HARVEST INTENSITY AND COMPETITION CONTROL IMPACTS ON LOBLOLLY PINE FUSIFORM RUST INCIDENCE

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Abstract—The Long Term Soil Productivity experiment tests the effects of soil compaction, surface organic matter removal, and understory control on net primary productivity. An unintended consequence of these treatments may be an effect on the incidence of fusiform rust [*Cronartium quercuum* (Berk.) Miy. ex Shirai f. sp. *fusiforme* Burdsall *et* Snow]. Loblolly pine (*Pinus taeda* L.) is highly susceptible to rust infection, and the combination of soil disturbances and the absence of understory may provide an environment favorable to fusiform rust. This paper describes the treatment effects on the annual incidence of fusiform rust in an 11-year-old loblolly pine plantation at the Croatan National Forest near New Bern, NC. Generally, increasing levels of organic matter removal resulted in increased incidence of fusiform rust. This trend was consistent throughout the experiment, but the magnitude of this effect diminished with time. Soil compaction did not have an effect on fusiform rust occurrence at any time during this study. Competition control resulted in significantly higher occurrence of stem galls after the trees were 5 years old.

INTRODUCTION

Fusiform rust disease reduces the growth and yield of pine plantations in the Southeastern United States. The rust occurs from Maryland south to Florida and west to southern Arkansas and Texas and causes widespread damage to loblolly (*Pinus taeda* L.) and slash pine (*P. elliotti* Engelm). The causal agent of fusiform rust is the fungus *Cronartium quercuum* (Berk.) Miy. ex Shirai f. sp. *fusiforme* Burdsall *et* Snow. The fungus is native to the Southeastern United States and became an economic threat when plantation forestry expanded in the 1940s (Powers and Matthews 1980, Starkey and others 1997, Tainter and Baker 1996). Increased use of fertilizers led to an increase in fusiform rust incidence in southern plantations, largely due to the increased rust susceptibility of rapidly growing trees (Rowan 1977, Rowan and Steinbeck 1977, Schmidt 1998). Some authors recommend that fertilizer application be delayed or eliminated in high rust hazard sites to minimize losses from the disease (Schmidt 1998, Tainter and Baker 1996). However, other studies note that the increased growth of fertilized trees often compensates for the increased incidence of rust in a plantation (Froelich and Schmidtling 1998).

The fusiform rust fungus completes its life cycle by alternating between pine and oak hosts. Pine hosts are infected through succulent new tissues that swell and form a gall in the wood tissue. The fungal infection increases resin flow in the wood and causes a reduction in wood density as the infection consumes the living wood cells (MacFall and others 1994). The sticky and often sweet sporulation by the fungus on the surface of the wood attracts secondary insects and fungi, which feed on the gall secretions and cause secondary damage to the tree. An infection often reduces the quality of the tree's wood and weakens the stem, increasing its susceptibility to breakage in wind and ice storms. The fusiform rust pathogen is a long-lived, perennially sporulating fungus that continues to invade more host tissue each year for the life of the tree. Often stem galls that appear after the tree is 5 years old develop from branch galls that have grown into the stem (Froelich and Schmidtling 1998). What starts as a gall on stem or branch tissue becomes a canker as the tree ages and secondary damage progresses.

The incidence of fusiform rust levels off after 6 years in young plantations. At that point, tree mortality increases as galls girdle the stems and branches. Many of the remaining galls are on trees that are described as "tolerant" because they manage to survive the initial 5 years of infection by growing and adapting their vascular system around the infection site. The probability of rust infection is not related to site quality or stand density variation but is heavily dependent on timing and severity of infection (Froelich and Schmidtling 1998). These parameters are influenced by fertilization application and subsequent production of succulent tissues where the fungus infects the young tree (Rowan 1977, Rowan and Steinbeck 1977).

Economic losses of wood quality and yield by fusiform rust are difficult to quantify since they include the value of aggregate increases in standing timber, merchandise products (saw timber), and losses to nursery stock and seed production. The combination of values translates into $20 to $35 million of annual losses to fusiform rust infection in southern pines (Anderson and others 1986, Powers and others 1974). Estimates by Pye and others (1997) have put that figure as high as $92 million per year.

The objective of this study was to quantify the effects of organic matter removal, compaction, and competition control on the incidence of fusiform infection on loblolly pine trees on the study site. This analysis was conducted as part of the Long Term Soil Productivity (LTSP) experiment. This LTSP study is part of an international effort designed to examine the effects of soil compaction, organic matter removal, and competition control on site productivity. Three levels of organic matter removal and three levels of soil compaction were chosen to represent disturbance regimes that ranged from minimal to severe. The competition control treatment was included to quantify plant growth potential on the site.

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METHODS

The study site was installed in 1992 and is located on the Croatan National Forest, near New Bern, NC. This area is part of the lower Coastal Plain and typically has cool winters and hot, humid summers (Goodwin 1989). The study design is a 3 by 3 factorial, split-plot, randomized complete block replicated on three blocks. Soils in Block 1 are predominately Goldsboro (fine-loamy, siliceous, thermic, Aquic Paleudults), and soils in Blocks 2 and 3 are predominately Lynchburg (fine-loamy, siliceous, thermic, Aeric Paleudults). Main effect treatments are organic matter removal (bole only – OM0; whole tree – OM1; whole tree and total forest floor removal – OM2), and soil compaction (none – C0; moderate – C1; severe – C2). Plots were split for competition control treatments (no competition control – H0; total competition control – H1). Each treatment plot is 0.2 ha and contains an 0.08-ha measurement plot. 1-0 loblolly half-sibling seedlings were planted in February 1992 at 3- by 3-m spacing. There were 80 trees per measurement plot, and each measurement plot was buffered on each side by 3 rows of trees. A complete description of treatment application is found in Eaton and others (2004).

Annual tree measurements and damage assessments were first made in January 1993 and continued through January 2002, with an additional damage assessment made in January 2004. Measurements and damage assessment were only performed on live trees. To reduce observer bias, the same person performed all damage assessments. Initially, only the most severe damage for each tree was recorded; after 3 years, the three most severe damages were recorded. For the purpose of this analysis, only trees that had stem infections as the most severe damage were classified as infected. Stem-infected trees were those with stem galls or branch galls located < 6 inches from the stem. There were no reports of fusiform infection at age 1.

Data were segregated by block and treatment and expressed as percentage of live trees infected with stem infections. Percentage data were transformed using the square root of the percentage + 1/2 (Steel and Torrie 1980). Analysis of variance and PROC MIXED were performed on the transformed data using SAS statistical software (SAS Institute, Cary, NC). Data were also separated by organic matter removal and competition control treatments, and additional analysis was performed. Only the highlights of the analyses are shown.

RESULTS

Organic Matter Removal Treatment

The temporal pattern of fusiform rust incidence was similar across all levels of organic matter removal (fig. 1). After age 2, rust infection on stems affected from between 5 and 15 percent of all live trees. The incidence of rust increased at age 3 then declined until age 6. There was a spike at age 7, largest in OM2 (3 percent) and smallest in OM0 (< 1 percent) followed by a slight decline through the age 11. The percentage of trees with rust was significantly higher ($P < 0.05$) in OM2 than OM1 and OM0 for all years except age 6. The rate of rust incidence for OM0 was significantly different from OM1 only for age 2.

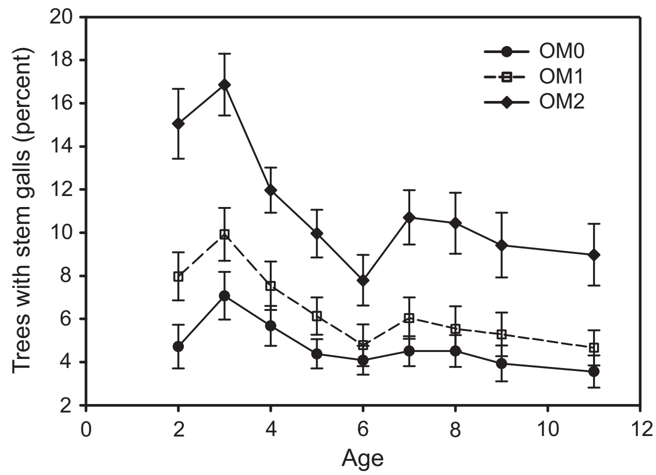

Figure 1—Percentage of trees with stem galls by age for three organic matter removal treatments (OM0 – bole only; OM1 – bole and branch; OM2 – bole, branch, and forest floor).

Compaction Treatment

At age 2, the level of rust infection ranged from 7 to 11 percent of the total number of live trees (fig. 2). The incidence of rust increased at age 3 and then declined until age 6. The spike in incidence at age 7 was largest in the C1 plots (2 percent) and smallest in the C0 plots (< 1 percent). This spike was followed by a slight decline in fusiform rust incidence through age 11 at all compaction levels. The percentage of trees with stem galls was higher for C2 than for the other compaction treatments in all years, but it was significantly different ($P = 0.049$) from C0 and C1 only at age 5.

Competition Control Treatment

For treatment H0, the incidence of stem infections generally decreased from age 3 through age 11 (fig. 3). For treatment H1, incidence of stem infections increased substantially from age 6 to age 8 and then declined through age 11. By age 7, and through the end of the measurement period, the infection incidence rate for H0 differed significantly ($P < 0.001$) from H1.

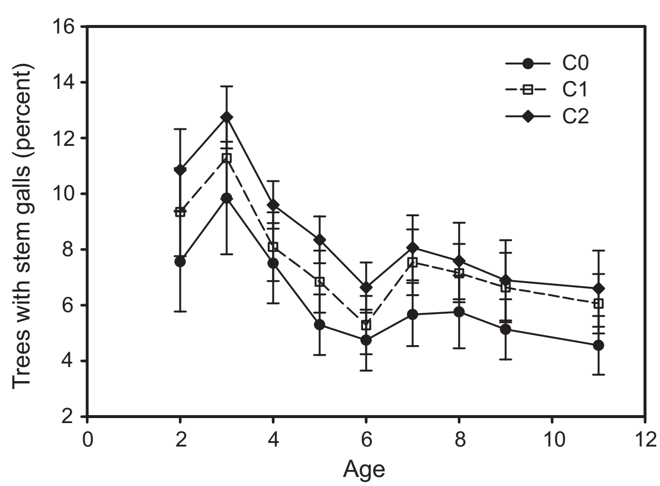

Figure 2—Percentage of trees with stem galls by age for three compaction treatments (C0 – no compaction; C1 – moderate compaction; C2 – severe compaction).

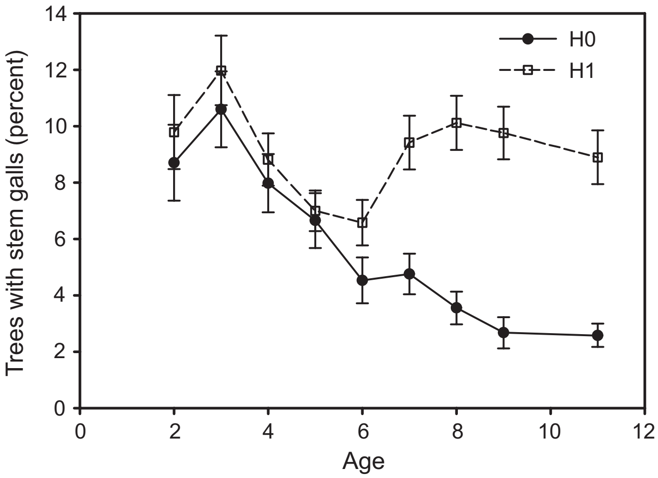

Figure 3—Percentage of trees with stem galls by age for two competition control treatments (H0 – no competition control; H1 – total competition control).

Treatment Interactions

There were no significant treatment interactions in fusiform rust incidence until age 11 (*P* < 0.02). However, after age 6 the differences between infection incidence on H0 and H1 were greater on the OM0 treatment plots than on the OM1 and OM2 plots (fig. 4).

DISCUSSION

Previous analysis showed the OM removal and compaction treatments did not affect height or diameter growth but that competition control treatment affected both height and diameter growth significantly (Sanchez and others 2005). We expected this analysis to show the incidence of fusiform infection to reflect tree growth rate. Instead we found significant differences by OM removal treatments, and the incidence of infection was higher on the most severely disturbed sites for both the OM removal and compaction treatments. Additional investigation showed that factors generally associated with

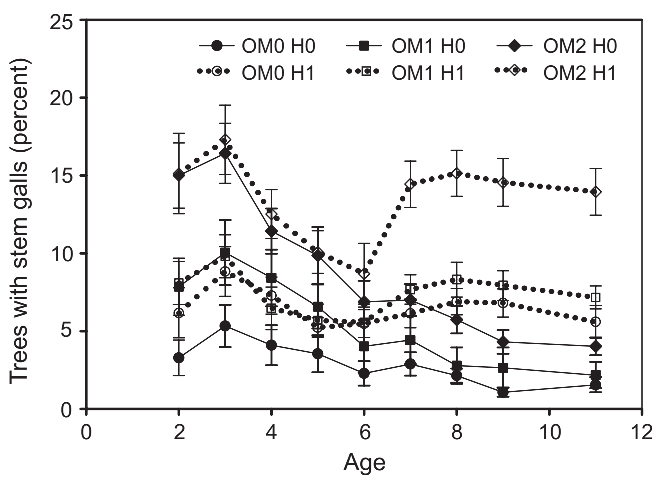

Figure 4—Percentage of trees with stem cankers by age for organic matter removal and competition control treatments (OM0 – bole only; OM1 – bole and branch; OM2 – bole, branch, and forest floor; H0 – no competition control; H1 – total competition control).

increased rate of tree growth, including soil and foliar nutrient levels, did not vary significantly from treatment to treatment.

Fusiform incidence was the same for both competition control treatments prior to age 7, although galls were more numerous in the H1 treatment. Height growth was significantly greater for H1 trees over this period (Sanchez and others 2005). This indicates that the infection rates may not be solely a function of growth. Starting at age 7, there was a significantly higher incidence of fusiform in the H1 plots than in the H0 plots (fig. 3). There is no obvious reason for this difference, although measurements show the height to live crown measurement of the planted pine trees increased by almost 2 m between ages 6 and 7 in the H1 treatment plots (Unpublished data. 2004. Robert Eaton, Biologist, USDA Forest Service, Southern Research Station, 3041 Cornwallis Road, Research Triangle Park, NC 27709). The height to live crown measurement in the H0 plots was always high due to competing vegetation and did not change as dramatically during the same time period. In addition, measurements taken at age 5 show significantly greater grass biomass and lower shrub biomass in the OM2 plots than in the other organic matter removal plots (Ludovici and others 2005). The comparatively low height of the major component of the understory in the OM2 and the decrease in the number of live lateral branches of the planted pine in the H1 plots when the time of infection rate increased indicate that the higher incidence of infection may have been the result of increased air movement through the treatment plots and increased transport of spores to susceptible tree tissue.

CONCLUSIONS

The incidence of fusiform infection was higher in the plots where the most intensive treatments were applied and significantly higher in the OM removal treatments. Faster growing trees are generally thought to be at higher risk for infection, and more rapid tree growth was associated with competition control in this study. Even though the competition control treatment had significantly higher growth rates, there was no significant difference in fusiform infection incidence until age 7 years. Characteristics that can affect air movement through the stand, such as height of the major understory component or height to live crown, were different or changed at the same time that fusiform infection rates changed. Amount of susceptible tissue, although important, may not be the only factor that affects incidence of fusiform rust infection. Although use of rust-resistant clones and moderation in site preparation and fertilization reduce the incidence of fusiform infection, it may be desirable to reduce accessibility to susceptible tissue, especially in areas of high rust occurrence.

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