

INITIAL RESPONSE OF LOBLOLLY PINE AND COMPETITION TO MID ROTATION FERTILIZATION AND HERBICIDE APPLICATION IN THE GULF COASTAL PLAIN

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Abstract—Application of N and P to mid-rotation loblolly pines (*Pinus taeda* L.) stands is a common silvicultural practice used to increase crop tree production in the Gulf Coastal Plain. Mid-rotation applications of herbicides or combined applications of herbicide and fertilizer are a less common practice. We applied herbicide (1.17 l imazapyr and 0.23 l surfactant/ha) and fertilizer (409 kg-urea and 196 kg-diammonium phosphate/ha) to four mid-rotation stands (17- to 22-years-old) in southern AR and northern LA to evaluate the response of pine and woody competition to each of these treatments as well as a combination of these two treatments. Three years after initial herbicide application 50 to 83 percent of the initial woody competition had died. Mortality of the woody competition from the herbicide application was significantly greater with the addition of fertilizer than without. Net pine basal area and merchantable volume growth was increased. Net basal area growth 2 to 3 years after initial treatment application was 10 to 15 percent greater with fertilization than without. Net volume growth was greatest with the combined herbicide and fertilization treatment.

INTRODUCTION

Nitrogen and phosphorus are the most limiting nutrients for loblolly pine growth in the Southern United States (Schultz 1997). Growth of loblolly pine can be significantly enhanced by applications of these nutrients during several stages of stand development. In the Gulf Coastal Plain, Sword-Sayer and others (2004) found that fertilization at ages of 11 and 17 increased biomass production of a loblolly pine stand by 43 to 48 percent. Other studies in this region have found significant but smaller volume or diameter growth responses to fertilization (Haywood and Tiarks 1990, Williams and Farrish 2000, Bataineh and others 2006). Weed control (woody and herbaceous) following stand establishment can also increase crop tree growth. Continuous weed control during the first 3 to 6 years following plantation establishment has been found to cause greater volume growth responses than fertilizer at these early stand ages (Borders and Baily 2001). Combinations of weed control with fertilization during these early periods of stand development usually provide the greatest pine growth responses (Borders and Baily 2001, Borders and others 2004). However, weed control and/or applications of herbicide in later stages of stand development have not always been found to improve loblolly pine growth. Williams and Farrish (2000) did not find a significant response to herbicide application when applied in 25 to 26 or 30 to 32-year-old stands in Louisiana. Diameter and volume growth was not significantly increased during the first four years following herbicide application in an 18-year-old loblolly pine plantation located in Texas (Bataineh and others 2006). Although growth responses of mid-rotation stands in some studies have been optimized by a combination of fertilization and herbicide application (Albaugh and others 2003) most studies in the Gulf Coastal Plain has shown no additive effects from the combination of these treatments (Williams and Farrish 2000, McInnis and others 2004, Bataineh and others 2006). To better understand the impacts of fertilization and herbicide application on loblolly pine growth and productivity within the Upper Gulf Coastal Plain, we established a study in four mid-rotation loblolly stands located in AR and LA.

METHODS

Study Site

The stands are located in the Upper Gulf Coastal Plain of AR and northern LA. Soils on the sites are either Paleudults or Fraglossudalfs. Three of the stands were plantations and were either planted to 1682 or 1793 trees/ha in 1985. The other stand was a natural stand and regenerated by seed tree regeneration. The seed trees at this site were removed in 1981. Each stand was thinned in either 2000 or 2001, one or two years prior to study establishment.

Experimental Design and Treatment

Twelve plots (between 0.06 and 0.10 ha) plots were established at each site (W. Crossett, S. Crossett, Marion, and Crossroads) during 2001 or 2002. All trees or other woody vegetation with a diameter at breast height (d.b.h.) ≥ 2.54 cm were permanently tagged and given a unique number. Herbicide (1.17 l imazapyr and 0.23 l surfactant/ha in 140.3 l/ha of water) was aerially applied during the fall following plot establishment to half the plots as well as a 50-m buffer around each plot. During January or February following the first growing season after herbicide application, 409 kg/ha of urea and 196 kg/ha of diammonium phosphate was applied to three plots and associated buffers that received the herbicide treatment and three that did not receive the herbicide treatment. Fertilizer was applied by hand at each plot.

Measurements and Statistical Analysis

D.b.h. of each tree and heights of each pine tree (d.b.h. ≥ 2.54 cm) in a plot were recorded prior to or just after herbicide application. D.b.h. of each tagged tree was measured annually and total height of each tagged pine tree was measured biennially there after. Mortality of the hardwoods (woody competition) was assessed annually during the early portion of the growing season. Ingrowth (d.b.h. ≥ 2.54 cm) of hardwood and other woody competition was assessed and tagged biennially after initial plot establishment. Total pine

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outside bark volume and total merchantable outside bark volume was computed biennially using volume equations by Amateis and Burkhart (1987). Total merchantable volume was calculated to a 7.62-cm top for trees with a d.b.h. greater than or equal to 14.2 cm. The experimental design of the study was a split plot with the herbicide treatment being the whole plot. Analysis of variance was used to determine differences between herbicide and fertilizer treatments. If there was a significant interaction, Tukey's mean separation test was used to determine differences between herbicide, treatment combinations. To evaluate differences in the proportion of hardwood mortality between fertilized and unfertilized herbicide treatment combinations, a Kolmogorov-Smirnov nonparametric test was used. All statistical tests were performed using $\alpha = 0.05$.

RESULTS AND DISCUSSION

Initial Stand Conditions

Initial pine and hardwood density varied considerably among the four sites. Pine basal area was respectively 26.8, 16.5, 12.9 and 16.0 m²/ha at the W. Crossett, S. Crossett, Marion, and Crossroads site. Hardwood basal area was the greatest at the Crossroads site (3.2 m²/ha) and least at the South Crossett site (0.7 m²/ha). Pine density was between 488 to 1291 trees/ha while hardwood density was between 366 to 833 trees/ha.

Hardwood Mortality

By the end of the third growing season following herbicide application, 50 to 80 percent of the hardwood basal area in plots receiving the imazapyr treatments had died (fig. 1). Only 2.4 percent of the hardwood basal area died in the plots that did not receive herbicide. The proportion of hardwoods that died in a plot following the application of imazapyr was negatively correlated with the basal area of pine within a plot prior to imazapyr application. A simple regression equation (1) fitted to the cumulative hardwood basal area mortality during the first two years of the study indicated that the predicted hardwood mortality would be between 31 to 58 percent over the range of initial plot pine basal areas (28.4 to 11.4 m²/ha) observed in the study. These results suggest that increased pine density increases non-target species interception of herbicide and thus reduces the amount of herbicide delivered to the hardwood foliage or soil which results in reduced hardwood mortality. Increasing the amount of water applied with the herbicide in stands with high pine densities may increase the transport of the herbicide to the hardwood competition thereby increasing hardwood mortality to more acceptable levels.

$$\text{PHBAM} = -0.0136 + 0.7033 \text{ IPBA} \quad r^2 = 0.173 \quad (1)$$

where: PHBA = Proportion of hardwood basal area mortality

IPBA = Initial pine basal area

Hardwood mortality was also impacted by fertilization. After three growing seasons hardwood mortality in the herbicided plots that were not fertilized averaged 1.20 but 1.42 m²/ha on plots receiving both herbicide and fertilizer. The proportion

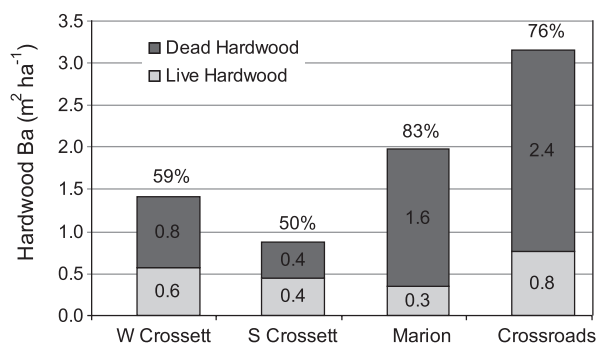


Figure 1—Basal area of hardwood and woody competition that was alive and died by the end of the third growing season following herbicide application at four sites in the Upper Gulf Coastal Plain.

of initial hardwood basal area that died during the first three years following herbicide application was consistently higher with fertilization (75.1 percent) than without fertilization (62.2 percent) for all sites (fig. 2). These differences were significant. Increases of hardwood mortality with fertilization are likely related to increased competitive ability of the pine. Nutrient amendment increases leaf area index of pine, which would likely reduce the amount of light and decrease available water for understory hardwood competition.

Pine Growth

Herbicide application did not significantly increase basal area growth of the pine during the first two years of the study (table 1). Basal area growth was significantly increased by the fertilization treatment. Although fertilizer was only applied during the start of the second year of the study, average annual basal area growth was 1.72 m²/ha per year in the fertilized plots compared to 1.56 m²/ha per year in plots without fertilization. This represented an overall 10 percent increase in growth during the initial two years of the study. Herbicide application appeared to decrease height growth while fertilizer had no effect on height growth of the pine during the first two years following study initiation. Average annual height growth was respectively 0.55 m with and 0.79 m without herbicide application. Short term stunting of pine height growth following application of imazapyr has also been reported in other studies (Quicke and others 1996). Although

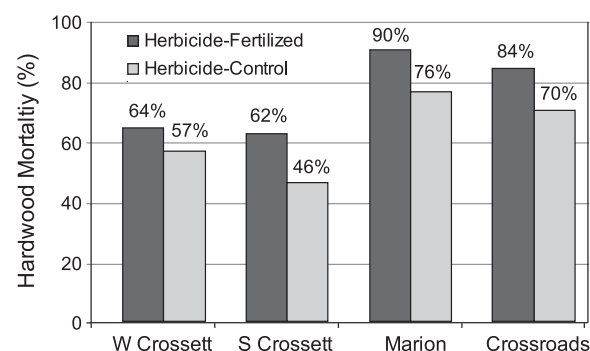


Figure 2—Cumulative proportion of hardwoods and woody competition that died by the end of the third growing season following herbicide application by fertilization treatment at four sites in the Upper Gulf Coastal Plain.

Table 1—Mean net annual pine growth (standard deviation) during the first two years of the study for each treatment combination at four study sites

Net Annual Growth	Control	Herbicide	Fertilizer	Herbicide+Fertilizer
Basal Area (m ² /ha)	1.53(0.24)	1.60(0.39)	1.63(0.23)	1.81(0.24)
Height (m/ha per year)	0.78(0.34)	0.52(0.33)	0.80(0.27)	0.58(0.30)
Total Volume (m ³ /ha per year)	18.0(3.5)	15.5(4.3)	18.5(2.6)	18.0(3.8)
Merchantable Volume (m ³ /ha per year)	19.2(3.0)	16.6(4.1)	19.3(2.4)	19.5(2.8)

the reduction in height growth was approximately 30 percent, differences were not significant. The lack of a statistically significant difference in height growth compared to basal area (d.b.h.) growth likely reflects the larger errors associated with height measurement compared to d.b.h. measurement.

Net total volume growth was consistently less than merchantable volume growth (table 1) due to the mortality of unmerchantable pine trees and ingrowth of trees into the merchantable size class. Trees that died were generally suppressed and were of low vigor prior to treatment applications. There was no significant response of net total volume growth to either the fertilizer or herbicide application. Annual total volume growth was very similar among the control, fertilizer, and fertilizer + herbicide treatments. The fertilization and herbicide interaction term was significant for net annual merchantable volume growth. Multiple range tests ranked merchantable volume growth in the following order: herbicide < control = fertilizer < fertilizer + herbicide. The poor growth of trees receiving herbicide in part was due to the higher rates of mortality associated with this treatment. Total merchantable volume mortality during the two year period was respectively 0.00, 0.63, 0.00, and 0.18 m³/ha for the control, herbicide, fertilization, and fertilization + herbicide treatments. Application of fertilizer appeared to mitigate the initial impacts of the herbicide application on merchantable volume growth but when applied without herbicide did not appear to enhance growth. Thus the combined fertilizer and herbicide treatment had the highest merchantable volume growth rate but differences between the combined treatment and control were relatively minor.

Three year basal growth responses could only be assessed for the W. Crossett, S. Crossett, and Crossroads sites because the pine at the Marian site was mistakenly thinned during the third growing season. Net basal area growth treatment responses for this three year period were similar to that for the first two growing seasons. Net basal area growth was significantly greater with fertilization than without (1.84 vs. 1.63 m²/ha per year). Fertilization increased net basal area growth by 13 percent but herbicide application had no significant effect on growth. The combined fertilizer and herbicide treatment consistently had the greatest growth but the interaction term in the ANOVA was not significant.

The lack of positive growth responses associated with herbicide application during the two to three year response period reported above are similar to that observed for a majority of sites evaluated by Albaugh and others (2003) and studies reported by Williams and Farrish (2000) and Bataineh and others (2006). Responses to herbicide

especially when applied with fertilizer frequently occur over greater periods of time (4 to 8 years) than was assessed in our study (Fortson and others 1996, Quicke and others 1996). The rapid growth responses associated with fertilization emphasize that these sites were nutrient limited and the benefit of fertilization in upper Gulf Coastal Plain pine plantations.

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