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Eleven Year Longleaf Pine Growth Response to Chemical Herbaceous Weed Control on Old-Field Planted Sites

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KEY POINTS

- First year, herbaceous weed control is an important management tool to initiate height growth and reduce time longleaf pine seedlings spend in the grass stage.
- Growth of longleaf pine planted on Upper Coastal Plain old-field sites can be improved with overtop, banded chemical herbaceous weed control (HWC) over untreated trees for over a decade when correct herbaceous weed control herbicides and application timings are utilized.
- Do not apply 10 oz/ac Oustar (1.6 oz ac^{-1} Oust + 8.4 oz ac^{-1} Velpar DF VU or ≈25 oz ac^{-1} Velpar L VU) or 4 oz ac^{-1} Arsenal Applicator's Concentrate (or 4 lb acid equivalent imazapyr product) overtop of longleaf pine within two months of planting. Longleaf pine survival was 17-30 percentage points lower when applied within two months of planting in late March compared to applications made during April or May. Planting containerized longleaf pine seedlings earlier in the winter or during the fall (if soil moisture is adequate) is a good strategy to allow initiation of seedling root growth and avoid potential herbicide phytotoxic effects that can occur with short intervals between planting and HWC applications.
- The 10 oz ac^{-1} Oustar treatment averaged across April and May application timings at three old-field sites produced 9.5 tons ac^{-1} more wood than the control (no herbaceous weed control) and 7.6 tons ac^{-1} more wood than the next closest HWC treatment tested after 11-years. The split Oust plus Arsenal treatments and Arsenal only treatments only produced 1.9- and 0.4-tons ac^{-1} more wood than the control, respectively. Long-term results for the 4 lb acid equivalent imazapyr treatment alone or a split application of sulfometuron methyl (late March application) and imazapyr (June) make these treatments difficult to recommend for longleaf pine HWC on sandy textured, old-field Coastal Plain sites.

INTRODUCTION

Chemical herbaceous weed control (HWC) is frequently used to improve the survival and growth of longleaf pine (*Pinus palustris*), and benefits to survival and growth are most pronounced the first five to six years after establishment. Research with other southern pine species have shown that HWC benefits can extend farther into the rotation. Chemical herbaceous weed control applied one or two years after planting with seedling slash (*Pinus elliottii*) and loblolly pines (*Pinus taeda*) can improve long-term growth and productivity for ten or more years (e.g. Wagner et al. 2006). The synergistic effects of high levels of herbaceous weed coverage (common on productive old-field and cutover sites), below average rainfall, and sandy soil texture can result in severe soil moisture stress to recently planted longleaf pine seedlings. Dry and/or warm springs the first growing season after planting can make HWC applications very important for seedling survival and improve the chances of seedlings growing out of the grass stage within two to three years after planting. Longleaf pine can remain in the grass stage for 15 or more years depending on genetic and site factors (Brockway et al. 2006). Height growth does not occur, and seedlings can be easily overtopped by grasses and broadleaf weeds. Herbicides applied at the correct rates and timing overtop of seedlings can drastically reduce the length of the grass stage (Haywood 2000, Nelson et al. 1985, Ramsey et al. 2003), yet minimal research has been published on longleaf pine growth and survival using operational or commonly used HWC herbicides and tank mixtures labeled for longleaf pine and applied during the spring of the first growing season. Information on the impacts of application timing during the spring on long-term survival and growth are also limited as very few studies on timing impacts have been published (e.g. McElvany et al. 2006). In addition, the magnitude of long-term (greater than six years) survival and growth benefits of HWC are unknown for longleaf pine.

The objectives of this study were (1) to assess long-term survival and growth performance of containerized longleaf pine planted on old-field sites following overtop applications of three common HWC herbicides and tank mixes applied the spring of the first growing season after planting, and (2) to evaluate long-term longleaf pine survival and growth performance following three different application timings.

MATERIALS AND METHODS

Study Sites

Study areas were located on old-field sites, with two study sites in Laurens (Dudley and Thigpen), and one in Treutlen County (Powell), Georgia (Figure 1). All three sites were located in the Atlantic Upper Coastal Plain within the Vidalia Upland (Griffith et al. 2001). Soils at the Dudley site were mapped as Orangeburg series, which is grouped in the University of Florida's Cooperative Research in Forest Fertilization (CRIFF) classification as a CRIFF E soil. These soils are moderately to well-drained and contain a clay or argillic horizon within 20 in of the surface (Fox 2004). The Dudley site had been in row crop agriculture for more than 50 years prior to the establishment of this study. Vegetation on site prior to study establishment consisted of camphorweed (*Heterotheca subaxillaris*), coffee senna (*Senna occidentalis*), broomsedge bluestem (*Andropogon virginicus*), Bermudagrass (*Cynodon dactylon*), southern crabgrass (*Digitaria ciliaris*), and minor components of other annual warm season grasses. Soils at the Thigpen site were from the Fuquay and Dothan series. Dothan soils are CRIFF E soils, while Fuquay are classified as CRIFF F soils. Soils in the CRIFF F category are moderately to well-drained and have a clay or argillic horizon deeper than 20 in within the profile. This site was in row crop agriculture for over 30 years prior to study establishment. Vegetation on site consisted of camphorweed, pigweed, Bermudagrass, southern crabgrass, and minor components of other native, annual warm season grasses. The Powell site had soils from the Norfolk and Dothan series, which are both CRIFF E soils. This site had also been in row crop agriculture for more than 50 years prior to study establishment. Vegetation on site consisted of coffee senna, nutsedge (*Cyperus rotundus*), Bermudagrass, and bahiagrass (*Paspalum notatum*). There were no woody species present at any of the three sites before the study began. Site index for longleaf pine at base age 25 ft ranges from 77 to 84 ft (USDA 1929). Soil nutrient reports by site and replication are presented in Table 1.

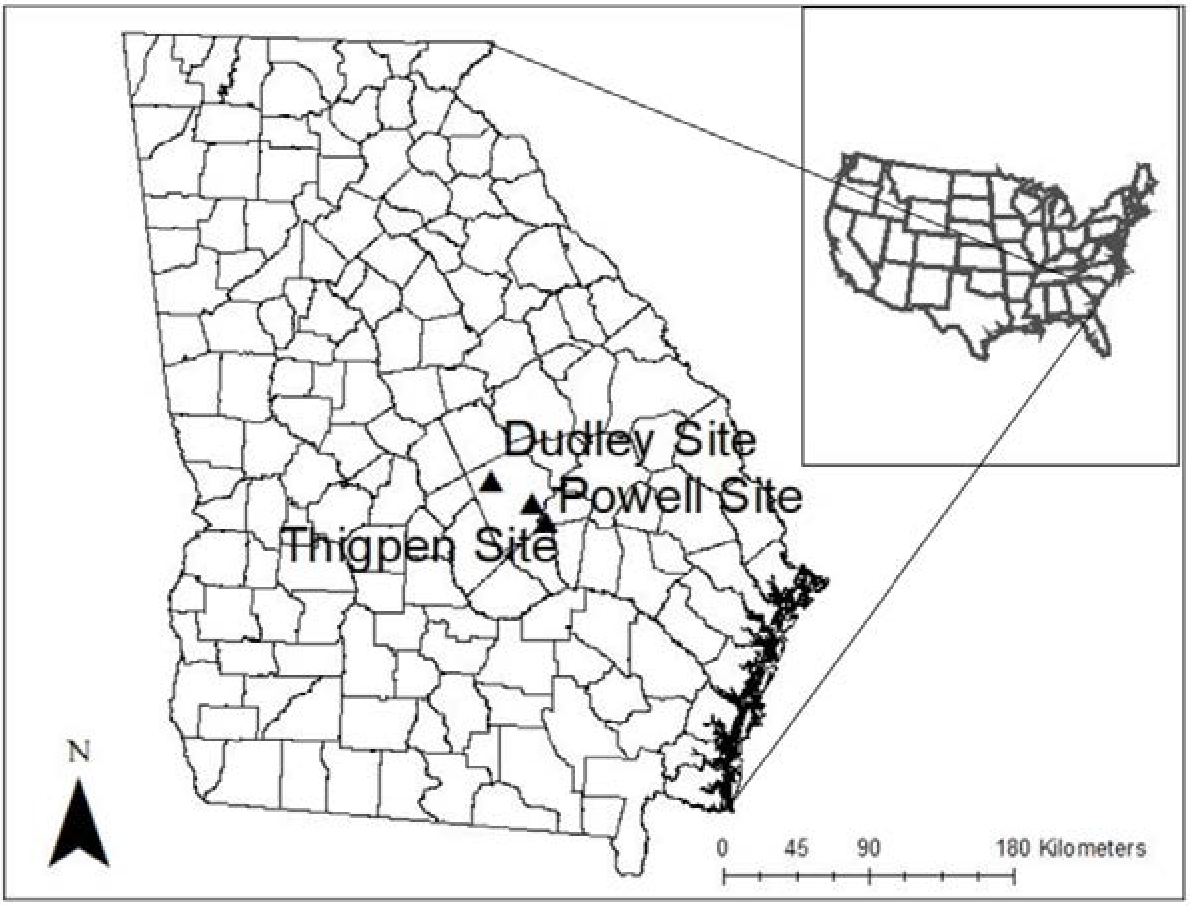

Figure 1: *Locations of the three, planted old-field longleaf pine herbaceous weed control studies in the Atlantic Upper Coastal Plain.*

Table 1. Soil pH and nutrient levels for the upper 6 in of soil at the three, old-field longleaf pine herbaceous weed control study areas. Soil nutrient and pH levels are presented by study area and replication.

Soil Property	Dudley			Powell			Thigpen		
	Replication			Replication			Replication		
	1	2	3	1	2	3	1	2	3
pH	5.85	5.81	5.99	5.17	5.15	5.11	5.69	5.64	5.84
Calcium (lb ac^{-1})	451.5	455.5	514.5	248.0	325.9	298.1	373	393.9	541.9
Potassium (lb ac^{-1})	45.1	47.9	44.5	43.9	47.2	48.8	22.0	23.0	28.9
Magnesium (lb ac^{-1})	49.5	50.0	62.5	37.9	42.1	39.4	30.9	30.9	42.02
Manganese (lb ac^{-1})	33.9	31.5	28.9	27.8	32.0	27.2	66.9	22.0	24.0
Phosphorus (lb ac^{-1})	49.5	37.0	35.4	27.8	32.0	25.8	46.9	42.0	33.0
Zinc (lb ac^{-1})	1.1	0.9	0.9	1.9	2.5	3.5	4.9	3.0	5.9

Site preparation was tailored to soil and vegetation conditions at each site. A single broadcast glyphosate application was applied during summer 2007 at the Dudley and Powell sites. The Thigpen site received three separate glyphosate applications during summer 2007. One site (Dudley) was scalped and ripped with a combination plow in September 2007 due to the presence of Bermudagrass. Scalping removed the topsoil in a three-foot band to a depth of 2-4 in and placed it to the sides of the planting row. These same sites were then subsoiled to a depth of 15 in to fracture the plow pan that had developed over years of agricultural production (Figure 2). Subsoiling was completed during the summer months as well to allow soil settling prior to planting. The sites were planted with containerized, 1-0 stock longleaf pines seedlings at a 6 x 12 ft spacing during the fall or winter of 2007/2008. The Powell site was machine planted in late September of 2007. The Dudley site was hand planted 6" offset of the rip in late January 2008. The Thigpen site was machine planted in mid-February of 2008.

Figure 2: ***Example of completed glyphosate and mechanical site preparation (scalp and subsoil) soon after planting at the Dudley site for the longleaf pine herbaceous weed control study.***

Treatment plots were established soon after planting. Gross treatment plots measured 48 x 120 ft (four rows of 20 trees), and measurement plots were 4 rows x 13 trees. The Dudley and Thigpen sites consisted of 24 plots and had three replications of two herbicides applied at three application timings, an untreated control, and one herbicide tank mix with one application timing (per label directions). The Powell site lacked a March application timing due to space limitations, which resulted in 18 plots with three herbicide treatments (April and May application timings only). Plots were randomly assigned an herbicide treatment and application timing. Table 2 shows treatment, application timing and site treatment combinations.

Table 2. Treatment, application timing and site combinations for the longleaf pine herbaceous weed control study. A '—' denotes that a treatment was present at a site and application timing.

	Location								
	Dudley			Powell			Thigpen		
	Application Testing								
Treatment	March	April	May	March	April	May	March	April	May
Control									
A4	--	--	--		--	--	--	--	--
10OS	--	--	--		--	--	--	--	--
20A4			--		--			--	

Herbicide was applied using a Solo hand pump four-gallon backpack sprayer with a pressure regulator as a 5 ft band overtop of seedlings at a rate of 15 gal ac^{-1} (Figure 3). Treatments included 10 oz ac^{-1} Oustar (63.2% hexazinone and 11.8% sulfometuron methyl—Bayer Environmental Science) applied during 21-25 March 2008 (Dudley and Thigpen only), 16-17 April 2008 (all sites), and 13-16 May 2008 (all sites). Oustar is no longer produced by Bayer. This treatment will be referred to as 10OS. The second treatment was 4 oz ac^{-1} Arsenal Applicator's Concentrate (AC) (BASF Corporation) applied the same dates as the 10OS treatment. This treatment will be referred to as A4 throughout the remainder of the paper. The last herbicide treatment was split application of 2 oz ac^{-1} Oust XP applied either during late March or mid-April (site dependent) plus 4 oz ac^{-1} Arsenal AC applied during the third week of June at all three sites. This treatment will be referred to as O2A4 throughout the remainder of the paper. This treatment was assigned an April application timing to make data analyses simpler.

Figure 3: ***Solo backpack sprayers with pressure regulator used to apply herbaceous weed control treatments to the old-field longleaf pine herbaceous weed control study areas during spring 2008.***

During the 11th growing season both the Thigpen and Dudley sites were prepared for pine straw raking by applying a foliar application of glyphosate for HWC in the understory. The Dudley and Thigpen sites were both raked once, by hand, before data were collected in the winter of 2019, but these operations most likely had minimal effects on growth rates since the stands were raked during the growing season prior to the final (11-year) measurements.

Trees within measurement plots were aluminum tagged at age eight so that measurements on individual trees could be recorded through time, and an inventory was conducted at stand age 11. Trees were assessed for diameter at breast height (DBH) and total height. Basal area per acre was calculated from these measurements, and green weight (total tree wood plus bark) was determined from weight equations by Baldwin and Saucier (1983) for stems ≥5 in DBH and stems <5 in DBH.

≥5 in DBH: Green Weight = -0.31359 + 0.85584 * log(DBH_2 * total tree height)
<5 in DBH: Green Weight = -0.75522 + 1.00514 * log(DBHv * total tree height)

Analyses were conducted with and without the March 10OS and A4 treatments to account for low survival of the March application timings. Statistical analyses are outlined in Clabo and Dickens (2021).

RESULTS

Using late-March Application Timings

When data were analyzed with the March treatments included, survival ranged from 77.1% at the Dudley site to 85.2% at the Powell site, but these differences were not statistically different. The site by application timing interaction was significant for survival. Longleaf pine survival for the March application timings at the Dudley and Thigpen sites were statistically less (17 to 30 percentage points) than April and May application timings (Figure 4). Diameter at breast height differed by treatment and site. The smallest observed diameter was in the Thigpen control treatment, which was 0.87 in less than the Dudley 10OS treatment, which had the greatest average DBH after 11 years (Table 2). Total average height also differed by treatment and site as well as site by application timing. The tallest average height was observed at the Thigpen site in the 10OS treatment, and the shortest in the Dudley A4 treatment (Table 3). Total heights for the March and April applications at the Dudley site were significantly shorter (30.4 ft and 31.7 ft, respectively) than April and May treatments at any of the three sites (Figure 4). In addition, green weight average tons per acre differed by treatment and site. The greatest average green weight per acre was observed in the Powell 10OS combination, while the least was found in the Thigpen 2OA4 combination (Table 3). The treatment by timing interaction was also significant for survival and basal area. Average survival was greatest for the 10OS treatment applied during April and least for the 10OS treatment applied during March. Basal area followed a similar trend as survival (Table 4). Herbicide application timing also significantly affected average green weight per acre totals at age 11 years. March applications averaged 47.4 tons per acre, while April and May applications were nearly identical (60.0 vs. 59.8 tons per acre, respectively).

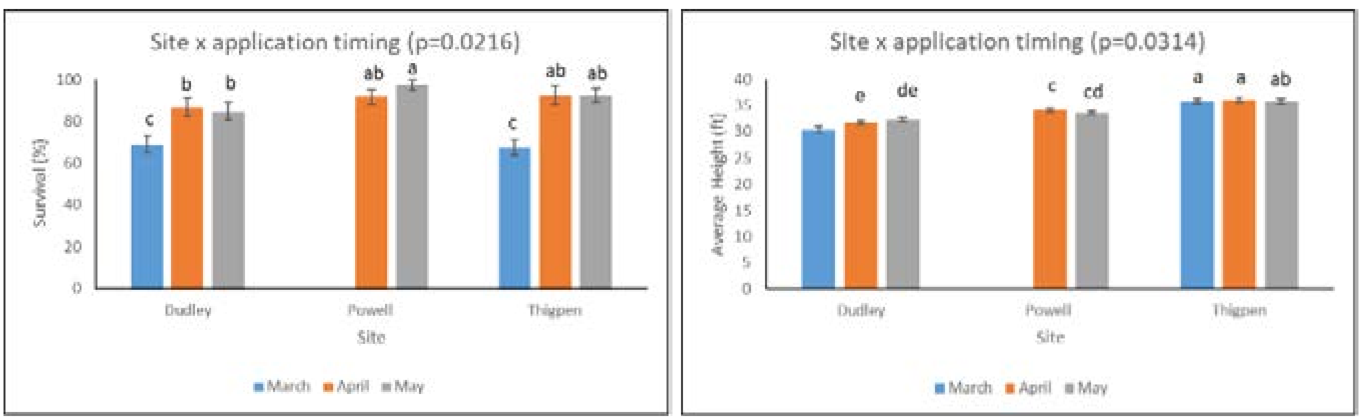

Figure 4: *Site x application timing interaction results for percent survival and average total height with March application timings included in the analyses. Error bars represent standard error. Columns that do not share a letter for a dependent variable are statistically different at the p=0.05 level.*

Table 3. Means, standard errors and letter groupings for significant treatment by site interactions at age eleven when March applications timings are used with analyses are presented for DBH (p=0.05), total height (p=0.02), and green weight per acre (p=0.03).

Treatment	Location								
	Dudley			Powell			Thigpen		
	DBH (in)	Height (ft)	Green Weight (t ac⁻¹)	DBH (in)	Height (ft)	Green Weight (t ac⁻¹)	DBH (in)	Height (ft)	Green Weight (t ac⁻¹)
10OS	6.5±0.11a	32.5±0..3d	60.1±3.0acd	6.2±0.11abc	34.1±0.7c	62.3±3.4ab	5.9±0.11cd	36.7±0.3a	52.1±3.0cdef
20A4	6.1±0.16bcd	31.8±0.7de	47.7±4.3de	6.4±0.16ab	34.8±0.6abc	62.1±4.3abc	5.9±0.16cd	35.8±0.7abc	44.9±4.3f
A4	5.8±0.11d	29.9±0.3f	52.8±3.0bef	6.0±0.11bcd	32.1±0.3de	50.7±3.4def	5.8±0.11d	35.8±0.3ab	49.6±1.2ef
Control	5.8±0.16cd	31.2±0.6ef	64.1±4.4a	5.9±0.16bcd	34.4±0.7bc	64.4±4.4a	5.6±0.15d	35.8±0.6abc	58.3±4.4abcde

*Means that do not share a letter for the same variable are statistically different at the p=0.05 level.

Table 4. Means, standard errors and letter groupings for significant treatment by application timing interactions at age eleven when March applications timings are used with analyses are presented for survival (p=0.02) and basal area per acre (p=0.03).

Treatment	March		April		May		No timing	
	Survival (%)	Basal Area (ft^2 ac^{-1})	Survival (%)	Basal Area (ft^2 ac^{-1})	Survival (%)	Basal Area (ft^2 ac^{-1})	Survival (%)	Basal Area (ft^2 ac^{-1})
10OS	60.6±2.9d	87.9±4.4d	89.1±2.8a	115.4±3.9a	88.9±2.7a	114.6±3.9a	--	--
20A4	--	--	80.4±2.6b	101.9±3.9b	--	--	--	--
A4	71.2±7.1c	91.0±4.4cd	84.4±2.7ab	97.6±3.9bc	86.4±2.7ab	101.9±3.9b	--	--
Control	--	--	--	--	--	--	84.0±2.7ab	100.2±3.9b

*Means that do not share a letter for the same variable are statistically different at the p=0.05 level.

Excluding March Application Timings

When March application timings were excluded from analyses, differences by site were found for DBH, total height and basal area per acre. Average DBH was least after 11 years at the Thigpen site (5.8 in) and greatest at the Powell site (6.1 in) (Table 5). The Thigpen site had the tallest trees on average (35.8 ft), while the Dudley site had the shortest trees (31.8 ft) (Figure 5). Average basal area per acre was least at the Thigpen site (90.2 ft^2 ac^{-1}) and greatest at the Powell site (112.4 ft^2 ac^{-1}) (Table 5; Figure 6). Treatment was statistically significant for all growth variables when the March application timing was removed from the analyses. Diameter at breast height was least in the control and A4 treatments (5.9 in each), while diameter was greatest in the 10OS treatment (6.2 in) (Table 6). Height followed a similar trend as DBH; average height in the control and A4 treatments was 33.1 and 32.8 ft, respectively, while the 10OS treatment averaged 34.8 ft. Green weight per acre was greatest in the 10OS treatment (63.3 t ac^{-1}), while the other three treatments were statistically similar and averaged 53.8 to 55.7 t ac^{-1} (Table 6). Basal area per acre followed the same trend as green weight per acre (Table 6).

Figure 5: *Pictured are the March 10OS and A4 treatments during July 2020 at the Dudley site. Note the gaps due to poor survival. In addition, the Dudley site had the shortest trees on average.*

Figure 6: *The May 10OS treatment (pictured during July 2020) at the Powell site had the greatest basal area per acre of any site and treatment combinations.*

Table 5. Means, standard errors and letter groupings for site significant effects at age eleven without March treatments included in analyses are presented for DBH (p=0.02), total height ((p<0.01), and basal area per acre (p=0.04).

Site	DBH (in)	Height (ft)	Basal area ($ft^2\ ac^{-1}$)
Dudley	6.1±0.12a*	31.8±0.7c	111.5±6.5a
Powell	6.1±0.12a	33.8±0.3b	112.4±6.5a
Thigpen	5.8±0.12b	35.8±0.7a	90.2±3.9b

*Means within a column that do not share a letter are significantly different at the p=0.05 level.

Table 6. Means, standard errors and letter groupings for treatment significant effects at age eleven without March treatments included in analyses for DBH (p=0.008), total height (p<0.01), green weight (p<0.01) and basal area (p=0.04).

Treatment	DBH (in)	Height (ft)	Green weight $t\ ac^{-1}$	Basal area $ft^2\ ac^{-1}$
10OS	6.2±0.12a*	34.8±0.7a	63.3±3.3a	114.9±5.2a
2OA4	6.1±0.12ab	34.4±0.3a	55.7±1.8b	102.8±6.5a
A4	5.9±0.12b	32.8±0.6b	54.2±4.2b	99.8±4.8b
Control	5.9±0.12b	33.1±0.7b	53.8±4.7b	101.5±7.8b

*Means within a column that do not share a latter are significantly different at the p=0.05 level.

With March treatments excluded from the survival analysis, the treatment x site interaction term was also significant. The Dudley site tended to have the lowest average survival rates across treatments at stand age 11, and the 2OA4 treatment had the lowest survival rate of any site x treatment combination (69.6%) (Figure 7). The Thigpen and Powell sites had similar survival rates across the four tested treatments. Statistical differences were only observed between the 10OS and 2OA4 treatments at the Thigpen site (Figure 7).

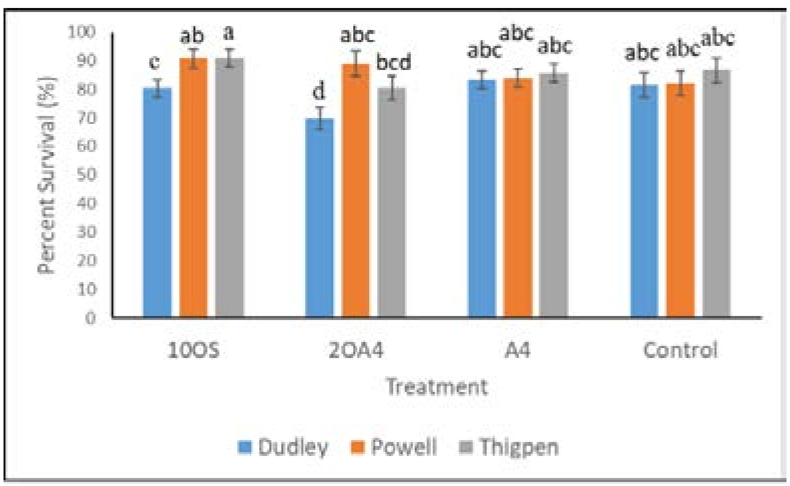

Figure 7: *Means, standard errors and letter groupings for the significant treatment x site interaction term at age eleven for survival (p=0.05) without March application treatments included in analyses. Means that do not share the same letter are statistically different at the p=0.05 level.*

DISCUSSION

Herbaceous weed control applications during late March resulted in a significantly lower survival rate (17 to 30 percentage points) in comparison to all other treatments including the control. Aside from May applications, there was a lack of significant differences in survival rates among sites by application timings, indicating that herbicide effects in most cases were ubiquitous across sites and that quality of establishment efforts such as planting did not differ. Without the March treatments included in survival analyses, the Dudley site tended to have lower survival rates for the 10OS and A4 treatments. This site had the latest planting date (February 2008) before March April, and May HWC applications. Survival rate differences in application timing, site x timing, and treatment x timing interactions with the March treatments included in analyses may be a result of herbicide phytotoxicity with late winter planting and early spring HWC. Herbaceous weed control applications within two months planting may be too soon after planting for longleaf seedlings due to the sandy soil texture of these sites, the soil activity of imazapyr, and to a lesser extent hexazinone soil activity and application during dry conditions (Fitzgerald and Fortson 1979, Longleaf Alliance 2000, Freeman and Jose 2009, Jose et al. 2010, Bayer Environmental Science 2021). Higher sand content in the soil can increase chances of phytotoxicity in young trees and below average rainfall can cause less herbicide uptake by targeted plants. Soils at these sites all contained 75%-100% sand content, which could have increased the chances of imazapyr and hexazinone phytotoxicity in the seedlings after treatment in March. In addition, rainfall was below the 30-year normal for the region during March and April 2008. Weed cover during March was also likely less than during April and May applications. Less weed coverage and minimal herbicide uptake by vegetation can increase the chances of herbicide phytotoxicity with soil active herbicides. Issues with sulfometuron methyl (i.e. Oust XP) phytotoxicity are unlikely given the sites' soil pH level (pH<6.2) and application rates used (2 oz ac^{-1}) (Michael 1985, Robertson and Davis 2010). Seedling phytotoxicity could be one of the causes of the differences in survival rates across treatments and sites. Do not apply 4 oz ac^{-1} Arsenal AC or 10 oz ac^{-1} Oustar (Or Oust XP and Velpar L VU or Velpar DF VU) within two months of planting longleaf pine seedlings.

Average DBH and total height were significantly greater with the 10OS treatment in comparison to all other treatments in this study after the March treatments were removed from analyses. If the March treatments are included in the data analyses, the 10OS treatment was similar to the control for all growth variables except for DBH growth improvements with the 10OS treatment at the Dudley site. This finding is in accord with one of the few other long-term studies that reported on longleaf pine growth response to overtop Oustar HWC. A five-year study by Freeman and Jose (2009) reported that longleaf pine seedling growth out of the grass stage was 1.3 times greater with Oustar than the control, while root collar diameter growth improvements were minimal with Oustar. Improvements in soil moisture relations for planted pines, less herbaceous coverage in close proximity to the pines, and lack of phytotoxicity due to active root growth are likely reasons for greater height growth in the April and May 10OS treatments compared to other treatments. Our study expands on prior longleaf HWC studies and shows that growth improvements past age ten are possible with proper rates and timing of HWC over grass stage longleaf pine seedlings.

If March treatments are included in the statistical analyses, the control treatment had the greatest average green weight due to its high survival rates. Late March 10OS and A4 treatments had approximately 20 percentage points lower survival than the control, mid-April, and mid-May 10OS and A4 treatments. If the March application timing is removed from analyses, average green weight per acre is significantly greater (7.6 to 9.5 t ac^{-1}) in the 10OS treatment than all other treatments. April and May 10OS HWC timings produced 12.5 t ac^{-1} more wood on average than the March 10OS treatment after 11 growing seasons. The Thigpen site had a smaller average DBH across all treatments than the Powell or Dudley sites, which affected green weight and basal area per acre site differences. The Fuquay soil type at the Thigpen site most likely caused the DBH difference because it is a better drained soil with a deeper depth to a clay or argillic horizon than the other sites (Fox 2004). These results again depict the importance of herbaceous vegetation coverage and active seedling root growth when HWC herbicides are applied overtop of longleaf pine seedlings. Active conifer root growth in temperate climates typically begins in March and peaks in early May (Burney and Jacobs 2009). Minimal seedling root growth initiation and lower soil temperatures associated with March applications following average to dry winter soil moisture conditions likely results in greater odds of phytotoxic seedling symptoms (e.g. root growth inhibition) or seedling mortality due to overtop HWC herbicide applications within two months of planting.

CONCLUSIONS

Herbaceous weed control survival and growth improvements can be evident for over ten years after application in planted longleaf pine stands on old-field sites, assuming correct application rates and timings are observed based on planting date and the presence of new seedling root growth. Survival was best in the control treatment when March treatments were included in analyses, but on average control treatment trees were smaller in size than trees in the 10OS treatment. These results revealed that the 10OS treatment had a similar average green weight and basal area per acre as the control while having a lower survival rate at age 11. When the March data were excluded from analyses, the 10OS treatment showed greater growth across all growth variables, and survival was similar to the control. Based on these results, no HWC should be performed within the first two months of planting longleaf seedlings, especially if using the 10OS or A4 treatments. Fall or early winter planting could be used to limit potential herbicide phytotoxic effects on seedlings, but fall plantings carry the risk of drought conditions as September and October are historically two of the driest months of the year in the Georgia Coastal Plain. HWC should take place in April or May for best survival and long-term growth of seedlings, with the least potential for damage. A practical approach to assess the 'readiness' of longleaf pine seedlings to overtop HWC applications is to dig up a few seedlings from throughout a stand and look for new root growth (two or more inches of fine, small diameter white or gray new root growth at the tips of a bareroot seedling or container plug root system). If new growth with a white or gray appearance is not evident, it is best to wait to apply overtop HWC herbicides. Waiting until April or May for overtop HWC applications can also allow for greater herbaceous vegetation coverage, especially if mechanical and/or chemical site preparation was utilized. Greater vegetation development (to an extent--vegetation should not be taller than ankle to calf height) at application will increase benefits of overtop HWC applications using Oustar or a tank mixed blend of liquid or dry-flowable hexazinone and sulfometuron methyl catered to site soil conditions.

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