# IMPACT OF PRESCRIBED FIRE AND THINNING ON HOST RESISTANCE TO THE SOUTHERN PINE BEETLE: PRELIMINARY RESULTS OF THE NATIONAL FIRE AND FIRE SURROGATE STUDY

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**Abstract**—The southern pine beetle (*Dendroctonus frontalis* Zimm.) is considered one of the most aggressive insect pests in the Southern United States. Resistance to southern pine beetle infestations in southern pines depends largely on oleoresin flow rate and total flow. Treatments, such as prescribed fire and thinning, can be used to reduce stand infestation susceptibility by increasing the vigor of residual pines. This study examines the short-term effect of prescribed fire and thinning on pine vigor and degree of southern pine beetle incidence. Pine vigor and beetle incidence data were compiled during the summer and fall of 2001 during a severe southern pine beetle outbreak. Although there were no significant short-term treatment effects on pine vigor or beetle incidence, 24-resin weight was found to be inversely related to both size of beetle infestations and number of beetles trapped in each stand. Direct relationships found between 24-resin weight and recent 5-year latewood percentages may indicate that increased host vigor is associated with increased area of latewood.

## INTRODUCTION

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimm., is the most important insect pest on southern pines in the United States. Infestations generally occur in overstocked stands of slow growing, low vigorous pines. However, during periods of beetle outbreak, all pines become susceptible to an attack (Payne 1980). An increase in the frequency and intensity of SPB outbreaks has been noticed in the past several decades (Price and others 1998). Increases in SPB activity appear to be closely related to changes in forest structure (Hedden 1978). Trends in land use during the past 100 years, such as fire exclusion, conversion of stands to high density pine forests, and frequent cuttings, have led to an increase of stand susceptibility to SPB attack (Cameron and Billings 1988).

Oleoresin flow is the primary tree defense against SPB infestations, and vigorous pines are thought to produce more resin than unhealthy pines (Lorio and others 1995). Reeve and others (1995) found that bark beetles have much greater reproductive success on trees with less resin. As beetles penetrate through the inner bark and expose xylem tissue in order to construct egg galleries, resin acts as a physical and chemical barrier (Payne 1980). Working from the growth-differentiation balance model proposed by Loomis (1932), Lorio (1986) postulated that during times of moderate water stress, resin flow is favored over tree growth, and beetle attack is reduced. Increased host resistance is associated with the transition of earlywood to latewood and the production of new vertical resin ducts (Lorio and others 1990). Until these new vertical ducts are formed, resin flow is limited to the vertical ducts of preceding years.

This study is a component of the National Fire and Fire Surrogate (NFFS) Study. The NFFS examines impacts of silvicultural treatments for fuel reduction on numerous ecosystem components in 13 ecosystems across the country. Silvicultural practices, such as those used in the NFFS, can be used to reduce losses from the SPB by reducing pine density and increasing individual tree vigor (Belanger and others 1993). Thinning has been shown to improve resin flow rates by increasing host crown size (Lombardero and others 2000). The disturbances caused by these silvicultural techniques, however, may cause short-term increases in SPB activity due to short-term adverse effects on tree and stand vigor (Hedden and Belanger 1985). Therefore, this study was conducted to determine the effects of prescribed fire and thinning on the incidence of SPB attack and on host resistance mechanisms.

## METHODS

### Experimental Design

A randomized block design, with blocking on tree size class, was used for this study in order to reduce the variability of tree-size classes on treatment effects. Each of the three blocks (replicates) contained four sites (treatment units) that underwent a specific treatment. The four treatments called for by the NFFS included an untreated control, prescribed fire, thinning, and a thinning with prescribed fire. Weather conditions prevented the application of prescribed fire within the thinning with prescribed fire treatment units prior to the sampling period for this study. Therefore, two thinned treatments were compared against the prescribed fire and untreated control units.

### Study Sites

Twelve study sites, one for each treatment in a replicate, were located on the Clemson Experimental Forest in the Upper Piedmont of South Carolina. These study sites were chosen on the basis of stand age, size, and management history. Each of the three replicates was dominated by different size classes of trees. Replication 1 was dominated by pulpwood-sized trees (d.b.h. 15-25 cm); Replication 3 was dominated by sawtimber-sized trees (d.b.h. > 25 cm);

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and Replication 2 was a mixture of both pulpwood and sawtimber-sized trees. All of the sites were predominately loblolly (*Pinus taeda* L.) or shortleaf (*Pinus echinata* Mill.) pines with a mixture of hardwoods in the under- and mid-story. Each treatment unit was comprised of a 10-ha measurement area and a buffer of at least one tree length surrounding the measurement area. Within the measurement area, 40 permanent grid points were established. Distance and spacing between each grid point was 50 m in one of the cardinal directions.

### Treatments

The levels of prescribed burning and thinning were defined by NFFS protocols to remove sufficient fuels so that if a wildfire occurred on a day with severe weather conditions ($80^{th}$ percentile for wind and humidity) during the wildfire season of the Piedmont of South Carolina - February through early April - 80 percent of the overstory trees would survive. Burning operations were conducted by the Clemson University Department of Forest Resources with assistance from U.S. Department of Agriculture Forest Service personnel. A backing fire was set by hand along the northeast side of the Replication 1 Burn to burn into the southwesterly wind. Strip headfires were set in parallel lines approximately 3 to 5 m apart. A backing fire was set by hand at the northern side of the Replication 2 Burn to burn into the southerly wind. Strip headfires were set in parallel lines approximately 3 to 5 m apart. A backing fire was set by hand along the northern side of the Replication 3 Burn to burn into the southerly wind. Flanking fires approximately 10 m long were set perpendicular to the backing fire, and spot fires were set in areas not covered by the flanking fires.

Thinning operations were conducted by contract in the winter of 2000 and 2001 and were specified as an operator select mechanized thinning. Small, diseased, damaged, or beetle-infested trees were selected first. Other trees were removed as necessary to provide a residual basal area of 18 $m^2$ $ha^{-1}$. Residual slash was spread over the treatment area.

### SPB Infestations

The presence and absence of SPB were monitored during the late fall of 2000 and 2001. At each grid point of a treatment unit, an ocular estimate of whether trees were infested with beetles was recorded. Signs of infestation included needle color change, pitch tubes along the bole of the tree, and wood dust in the crevices of bark or around the base of the tree.

The boundaries of beetle-infested spots from years 2000 and 2001 were mapped in February of 2002 using a GeoExplorer Model 3 Global Positioning System (GPS) unit and GPS Pathfinder Office 2.70 software (Trimble Navigation Limited, Sunnyvale, CA). These areas were then overlaid in ArcView GIS 3.2 against existing treatment unit maps, and size was determined for each beetle infestation (Environmental Systems Research Institute, Inc., Redlands, CA).

### SPB Trapping

Collection of beetle specimens began in May of 2001 and ended in October of 2001. A total of 20 flight-intercept traps (Hines and Heikkenen 1977) was placed in each of the 4 treatment units of a single replication for a 7-day period. In each treatment unit, five grid points were randomly chosen for trap location. Following the 7-day trap period, traps were removed from the four treatment units of that replication to the four treatment units of the next replicate.

Each trap was constructed from two pieces of 30- by 40-cm medium-grade Plexiglas and a 30-cm diameter plastic funnel. Using a band saw, a 20-cm slit was cut into the long side of each of the pieces of Plexiglas. The two pieces were then connected at the slits and held together with epoxy glue. Four 2.5-cm slits, each at 90° angles from one another, were cut into the top of the rim of the plastic funnel using a band saw. The connected pieces of Plexiglas were fitted and glued into these slits. Two small holes were drilled at the top of each of the two pieces of Plexiglas.

A 25-pound test fishing line was tied to a metal weight and tossed over a live, thick pine branch. The end of the line was then tied through the holes at the top of the flight-intercept trap. A 125-ml plastic jar with a 3-cm-wide mouth was half-filled with water and a drop of laundry detergent. The jar was fitted against the stem of the funnel, and the trap was hoisted in the air until it reached a height that represented the average mid-bole height of the pines surrounding the particular grid point. The trap was brought down after a week of sampling. Contents of the plastic jar were examined in the laboratory, and only beetle specimens from Scolytidae were counted and identified to species.

### Oleoresin Flow

Oleoresin flow was measured during July 2001 on four randomly selected pines at the same five grid points per treatment unit that flight-intercept traps were placed. Using a 2.54-cm arc punch, one north-facing core and one south-facing core were drilled into the bole of the sampled tree at breast height. A piece of aluminum flashing was constructed into the shape of a funnel and placed below each of the circular tree cores. A pre-weighed 15-ml plastic centrifuge tube was placed below the flashing. After a 24-hour period of collecting resin, each tube was weighed to determine the relative amount of resin flow in each pine (McCall 2000).

### Latewood Percentage

Increment cores were removed during the winter of 2002 from the same four pines at each grid point that had been sampled for oleoresin flow. Cores were placed in mounting blocks constructed from shelving. The length of earlywood and latewood bands from the past year and the past 5 years was measured using a Bannister incremental measuring machine (Jacobi 1987).

### Statistical Analysis

The number of SPB caught in each treatment unit throughout the 6-month trapping period was used as an index of stand-level beetle incidence. Infestation size per treatment unit was also used as an index of incidence. Averages of infestation size and total trap catch were used to determine the level of SPB incidence across a treatment type. Mean 24-hour resin weight per pine and recent 5-year latewood percentage were used to determine the level of host resistance across treatment units. Analysis of variance was used to determine treatment differences on both SPB incidence and host resistance. Regression analysis was used to determine correlations between host resistance and SPB incidence across a stand level.

## RESULTS AND DISCUSSION

### SPB Response to Treatments

During the sampling period, populations of SPB throughout the Piedmont of South Carolina reached epidemic levels. A total of 210 SPB was caught in flight-intercept traps throughout the 6-month trapping period (fig. 1). Post-treatment 2001 SPB infestations were found on all but 1 of the 12 treatment units (table 1). Initial examination of infestation size and trap-catch data indicated that both prescribed burning and thinning had no effect on short-term incidence of SPB (table 2). The non-homogenous variance in these data could be explained by the presence or absence of a flight-intercept trap in the path of an active SPB spot head. If a trap was not up when an active spot head moved through a grid point, then trap catch numbers were much lower than if the trap had been up when the spot moved through. This may help to explain why trap catch numbers were so disparate between treatment units that had large SPB infestation sizes—Replication 1 Control, Replication Thin A, Replication 2 Burn, and Replication 3 Thin B.

Coster and Searcy (1981) reported that site factors, rather than stand condition, were related to the occurrence of infestations of SPB in the Piedmont. These site factors include percentage of clay in the soil surface, slope percentage, and specific tree density. Silvicultural treatments such as prescribed burning and thinning may reduce a stand's susceptibility to a beetle attack. However, if site factors are present that increase the likelihood of an attack, then these treatments could possibly play no part in reducing stand susceptibility. Furthermore, burning and thinning actually can cause short-term increases of SPB due to short-term tree stress. However, burning and thinning can reduce overall beetle incidence by reducing pine density (Hedden and Billings 1979).

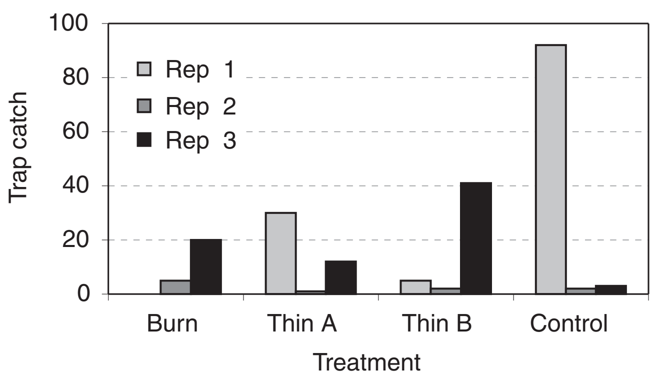


Figure 1—Number of SPB caught in flight-intercept traps from May through October 2001.

**Table 1—Area of SPB infestations in each of the 12 treatment units**

| Replication | Treatment | 2001 infestation size |
|---|---|---|
| | | *ha* |
| 1 | Burn | 0.29 |
| 2 | Burn | 3.31 |
| 3 | Burn | 1.31 |
| 1 | Thin A | 4.81 |
| 2 | Thin A | 0.49 |
| 3 | Thin A | 0.22 |
| 1 | Thin B | 0.00 |
| 2 | Thin B | 0.14 |
| 3 | Thin B | 1.26 |
| 1 | Control | 4.24 |
| 2 | Control | 0.78 |
| 3 | Control | 0.38 |

**Table 2—Mean response of Southern Pine Beetle incidence and host vigor characteristics to treatments**

| Treatment | Trap catch | 2001 infestation size | 24-hour resin weight | Recent 5-year latewood percentage |
|---|---|---|---|---|
| | | *ha* | *g* | |
| Burn | 8.3a ± 6.0 | 1.64a ± 0.89 | 9.15a ± 2.16 | 43.80a ± 1.35 |
| Thin A | 14.3a ± 8.5 | 1.84a ± 1.49 | 10.33a ± 3.01 | 43.67a ± 2.28 |
| Thin B | 16.0a ± 12.5 | 0.47a ± 0.40 | 9.18a ± 0.83 | 46.14a ± 1.73 |
| Control | 32.3a ± 29.8 | 1.80a ± 1.23 | 8.05a ± 2.17 | 45.34a ± 3.41 |

Means ± standard error followed by same letter in each column are not significantly different at the $P < 0.05$ probability level

## Host Vigor Characteristics and SPB Activity

July oleoresin flow and latewood percentages were not affected by any of the treatments (table 2). There were, however, stand level interactions between SPB activity, resin flow, and recent 5-year latewood percentages. We observed significant relationships between both trap catch (fig. 2), ($p = 0.04$)) and the size of 2001 SPB infestations (fig. 3), ($p = 0.003$) with the log of 24-hour resin weight. This pattern suggests that as total resin flow across a treatment unit increased, beetle activity within that stand decreased. The three treatment units with the largest beetle infestations in year 2001—Replication 1 Control, Replication 1 Thin A, and Replication 2 Burn—had the lowest total resin weight of all treatment units. These results are consistent with the previous understanding that the oleoresin system of pines is the primary defensive mechanism against attacking SPB (Lorio and others 1995).

There was a stand level positive relationship between 24-hour resin flow and recent 5-year latewood percentages (fig. 4), ($p = 0.007$). The data presented here suggest that the relative amount of latewood a tree establishes has effects on the amount of resin flow that is produced. Latewood percent in mature pines may be a good indicator of resistance to SPB attack. Strom and others (2002) recently showed that progeny of pines, which escaped or survived SPB attack when surrounding pines were killed, had significantly greater resin flow when compared to the progeny of randomly sampled, unattacked pines from the same area. Latewood percent and resin-duct density are just two of several factors controlling oleoresin flow. Other factors include the moisture status of the tree and the amount of photosynthate produced. Photosynthate production is closely related to the crown percent and total leaf area of the pine (Dunn and Lorio 1992). Pines with large crowns will have greater oleoresin flow than trees of the same age with small crowns.

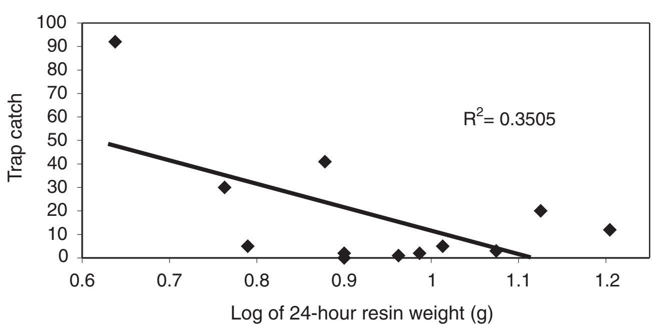


Figure 2—Relationship between the total number of SPB caught and a logarithmic transformation of mean 24-hour resin weight within each treatment unit (n = 12).

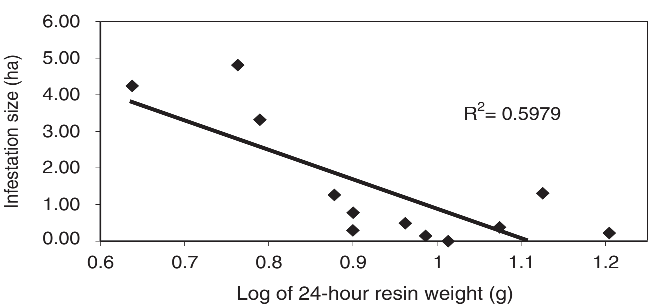


Figure 3—Relationship between the SPB infestation size and a logarithmic transformation of mean 24-hour resin weight within each treatment unit (n = 12).

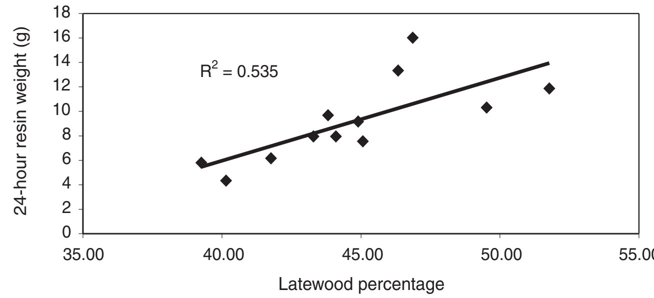


Figure 4—Relationship between mean 24-hour resin weight and mean recent 5-year latewood percentage within each treatment unit (n = 12).

Changing environmental conditions such as drought can also substantially affect the percentage of latewood in the annual ring (Zahner 1962). During periods of drought, the transition of latewood occurs earlier than in wetter years (Lorio and others 1990). Northwest South Carolina was undergoing a period of severe drought during this study. We speculate that the severe drought accentuated differences in latewood percentage, and, consequently, the vertical resin duct density in trees between sites. These differences apparently had a significant effect on stand level resistance to SPB mortality.

Even though there were no significant short-term effects of thinning and fire on SPB mortality in this study, the long-term effects could be pronounced. Thinning, and possibly burning, will reduce intra-tree competition, therefore providing for an increase in leaf area, which should result in a greater supply of photosynthate available for oleoresin production. Response of latewood production following thinning and fire will probably be site specific (Megraw 1985). Where moisture is limiting, increased water status can lead to a significantly greater percentage of latewood (Megraw 1985, Zahner 1962). However, in general, the absolute amount of latewood produced will be directly related to the growth rate of the tree whereas the percentage of latewood will be unaffected (Zobel 1995). Because the resin duct system of the pine is the site of oleoresin production, increased amounts of latewood—everything else being equal—will result in greater oleoresin flow and reduced mortality due to SPB attack.

## CONCLUSIONS

Total 24-hour resin flow had a significant positive correlation with recent 5-year latewood percentages across treatment units. Also, resin flow was inversely related to beetle activity. These data provide further evidence to the hypothesis that resin flow is the primary host defense mechanism against invading SPB. Furthermore, the amount of recent latewood formed may be a critical factor in the determination of total amount of resin flow produced by the host conifer.

Fire and thinning had no short-term effects on SPB incidence of attack or host resistance mechanisms. It is yet to be determined what long-term effects fire and thinning have on SPB spot occurrence and growth in the Piedmont. However, reduction in stand density along with increased tree vigor should result in lower long-term susceptibility to SPB attack.

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## LITERATURE CITED

Belanger, R.P.; Hedden, R.L.; Lorio, P.L. 1993. Management strategies to reduce losses from the southern pine beetle. Southern Journal of Applied Forestry. 17: 150-154.

Cameron, R.S.; Billings, R.F. 1988. Southern pine beetle: factors associated with spot occurrence and spread in young plantations. Southern Journal of Applied Forestry. 10: 105-108.

Coster, J.E.; Searcy, J.L., eds. 1981. Site, stand, and host characteristics of southern pine beetle infestations. Tech. Bull. 1612. U.S. Department of Agriculture, Combined Forest Pest Research and Development Program. 115 p.

Dunn, J.P.; Lorio, P.L. 1992. Effects of bark girdling on carbohydrate supply and resistance of loblolly pine to southern pine beetle (*Dendroctonus frontalis* Zimm.) attack. Forest Ecology and Management. 50: 317-330.

Hedden, R.L. 1978. The need for intensive forest management to reduce southern pine beetle activity in east Texas. Southern Journal of Applied Forestry. 2:19-22.

Hedden, R.L.; Belanger, R.P. 1985. Predicting susceptibilty to southern pine beetle attack in the Coastal Plain, Piedmont, and Southern Appalachians. In Branham, S.J.; Thatcher, R.C., eds. Integrated pest management research symposium: the proceedings. Gen. Tech. Rep. SO-56. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 171-175.

Hedden, R.L.; Billings, R.F. 1979. Southern pine beetle: factors influencing the growth and decline of summer infestations in east Texas. Forest Science. 25: 547-556.

Hines, J.W.; Heikkenen, H.J. 1977. Beetles attracted to severed Virginia pines. Environmental Entomology. 6: 123-127.

Jacobi, J.C. 1987. Dendroclimatic examination of white oak along a soil-moisture gradient in the Piedmont of South Carolina. MS Thesis. Clemson, SC: Clemson University. 66 p.

Lombardero, M.J.; Ayers, M.P.; Lorio, P.L. [and others]. 2000. Environmental effects on constitutive and inducible resin defenses of *Pinus taeda*. Ecology Letters. 3: 329-339.

Loomis, W.E. 1932. Growth-differentiation balance vs. carbohydrate-nitrogen ratio. Proceedings of the American Society for Horticulture Science. 29: 240-245.

Lorio, P.L. 1986. Growth-differentiation balance: a basis for understanding southern pine beetle-tree interactions. Forest Ecology and Management. 14: 259-273.

Lorio, P.L.; Sommers, C.A.; Blanche, J.D. [and others]. 1990. Modeling pine resistance to bark beetles based on growth and differentiation balance principles. In Dixon, R.D.; Meldahl, R.S.; Ruark, G.A.; Warren, W.G., eds. Process modeling of forest growth responses to environmental stress. Portland, OR: Timber Press: 402-409.

Lorio, P.L.; Stephen, F.M.; Paine, T.D. 1995. Environment and ontogeny modify loblolly pine response to induced acute water deficits and bark beetle attack. Forest Ecology and Management. 73: 97-110.

McCall, J.S. 2000. The role of bluestain fungus in the death of pine trees attacked by the southern pine beetle. MS Thesis. Clemson, SC: Clemson University. 59 p.

Megraw, R.A. 1985. Wood quality factors in loblolly pine. Atlanta, GA: Tappi Press. 88 p.

Payne, T.L. 1980. Life history and habits. In: Thatcher, R.C.; Searcy, J.L.; Coster, J.E.; Hertel, G.D., eds. The southern pine beetle. Tech. Bull. 1631. U.S. Department of Agriculture, Forest Service: 7-28.

Price, T.S.; Doggett, C.; Pye, J.M. [and others]. 1998. A history of southern pine beetle outbreaks in the Southeastern United States. Atlanta, GA: Georgia Forestry Commission. 71 p.

Reeve, J.R.; Ayres, M.P.; Lorio, P.L. 1995. Host suitability, predation, and bark beetle population dynamics. In: Cappuccino, N.; Price, P.W., eds. Population dynamics: new approaches and synthesis. Sam Diego, CA: Academic Press: 339-357.

Strom, B.L.; Goyer, R.A.; Ingram, L.L. [and others]. 2002. Oleoresin characteristics of progeny of loblolly pines that escaped attack by the southern pine beetle. Forest Ecology and Management. 158: 169-178.

Zahner, R. 1962. Terminal growth and wood formation by juvenile loblolly pine under two soil moisture regimes. Forest Science. 8: 345-352.

Zobel, B.J.; Jett, J.B. 1995. Genetics of wood production. Berlin: Springer-Verlag. 337 p.