FIRST YEAR HEIGHT PERFORMANCE OF PLANTED LOBLOLLY PINE FOLLOWING SITE PREPARATION AND HERBACEOUS RELEASE TREATMENTS ON A LOWER COASTAL PLAIN SITE

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ABSTRACT

Chemical applications for site preparation and herbaceous release are critical for establishing stands of loblolly pine in the Southeastern United States. Sandy soils commonly found in lower Coastal Plain sites require lower herbicide application rates compared to other soil types but experience reduced length of competition control. This study examines conducting both treatments (fall site preparation and spring herbaceous release) as opposed to individual applications of site preparation or herbaceous release only on lower Coastal Plain sites. A complete block design was utilized to evaluate five treatments: Two individual site preparation treatments utilizing either (1) glyphosate + triclopyr, (2) imazapyr + triclopyr + glyphosate + metsulfuron methyl, (3) herbaceous release treatments using a midrange (but high for sandy soil) label application rates of hexazinone + sulfometuron methyl, (4) a combination of the second site preparation treatment above plus a lower application rate of herbaceous release mixture, and (5) control. A clearcut harvest occurred in 2018; site preparation treatments were applied in early fall of 2019; loblolly pine seedlings were planted in February 2020; and the herbaceous release treatments were applied during May 2020. Vegetation on these sites was well established after a full growing season following clearcutting. All herbicide treatments enhanced seedling ground line diameter compared to control. First year height growth was similar for control and one-time applications, however combined site preparation plus herbaceous release caused stunted growth which was statistically significant. Implementation of release treatments after chemical site preparation treatments should be delayed until after completion of the first growing season.

INTRODUCTION

Land managers must routinely decide when to apply herbicides to sites intended for loblolly pine (*Pinus taeda*) production. In some instances, the application window may be less than ideal with possible restrictions on timing and weather, applicator readiness, or herbicide availability. Individuals may question the necessity of using soil active herbicides versus those that do not bind with soil colloids and whether better growth and yield can be achieved through conducting both site preparation and seedling release treatments on sandy sites. Research has suggested that loblolly pine establishment and growth can be enhanced by controlling competing hardwood trees (Borders and Bailey 2001, Glover and Zutter 1993, Miller and others 1991). Chemical applications can produce greater gains compared to mechanical site preparation (Shiver and Martin 2002). Use of chemical site preparation without mechanical treatments can also alleviate some of the financial burden to landowners.

The land manager must decide which herbicide(s) are optimal for the control of vegetation communities on the site and optimal seasonal application dates. Various soil active herbicides have been researched for both site preparation and herbaceous release applications. Hexazinone herbicides have provided positive loblolly pine diameter and height growth when applied as a site preparation treatment (Wittwer and others 1986). Post-planting herbicide release combined with a chemical site preparation treatment can increase pine growth at a level greater than site preparation alone (Zhao and others 2008). An increase in application rate of hexazinone pellets (1.12, 1.68, and 2.24 kg active ingredient ha^{-1} treatment rates per acre) applied in March resulted in greater hardwood control along with improved pine seedling diameter and height growth (Zutter and others 1988). Increased rates of hexazinone controlled a greater range of competing hardwood species in pine plantation over 3 years of age (Zutter and Zedaker 1987). Herbaceous release using solutions of hexazinone with sulfometuron methyl can improve pine growth and extend vegetation control into the growing season (Yeiser and Ezell 2004). Herbaceous and woody control improve pine diameter at breast height, basal area, and individual tree volume growth when applied singularly, but the greatest gains result from combined applications (Zutter and Miller 1998). Summer

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applications of 2 pounds active ingredient imazapyr appeared optimal for controlling hardwoods in a young pine plantation. Hexazinone applied at 2 pounds active ingredient with metsulfuron methyl had better results when compared to summer applications of imazapyr at lower application rates (Quicke and others 1996a). Applications of hexazinone (pre-plant) with sulfometuron methyl (release) had similar growth response compared to post-plant applications of imazapyr with metsulfuron methyl (Blazier and Clason 2006). Post-applications of hexazinone (4 pounds after ingredient) were statistically similar to imazapyr + metsulfuron. Gardiner and Yeiser (1991) found a mixture of hexazinone with sulfometuron applied as herbaceous release promoted pine seedling development at a higher level than mixtures containing imazapyr and sulfometuron methyl. The reliability of the aforementioned herbicides in vegetation management within pine stands has been consistent for over two decades. Thus, these herbicides are typically the preferred choice by land managers.

OBJECTIVES

This study investigated chemical site preparation and herbaceous weed control applications to establish loblolly pine plantations. Analyses aimed to determine if differences in pine seedling diameter and height growth exist between (1) two individual site preparation treatments only, (2) chemical herbaceous release only (applied at the middle of the standard release rate, higher than typically used on sandy soils) using hexazinone and sulfometuron methyl, and (3) chemical site preparation with a chemical herbaceous release applied during the first growing season after planting. The increased application rate for the release only treatment was used to determine if sufficient control of both woody (need for more active ingredient–hexazinone) and herbaceous stems could be accomplished with a one-time spring treatment.

STUDY SITE

The research installation is located on Interfor Corporation property outside of the town of Andrews, SC in Georgetown County. Two soil types (Echaw and Lynn Haven sands) exist within the 7.5-acre study site. Echaw sand is well-drained with a site index value of 85 feet; base age 50 for loblolly pine. Lynn Haven sand is poorly-drained with a loblolly pine site index value of 80 feet; base age 50 (USDA NRCS Soil Survey Staff 2021). The previous stand was clearcut and removed all standing trees with the exception of live oak (*Quercus virginiana*). Live oak remained due to an ordinance in Georgetown County that restricts felling of the species. The timber harvest occurred during the winter of 2019. There was no mechanical site preparation applied on the site. Research installation occurred at the end of the initial growing season after the disturbance. Competing herbaceous and woody vegetation on the site included asters (*Pityopsis* spp.), dogfennel (*Eupatorium capillifolium*), eastern baccharis (*Baccharis halimifolia*), fireweed (*Erechtites hieracifolia*), gallberry (*Ilex glabra*), large gallberry (*Ilex coriacea*), greenbriars (*Smilax* sp.), panic grasses (*Panicum* sp.), partridge pea (*Chamaecrista fasciculata*), sumacs (*Rhus* spp.), swamp titi (*Cyrilla racemiflora*), muscadine grape (*Vitis rotundifolia*), water oak (*Quercus nigra*), red maple (*Acer rubrum*), sweetbay magnolia (*Magnolia virginiana*), and bracken fern (*Pteridium* sp.). Site preparation treatments were applied in September/October of 2019. Loblolly pine was planted by hand crews in February 2020. Herbaceous release was applied in May 2020.

METHODS

The study area and treatment unit boundaries were established in August/September of 2019 by use of a handheld compass and 100-foot reel tape. The installation was a complete block containing 15 individual, ½-acre treatment units. Treatment unit dimensions were approximately 175 feet × 125 feet. Five individual treatments were conducted including two distinct site preparation applications: (1) site prep #1 (SP1), (2) site prep #2 (SP2), (3) a seedling release only (REL) applied near the middle range of the recommended label release rate (higher rate than normally used for sandy soils), (4) a site preparation using SP2 mixtures plus seedling release at slightly less than the standard label application rate for sandy soils (RSP), and (5) control. Site preparation treatments included DLZ® surfactant (incorporated into solution at ½-percent) which is a blend of methylated seed oil, paraffinic oil, and non-ionic surfactant. Release treatment applications excluded DLZ® from the mixture solutions. Spray treatments were applied at 20 gallons of solution per acre in late September of 2019 using 4-gallon backpack sprayers on site preparation units. All unit's housing release applications only received 8 gallons per acre of solution applied with backpack sprayers. SP2 treatment units were sprayed using a Model T® CO2 pressurized backpack sprayer by Bellspray, Inc. Follow-up treatments within site preparation spray units, to control "missed" vegetation targeted any remaining live vegetation. Follow-up sprays were conducted approximately 1 month (late October 2019) after the initial treatments. These sprays were incorporated into the rates depicted in table 1. Untreated vegetation was easily discernable (healthy appearance) from treated vegetation. The SP1 treatment utilized a solution of 41 percent glyphosate product (Winnfield® product) + triclopyr acid (Trycera®) + surfactant (DLZ® by Helena Chemical®). The SP2 treatments consisted of imazapyr (Polaris®) + triclopyr acid + 41 percent glyphosate + metsulfuron methyl (MSM60®) + surfactant.

Herbaceous release only treatments incorporated hexazinone + sulfometuron methyl applied at double the rate used for the RSP treatment. Treatment application rates are presented in table 1.

Table 1—Treatment herbicide application rates

Treatment	Herbicide	Application rate per acre (oz. product)
Site Prep #1 (SP1)	41% glyphosate	72
	Trycera®	72
Site Prep #2 (SP2)	Polaris®	36
	Trycera®	48
	MSM60®	3
Release only - double rate (REL)	Velossa®	34
	Oust XP®	2.66
Site Prep #2 + Release (RSP)	Polaris®	36
	Trycera®	48
	MSM60®	3
	Velossa®	17
	Oust XP®	1.33

REL treatment rate is twice the amount used in the RSP treatment. The REL rate is near the midrange of the amount advised on the product label. This rate is high for sandy soils, however.

Two of the 15 treatment units were submerged prior to seedling measurement and experienced total seedling mortality. These units (SP2 and Control) were likely inundated for a lengthy duration due to the extensive mortality rate. These treatment units were dropped from the analysis. Second generation loblolly pine seedlings were planted using 7 feet × 10 feet spacing in the research installation in February 2020.

The experimental design was a complete block design (CRD) with sampling to analyze ground line diameter and total height measurements taken on the pine seedlings in November 2020. Fifty samples per treatment unit with a total of 550 seedlings (150 seedlings for RSP, SP1, and REL). The SP2 and Control treatments only had 100 samples each available for analysis due to unit inundation by water (two inundated treatment units excluded from analysis). All seedlings were numbered with aluminum tags and flagged with florescent flagging for future measurement collection. Ground line diameter was taken near the ground surface with digital calipers. Total height was taken with a retractable tape measure. Individual analyses were performed to determine if differences existed between treatments for seedling diameter and seedling height growth. Treatments were considered a fixed variable in the model. Random variables included the replicates and seedlings. Statistical analyses were conducted using analysis of variance PROC Glimmix; SAS version 9.4 (SAS Institute 2018) at a 95-percent alpha level. The Kenward-Roger test was also used for approximation of degrees of freedom.

Percent ground cover was quantified using ocular estimation for each treatment unit. Plant coverage was calculated to the nearest 5 percent. Vegetative resistance to herbicide or coverage by live plants was not statistically analyzed in this project.

RESULTS

The degree of plant control was maximized with the combined RSP treatment over all other treatments. The RSP units had less than 5 percent live vegetation cover (close to bare ground conditions) on each unit. SP1 and SP2 treatments also decreased live plant abundance to less than 15 percent ground coverage. The REL treatment had the greatest coverage by resistant plants (primarily woody stems, in particular large gallberry). These treatment units had an ocular estimation of approximately 60 percent live vegetation coverage during seedling measurement in November. Most of the vegetation controlled was herbaceous only. Thus, the REL treatment was ineffective at controlling most of the woody stems at the increased application rate. Increased growth gains experienced in the first year will likely diminish with the advancement in competitive status by uncontrolled woody plants.

A difference in pine diameter growth was detected between treatments and the untreated check (P = 0.0404). The

Table 2—Loblolly pine diameter and height results taken after initial first full growing season

Treatment	n	Ground diameter Mean	Ground diameter Standard deviation	Total height (inches) Mean	Total height (inches) Standard deviation
RSP	150	0.523 a	0.0325	18.0 b	1.66
SP1	150	0.516 a	0.0325	26.3 a	1.66
SP2	100	0.557 a	0.0399	25.0 a	2.03
REL	150	0.552 a	0.0325	26.0 a	1.66
Control	100	0.363 b	0.0399	23.6 ab	2.03

n = number of seedlings samples for each treatment; RSP = Site Prep #2 plus seedling release; REL = seedling release only. The release only was at double the rate used for the RSP release.

control treatment had a significantly lower mean (0.363 inches) compared to all herbicide treatments. Herbicide treatments ranged from a low mean diameter of 0.516 inches for SP1 to a high of 0.557 for SP2 (table 2). Thus, herbicide treatments yielded comparable results after one complete growing season.

A difference was also found to exist for height growth between the one-time applications (SP1, SP2, REL) compared with the combination RSP treatment (P = 0.0442). Average seedling height in the RSP treatment mean was 18.0 inches (table 2). The control treatment mean (23.6 inches) was not significantly different from the RSP treatment in regard to seedling height. The SP1 treatment yielded the greatest average height (26.3 inches). However, no significance difference was detected among the untreated control and one-time herbicide application treatments.

DISCUSSION

Pine mortality with the two units dropped from the analysis due to water inundation that could have been avoided with mechanical site preparation. Bedding may have provided improved aerated soil conditions more preferred by loblolly pine. Land managers should address such concerns that may be encountered within lower elevation areas in the Coastal Plain.

Some vertical stunting was evident with the more intensive site preparation plus release treatment. One potential explanation may entail that the use of four herbicides with residual soil activity (imazapyr, hexazinone, sulfometuron methyl, and metsulfuron methyl) applied with approximately 7 months between applications, could have obviated vertical height growth. First year stunting of loblolly pine following herbicide applications has been noted in previous research involving some of these herbicides (Gardiner and Yeiser 1991, Quicke and others 1996b). Usage avoidance of these four soil active herbicides within a short timespan should be acknowledged. A period of approximately 4 months transpired between site preparation treatments and tree planting which should have been adequate time for herbicide degradation and thus minimized detrimental effects to planted seedlings. These herbicides have both pre- and post-emergent properties which can impact root growth. Barnes and others (1989) found that greenhouse grown loblolly pine root growth was decreased within 28 days following sulfometuron methyl applications. Findings from Gardiner and Yeiser (1991) suggest that a combination of imazapyr + hexazinone + sulfometuron methyl was more antagonistic to seedling development as the combination caused the most visual seedling injury, reduced root biomass, and inhibited height growth compared to individual or two-way mixes of soil active herbicides. However, seedlings in these studies rebounded and experienced enhanced growth at the end of the first growing season or in subsequent growing seasons. Given the sandy soils present, soil active herbicides could be more available for pine seedling uptake as it may not be as readily absorbed by soil particles.

Seedling height stunting related to these tank mixes should be alleviated by delaying herbaceous release until the onset of the second growing season. McCaskill and others (2019) suggest that imazapyr applications conducted two growing seasons after longleaf pine establishment coupled with a previous site preparation treatment yielded optimal growth on flatwood sites as opposed to herbaceous release applied in the initial growing season. Lauer and Glover (1995) found combining shrub control with herbaceous weed control did not promote pine growth over either treatment applied alone. The extended timing may enable applicators to use three or more soil persistent herbicides on a particular site without potential losses in growth. An applicator may also opt to avoid the use of all soil residual herbicides if a herbaceous release treatment is scheduled for the immediate growing season following chemical site preparation. Early competition to pine seedlings in the first 3 years is most commonly affected by herbaceous vegetation. Woody vegetation becomes the greater competitor thereafter. Use of non-soil active herbicides, such as the active ingredients used in SP1, may provide more beneficial results in lieu of imazapyr and metsulfuron methyl.

The herbaceous REL treatment had minimal efficacy on controlling the majority of hardwood species on site. The REL units contained more plant competition for loblolly pine compared to all other herbicide treatments but did provide a scattered bare ground condition due to the deadening of herbaceous plants including bracken fern. This treatment did provide better first-year groundline diameter and height growth over the control. No significant separation was found between release and site preparation treatments leaving uncertainty that release applications may be substituted for site preparation treatments. Future measurements are expected to show that release only treatment areas will have inferior growth compared to site preparation treatment areas.

A more distinct separation between treatments and control will likely become apparent at the conclusion of the second growing season. The deleterious stunting by the combined site preparation with herbaceous release may decrease as the visibly greater control of competing vegetation may extend into the second growing season as weed emergence may be dependent on off-site windblown seed invasion. This prolonged suppression of weed species may promote growth gains more so than single application treatments.

SUMMARY

All site preparation mixtures, herbaceous release, and the combination site preparation plus release treatment significantly improved first-year loblolly pine groundline diameter growth. One-time applications for site preparation only or release only significantly increased pine height growth. The combined site preparation plus release treatment resulted in height stunting. The use of four soil-active herbicides (sulfometuron methyl, metsulfuron methyl, imazapyr, and hexazinone) within approximately 7 months was the most probable cause for this deleterious result. The release only treatment applied at a higher rate for sandy soil provided marginal control of woody plants. The continued presence of competitor plants is expected to yield inferior growth compared to the other chemical treatments in subsequent years. Land managers may opt to avoid using four soil active herbicides altogether or utilize release applications at least one complete growing season following site preparation. A REL treatment applied at a high application rate for sandy soils may only provide early growth promotion but yield inferior long-term results compared to chemical site preparation.

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