# LONG-TERM EFFECTS OF SEASON OF PRESCRIBED BURN ON THE FINE-ROOT GROWTH, ROOT CARBOHYDRATES, AND FOLIAR DYNAMICS OF MATURE LONGLEAF PINE

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**Abstract**—Depending on the season and intensity of fire, as well as the phenology of foliage and new root growth, fire may damage foliage, and subsequently decrease whole-crown carbon fixation and allocation to the root system. In central Louisiana the authors investigated how season of prescribed burning affects fine-root dynamics, root carbohydrate relations, and leaf area production in 45-year-old longleaf pine. After achieving a steady state, fine-root production was greater in plots burned in March and May than in those burned in July. In both 1998 and 2000, root starch metabolism was lower on plots burned in July than on those burned in May. Month of biennial prescribed fire did not appear to affect leaf area production. However, foliar magnesium concentration was greater in plots burned in March and May than in those burned in July. These results indicate that additional mechanisms of reduced root growth in response to repeated burning are possible. The authors speculate that on this study site, season of prescribed burn influenced root growth by affecting mineral nutrition and root carbohydrate metabolism.

## INTRODUCTION

The acquisition of water and mineral nutrients by roots is required for sustained forest growth. Root growth and function depend on carbon fixation in the crown and allocation to the root system. Fire damage to the crown of longleaf pine (*Pinus palustris* Mill.) may reduce the amount of carbon available to the root system (Johansen and Wade 1987, Sword and Haywood 1999). Furthermore, the risk of fire-induced damage to the crown increases as foliage production and drought potential increase during the growing season. Thus, the potential impact of repeated prescribed fire on root growth and function may vary by season. The objective of this study was to determine if longleaf pine fine-root production and carbohydrate concentrations respond differently to repeated prescribed fire in March, May, and July.

## MATERIALS AND METHODS

The research area is located in a 45-year-old longleaf pine stand on the Palustris Experimental Forest in the Kisatchie National Forest, Rapides Parish, LA. The study site is described in Haywood and others (2001). Measurements were conducted in three- to four- and six- to seven-tree clusters in two replications of three prescribed-burning treatments (March, May, or July biennial burns) in a completely randomized design. Biennial prescribed burning treatments were applied as strip head fires beginning in 1966, with the latest in 1998. Volume and basal area of the clusters were not affected by the month of prescribed burning.

Leaf area index was monitored monthly using two LI-COR LAI-2000 Plant Canopy Analyzers (LI-COR, Inc., Lincoln, NE) from March 1998 to April 2001. The monthly readings were taken along permanent transects in each six- to seven-tree cluster and in a nearby open field for comparative purposes. Fine-root quantity and biomass on an ash-free basis were determined using 785-$cm^3$ in-growth cores (Vogt and Persson 1991) installed on a 0.3-$m^2$ grid within 5 m of trees in six- to seven-tree clusters. The cores were installed in February 1998. Six in-growth cores were extracted from all plots every 2 months between August 1998 and February 2000. Root carbohydrate concentration was measured monthly in three- to four-tree clusters. Five soil cores were extracted from random locations in the periphery of the clusters. Roots (2 to 5 mm in diameter) from the cores were pooled, washed, freeze dried, and ground to pass through a 20-mesh screen. Concentrations of root starch, sucrose, and glucose were determined enzymatically (Jones and others 1977). Foliar samples from the upper crown of three trees per plot were collected in January 2001. A LECO CNS-2000 elemental analyzer was used to determine foliar nitrogen (N) concentration. Foliar phosphorus (P) concentration was determined colorimetrically (John 1970), and foliar potassium (K), calcium (Ca), and magnesium (Mg) concentrations were determined by atomic absorption (Isaac and Kerber 1971). Treatment differences in fine-root quantity and biomass, root carbohydrate concentrations, and foliar nutrients were statistically tested using analysis of variance procedures.

## RESULTS AND DISCUSSION

Month of biennial prescribed fire did not affect leaf area production. Prolonged drought during the 1998 to 2000 study period (Haywood and others, in press) may have reduced leaf area production and interfered with the seasonal pattern of foliage senescence. As a result, prolonged drought may have interfered with potential leaf area responses to prescribed burning treatments. After achieving a steady state of root production 14 months after in-growth core installation, month of prescribed burn significantly affected total (live plus dead) fine-root quantity [probability of a greater F-value ($P$) = 0.0536] and live fine-root quantity ($P$ = 0.0392) (fig. 1A). Similarly, live fine-root

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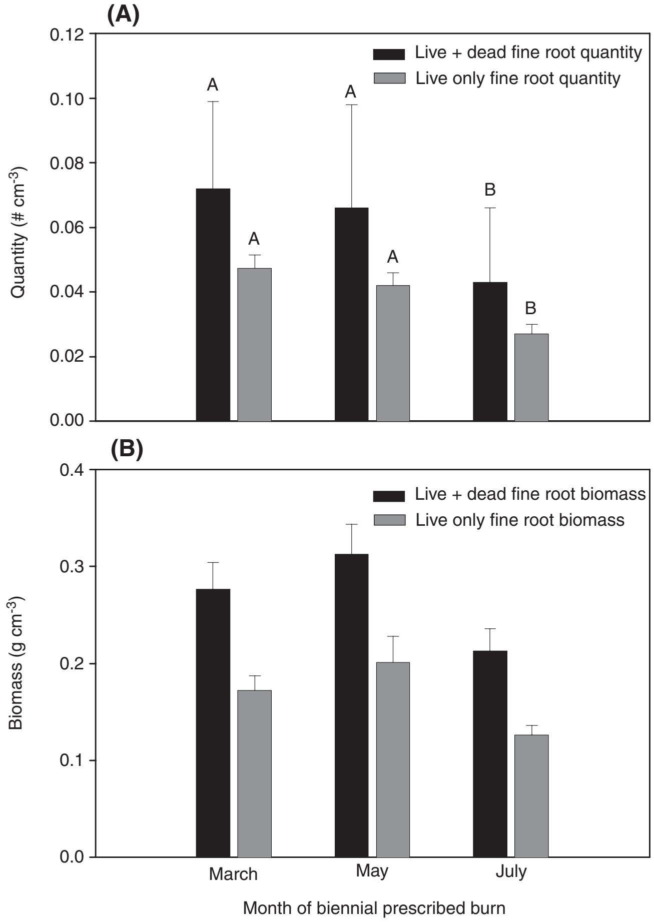


Figure 1—Mean total (live plus dead) and live-only longleaf pine fine-root quantity (number/cm³) (A) and biomass (g/cm³) (B) between April 1999 and February 2000 in response to month of biennial prescribed burn. Means associated with a different letter are significantly different at a *P* d” 0.10 by least squares means.

biomass was differentially impacted by sampling date and month of prescribed burn ($P = 0.0345$). In April 1999, May-burn root biomass was significantly greater than March- and July-burn biomass; however, in December 1999, the May-burn biomass was only significantly greater than the July-burn biomass (fig. 1B). These main and interaction effects indicate that fine-root production was lower on plots that were prescribed burned in July than on those that were prescribed burned in March or May.

Root starch and glucose concentrations varied seasonally. A reduction in annual peak starch (21 percent in 1999 and 2000 compared with 1998) and glucose (28 percent in 2000 compared with 1998 and 1999) was observed. Mean annual root sucrose concentration increased 125 percent in 2000 compared with 1998 and 1999. Root starch concentrations were significantly different by sampling date and month of prescribed burn ($P = 0.0807$). Specifically, the rate of starch depletion from roots between May and October was lower on the July-burned plots than on the May-burned plots in 1998 and 2000 (fig. 2).

Foliar nutrient concentrations indicated that P was deficient, N and Ca were nearly deficient, and Mg and K were sufficient in all treatments as defined by Blevins and others (1996). Foliar Mg concentration was significantly lower ($P = 0.0100$) on the July-burned plots than on the March- and May-burned plots (table 1).

These results demonstrate consistent effects of season of prescribed fire on fine-root production, root starch metabo-

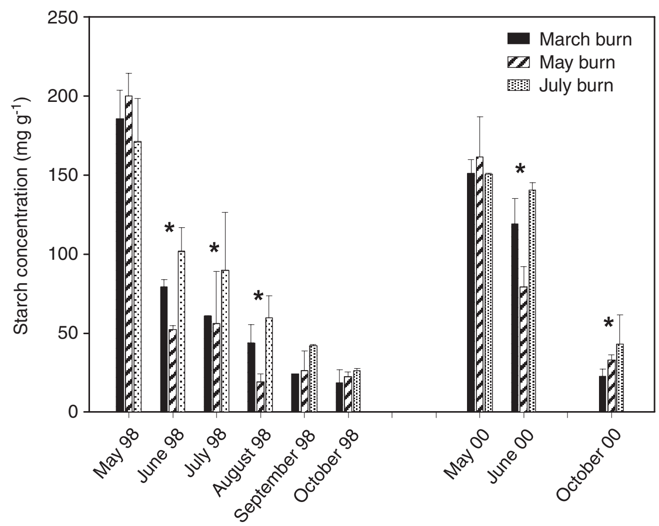


Figure 2—Longleaf pine root starch concentration (mg/g) between May and October of 1998 and 2000 in response to month of biennial prescribed burn. An asterisk (*) above the group of bars indicates statistical significance between May- and July-burn treatments at a *P* d” 0.05 by least squares means. Data from November 1998 to April 2000 are not shown. Between July and September 2000, root samples were not collected.

**Table 1—Dormant season mean longleaf pine foliar nutrient levels (± 1 standard error) in response to month of biennial prescribed burn**

| Nutrient | Critical level[a] | Month of biennial prescribed burn: March | May | July |
|---|---|---|---|---|
| N (*percent*) | 0.95 | 1.02 (0.09) | 0.97 (0.03) | 0.92 (0.03) |
| P (*g kg*$^{-1}$) | 0.80 | 0.71 (0.06) | 0.70 (0.05) | 0.70 (0.04) |
| K (*g kg*$^{-1}$) | 3.00 | 3.61 (0.17) | 3.20 (0.17) | 3.19 (0.40) |
| Ca (*g kg*$^{-1}$) | 1.00 | 0.95 (0.10) | 0.94 (0.04) | 1.13 (0.13) |
| Mg (*g kg*$^{-1}$) | 0.60 | 0.97 (0.06)a[b] | 1.07 (0.05)a | 0.78 (0.07)b |

[a] Concentration below which the nutrient is considered deficient (Blevens and others 1996).

[b] Means followed by different letters are significantly different at a probability less than or equal to 0.05 by Least Squares Means.

lism, and foliar Mg concentration. Because leaf area production was unaffected by season of prescribed fire in this study, conclusions about how seasonal fire regimes affect leaf area production and carbon allocation to fine-root production cannot be made. Prolonged drought may have distorted root carbohydrate relations by increasing the sucrose concentration (in 2000) and decreasing peak glucose (in 2000) and starch (in 1999 and 2000) concentrations. A similar interference may have occurred with leaf area and fine-root production and with foliar nutrition. Continued research is warranted to understand the long-term effect of season of repeated prescribed fire on fine-root production.

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