of the sites. These results back up Miller's claims that fertilization increases the rate of stand development (1981).

Evaluating mean annual increments (MAI) allows for treatments to be compared across a time span. The highest overall MAI rate was seen in the Waycross - Dry 1993 HF treatment, which peaked at 15.5 tons/acre/year at age 14 (Table 3.118). Majority of the sites had their individual maximums occur on HF treatments. The Waycross - Wet MAI maximum occurred on the 1993 HF treatment, reaching 14.3 tons/acre/year at age 12 and the Dawsonville - Bottom site reached its maximum MAI value of 12.1 tons/acre/year in the 1989 HF treatment at age 18 (Tables 3.142, 3.65). Several sites had maximum MAI values occur on H treatments. The Tifton 1988 H treatment had the highest overall site MAI, reaching 11.0 tons/acre/year at age 19 (Table 3.100). For a majority of these individual treatments that had the greatest MAI values, they also had the greatest over total green weight (GT). MAI can also be used as an indicator for BA crashes. Because GT declined in relation to BA declines, MAI showed decreases. The Eatonton - Powerline 1988 HF treatment, which crashed after the 19^{th} growing season, showed overall declines in BA, GT, and MAI (Tables 3.38, 3.46, 3.48). One reason for conducting this study was to understand why loblolly pine grew so well in international environments and why growth rates achieved in these areas was greater than what was observed in the US. Responses from this study showed comparable growth rates with rates achieved in South Africa, Brazil, and Australia (Borders and Bailey, 2001).

Product development on the stump is a necessary concept to understand for forest managers. While certain treatments may promote the highest overall total green weight production, they may not produce the greatest amounts of higher value products, such as chip-n-saw or sawtimber. Total green weight development is a factor of stand density and basal area whereas products are defined by diameter. Increased diameters are a result of lower stand density. In the case of the 1988 time replicate on the Tifton site, the H and C treatments had the highest overall total green weight values achieved (Table 3.99). When it came to individual product development, it was the HF and F treatments that had the greatest sawtimber values (Table 3.104). These differences are explained by greater quadratic mean diameters achieved by the HF and F treatments due to greater rates of stem mortality and lower stand density indices (Tables 3.101, 3.98, 3.96). Density management is an important concept to understand for those growing trees for higher value timber. To produce higher value products, one must reduce density so crop trees can increase diameter at a greater rate. For those growing trees solely for biomass or where total achievable tons is the goal, dense stands are the way to go.

Overall, intensive cultural treatments were shown to only speed up the stand dynamics process, not change them. As it can be seen in the development of BA, TGW, SDI, and other variables that the first stage of stand dynamics, stand initiation, is completed earlier in the most intensive treatments. Stem exclusion, categorized by increased rates of stem mortality due to lack of growing space, was reached most quickly on those sites receiving intensive cultural treatments. Total carrying capacity was affected very little by these treatments, only the time in which it took to reach that point changed. This reduction of the stem initiation stage reduces the time forest managers have to wait before being able to use thinning treatments to remove standing wood. These earlier thinnings promote earlier final harvests of stands, leading to better economic returns.

The breadth of ways that data collected in this study can be used in future studies is enormous. Twenty-five years of individual tree data for multiple sites, multiple planting years, and various treatments that included measurements of several variables allows for researchers to look at this data in a whole new light. These possible studies include examining weather information to determine how it may affect the rate of cronartium infection in pines. Further studies that may be of interest to many practicing foresters and those in the wood products industries are examining wood quality attributes expressed by trees growing on these high production sites. Other future research could use this data to create a stand development index, used to describe the stand in terms of stages of stand development, rather than age. Using this index, a manager will know where a stand is in relation to where stand initiation ends and stem exclusion begins. Although this study was not meant to be operational, an economic analysis may investigate the growth rates and the costs of treatments to see what kind of returns annual fertilization and competition control regimes may provide.

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