CROWN PHYSIOLOGY AND GROWTH OF SAPLING LONGLEAF PINE AFTER FIRE

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Introduction

Fire affects foliage and thus, whole-crown C fixation potential. When repeated throughout a rotation, therefore, fire has a potential impact on stemwood growth and C allocation among the foliage, stem and roots. Depending on frequency and intensity, prescribed fire causes foliage damage that may lead to a long-term reduction in stand growth. Past research, however, is inconclusive regarding the effect of repeated prescribed fire on tree growth (Boyer 1987, Waldrop et al. 1987, Brockway and Lewis 1997).

Longleaf pine ecosystems benefit from prescribed fire every two to four years (Brockway and Lewis 1997, Outcalt 2000). We need a better understanding of how the frequency and intensity of fire affect the foliage dynamics and C allocation of this fire-adapted species, as well as knowledge of physiological mechanisms that restore this species' C fixation potential after fire. This information will provide physiology-based guidelines relevant to the timing and burning conditions that minimize leaf area and physiological limitations to stemwood growth and sustained forest productivity.

We hypothesize that the fascicle physiology and leaf area dynamics of sapling longleaf pine are affected by prescribed fire. Effects may be negative with lower physiological function of residual foliage and reduction in leaf area by crown scorch. Alternatively, effects may be positive by accelerated rates of net photosynthesis and leaf area production immediately after fire. Our present objectives are to report the effects of prescribed fire on the fascicle physiology, crown leaf area, and branch phenology of sapling longleaf pine one year after burning.

Materials and Methods

Study site

The study is being conducted in two longleaf pine plantations on the Calcasieu Ranger District of the Kisatchie National Forest, Rapides Parish, LA. In either 1996 or 1997, one study site each was prepared for planting by chopping and burning and treatment plots (22 x 22 m; 0.048 ha) were delineated and blocked. Three vegetation management treatments were applied in two blocks at one location and in three blocks at the second location. One location each was planted, 1.8 x 1.8 m, in March of 1997 or 1998 with container-grown longleaf pine seedlings from one genetically improved, Louisiana seed orchard source.

Soils

The soil at one study site is predominantly Ruston with some Gore and Malbis. The Ruston fine sandy loam is well drained, and moderately permeable. The Gore silt loam is moderately well drained, and very slowly permeable. The Malbis fine sandy loam is well drained to moderately well drained, and moderately slowly permeable. The soil at the second site is Beauregard silt loam which is moderately well drained, and slowly permeable.

Experimental design

The study design is a randomized complete block design with three treatments and five blocks. Two or three blocks were established at one of two locations in consecutive years. Plots were blocked by apparent permeability. The vegetation management treatments are: (1) Control (C): No vegetation management after planting, (2) Chemical control of woody and herbaceous vegetation (H): Preplant broadcast application of Roundup (glyphosate, 5% solution) , post-plant application of Velpar L (hexazinone, 0.4% solution) in 0.9 m bands over seedlings in spring for two years and direct application of Garlon 4 (triclopyr) as needed to woody competition as a directed foliar spray until runoff (5% solution), or as a directed basal spray (20% solution), and (3) Biennial prescribed burning in May-June (B): Strip-headfires were applied in June 2000 and May 2003.

Measurements

Fascicle physiology. In fall 2003, three saplings of average height per measurement plot were randomly selected. In May, July and September 2003, the physiology of detached fascicles from the upper and lower one-half of crowns were measured with a portable photosynthesis system (Model 6400, Li-Cor, Inc.

Lincoln, NE) and standard needle chamber equipped with a LED light source. All physiological measurements were conducted at 1400 umol m^{-2} sec^{-1} photosynthetic photon flux density (PPFD) between 0900 and 1500. Measured variables were net photosynthesis (P_n), transpiration (E), and stomatal conductance (g_s). Measurements are expressed on a leaf surface area basis.

Leaf area production. For each treatment plot, 33^{rd} percentiles of sapling height in early 2003 were determined. In September 2003, three healthy saplings, one randomly selected from each 33^{rd} percentile, were destructively harvested from the two-row buffer of each treatment plot.

The live crown was divided and fascicles were excised from the upper and lower one-half of crowns. Foliage that developed in 2002 was pooled and foliage that developed in 2003 was separated into three age classes: cohort 1, cohort 2 and cohort 3 and greater. Foliage was dried to equilibrium at 70^oC and weighed. Before drying, five fascicles each of the 2002 foliage and cohort 1 of 2003 in the upper and lower crown were sub-sampled for development of regression equations that predict total leaf area (TLA) from foliage dry weight. The TLA of foliage samples was determined by the displaced needle volume method (Johnson 1984). Equations developed for the 2002 foliage were used to predict the TLA of the 2002 foliage, and those for the first flush of 2003 were used to predict the TLA of all cohorts produced in 2003. Stems and upper and lower crown branches were dried to equilibrium at 70^oC and weighed.

Branch phenology. For each of 6 randomly selected saplings of average height per measurement plot, two live branches each in the upper and lower one-half of crowns were permanently marked. Internode length and fascicle length were measured in June through August 2003 at a 2- to 3-week interval after prescribed burning in May 2003.

Data analyses

Fascicle physiology was analyzed by analysis of variance using a randomized complete block split plot in space and time design with five blocks. Vegetation management treatment was the whole plot effect, and crown level and date were sub-plot effects. Similarly, stem dry weight (SDW) and TLA in September 2003, and monthly internode and fascicle lengths during June through August 2003 were analyzed using a randomized complete block design with five blocks. Comparison of total leaf area among cohorts was done by analysis of covariance using a randomized complete block design with stem dry weight as the covariate. Relationships between total leaf area and stem dry weight were evaluated by regression analyses. Main and interaction effects were considered significant at $P \leq 0.05$ and significantly different treatment means were compared with the least significant difference test at $P \leq 0.05$.

Results

Values of P_n, g_s, and E were significantly greater in the upper crown than in the lower crown. Significant main effects of vegetation management treatment indicated that P_n, g_s, E were lower on the H plots than on the B plots and that values on the B and C plots were similar. This response is attributed to differences in light availability among the treatments. Saplings on the H plots were larger than those on the C and B plots. As a result, crown closure and shading on the H plots caused light limitations that were not apparent on the C and B plots. Both P_n and g_s were significantly affected by an interaction between crown position and treatment. In general, upper crown P_n and g_s were greater on the C and B plots compared to the H plots, and lower crown P_n and g_s were greater on the B plots compared to the C and H plots (Figure 1).

Differences in lower crown physiology on the B and H plots were due to light limitations in the lower crown of the H plots. We hypothesize that differences in lower crown physiology on the C and B plots were due to less competition for light in the lower crown of the B plots compared to the C plots. Observation of P_n by date indicates that significant increases in P_n on the B plots occurred in July 2003, but not in September 2003. Burning-induced increases in P_n may have been limited to two to three months, or stand conditions in September 2003 could have restricted P_n across the treatments.

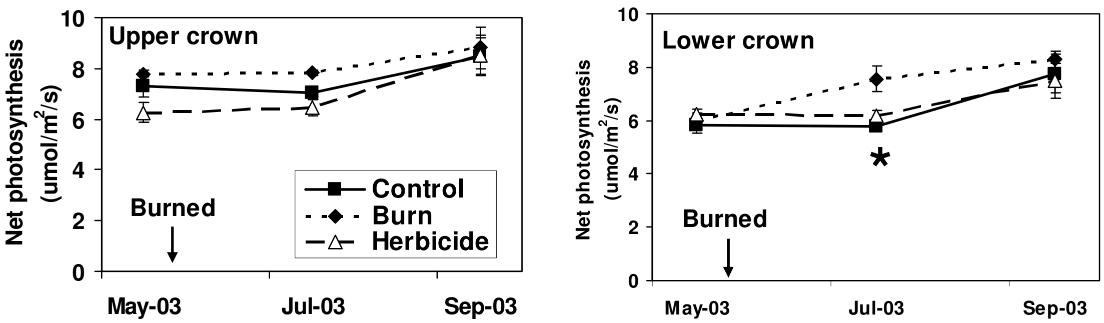

Figure 1. Net photosynthesis in the upper and lower one-half of 5-year-old sapling longleaf pine crowns before prescribed burning in late May 2003 and afterward in July and September 2003 in central Louisiana.

Values of TLA and SDW per tree were significantly greater on the H plots compared to the C and B plots, and TLA and SDW per tree were similar between the C and B plots. When mean values of TLA per cohort in the upper and lower crown were adjusted by SDW, two significant treatment effects were observed. First, the TLA of the first flush of 2003 in the lower crown was significantly lower on the B plots compared to the C plots. Reduced first flush TLA in the lower crown on the B plots could be attributed to crown scorch. Second, the TLA of the second flush of 2003 in the upper crown was significantly greater on the B plots compared to the C plots. Furthermore, we observed a greater amount of upper crown second flush TLA per unit of SDW on the B plots compared to the C and H plots (Figure 2). Because prescribed fire causes foliage and branch damage in the lower crown and the second flush of 2003 initiated immediately after burning, we hypothesize that the pattern of C allocation to flush growth in the upper and lower crown, stem growth and root production differs between the B plots and the C and H plots.

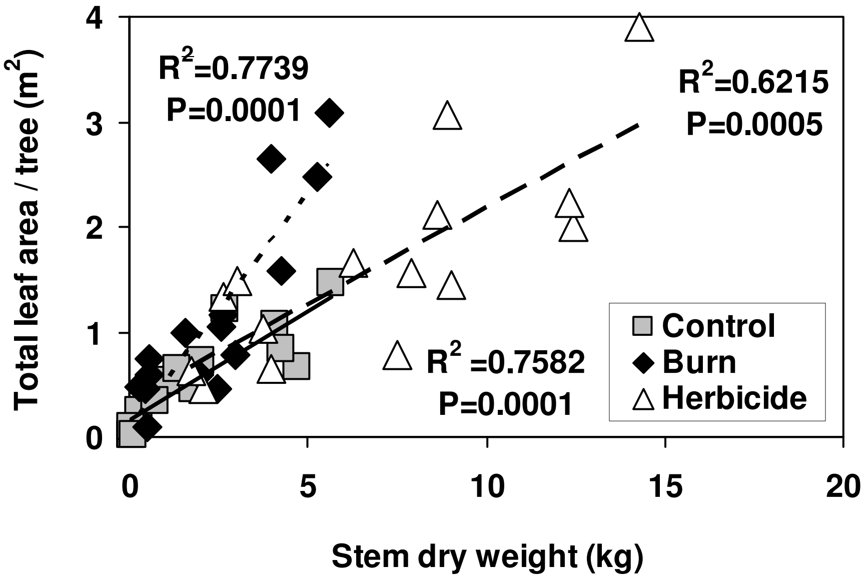

Figure 2. Relationship between total leaf area of the upper crown second flush and stem dry weight of 5-year-old sapling longleaf pine in September 2003 after a late May 2003 prescribed fire in central Louisiana.

First flush expansion in the lower crown, and first flush fascicle expansion in the upper crown were significantly affected by vegetation management treatment. Specifically, expansion of the first flush in the lower crown was significantly less on the C plots compared to the H and B plots in June and July 2003. The expansion of first flush fascicles in the upper crown was significantly greater on the B plots compared to the C and H plots in June and July 2003. There were no significant treatment effects on the expansion of second, third and fourth flush internodes and fascicles.

Our results demonstrate potential reductions in longleaf pine C-fixation potential by fire with the loss of leaf area in the lower crown. However, we also observed an increase in lower crown P_n and an increase in upper crown second flush TLA with prescribed fire. Research will continue to evaluate how the negative and positive effects of prescribed fire affect whole-tree C allocation and biomass production by longleaf pine.

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