INTRODUCTION
Crown dimension measurements are commonly used to study habitat for wildlife, encroachment rates into tree gaps, and many other aspects of tree growth (Fajvan and Grushecky 1996, Vales and Bunnell 1988, Zeide and Gresham 1991). Larger crown area often translates into more photosynthetic surface area, which can increase stem development. Many factors can affect crown size, including silvicultural treatments, thinning (Smith and others 1997), chemical control of woody competitors (Ezell and others 1997), prescribed fire (Wade and Johansen, 1986), and fertilization (Williams and Farrish 1994).

Crown growth represents the biological basis for the desired outcomes of increased tree growth and optimal use of limited space. However, few studies have systematically examined the impacts of fire, herbicide, fertilizer, and thinning practice on individual tree growth. This is a preliminary report of such a study in mid-rotational loblolly pine in East Texas.

METHODS
Study Sites
The study area consisted of two sites on land owned by International Paper Company in northeastern Texas. Both sites were thinned in 1998, 1 year before plot establishment. Site 1 was hand-planted on 1.8 m by 3.1 m spacing, and row-thinned and thinned within the rows to a basal area of 13 m²/ha before plot establishment. Soils were of the Darco, Tenaha, and Osier series; slopes ranged from 3-15 percent. The site index was 65 at base age 25 years.

Site 2 was machine-planted on 1.8 m by 3.7 m spacing, and row-thinned to a basal area of 22 m²/ha one year before plot establishment. Soils were of the Ruston and Attoyac series, with slopes ranging from 3-15 percent. The site index was 71 at base age 25 years.

Five replicates at both sites were established in 1999. Each replicate consisted of 8 treatment subplots (40 plots per site) each 0.10 ha in size. A central 0.04 ha...
A measurement plot was established within each subplot. A randomized-block-split-plot design was used in which half of each replicate was randomly chosen for application of fertilizer, and each treatment (control, herbicide, prescribed fire, and herbicide/prescribed fire) was randomly assigned to the treatment subplots. A 10-m buffer separated each treatment subplot. All trees greater than 5 cm in diameter located within the subplots were tagged, identified to species, and measured for total height and DBH. There were approximately 20 and 35 trees per subplot at Sites 1 and 2, respectively.

**Treatments**

Due to a late summer drought, herbicide was applied in October, 1999. A herbicide mixture of 4.5 L/ha Chopper®, 2.2 L/ha Accord®, 11.2 L/ha Sun-It® II oil, and 76.7 L/ha water was applied at Site 2. The same mixture was applied at Site 1, except that the amount of Accord® was increased to 2.5 L/ha, in an attempt to control a more dense understory. The mixtures were broadcast using a CO₂ backpack sprayer with a 3.66 m boom. Competing woody vegetation taller than 3.66 m was injected with a mixture of 100 ml ArsenalAC diluted in 300 ml of water.

Firelines were installed around each burn plot to preserve the 10-m buffer. Prior to burning, ceramic tiles coated with strips of heat-sensitive paint (Tempilaq®) were installed at each plot center. The paint disintegrated at 100, 200, 400, 800, or 1000°C, thereby allowing for an estimate of fireline intensities. Four painted tiles per plot center were suspended from a rebar post at 4 levels: subsurface, surface, 0.3 m and 0.6 m aboveground.

The plots were prescribe-burned in March, 2000, using strip backfires. A backfire was used in an attempt to limit canopy damage due to scorch. Scorch heights (if any) were determined for each tagged tree.

In April following the burn, the fertilizer treatment was applied using a standard spreader. Diammonium
Measurements
The crown area of each tree was determined in June, 2000 as follows (Farr and others 1989, Laroque and Marshall 1994, Peterson and others 1997). The length of the longest branch in each cardinal direction between the branch tip and tree stem was obtained using an electronic distance meter (Forestor Vertex, Haglof, Sweden). The area of the resulting polygon was calculated, after correcting for the radius of the tree. To ascertain the accuracy of the method, the results were compared with those calculated using 12 measurements per tree made at equal angular increments from a reference line. Use of 4 measurements consistently underestimated the crown area, but by less than 10 percent. The reproducibility of the measurement method was determined by making crown-area determinations on 10 different days, using 4 measurements per tree (5 trees). The average variation in the measurements was less than 7 percent.

The total height and outside bark DBH of each tagged tree were measured in December, 2000.

Study Metric and Statistical Analysis
To study the effect on tree growth of vegetative control (fire and herbicide), fertilizer, and thinning practice, it was necessary to control for any differences in tree diameter that existed prior to commencing the experiment. This was accomplished using a leaves-to-tree (LT) metric defined and calculated as follows. For each tree, the diameter (in cm) measured in December, 2000 was divided by the corresponding crown area (in m²) measured in June, 2000. LT was, therefore, a simple measure of growth that related the diameter of the tree to its crown area measured 6 months earlier. The aim of the study was to determine how LT was affected by the study factors. For simplicity in interpretation, this was done on the basis of simple comparisons. Because LT was not normally distributed, differences were analyzed using the Mann-Whitney U test.

RESULTS AND DISCUSSION
At Site 1, herbicide treatment significantly increased growth, as assessed using LT (figure 1). The effect of fire was marginal, and it antagonized the effect of herbicide when the two treatments were combined (figure 1). Similar results occurred in both fertilized and unfertilized plots.

At Site 2, treatment with fire plus herbicide produced a significant increase in LT on both unfertilized and fertilized plots (figure 2). Either treatment alone had no beneficial effect.

Significant inter-site differences were seen in the response of the trees per unit of crown area to vegetative control. The differences could be due to the different thinning methods used at each site. Alternatively, they could be due to the slightly higher productivity at Site 1. the effect of thinning was likely more important because the addition of fertilizer had essentially no effect at either site.
