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GROWTH RESPONSE FROM HERBICIDE, PRESCRIBED FIRE, AND FERTILIZER TREATMENTS IN MIDROTATIONAL LOBLOLLY PINE: FIRST-YEAR RESPONSE

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Abstract—This study was initiated to determine growth response resulting from the application of prescribed fire and herbicide, with and without fertilization. In southeast Texas, herbicide, prescribed fire and fertilizer treatments were applied in mid-rotational loblolly pine plantations 1.5 years after thinning. Five replications were established at each of two study sites located on similar soils, aspects and slopes. Half of each replication was randomly selected and fertilized. Eight treatment plots were established in each replication with one of each of the four treatments of control, herbicide, fire, and herbicide/fire randomly applied to fertilized plots and one of each of the four treatments randomly applied to non-fertilized plots. Pre-treatment measurements were taken in a 0.04 ha measurement plot nested within each treatment plot. A late season herbicide treatment of Imazapyr and Arsenal was applied in October 1999. Burning was conducted in early spring of 2000 followed by fertilizer applications of diammonium phosphate and urea. Post-treatment measurements were taken in December 2000. Growth response and significant treatment differences are presented in this paper.

INTRODUCTION

Loblolly pine (*Pinus taeda*) plantations often receive little or no treatment between the time of stand establishment and harvest (Nyland 1996). However, studies have shown the benefit of mid-rotation manipulation in terms of increased pine growth rate, improved species composition, and wood quality (Zutter and Miller 1998, Haywood and others 1998, Borders and Bailey 1997, Cain and Yaussy 1984).

Intermediate treatments include release cuttings to improve species composition, the application of prescribed fire to remove competition and reduce crown fire hazard (Nyland 1996), the application of herbicides to remove competition (Haywood and others 1997), and fertilization to improve growth (Young and Giese 1992).

Because loblolly pine is naturally found on low and moist sites, it has evolved with no special adaptation to fire in its early years (Wright and Bailey 1982). Therefore, the use of fire in loblolly pine stands is often limited to site preparation or competition control and fire hazard reduction at mid-rotation. Although loblolly pine is less fire resistant when young, as trees age, bark thickens (Villarrubia and Chambers 1978, Cooper and Altobellis 1969) resulting in a higher tolerance to moderate fires. In addition, sunlight deprived lower limbs will fall, causing the tree crown to be less accessible to damaging flames. Both of these factors increase the tolerance of loblolly pine to moderate fire (Wade and Lunsford 1988).

Herbicides may be used as an intermediate treatment to remove competing woody vegetation, herbaceous vegetation, or both woody and herbaceous vegetation (Borders and Bailey 1997). Mid-rotational loblolly pine benefits from the removal of woody competition that severely limits its diameter growth and its ability to completely occupy a site (Hodges 1990). However, growth response may vary due to site quality, season of treatment, and type and density of competing vegetation (Lauer and Glover 1990, Hodges 1990). Herbicide and prescribed fire are often applied together as a mid-rotational treatment in loblolly pine stands (Borders and Bailey 1997).

Fertilizer may be used to improve pine tree growth in mid-rotational loblolly pine plantations. Studies over the past 20 years have shown increases in tree growth due to the use of fertilization at mid-rotation (Allen and others 1983, Gent and others 1986). Fertilization may also be best used at mid-rotation when the stand has filled most of the growing space and more nutrients are becoming tied up in living and dead plant material (Smith 1986). Fertilization alone may result in a shift toward competing vegetation, causing increases in pine mortality (Borders and Bailey 1997). It is possible that the addition of fertilizer may result in further reductions in the thickness of loblolly's already moderately protective bark (Tiarks and Haywood 1993). Growth response to fertilization may vary from site to site depending on pre-treatment soil conditions such as nutrients, soil type, and water availability (Borders and Bailey 1997). Chemical herbicide control of competing vegetation may be

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combined with fertilization. Mid-rotational loblolly pine growth may be increased when chemical competition control is added to fertilization (Borders and Bailey 1997).

OBJECTIVES

1. Determine the effect on growth in mid-rotational loblolly pine resulting from the application of prescribed fire and herbicide, with and without fertilization.
2. Compare the effect of fire and/or herbicide applications on competition control in mid-rotational loblolly pine plantations, as well as, determine if any fertilization interaction exist between either or both fire and herbicide.

METHODS

Study Area

Site one is known as the Cherokee Ridge site. This site was hand planted on a 1.83 m X 3.05 m spacing in 1985. In July 1998 this site was thinned to a basal area of 13.10 m^2ha^1. Approximately 465 trees per hectare remain. Soils consist of moderately well-drained to well-drained sandy loam or fine sandy loam surface soil. Slopes range from 3 to 15 percent.

The second site is known as the Sweet Union site. This site was machine planted on a 1.83 m X 3.66 m spacing in 1982. In 1998, the site was thinned to a basal area of 22.26 m^2ha^1. Surface soils consist of loamy sand on slopes that range from 3 to 15 percent. Both sites are located on International Paper Company property.

Plot Establishment

The experimental design for this study is a split plot with fertilizer treatment as the whole plot and vegetation control treatments as sub-plots. Five replications were established at each of the two sites. One–half of each replication was randomly selected and treated with fertilizer. In each replication, 8 treatment plots measuring 0.1 ha were randomly established, leaving approximately a 10-meter buffer between each treatment plot. A measurement plot measuring 0.04 ha was nested within each 0.1 ha treatment plot. The four treatments of control, herbicide, fire, and herbicide/fire were randomly located in the eight 0.1 ha treatment plots, with one of each of the four vegetative control treatments conducted for fertilized and one of each of the four vegetative control treatment conducted for the unfertilized area.

Methodology

Before treatment, each tree within the 0.04 ha measurement plots was identified to species and tagged with a numbered metal tag nailed to the tree at DBH. Treatments were applied after the completion of baseline data collection, approximately 1.5 years after thinning. A late season, ground-applied herbicide treatment was applied in October 1999 to remove competing vegetation. This included the herbicide application for the prescribed-fire/herbicide treatment. Imazapyr and Arsenal was applied at the rate of 5.5-6.9 kg per ha. An early spring burn was conducted in March 2000 prior to green-up to remove competing aboveground stems. Fertilizer treatments were applied with a hand spreader following the fire.

At the end of the 2000 growing season, the height of each numbered tree within the 0.04 ha measurement plot was re-measured using a clinometer and the diameter was re-measured using a diameter tape. Parameters evaluated were height and diameter growth of individual trees.

Analysis of variance for a Randomized Complete Block Design was conducted on data to test for treatment differences and Duncan's multiple range test was used to identify significant treatment differences at the significance level of 0.1 for the response variables of height and diameter growth.

Table 1—Mean height growth (m.) and diameter growth (cm.) in Loblolly pine (*Pinus* taeda) for the Sweet Union and Cherokee Ridge study sites in southeast Texas for the four treatments of control, herbicide, fire, and herbicide/fire. Height (m.) and diameter (cm.) growth for fertilized and non-fertilized plots

	Control		Herbicide/Fire Height		Fire		Herbicides	
	Height	Diameter	Height	Diameter	Height	Diameter	Height	Diameter
Sweet Union	0.82*	0.54	0.75	0.61	0.65	0.62	0.71	0.68
Cherokee Ridge	0.78	1.10*	0.82	1.00	0.71	0.91	0.65	1.12*

	Fertilized		Non-Fertilized	
	Height	Diameter	Height	Diameter
Union	0.76 *	0.60	0.69	0.64
Cherokee Ridge	0.70	1.04	0.77	1.02

*Significant treatment effect at p=0.1 level

RESULTS

Analysis of variance indicated significant treatment effects for the treatments of control and herbicide/fire, as well as, a site/fertilizer interaction for height growth. The site/fertilizer interaction occurred on the Sweet Union site, which possessed greater height growth on control plots that received fertilizer (table 1). In addition, height growth seems to have been affected to a lesser degree on herbicide/fire plots which also received fertilizer. However, too much overlap exists between herbicide/fire and other treatments to consider this significant. Analysis of variance also indicated that diameter growth was significant on the Cherokee Ridge site (table 2). While no fertilization interaction occurred on this site, Duncan's Multiple range test revealed that herbicide and control plots produced significant increases in diameter growth. The mean increase in diameter growth at the Cherokee Ridge site was twice as great as the increase at the Sweet Union site (table 2). Analysis of variance conducted on pre-treatment heights and diameters indicated a significant difference between the two sites for both height and diameter (table 2). The Cherokee Ridge site had taller, larger diameter trees before the application of treatments than the Sweet Union site. Analysis of second year data indicated that while Cherokee Ridge still had taller trees, height growth at the Sweet Union site had increased at the same rate and narrowed the difference between the two sites (table 2). The Sweet Union site, however, has not been able to produce the diameter growth found on the Cherokee Ridge site, which still possessed larger diameter trees and exhibited a significant increase in diameter growth. Significant height and diameter growth was recorded on Replication 2 at the Cherokee Ridge site while significant diameter growth was indicated on Replication 1 at the Cherokee Ridge site.

DISCUSSION

The Cherokee Ridge and Sweet Union study sites were impacted by different silvicultural treatments applied prior to this study. Both sites were thinned in 1998. However, the Cherokee Ridge site was left with a basal area of 13.10 m^2ha^1. Trees were row thinned, as well as, removed from within rows. The Sweet Union site was thinned only by row and left with a basal area of 22.26 m^2ha^1.

Because height growth is less sensitive than diameter growth to stocking density, the Sweet Union site may be responding to less crowded conditions by shifting resources toward height rather than diameter growth. Although both of these stands were seventeen-years-old, significant height and diameter differences were present before treatment. Trees at the Sweet Union site possessed less height than those trees at the Cherokee Ridge site. At one year post-treatment, there were no significant differences between the mean height growth at either site. While trees at the Cherokee Ridge site were still taller, height difference between the two sites has decreased. The fact that height increases at the Sweet union site were significant on fertilized control plots suggests that increases in height growth were a combination of fertilizer and thinning effects. More densely stocked conditions forced trees upward for available sunlight. Trees that were already responding to thinning with height growth, gained more benefit from the additional treatment of fertilizer.

In addition to fertilized control plots, height growth at Sweet Union was also significant on herbicide/fire treatments. Because herbicide was applied prior to the application of fire, hardwood and herbaceous competition was very dry resulting in a more intense fire. Why a more intense fire would result in improved height growth can not be explained at this time. However, it could be speculated that height growth response was more a result of the application of fertilizer rather than the application of herbicide or fire. The fact that significant height growth response was indicated on fertilized control plots that received no other treatment supports this speculation. Diameter at the Cherokee Ridge site was significantly greater prior to treatment than diameter at the Sweet Union site. Because diameter is more responsive to decreases in stocking density, the Cherokee Ridge site may still be responding to less dense conditions with increases in diameter. This may explain the increase in diameter associated with the herbicide treatment. Removal of competition within a plot already responding with diameter increases to less dense conditions increased beneficial results. In both cases, the conclusion may be that trees, which were responding well in either height, diameter, or both, experienced even more improved tree growth with additional treatment. It is important to note that significant treatment effects were calculated using mean increases in height and diameter. Therefore, a tree 30-centimeters in diameter and 18 meters tall had no advantage in statistical calculations over smaller diameter trees that had acquired less height except as an indicator of site productivity prior to treatment. Because control plots received no competition control treatments, treatment effects noted at both sites in control plots for both height and diameter increases indicated lingering thinning responses.

Table 2—Mean pre-treatment and post-treatment height (m.) for Loblolly Pine (*Pinus taeda*) and diameter (cm.) for the Sweet Union and Cherokee Ridge study sites in southeast Texas

Site	Pre-Treatment		Post-Treatment		Increase	
	Height	Diameter	Height	Diameter	Height	Diameter
Sweet Union	15.33*	17.50	16.06	18.11	0.73	0.61
Cherokee Ridge	15.71	19.95*	16.41	20.98*	0.70	1.03*

*Significant at p=0.1 level

CONCLUSIONS

It appears that on both sites, trees that were growing well before treatment were growing as well or better after treatment. Study trees at both sites were among healthy well-growing populations, which appear to have maintained growth with little mortality during this study year, in which southeast Texas experienced a significant drought. Subtle difference occurring among treatments in such a population may be difficult to detect with first year data. Even in a year of normal rainfall, a study with results from only one year cannot reliably answer questions about the use of fertilization and its ability to improve tree growth. Nor do one year's results answer long-term questions about improved growth resulting from the use of competition control. In future years, treatments that appeared to have had no significant impact in first year's data may, in fact, become significant.

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