SITE PREPARATION FOR SHORTLEAF PINE CLUSTER PLANTING AND RESTORATION OF SHORTLEAF PINE-HARDWOOD MIXTURES: FIRST YEAR RESULTS

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ABSTRACT

Shortleaf pine (*Pinus echinata*)-hardwood restoration continues to be a management goal throughout the interior South. Cluster or group planting involves placing groups of tightly spaced trees on favorable microsites or easily accessible areas in clearcut or partially harvested stands. Management operations for cluster planting may be focused on smaller areas reducing costs and easing access for areas with difficult topography. The objective of this study was to investigate site preparation methods to establish shortleaf pine using cluster planting in an upland mixed hardwood stand that had received a two-aged deferment harvest. The study area was located in Dade County, GA, near the summit of Sand Mountain. Four treatments were installed as three replications on 60-foot by 60-foot experimental units. All site preparation treatments included felling of understory hardwoods during late summer 2021. Treatments included (1) fell only (control); (2) fell and burn; (3) fell, herbicide, and burn; and (4) fell and herbicide. Bareroot, 1-0 stock shortleaf pine seedlings were planted during December 2021 at a 5-foot by 5-foot spacing. First-year results indicated better survival for treatments that included burning and ranged from 43.6 to 69.5 percent. Growth was greatest with the most intense treatment (fell-herbicide-burn). Naturally regenerating oak species (*Quercus* spp.) and other desirable hardwoods and natural shortleaf pine did not differ in stem densities across treatments, while red maple (*Acer rubrum*) and gums (*Nyssa sylvatica* and *Liquidambar styraciflua*) were plentiful in the least intensive treatments. Future release treatments will be needed to promote shortleaf pine and improve hardwood species composition.

INTRODUCTION

Restoration is a management goal throughout the 23-state native range of shortleaf pine (*Pinus echinata*). Shortleaf pine often occurs in mixedwoods or pine-hardwood mixtures with hardwoods [preferably oaks (*Quercus* spp.), hickories (*Carya* spp.), and other economically or ecologically important hardwood species] and other pines where shortleaf or hardwoods may compose as much as 80 percent of stand stocking (Anderson and others 2016, Deal 2018, Guldin and Black 2018). Many suitable sites for shortleaf pine in the eastern half of its range either lack a shortleaf pine seed source, or have scattered, older, and less vigorous remnant trees (Moser and others 2007). Conditions in stands like these can cause difficulties with natural regeneration of shortleaf pine, making artificial regeneration an important option.

A form of artificial regeneration known as underplanting can be used to help restore shortleaf pine in stands where hardwoods have become dominant along with prescribed fire, herbicide applications, thinnings or harvests that allow more sunlight into the understory. Underplanting may be an attractive option for restoration efforts as residual overstory shade can slow fast-growing intolerant hardwood species, shortleaf pine is moderately shade tolerant as a seedling, and vertical structure and potential mast-producing trees are left in the stand for wildlife (Kabrick and others 2015, Schnake and others 2021). Cluster planting is a form of underplanting where seedlings are selectively planted within suitable microsites (often <0.25

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acres), canopy openings, or easily accessible locations to improve stocking with desirable species (Saha and others 2017, Schönenberger 2001). The location and number of clusters across a stand can be adjusted to obtain stocking and restoration goals. Within clusters, tight spacings (often less than 6 feet by 6 feet) are used to accelerate natural pruning and intraspecific competition (and potentially interspecific competition for mixed plantings or if natural hardwood regeneration is allowed to develop) of planted trees, with the expectation of natural thinning as clusters develop. Cluster planting has previously been tested as a restoration technique for shortleaf pine-hardwood mixedwoods in the Cumberland Plateau region with promising early results (Clabo and Clatterbuck 2020b). The purpose of this study was to expand on those results by investigating other techniques to improve survival and development of shortleaf pine and beneficial hardwoods.

The objectives of this study were to assess first-year survival and growth of underplanted shortleaf pine following various site preparation treatments in a two-aged mixed hardwood stand, and to determine if natural regeneration species composition and densities can be improved by various site preparation practices.

MATERIALS AND METHODS

The study area was located on privately owned land in Dade County, GA (34.947941, -85.491797). This area is part of the Cumberland Plateau physiographic province near the summit of Sand Mountain. The landform is characterized by narrow ridges and convex upper slopes with elevations ranging from 1,250 to 1,290 feet and a predominately southeast aspect (Smalley 1979). Soils were characterized as Hector Complex with 5- to 60-percent slopes. These shallow soils are classified as loamy, siliceous, subactive, thermic Lithic Dystrudepts, and rock composes up to 50 percent of the A horizon by volume (USDA NRCS 2023). The area averages 51.9 inches of rainfall annually (UGA CAES 2023).

Stand conditions prior to study establishment consisted of an average of 21 square feet per acre of overstory basal area consisting primarily of white oak (*Quercus alba*), chestnut oak (*Quercus montana*), black oak (*Quercus velutina*), mockernut hickory (*Carya tomentosa*), shortleaf pine, and blackgum (*Nyssa sylvatica*) >6 inches in diameter at breast height (d.b.h.). Approximately 5 years prior to study establishment, the stand received a deferment harvest to establish a two-age system, a shelterwood with reserves structure (Stringer 2006). During the interim 5 years prior to study establishment, approximately 2,000–5,000 hardwood seedlings and saplings per acre developed in the understory ranging from 1 to 15 feet tall. Regenerating species composition consisted of white oak, post oak (*Quercus stellata*), chestnut oak, black oak, scarlet oak (*Quercus coccinea*), blackgum, red maple (*Acer rubrum*), yellow-poplar (*Liriodendron tulipifera*), sweetgum (*Liquidambar styraciflua*) mockernut hickory, sand hickory (*Carya padilla*), shortleaf pine, *Vaccinium* spp., sumac (*Rhus* spp.), sassafras (*Sassafras albidum*), winged elm (*Ulums alata*), black birch (*Betula lenta*), dogwood (*Cornus florida*), and black cherry (*Prunus serotina*).

Study installation began during July 2021 when twelve 60-foot by 60-foot cluster planting plots were established along the slope contour. One of four treatments were randomly assigned to clusters but burn treatment clusters were established in close proximity to one another due to required installation of a firebreak around these treatments. Treatments consisted of fell only (control), fell and burn, fell and herbicide, and fell, herbicide, and burn. All woody stems, woody vines and brambles >6 inches tall within clusters and 5 feet outside of clusters were cut as close to ground level as possible during September. This treatment was done to simulate stand conditions immediately after the overstory deferment harvest. For the herbicide treatments, a cut stump herbicide application was used within 15 minutes after woody stem, vine, or bramble cutting. A 4-pound acid equivalent Triclopyr ester herbicide (Alligare® Triclopyr 4, Opelika, AL) was used at a 25-percent rate in basal oil and applied to all sides of cut stumps. The burn treatment was completed November 9, 2021 using a backing fire ignited downslope. Burn coverage was 100 percent within these clusters. Bareroot, second-cycle shortleaf pine seedlings were hand planted December 27, 2021, by a professional planting crew. Trees were planted at a 5-foot by 5-foot spacing totaling 156 trees per cluster.

Permanent sampling plots were established with six rows of six trees located in the center of each cluster. The first and last tree of each row were tagged. Baseline shortleaf pine survival and height were recorded prior to the start of the growing season. In addition, seedling damage that could be attributed to browse or freeze damage was recorded. At the center of the shortleaf pine sampling plots, a circular 0.01-acre natural regeneration plot was established and permanently marked. Photosynthetically active radiation (PAR) was measured to ensure that understory light conditions were similar across clusters, and to improve shortleaf pine and natural regeneration development comparisons among treatments. During August of the first growing season, PAR measurements were taken on a uniformly overcast day within 2 hours of solar noon (Parent and Messier 1996). In-stand point PAR measurements were taken with a LP-80 LAI ceptometer (Meter Group®, Pullman, WA) with an external calibration sensor located at d.b.h. height at the four corners of each cluster facing the nearest ordinal direction. Open PAR measurements were taken approximately 500 feet from the study area in a large food plot opening. Open sky measurements were taken with a PAR photon flux sensor (Meter Group®, Pullman, WA) operated by a ZL6 data recorder (Meter Group®, Pullman, WA) calibrated to automatically record PAR measurements every 5 minutes. In-stand measurements were then paired with the corresponding time an open sky measurement at each timestamp to give an estimate of percent full sunlight.

Shortleaf pine and natural regeneration were assessed during the 2022–2023 winter. For shortleaf pine, survival, groundline diameter, total height, and presence of obvious damage were recorded. Within the natural regeneration sampling plots, information for all woody species >6 inches tall was recorded, including species and height class to the nearest foot. One-way analysis of variance (ANOVA) with a completely randomized design and treatment or location (direction) within a cluster as the fixed factor was used to analyze percent full sunlight across treatments. Statistically similar sunlight levels would indicate that comparisons of survival and growth across treatments were appropriate. The same analysis with only treatment as a fixed factor was used to assess planted shortleaf pine survival and height (h) before and after the first growing season, change in height growth, groundline diameter (gld) post-first growing season, and volume index (vi) as in Spurr (1952):

$$vi = gld^2 \times h \tag{1}$$

All clusters did not have the same regenerating species so species groups were assigned for analysis (Clabo and Clatterbuck 2020b). Groups consisted of oaks (denoted as OAK—chestnut, white, post, scarlet, and black oak), gums (GUM—blackgum and sweetgum), red maple (RM), undesirable (UND) hardwood tree and shrub species (winged elm, *Vaccinium* spp., sumac spp., sassafras, black birch, dogwood, and black cherry), while the group with other desirable (DES) hardwood species and pine consisted of yellow-poplar, hickory species, and shortleaf pine. An ocular percent cover assessment (5-percent intervals) of grape vine (*Vitis* spp.) and blackberry (*Rubus* spp.) was also completed for each plot. Natural regeneration data were analyzed using a two-factor ANOVA in a completely randomized design with treatment and species group as fixed factors. All analyses were completed using Proc Mixed in SAS 9.4 (SAS Institute 2012). Least squares means were separated using Fisher's protected least significant difference and an alpha of 0.10. The 10-percent significance level was chosen to reduce Type II error rate due to low replication, and to increase the power to detect a treatment difference that could be used as a practical site preparation alternative for sites with similar vegetation (Remington and Schork 1985). The shortleaf pine volume index and natural regeneration stem density and height by species group analyses were log transformed and untransformed means and standard errors are reported.

RESULTS

Percentage of full sunlight results revealed no significant differences among treatments (P = 0.401) or by location within clusters (P = 0.601), with percentage of full sunlight ranging from 54.8 to 68.5 across treatments and 56.6 to 62.0 by location within a cluster. No survival differences prior to the first growing season were detected (P = 0.598), and survival ranged from 95.6 to 98.7

percent, though 12.6 percent of live seedlings had evidence of freeze or browse damage. Survival differences did occur after the first growing season ($P = 0.074$). Survival was least in the fell-only (control) treatment and greatest in the fell-herbicide-burn treatment (table 1). After the first growing season, 33.6 percent of live seedlings had evidence of browse damage or insect defoliation (fig. 1). Treatment differences for average height at planting did occur ($P < 0.0001$) (range 7.9 inches for fell-herbicide-burn to 9.4 inches for the fell-only treatment), but these differences were not evident by the end of the first growing season because height did not differ among treatments ($P = 0.909$) and ranged from 11.6 to 11.8 inches. Differences in first growing season height growth did occur ($P = 0.067$) (table 1), with greatest growth occurring in the fell-herbicide-burn treatment. Differences in first growing season groundline diameter growth occurred ($P = 0.008$) (table 1). Growth was greatest in the fell-herbicide-burn treatment and least in the fell-only (control) treatment. Shortleaf pine average volume index differences were detected ($P = 0.056$) as well with the fell-herbicide-burn treatment having greater average volume index than the fell-only (control) and fell-herbicide treatments which were statistically similar (table 1).

Table 1—Mean survival, height growth, groundline diameter, and volume index for planted shortleaf pine one growing season after planting for a shortleaf pine cluster planting site preparation study

	Survival		Height		Groundline diameter		Volume index	
Treatment	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	percent		*inches*		*inches*			
Fell, burn, and herbicide	69.5a	6.2	4.0a	0.36	0.19a	0.005	781.3a	66
Fell and burn	64.9a	6.6	3.4ab	0.36	0.18a	0.007	756.9ab	67
Fell only	43.6b	6.1	2.4b	0.39	0.15b	0.005	532.0b	73
Fell and herbicide	58.4ab	6.0	3.1ab	0.34	0.16b	0.004	532.9b	63

SE = standard error of the mean.
Treatment means in a column followed by the same letter do not differ statistically at $P = 0.10$.

Figure 1—Examples of shortleaf pine (left) freeze and (right) browse damage approximately 2 months after planting. (Photos courtesy of David Clabo)

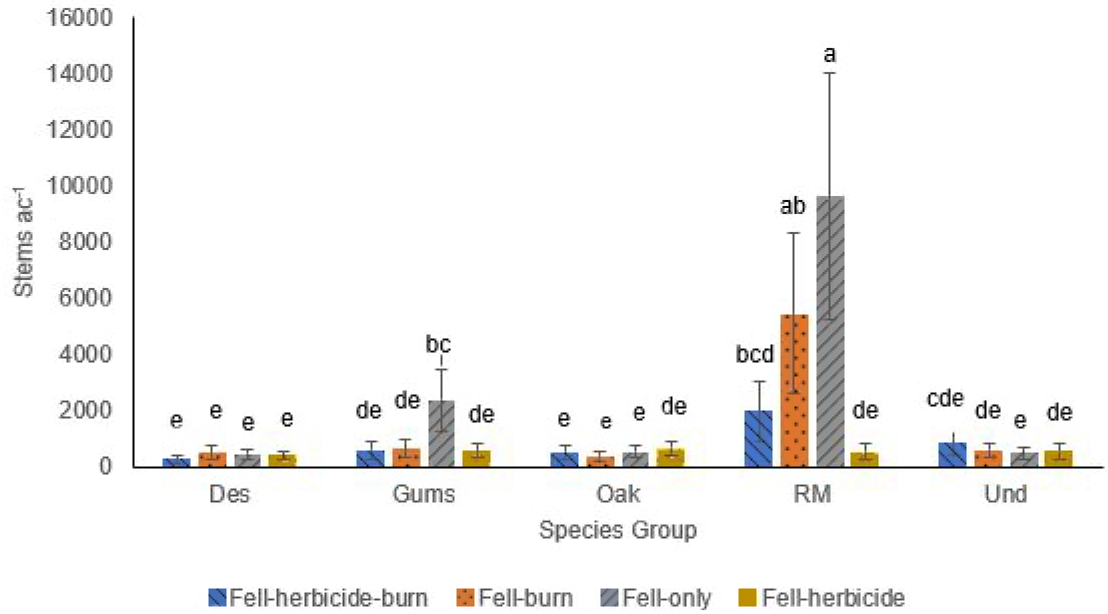

Figure 2—Natural regeneration stem density averages and standard error bars. DES is yellow-poplar, hickory, and shortleaf pine; GUM is blackgum and sweetgum; OAK is chestnut, white, post, scarlet, and black oak; RM is red maple; and UND is winged elm, *Vaccinium* spp., sumac, sassafras, black birch, dogwood, and black cherry. Bars with similar letters are not statistically different at $P = 0.10$.

Table 2—Mean height of natural regeneration one growing season after study establishment for a shortleaf pine cluster planting site preparation study

Treatment	Stem height	
	Mean	SE
	~~ *inches* ~~~~~~~	
Fell, burn, and herbicide	15.8b	6.5
Fell and burn	42.1a	5.6
Fell only	21.6b	6.4
Fell and herbicide	12.1b	5.6

Treatment means in a column followed by the same letter do not differ significantly at $P = 0.10$.
SE = standard error of the mean.

The natural regeneration stem density treatment by species group interaction was significant ($P = 0.012$) (fig. 2). Red maple was prevalent in all treatments except the fell-herbicide-burn treatment. Gum species were common in the fell-only treatment, while the OAK and DES groups did not differ in stem density across treatments (fig. 2). Nine of 12 clusters had greater than 10 percent grape or blackberry coverage at the end of the first growing season. Only treatment was significant ($P = 0.013$) for the natural regeneration height analysis. Stems in the fell-burn treatment were significantly taller than the three other treatments, which did not differ (table 2).

DISCUSSION

The light analyses revealed that treatments and clusters did not differ in percentage of full sunlight, which simplified comparisons of shortleaf pine and natural regeneration variables across treatments. Growing season light levels in this study were similar 5 years after harvest to a similar 25 percent retention level (38 square feet per acre) shelterwood study (66.7 percent full light) conducted across three sites in neighboring Jackson County, AL (Schweitzer and Dey 2011).

Shortleaf pine survival was still acceptable for cluster planting restoration purposes across all site preparation treatments following one growing season, but was poorer across treatments than a similar underplanting study (76 percent survival after one growing season) conducted in Missouri (Kabrick and others 2011). Due to the high planting densities within clusters, greater early mortality may be acceptable with cluster planting below minimum stocking thresholds. Site preparation may offer better early survival than release treatments. Site preparation tended to result in better survival after one growing season for all treatments except the fell-only treatment compared to similar shortleaf pine cluster release treatments after two growing seasons conducted by Clabo and Clatterbuck (2020b) on similar sites in Tennessee. More time will indicate if that trend continues. Treatments that included site preparation burning usually had better survival and larger seedlings than fell-only or fell-herbicide treatments. Site preparation burning has been recognized as important for improved long-term shortleaf pine growth in other studies (Gwaze and others 2007). Average growth with the fell-herbicide treatment tended to be less than with the fell-herbicide-burn treatment, similar to findings by Clabo and Clatterbuck (2020a). Burning appears to give added vegetation control during the first growing season, especially compared to herbicide treatments that only target woody and semiwoody vegetation stumps.

Oak stem densities did not differ across treatments after one growing season. This result should be expected as other studies have not shown oak stem density increases due to sprouting or new seedling establishment following cutting and prescribed fire especially when aggressive mesic species such as red maple, blackgum, and sassafras are present (Schweitzer and others 2016). Herbicide treatments also would have reduced oak stem densities in those treatments where they were applied. Sprout height and density of red maple stems increased significantly with the fell-only and fell-burn treatments. Red maple sprouts can grow quickly compared to competitor species in relatively high light and drought-prone sites similar to the sites used in this study (Abrams 1998). Other studies have reported increases in stem density and height of mesic species such as red maple and blackgum following a single prescribed burn due to prolific sprouting (Arthur and others 1998, Elliott and Vose 2005). The rapid sprout growth of species such as red maple and sassafras following cutting and topkill by prescribed fire along with more open canopy conditions associated with the two-age deferment harvest likely explains the significantly greater height growth of natural regeneration (predominately red maple) in the fell-burn treatment (Alexander and others 2008, Arthur and others 1998, Fei and Steiner 2009, Schweitzer and others 2016). The mesic species that have established will likely require release treatments to improve ingrowth to the canopy of shortleaf pine, oaks, and other desirable hardwoods (Guldin 2019, Schweitzer and Dey 2011).

CONCLUSIONS

Shortleaf pine underplanting in clusters is a potential management tool to restore scattered pockets of shortleaf pine in hardwood-dominated systems. More intensive site preparation that includes herbicide application and prescribed fire can improve early pine survival and growth. Due to shortleaf pine's slow growth after planting, added release treatments to suppress fast-growing competitor hardwood species and vines may be needed to foster shortleaf pine's competitive status on similar sites until shortleaf pine begins more rapid height growth 3–4 years after planting.

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