CASE STUDY TO EXAMINE THE EFFECTS OF A GROWING-SEASON BURN AND ANNOSUM ROOT DISEASE ON MORTALITY IN A LONGLEAF PINE STAND

Michelle M. Cram, Dan Shea, and Ken Forbus[1]

Abstract—A case study of a growing-season burn in a longleaf pine (*Pinus palustris*) stand affected by annosum root disease was conducted at Savannah River Site, SC. The project utilized a longleaf pine stand from a 1995 evaluation of a stump applicator system. The Tim-bor® (disodium octaborate tetrahydrate) and no stump treatment blocks (NST) were divided into sections for a burn treatment. Prior to the burn, woody debris was added to selected plots in each of the burn areas to simulate a midstory cut of hardwoods. The fire applied in April 2003 was designed to mimic spot ignitions of a plastic sphere dispenser (PSD) machine. In 2003 to 2005, the percent increase of dead trees per acre with annosum root disease was greater in the burn areas than in the no burn areas in both the Tim-bor® and the no stump treatment blocks. Mortality related to fire/heat damage was greater in the midstory plots of the Tim-bor® block than in the NST block. Annosum root disease was confirmed in 256 trees out of 589 total dead trees, but caused less then 10 percent timber loss over 10 years. Mortality related to the burn resulted in 86 dead trees, and losses due to an ice storm resulted in 56 dead trees. Other timber losses occurred from mechanical damage, lightning, fusiform rust/wind, and no primary cause determined.

INTRODUCTION

Prescribed burning in longleaf pine (*Pinus palustris*) stands is an important tool for managing hazardous fuels (Outcalt and Wade 2004), regenerating longleaf pine (Croker and Boyer 1975), and suppressing other tree species (Hille and Stephens 2005). Longleaf pine is adapted to frequent low intensity fires (Chapman 1932); however, the use of prescribed fire in longleaf pine is not without risk. There have been individual cases of high mortality in longleaf pine stands after a prescribed burn (Sullivan and others 2003, Varner and others 2005). Severe fire can damage pines through crown scorch, meristem damage, stem char, vascular damage and root damage (Varner and others 2005). Mortality of longleaf pine has been correlated with the severity of the burn (Sullivan and others 2003), and combustion of excessive litter resulting in root and/or cambium damage (Brockway and others 2005, Varner and others 2005).

A prescribed burning study at the Savannah River Site (SRS), SC, found that soil heating and surface consumption of duff was correlated to mortality of mature longleaf pine (Sulivan and others 2003). This study also found annosum root disease, caused by *Heterobasidion annosum*, was present and associated with root infections and mortality (Otrosina and others 2002, Sullivan and others 2003). The physiological stress resulting from fire damage can render southern pines more susceptible to insects and disease (Hanula and others 2002, Sullivan and others 2003, Varner and others 2005), which can lead to mortality. There has been little research on the possible interaction between annosum root disease and prescribed fire. Annosum root disease development occurs over a 10-year period in southern pine stands (Tainter and Baker 1996) and its impact can be underestimated when surveys are only a couple of years in duration. Infection of a stand by *H. annosum* can also be highly variable and not evenly distributed. Long-term annual monitoring of dead and dying trees for the presence of root disease is needed to examine possible interactions of annosum root disease and prescribed fire.

The primary objective of this case study was to quantify tree mortality in a longleaf pine stand with annosum root disease before and after prescribed fire. A longleaf pine stand that had once been part of a study on the SRS provided the initial long-term annual monitoring of annosum root disease. This 89-acre stand was the only remaining stand from a 1995 stump applicator system study for suppression of annosum root disease. The stand had been monitored from 1996 to 1999 for root disease and other causes of mortality within the treatments. The treatments consisted of Tim-bor® (disodium octaborate tetrahydrate), *Phlebiopsis gigantea* and NST (No stump treatment) blocks. The first four years data on the site indicated that Tim-bor® had excluded *H. annosum* from treated stumps and that annosum root disease was present in the NST (No stump treatment) block. The *Phlebiopsis gigantea* stump treatment failed due to applicator error (20 percent stumps not treated), therefore only the Tim-bor® and NST blocks where used for the case study.

Midstory cuts, where hardwoods are chainsaw felled before burning, are common practices in restoring longleaf pine stands on the SRS (Barton and others 2005). Midstory cuts increase the fuel load in a stand, which can be a contributing factor to increased burn severity under some conditions. Forest Management at the SRS was interested in obtaining information on temperatures generated at the upper layer of mineral soil with different fuel levels and weather conditions.

METHODS

The longleaf pine stand (Lat. 33°21’30”, Long. 81°30’0”) selected for this case study had a soil type of Blanton sand and a site index of 70. The stand was established in 1955 and thinned to a basal area of 72 square feet in 1995. The original stump treatments (NST, Tim-bor®, *Phlebiopsis*

[1]Plant Pathologist, USDA Forest Service, Forest Health Protection, Athens, GA; Fire Planner, Savannah River, Region 8; USDA Forest Service, New Ellenton, SC; Systems Analyst, RWU 4156, Southern Research Station USDA Forest Service, Athens, GA, respectively.

Citation for proceedings: Stanturf, John A., ed. 2010. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

gigantea) had been applied in randomized blocks within each of three longleaf pine stands during the 1995 thinning. Only the Tim-bor® and NST treatment blocks were used in this case study. The Tim-bor® block was 36.56 acres and the NST block was 28.47 acres. A prescribed burn treatment (ignited April 2003) was imposed on of each treatment block (Tim-bor® 11.89 acres; NST 11.12 acres).

A 100-percent survey of tree mortality was conducted in the Tim-bor® and NST blocks each fall from 1996 to 1999, and was continued from 2001 to 2005. All dead trees were assessed yearly for root disease using the two root method (Alexander and Shelly 1974). Symptomatic root segments with resin-soaking or white-stringy-rot were cut up and placed on a selective media for basidiomycetes (Russell 1956). All dead trees confirmed to have *H. annosum* were mapped with GPS (global positioning system).

In 2001, the 63 variable plots (10-factor prism) in the blocks from the previous stump project were used to establish 0.10-acre fixed plots. The plot centers were established on a 2 chain (66 feet) x 2 chain grid. All trees within the fixed plots were measured for d.b.h. within 0.1 inch. The boundaries and acreage of the individual blocks and burn treatment areas were measured with GPS. The number of trees estimated for each area was based on the fixed plot measurements and the acres in each treatment area.

Three plots within each burn treatment area were systematically selected along a centered transect (Northeast to Southwest) to simulate midstory cuts. In August and September 2001, small trees (less than 5 inch d.b.h.) in and around the 0.1-acre midstroy plots were cut and added to a fuel depth of 1.5 to 2.5 feet on top of the natural fuel load, which averaged 0.9 inches litter and 1.5 inches duff. Thermometers (maximum temperature) were placed at 0.5 and 2 inches below the duff within and outside the midstory plots. Campbell Scientific Microloggers were also utilized in the centeral midstory plot of each burn area to determine ground temperature change over time under high fuels and natural fuels. The microloggers were placed below ground in a styrofoam container on the east side of the plot. The probes used were high temperature quick-disconnect thermocouple (grounded K) on 12 feet of insulated thermocouple wire duplex (insulated K; Omega Engineering Inc.). Each micrologger had two sets of temperature probes in the midstory plot and two sets of probes outside the plot. Each set of probes consisted of a probe at 0 inches and another at 2 inches below the duff. Two sets of probes were located 6 to 10 feet apart within the midstory plot and the other two sets were placed outside the plot at 6 to 10 feet apart.

Prescribed burns had been applied to the stand every 3 to 5 years through the winter of 1996. No fire related mortality occurred following the 1996 prescribed fire. The stand was not burned again until the prescribed treatment burn was ignited on April 24, 2003. The burn technique used was spot fires applied in strips with drip torches designed to mimic spot ignitions of a plastic sphere dispenser (PSD) machine. The burn began at 10:44 a.m. in the Tim-bor® block moving southeast into the NST block at 12:15 p.m. At initiation of the burn it had been 5 days since rain (0.6 inch), KBDI was 93, and the lowest 10 hour fuel stick moisture was 9 (SavRiv 383101). During the burn relative humidity ranged from 35 to 41 percent and air temperature ranged from 70–80 °F. Wind movement within the stand was 0 mph when the burn started and steadily increased to 4 mph by 14:00 in the afternoon. The duff and litter consumption was noted when thermometers were removed. The height of bole char was recorded on trees within plots.

In November 2005, increment cores were taken from 3 live trees in 3 plots of each burn and stump treatment areas. Cores were taken on the side of the tree facing the center of the plot. Sample trees were selected based on diameters closest to 11.5 inches d.b.h. within the first three quadrants. All trees measured for radial growth were codominant. Radial growth was measured for each year from 1996 through 2005.

RESULTS

The highest temperature recorded by the maximum thermometers was 88 °F. The temperatures recorded by the maximum thermometers were similar to the recorded temperatures from the Campbell temperature probes from the Tim-bor® treated block (fig. 1). One of the Campbell temperature probes (0 inches, NST block) recorded a temperature of 169 °F (fig. 2), which was likely due to that probe's location under a log. Fuel was not consumed down to the mineral soil, with the exception of one plot in the NST block (the northwest corner).

The locations of dead trees with annosum root disease before and after the April 2003 burn are shown in figure 3. *Heterobasidion annosum* was the most common primary damaging agent over the entire 10 year period, representing 44 percent of 589 dead trees. Although there was an increase in the percentage of mortality with *H. annosum* in the burn treatments (fig. 4), most of the post-burn annosum root disease occurred at locations where the disease had been active prior to burning. The second and third causes of mortality included fire/heat at 14.6 percent (12.5 percent excluding the midstory plots), and an ice storm (January 26-30, 2004) at 9.5 percent. Other causes included mechanical (logging), lightning, fusiform rust/wind, or no cause determined (28 percent). *Leptographium* spp. were found in roots of 1.7 percent of dead trees with no primary damaging agent determined. *Leptographium* species were associated with 1.2 percent of the annosum root disease mortality, 4.7percent of the fire mortality, and 8.9 percent of the storm-related mortality. The majority of *Leptographium* species isolated appeared to be *L. procerum* and *L. terebrantis*. One isolate of a *Leptographium*-type species, taken a root predominantly colonized by *H. annosum*, was later identified as *Ophiostoma huntii* (pers. comm., Dr. Thomas Harrington, Dept. of Plant Pathology, Iowa State University, Ames IA 50011).

Galleries and pitch tubes characteristic of *Dendroctonus terebrans* and *Ips* spp. bark beetles were found in almost all dead and dying trees. *Dendroctonus terebrans* damage was also documented in a few live trees with bark char in the midstory plots that survived to 2005. *Dendroctonus terebrans* and *Ips* spp. bark beetles are commonly associated with

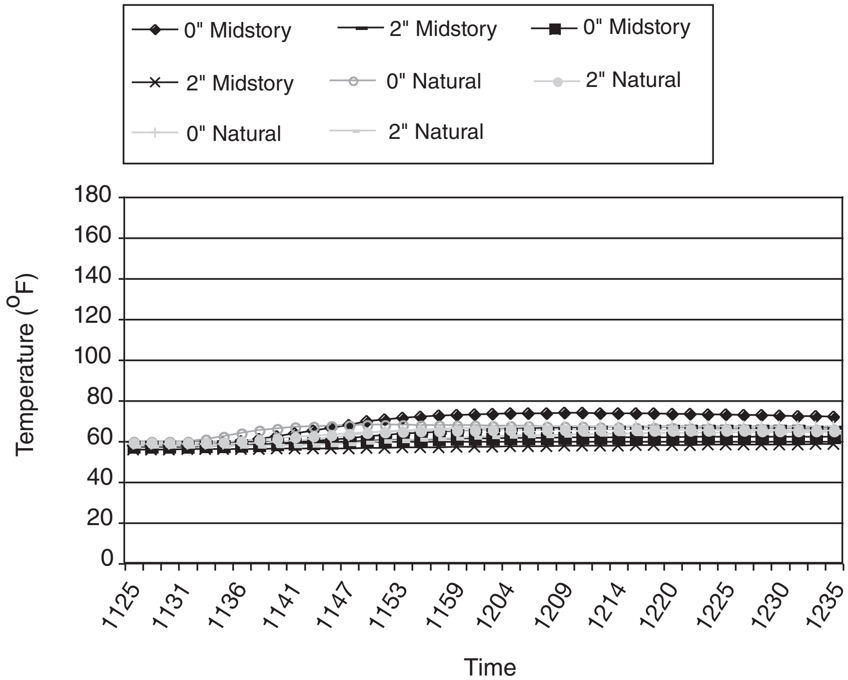

Figure 1—Temperatures (°F) in the block treated with Tim-bor® during a spring burn from probes at 0 and 2 inches below the duff in a plot with added midstory fuel and a an adjacent natural fuel plot.

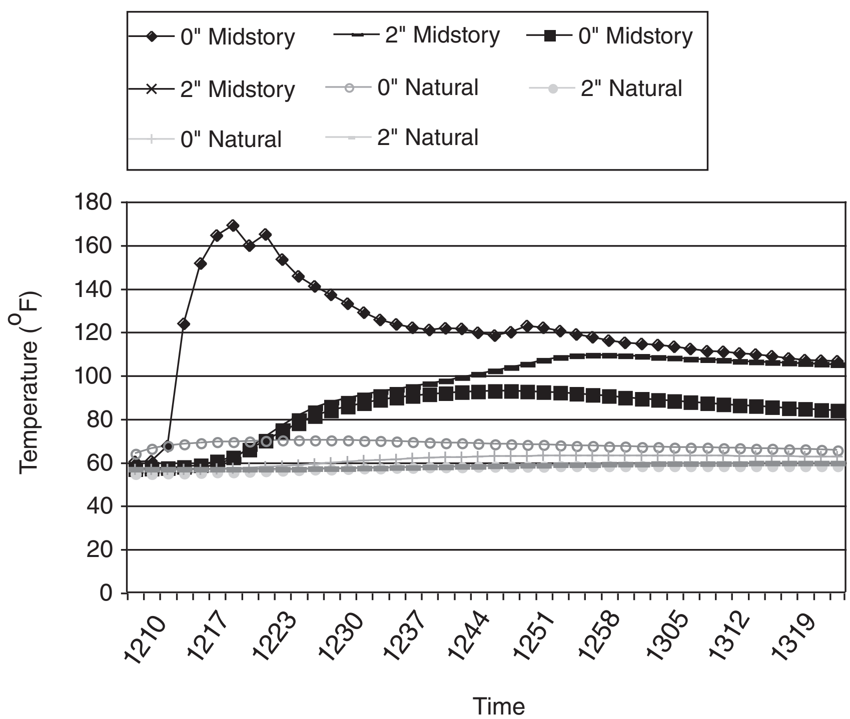

Figure 2—Temperatures (°F) in the No Stump Treatment block during the burn from probes at 0 and 2 inches below the duff in a plot with added midstory fuel and in an adjacent natural fuel plot.

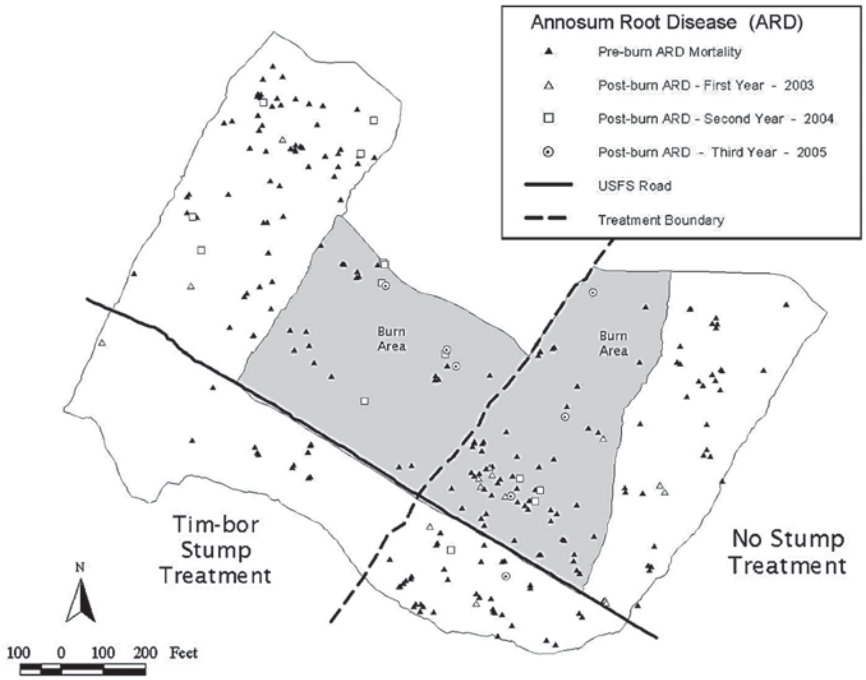

Figure 3—Location of individual trees with annosum root disease pre- and post-burn in different treated areas of longleaf stand on the Savannah River Site, SC.

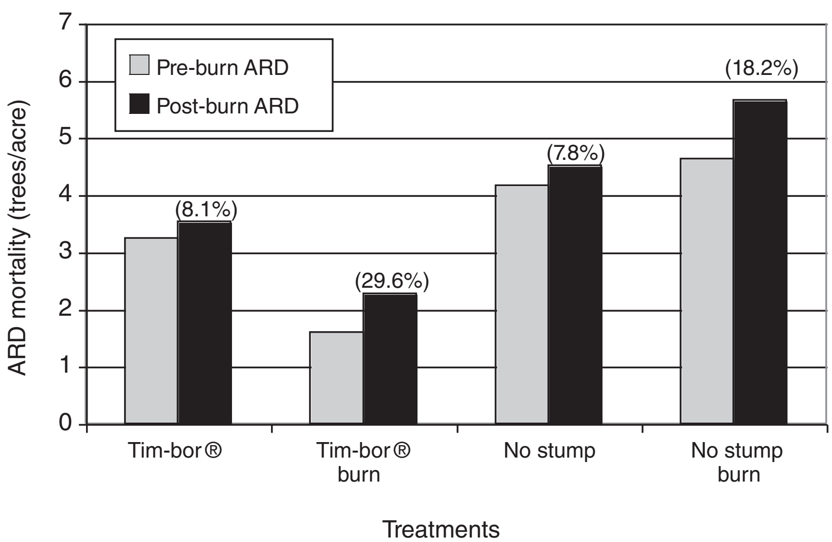

Figure 4—Annosum root disease (ARD) mortality before and after burning by stump and burn treatments (percent increase).

damaged and dying trees (Coulson and Witter 1984) and are not considered a primary damaging agent in this study.

Mortality was substantially greater in the Tim-bor® midstory plots (fig. 5). The height of bole char was also observed to be greatest on the trees in the Tim-bor® midstory plots (average 12 feet) than in the NST midstory plots (6-8 feet on one side). Bark char was 1 to 2 feet high in plots with natural fuels. Only 6.5 percent of fire-damaged trees were dead by the fall sampling in 2003. The majority of the mortality related to fire (83 percent) occurred in 2004. In 2005, an additional 10.5 percent of fire damaged trees died.

The percent of total mortality (excluding midstory plots) by different treatment areas from 1996 to 2004 is shown in figure 6. The loss of longleaf pine from the fall of 1996 to 2005 was greatest (12.7 percent) in the burn-NST area. The average annosum root disease mortality was higher in the NST block than in the Tim-bor® block, with the exception of the NW corner of the Tim-bor® block where a logging deck was located during the 1995 thinning.

The average annual growth rate of the trees in different burn plots indicated that growth slowed initially after the burn (fig. 7). By the second growing season, the burned plots with normal fuel loads had recovered. The surviving trees in the midstory plots appear to be recovering from the burn by the third growing season. The average growth rate in the individual plots indicates that growth increased in the third year in all plots except in one midstory plot in the NW corner of the NST block (data not shown).

DISCUSSION

This case study is unique in that 100 percent of the mortality was evaluated for root disease over a 10-year period. The most common primary causal agent of mortality was annosum root disease; however, the loss to the residual stand in all treatment areas from this disease over 10 years was under 10 percent. This relatively low level of disease response is not unexpected given the lower susceptibility of longleaf pine to annosum root disease (Hodges 1974).

The finding of annosum root disease in the Tim-bor® block by 2001 was unexpected given that the stump treatments were successful and mortality related to annosum occurred in the first 4 years was negligible. However, it has been well documented that stump treatments do not restrict infection to the roots or residual trees damaged by equipment (Hendrix and Kuhlman 1964, Hodges 1970, Kuhlman 1969, Rishbeth 1959). The higher level of annosum root disease surrounding the logging deck in the NW corner was likely due to heavy equipment damage to roots and trees that would allow *H. annosum* to become established in the stand despite effective stump treatment.

Heterobasidion annosum was a relatively minor factor in the mortality that occurred after the April burn. Mortality associated with annosum root disease increased in the burn areas, but most of this mortality was adjacent to locations where the disease occurred prior to the burn. Prescribed fire can have a negative effect on longleaf pine growth (Boyer 1987, Sayer and Haywood 2006), and this stress combined with annosum root disease would be expected to accelerate tree mortality.

The high occurrence of fire-related mortality found in the artificially created midstory plots of the Tim-bor® block indicates that the higher fuel load was an important factor. The damage appeared to be related to above ground temperatures, since the below ground temperatures remained low according to most of the temperature probes and thermometers. The one probe that did record lethal temperatures was positioned under a 4-inch d.b.h. log. This result indicates that there could be zones of lethal temperatures among larger fuels, which could result in localized damage to roots.

The low temperatures at 0 and 2 inches below the duff layer were likely due to the high moisture saturation of the duff and soil, which has been shown to greatly reduce surface soil temperatures (Frandsen and Ryan 1986) and can help to protect the fine roots and cambium at the base of the tree (Brockway and others 2005). During this case study, no measurement was made of above-ground temperatures, or cambium damage at the butt of trees, so it is unclear if damage occurred to the cambium in the midstory plots. Bole char height may not be considered as good as percent crown loss for predicting mortality in southern pines (Outcalt and Wade 2004); however, bole char has been correlated with greater mortality of southern (Hanula and others 2002) and western pines (McHugh and Kolb 2003, Swezy and Agee 1990, Thies and others 2006) and could be considered an analog of crown damage (Wade and Johansen 1986). In this

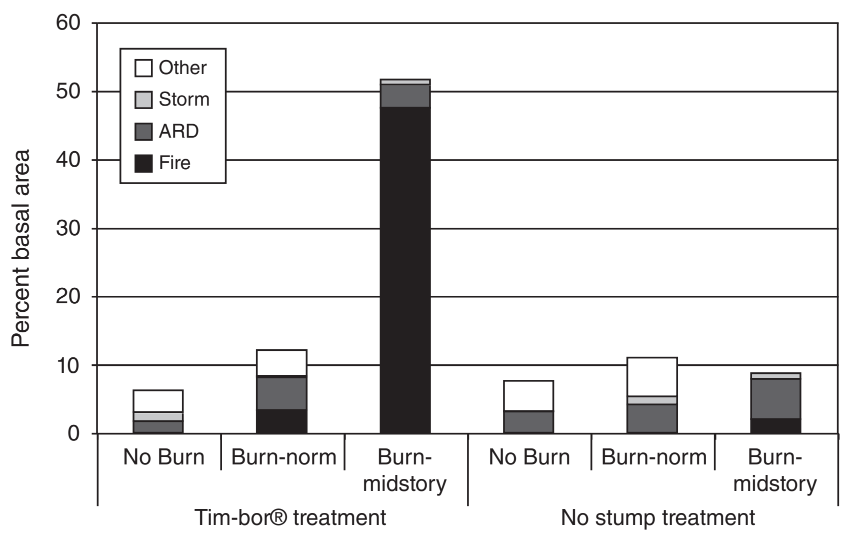

Figure 5—Percent basal area lost by primary cause within fixed plots from 1996 to 2005.

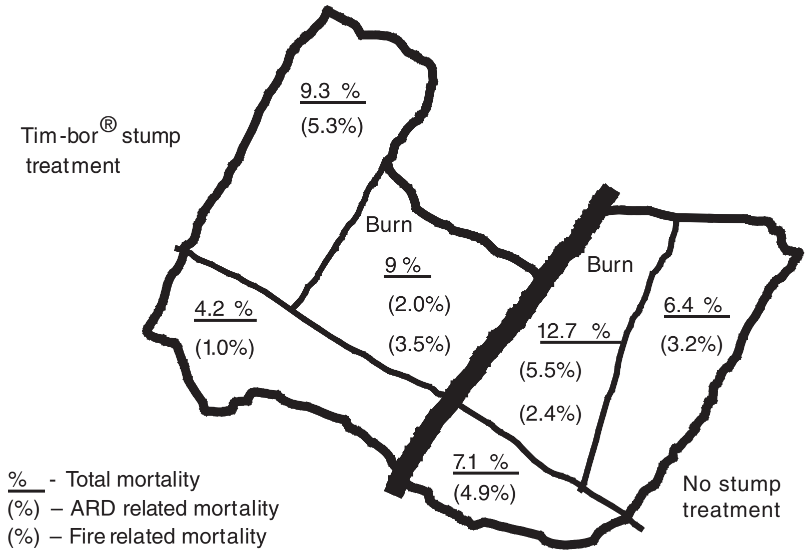

Figure 6—Percent of total tree mortality (excluding the midstory plots) by treatment block from 1996 to 2005.

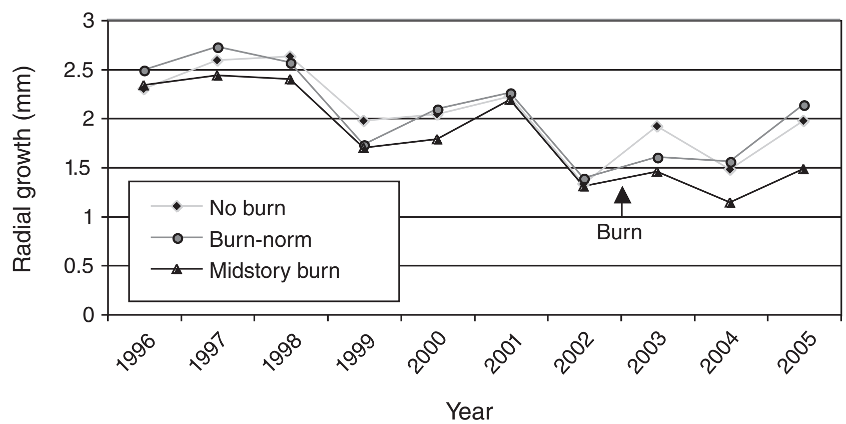

Figure 7—Average radial growth of surviving trees within different treatment plots of a longleaf stand on the Savannah River Site, SC.

case study, the plots with the most mortality were observed to have the highest bole char.

A factor that may have influenced mortality in the Tim-bor® and NST midstory plots was the wind speed and movement of heat in these blocks. During the first half of the burn in the Tim-bor® block, the wind speed in the stand was 0 MPH, which would allow heated air to rise directly into the crown (Wade and Johansen 1986). The increase in wind speed in the latter part of the day should have assisted dissipating the heat in the NST block (Wade and Johansen 1986). The three NST midstory plots also had nearby openings in the canopy (a clear-cut, skid trail, annosum root disease center) which would have allowed for greater air movement.

In many studies involving fire damage, mortality of mature trees largely occurs in the first 2 years after the burn (McHugh and Kolb 2003, Outcalt and Wade 2004, Thies and others 2006). The mortality related to fire damage in this case study occurred primarily within the first year and a half after the burn. By the second or third growing seasons after the burn, the residual trees in the burn plots appeared to recover annual radial growth rates similar to the unburned plots. Only one plot was negative for radial growth in the third year. This plot was located in the NW corner of the NST block where all fuel was consumed to the mineral soil, a factor that could be linked to higher mortality (Outcalt and Wade 2004). Annosum root disease was also present in this plot and could be a reason for a continued decline in annual growth.

The data presented in this paper only provides a single case study on the interaction of one spring burn and annosum root disease on mortality. The conditions under which prescribed fire is applied can affect the severity of the burn, and under different conditions (fuel loads, weather, duff moisture, wind speed, etc.) results can vary. The results of this case study indicate that fuels and burn conditions had a greater influence on catastrophic loss than annosum root disease. Although there was an increase in annosum root disease loss in burned areas with natural fuels, the losses appeared to be limited to trees already infected by the disease.

ACKNOWLEDGMENTS

The U.S. Department of Energy–Savannah River Operation Office through the U.S. Forest Service Savannah River provided financial support. The Forest Service staff at the Savannah River provided input, the site, fieldwork, fire crews, and GPS support for this case study. The RWU 4156 unit of the Southern Research Station USDA Forest Service in Georgia provided the Campbell scientific microloggers. Review comments were provided Kenneth Outcalt and William Otrosina.

LITERATURE CITED

Alexander, S.A.; Skelly, J.M. 1974. A comparison of isolation methods for determining the incidence of Fomes annosus in living loblolly pine. European Journal of Forest Pathology. 4: 33-38.

Barton, C.D.; Blake, J.I.; Imm, D.W. 2005. Ecological restoration. In: Kilgo, J.C.; Blake, J.I. (eds.) Ecology and Management of a Forested Landscape: 50 Years on the Savannah River Site. Island Press, Washington: 84-102.

Boyer, W.D. 1987. Volume growth loss: a hidden cost of periodic prescribed burning in longleaf pine? Southern Journal of Applied Forestry. 11: 154-157.

Brockway, D.G.; Outcalt, K.W.; Tomczak, D.J. [and others]. 2005. Restoration of longleaf pine ecosystems. Gen. Tech. Rep. SRS-83. U.S. Forest Service, Southern Research Station, Ashville, NC: 9-17.

Chapman, H.H. 1932. Is the longleaf type a climax? Ecology. 13: 328-334.

Coulson, R.N.; Witter J.A. 1984. Forest Entomology: Ecology and Management. John Wiley & Sons, Inc., New York: 669 p.

Frandsen, W.H.; Ryan, K.C. 1986. Soil moisture reduces belowground heat flux and soil temperatures under a burning fuel pine. Canadian Journal Forest Research. 16: 244-248.

Hanula, J.L.; Meeker, J.R.; Miller, D.R. [and others]. 2002. Association of wildfire with tree health and numbers of pine bark beetles, reproduction weevils and their associates in Florida. Forest Ecology and Management. 170: 233-247.

Hendrix, F.F., Jr.; Kuhlman, E.G. 1964. Root infection of *Pinus elliottii* by *Fomes annosus*. Nature. 210: 55-56.

Hille, G.G.; Stephens, S.L. 2005. Mixed conifer forest duff consumption during prescribed fires: tree crown impacts. Forest Science. 51: 417-424.

Hodges, C.S., Jr. 1974. Relative susceptibility of slash, loblolly and longleaf pines to infection by *Fomes annosus*. In: Kuhlman, E.G. (ed.) Proceedings of the fourth international conference on *Fomes annosus*. International Union of Forest Research Organizations, Section 24: Forest Protection. U.S. Forest Service, Washington DC: 86-91.

Hodges, C.S., Jr. 1970. Evaluation of stump treatment chemicals for control of *Fomes annosus*. In: Hodges, C.S., Jr.; Rishbeth, J.; Yde-Andersen, A. (eds.) Proceedings of the third international conference on *Fomes annosus*. International Union of Forest Research Organizations, Section 24: Forest Protection. U.S. Forest Service, Washington DC: 43-53.

Kuhlman, E.G. 1969. Survival of *Fomes annosus* spores in soil. Phytopathology. 59: 198-201.

McHugh, C.W.; Kolb, T.E. 2003. Ponderosa pine mortality following fire in northern Arizona. International Journal of Wildland Fire. 12: 7-22.

Otrosina, W.J.; Walkinshaw, C.H.; Zarnoch, S.J. [and others]. 2002. Root disease, longleaf pine, and prescribed burning. In: Outcalt, K.W. (ed.) Proceedings of the eleventh biennial southern silviculture research conference. Gen. Tech. Rep. SRS-48. U.S. Forest Service, Southern Research Station, Asheville, NC: 551-557.

Outcalt, K.W.; Wade, D.D. 2004. Fuels management reduces tree mortality from wildfires in southeastern United States. Southern Journal of Applied Forestry. 28: 28-34.

Rishbeth, J. 1959. Stump protection against *Fomes annosus*. II. Treatment with substances other than creosote. The Annals of Applied Biology. 47: 529-541.

Russell, P. 1956. A selective medium for the isolation of basidiomycetes. Nature. 177: 1038-1039.

Sayer, M.A.S.; Haywood, J.D. 2006. Fine root production and carbohydrate concentrations of mature longleaf pine (*Pinus palustris* P. Mill.) as affected by season of prescribed fire and drought. Trees. 20: 165-175.

Sullivan, B.T.; Fettig, C.J.; Otrosina, W.J. [and others]. 2003. Association between severity of prescribed burns and subsequent activity of conifer-infesting beetles in stands of longleaf pine. Forest Ecology and Management. 185: 327-340.

Tainter, F.T.; Baker, F.A. 1996. Forest Pathology. John Wiley, New York: 805 p.

Thies, W.G.; Westlind, D.J.; Loewen, M. [and others]. 2006. Prediction of delayed mortality of fire-damaged ponderosa pine following prescribed fires in eastern Oregon, USA. International Journal of Wildland Fire. 15: 19-29.

Varner, J.M. III; Gordon, D.R.; Putz, F.E. [and others]. 2005. Restoring fire to long-unburned *Pinus palustris* ecosystems: novel fire effects and consequences for long-unburned ecosystems. Restoration Ecology. 13: 536-544.

Wade, D.D.; Johansen, R.W. 1986. Effects of fire on southern pine: observations and recommendations. Gen. Tech. Rep. SE-41. U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, NC: 14 p.