FOUR-YEAR RESULTS OF A CHOPPER® GEN2™ AND FORESTRY GARLON® XRT RATE AND TIMING STUDY FOR LOBLOLLY PINE SITE PREPARATION ON THE LOWER COASTAL PLAIN OF GEORGIA

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ABSTRACT

Chopper® GEN2™ and Forestry Garlon® XRT are frequently applied as a tank mix for chemical site preparation in the Coastal Plain region of the Southeastern United States. The purpose of this study was to assess age 4 loblolly pine (*Pinus taeda*) survival and growth following four site preparation application rates of these herbicides (alone and in tank mixes), discern potential growth and survival differences among three application timings, and compare loblolly pine growth and survival with chemical site preparation alone to chemical site preparation plus first-year herbaceous weed control (HWC). Loblolly pine survival was not improved by any chemical site preparation treatments compared to the control, while height, diameter, and volume index were all significantly greater with chemical site preparation than the control. The early application timing (July) resulted in less growth than September or October applications. First year HWC improved loblolly pine volume index by as much as two times over no HWC.

INTRODUCTION

Chemical site preparation is recognized as one of the most important and cost-effective steps in successful pine plantation establishment throughout the South. Certain herbicides may be used alone during application, but more often compatible herbicides are tank-mixed to broaden the spectrum of control of competing vegetation on a given site. Effective site preparation that combines chemical, mechanical and/or prescribed fire can minimize woody plant influence on planted pines for 4 or more years (Tiarks and Haywood 1986). Imazapyr is frequently used for forestry site preparation in the South because of its low toxicity and the broad spectrum of plants controlled (Dickens and others 2020). It can also be used in tank mixtures with other forestry herbicides to control specific species or vegetation types, which imazapyr does not control well alone (Lauer and Quicke 2006). In the Flatwoods region of the Lower Coastal Plain, imazapyr and ester triclopyr are often tank-mixed as the triclopyr offers improved control of species with thick and/or waxy leaf cuticles. These waxy leaf species may include: gallberry (*Ilex* spp.), saw palmetto (*Serenoa repens*), bayberry (*Myrica* spp.), blueberries (*Vaccinium* spp.), and sweetbay (*Magnolia virginiana*) (Lauer and Quicke 2006, Lowery and Gjerstad 1991, Shiver and others 1991). Chemical site preparation applications using these chemicals can be completed any time after full leaf development during the growing season but are more commonly applied during late summer into fall before leaf color change.

Chopper® GEN2™ is an aqueous solution of a 2-pound acid equivalent (ae) imazapyr product that can be mixed with water or applied as an emulsion with a seed oil for improved uptake. Forestry Garlon® XRT is a relatively new 6.3-pound ae equivalent ester triclopyr product that can be applied at lower rates than previous 4-pound ae ester triclopyr products (Dow AgroSciences 2008). Forestry site preparation application rates for Chopper® GEN2™ range from 32 to 64 ounces per acre for loblolly pine site preparation (BASF Corporation 2021), while for Forestry Garlon® XRT, pine site preparation rates range from 80 to 128 ounces per acre when applied alone and 40 to 80 ounces per acre when applied in tank mixes. Studies have investigated rate and timing of Chopper® GEN2™ site preparation applications (Ezell and others 2013, Grogan and others 2015, Lauer and Quicke 2013), but no published studies have reported on side-by-side comparisons of Chopper® GEN2™ applied alone, Forestry Garlon® XRT applied alone, and various labeled tank mixtures and application timings of these two herbicides and long-term loblolly pine growth on Lower Coastal Plain sites. Additionally, the impacts of first-year, post-plant herbaceous weed control (HWC) combined with Chopper® GEN2™ and Forestry Garlon® XRT chemical site preparation

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on loblolly pine survival and growth has not been thoroughly investigated with tank mixtures of these herbicides.

OBJECTIVES

The objectives of this study were (1) to assess loblolly pine survival and growth response to Chopper® GEN2™ and Forestry Garlon® XRT chemical site preparation with each herbicide applied alone and in two tank mixes, (2) to investigate if loblolly pine survival and growth differences occur with three distinct application timings, and (3) to determine if first growing season post-plant HWC in addition to chemical site preparation improves loblolly pine survival and growth over chemical site preparation alone.

STUDY SITE

The study was installed at a site near Egypt, GA (32.482525°N -81.504423°W) under industrial ownership. This region of Georgia is known as the Sea Island Flatwoods ecoregion (Griffith and others 2001). This ecoregion is characterized by mostly poorly drained, flat plains with minor areas of better drained soils. Soils at the site were primarily form the Pelham series with a minor component of Orsino soils. Pelham soils are loamy, siliceous, subactive, thermic Arenic Paleaquults, while Orsino soils are hyperthermic, uncoated Spodic Quartzipsamments (Sowell 2015). Previously, the site was a mature loblolly pine stand. Woody vegetation onsite prior to study installation consisted primarily of grapevine (*Vitis* spp.), sweetgum (*Liquidambar styraciflua*), rusty staggerbush (*Lyonia ferruginea*), and red maple (*Acer rubrum*). Abundant grass, broadleaf weeds, and brambles including blackberry (*Rubus* spp.) were present onsite prior to study establishment.

METHODS

Study installation began during early July 2014 with mechanical site preparation on the 21.4-acre site. The site was sheared during early July and bedded during early September at a 90-degree angle to windrows still present from the previous stand. Three replications of five chemical site preparation treatments (including an untreated control) and three application timings were assigned to 39 experimental units. Experimental units were 150 x 120 feet (10 planting rows per experimental unit). Each experimental unit was divided into two sub-plots (five planting rows per sub-plot) and assigned first-year HWC or no HWC. Chemical site preparation treatments included: (1) 24 ounces per acre Chopper® GEN2™ plus 96 ounces per acre Forestry Garlon® XRT (C24G96), (2) 32 ounces per acre Chopper® GEN2™ plus 48 ounces per acre Forestry Garlon® XRT (C32G48), (3) 48 ounces per acre Chopper® GEN2™ (C48), (4) 96 ounces per acre Forestry Garlon® XRT (G96), and (5) an untreated control (control). All treatments received 1.25 percent v/v methylated seed oil in 20 gallons of water per acre. A utility task vehicle (UTV) was used to apply the late July site preparation treatments. A boomless sprayer attached to the back of the UTV with two Boominator® 1250 nozzles was used under constant speed and pressure settings to apply the chemical site preparation treatments. Due to the bedding treatment, the UTV could not be used for the September and October application timings. A solo backpack sprayer with a pressure gauge and a 48-inch boom with three TeeJet® 8003 flat fan nozzles was used to apply the September and October application timings. Constant pressure and boom height were maintained to apply 20 gallons of solution per acre. The three application timings during 2014 were July 31, September 18-21, and October 29-30. Select, bare-root (1-0) loblolly pine seedlings were machine planted February 4-7, 2015 at 6 x 12 feet spacing. The HWC application was applied April 29, 2015 as a 4 feet wide band with the planted seedling as the center of the band. Oustar® (63.2 percent active ingredient hexazinone and 11.8 percent sulfometuron methyl) was applied using a Solo backpack sprayer with a pressure regulator at a rate of 10 ounces per acre in 10 gallons of water per acre. This treatment was applied to one-half of a sub-plot in all experimental units (including the no chemical site preparation control treatment). The entire research area received two aerial fertilizer applications (industry protocol) between establishment and an age-4 assessment.

At age 4, within the no HWC internal measurement plots, an average of 43 trees per sub-plot were aluminum tree tagged and nailed, while an average of 45 trees were tagged in the HWC internal measurement plots. Fourth year assessments were conducted during February 2019. Survival was assessed, and measurements included diameter at breast height (DBH) and total height. Volume index per tree (vi) was derived from DBH (inches) and tree heights (feet) (Spurr 1952).

$$vi = DBH2 \times height$$

Data were analyzed using analysis of variance (ANOVA) as a randomized complete block experimental design with replication and sampling, and a split-plot treatment design. Response variables included survival, DBH, total height, and volume index. Fixed model factors included treatment, application timing, and HWC status (yes or no). Block was the random term in the model. Blocking was used to account for soil drainage differences across the site. Fisher's protected least significant difference test was used for all pairwise comparisons of least-squares means to detect survival and growth differences among treatments. An alpha level of p=0.05 was used for all analyses. The binomial distribution was used for the survival analysis. All analyses were conducted in SAS 9.4 using the Proc Mixed procedure (SAS Institute 2012).

RESULTS

Loblolly pine survival results indicated no significant differences (p=0.081) among chemical site preparation treatments after 4 years. Survival ranged from 84.4 percent in the control treatment to 95.2 percent in the C48 treatment. Application timing did not significantly affect loblolly pine survival (p=0.438). Survival rates ranged from an average of 90.3 percent with the July application timing to 93.1 percent with the September application. The HWC application did significantly affect survival (p=0.035), and survival was greater in the no-HWC treatment (93.0 ± 1.9 percent) versus the HWC treatment (91.1 ± 2.1 percent). The chemical site preparation treatment by application timing interaction was not statistically significant (p=0.599).

Diameter growth was significantly different (p=0.012) among the five chemical site preparation treatments. All four treatments that included chemical site preparation had significantly greater average diameters than the control, but they were not statistically different than each other (table 1). Average diameter was least in the control treatment (2.0 inches) and greatest in the G96 and C24G96 treatments (2.6 inches each). Application timing also was significantly different (p=0.019) among treatments (table 2). July application resulted in significantly smaller average loblolly pine diameter at age 4 (2.2 inches) compared to September and October (2.5 inches each) applications. Trees that received the HWC treatment had significantly greater diameters (p=0.039, 2.8 ± 0.1 inches) after 4 years compared to the no-HWC treatment (2.2 ± 0.1 inches). The chemical site preparation treatment by application timing interaction was significant for DBH (p=0.039). The control treatment had the smallest average diameter (2.0 inches) while the C24G96 treatment when applied during October had the greatest average diameter (2.8 inches) (fig. 1).

Table 1—Average DBH growth by chemical site preparation treatment at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Treatment	Estimate	Standard Error	Letter grouping
	inches		
C24G96	2.6	0.08	a
C32G48	2.4	0.08	a
C48	2.5	0.08	a
G96	2.6	0.07	a
Control	2.0	0.09	b

Note: Treatments with the same letter are not significantly different at the p=0.05 level.

Table 2—Average DBH growth by application timing at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Month	Estimate	Standard error	Letter grouping
	inches		
July	2.2	0.07	b
September	2.5	0.08	a
October	2.5	0.08	a

Note: Months with the same letter are not significantly different at the p=0.05 level.

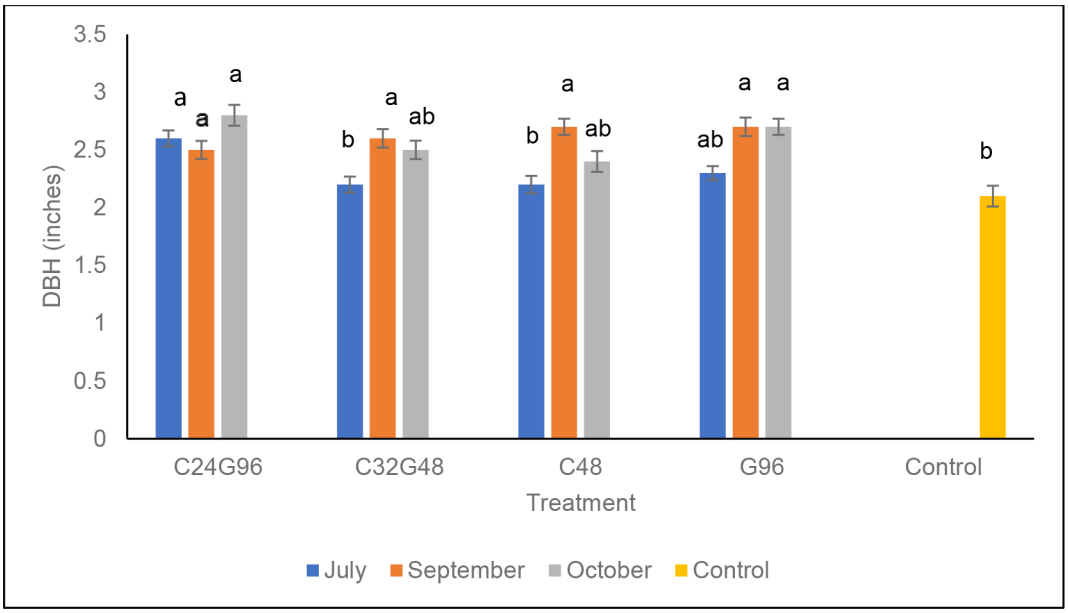

Figure 1—Diameter at breast height means, standard errors, and letter groupings for the statistically significant treatment by month interaction term (p=0.039) at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA. Individual treatment and month combinations that do not share a letter are significantly different at the p=0.05 level.

Loblolly pine total height was significantly different among the chemical site preparation treatments (p=0.036). Average height was greatest in the C24G96 treatment (13.8 feet) and least in the control (11.3 feet) (table 3). Application timing effects on height growth were significant (p=0.042). July applications resulted in significantly shorter average height (12.1 feet) than the September application (13.4 feet) (table 4). The addition of HWC resulted (p<0.001) in a nearly 3 feet height growth improvement (14.3 feet) over no HWC (11.4 feet). The treatment by application interaction term was significant for loblolly pine height (p<0.001). The control treatment had the shortest average heights (11.3 feet), whereas the C24G96 October application had the tallest average height (14.2 feet) (fig. 2).

Table 3—Average total height by chemical site preparation treatment at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Treatment	Estimate	Standard error	Letter grouping
	feet		
C24G96	13.8	0.3	a
C32G48	12.7	0.3	ab
C48	13.0	0.3	a
G96	13.5	0.2	a
Control	11.3	0.3	b

Note: Treatments with the same letter are not significantly different at the p=0.05 level.

Table 4—Average total height by application timing at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Month	Estimate	Standard error	Letter grouping
	feet		
July	12.1	0.2	b
September	13.4	0.3	a
October	13.0	0.3	ab

Note: Months with the same letter are not significantly different at the p=0.05 level.

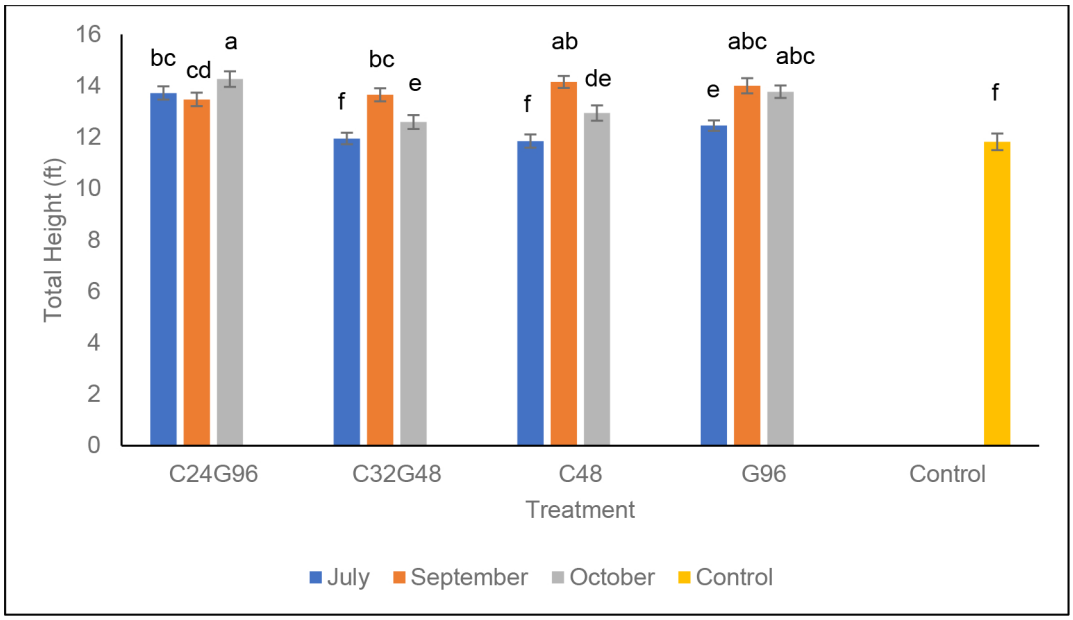

Figure 2—Total height means, standard errors, and letter groupings for the statistically significant treatment by month interaction term (p<0.001) at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA. Individual treatment and month combinations that do not share a letter are significantly different at the p=0.05 level.

Volume index per tree had similar trends as diameter. Volume index was significantly different (p=0.014) among the five chemical site preparation treatments. All four treatments that included chemical site preparation had significantly greater average volume index than the control, but they were not statistically different amongst themselves (table 5). The July application timing had significantly (p=0.003) smaller average loblolly pine volume index than September or October applications (table 6). Average volume index for the HWC treatment (133.5) was more than twice as great for the no-HWC treatment (64.0) (p<0.001). The treatment by month interaction term was statistically significant (p=0.014). The July C48 treatment had the smallest average volume index, and values tended to be low for all chemical site preparation treatments applied during July. Again, the C24G96 treatment applied during October was the early leader in average volume index per tree (fig. 3).

Table 5—Average volume index per tree by chemical site preparation treatment at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Treatment	Estimate	Standard error	Letter grouping
C24G96	122.4	7.5	a
C32G48	98.9	6.2	a
C48	99.5	6.5	a
G96	113.9	6.1	a
Control	58.8	5.8	b

Note: Treatments with the same letter are not significantly different at the p=0.05 level.

Table 6—Average volume index per tree by application timing at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA

Month	Estimate	Standard error	Letter grouping
July	76.0	5.3	a
September	111.6	7.2	b
October	108.6	7.3	b

Note: Months with the same letter are not significantly different at the p=0.05 level.

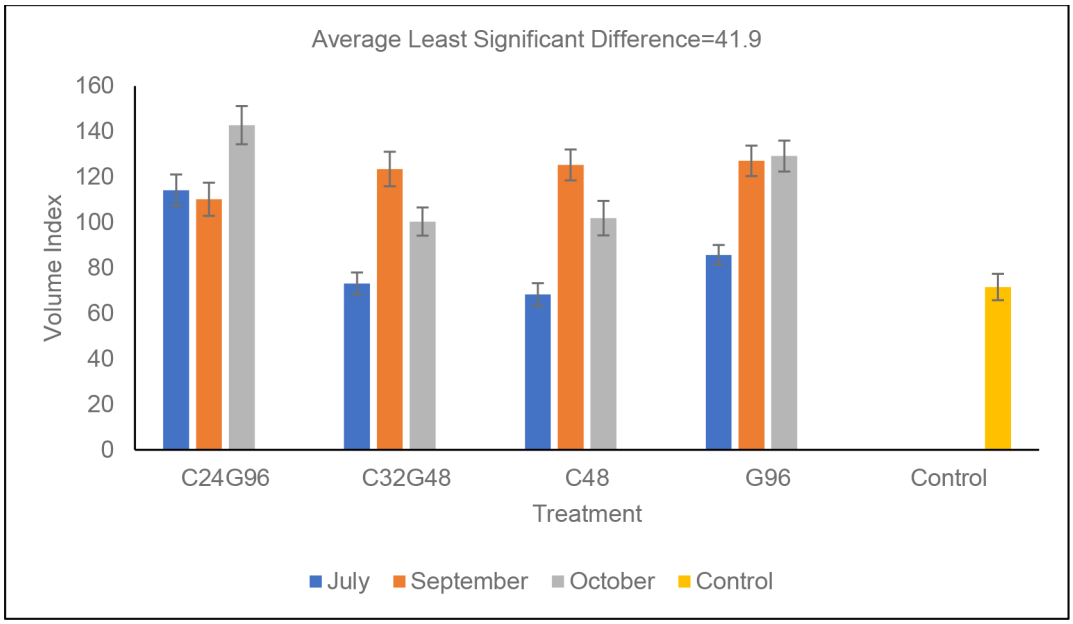

Figure 3—Volume index per tree means, standard errors, and letter groupings for the statistically significant treatment by month interaction term (p=0.014) at age 4 for the Lower Coastal Plain loblolly pine chemical site preparation rate and application timing study near Egypt, GA. Individual treatment and month combinations that differ by more than a value of 41.9 are significantly different at the p=0.05 level.

DISCUSSION AND CONCLUSIONS

Loblolly pine survival rates were excellent through 4 years. Chemical site preparation improved survival rates by 7 to nearly 11 percent over the control, but these differences were not statistically significant among treatments. Other studies have reported similar survival trends for young loblolly pine plantations. Minogue and Quicke (1999) tested three rates of 2-pound ae imazapyr, two rates of 2-pound ae imazapyr and glyphosate, two rates of 2-pound ae imazapyr and triclopyr and one rate of 4-pound ae imazapyr at sites throughout the Piedmont and Coastal Plain regions. Two-years post application, they noted no loblolly pine survival differences among treatments, but survival rates were less than this study (survival ranged from 63 to 70 percent). Application timing did not impact survival rates in this study, unlike another Chopper® GEN2™ timing study (Grogan and others 2015) that tested early July, mid-August, and late September application timings with one application rate (32 ounces per acre) on planted loblolly pine performance. At two of the three sites in that study, the average mid-August survival rate was less than July or September applications at age 5. Other studies have suggested that hardwood and shrub competition, which are the focus of control with chemical site preparation, may take longer to impact pine stand survival and growth than herbaceous weeds as herbaceous weeds typically affect pine plantations from establishment to potentially age 5 or 6 (Minogue and others 1991, Zutter and others 1995). This study has likely not reached an age where site preparation survival differences may become more apparent. The significant difference in HWC versus no HWC on survival could be explained by low weed pressure and above average first year precipitation (University of Georgia Weather Network 2021).

Diameter, height and volume index per tree trends were similar across the five site preparation treatments. In general, growth was greater with the four chemical site preparation treatments than the control. By age 4, no chemical site preparation treatments had differentiated in diameter growth from one another, but height growth associated with the C32G48 treatment was statistically similar to the control. Similar growth results were reported for 2-year-old, planted loblolly pine stands at three sites in the Piedmont and Coastal Plain regions. Eight treatments containing a 4-pound ae imazapyr alone or in tank mixes showed no significant differences in loblolly pine growth (Harrington and others 1998). Application timing did significantly affect diameter, height and volume index. The July application resulted in significantly less growth than September or October application timings. This result may originate from the timing of shearing (early July) and the stage of vegetation development when the late July chemical site preparation application was completed. Lauer and Quicke (2006) suggested that shearing and other forms of mechanical site preparation that sever competing vegetation stems and roots and lack of development of resprouts for several weeks following mechanical site preparation may limit herbicide uptake when herbicide applications are made soon after these types of mechanical treatments. The bedding treatment in early September may have also prevented optimal imazapyr uptake by competing vegetation through the soil because bedding was completed within 40 days after the July chemical site preparation treatment. Lauer and Quicke (2006) stated that 2-year pine volume index is not impacted by competing vegetation if bedding is completed about 3 or more weeks prior to chemical site preparation. This may explain why growth associated with the September application timing was not impacted. The treatment by timing interaction term was significant for all three growth variables. The October timing of the C24G96 treatment resulted in the best growth across all treatment and timing combinations. It is likely given sufficient precipitation during this period, that competing vegetation was more developed by late October following the two mechanical herbicide treatments in early July and early September. Improved plant uptake of the herbicides (especially triclopyr which has limited soil activity) would have been more likely with greater plant development (Lauer and Quicke 2006).

The impacts of HWC on growth were significant and volume index growth improved by more than two-fold over no HWC. Improvements in loblolly pine volume index with Chopper® Gen2™ site preparation and post-plant HWC application versus Chopper® Gen2™ without HWC were similar (greater than two-fold volume index improvement) in a study by Lauer and Quicke (2013). Survival and growth improvements with HWC tend to increase with greater weed pressure and dryer first spring conditions.

Overall, planted loblolly pine responded well to the Chopper® Gen2™ and Forestry Garlon® XRT chemical site preparation treatments and application timings utilized in this Lower Coastal Plain study. Growth was significantly improved over an untreated control with all four treatments tested. Chemical site preparation completed between two mechanical site preparation treatments separated by 2 months may not be optimal for herbicide control of competing vegetation and future pine growth. First-year HWC should be used to improve pine growth as volume gains can be large (two-fold) after 4 years.

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