EARLY LONGLEAF PINE SEEDLING SURVIVORSHIP ON HYDRIC SOILS

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Abstract—We established a study to evaluate site preparation in restoring longleaf pine on poorly drained sites. Most existing longleaf pine stands occur on drier sites, and traditional approaches to restoring longleaf pine on wetter sites may rely on intensive practices that compromise the integrity of the ground layer vegetation. We applied silvicultural treatments to improve soil conditions that impede longleaf survival and growth on poorly drained soils. The study design is a split-plot with eight treatments replicated on six blocks. Treatments were an herbicide application or a single-pass chop prior to burning, followed by flat planting, mounding and planting, or bedding and planting. Flat planting had the highest survivorship, and we detected significant differences ($p \leq 0.05$) among treatments on seedling survival at 6 months but none after 1 year.

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) has often been replaced by other southern pine species due its long-standing reputation of being difficult to regenerate (Boyer 1988). In artificially regenerated longleaf stands, poor survival is attributed to the quality of nursery stock, quality of planting, or unsatisfactory field conditions during planting and through the first year (Boyer 1988, Larson 2002). Longleaf seedlings are sensitive to competing vegetation, so controlling the vegetation in the first growing season supports early emergence from the grass stage (Larson 2002). Additionally, site preparation prior to planting can improve difficult field conditions such as poor drainage (Boyer 1988).

Larson (2002) defined quality longleaf seedlings as those with needle length ≥ 15 cm, a firm and moist plug with an air-pruned taproot, and a root-collar diameter (RCD) of approximately 0.65 cm with a dormant visible bud. Lauer (1987) determined no relationship between RCD and survival rates, but RCD did hinder growth and height initiation out of the grass stage. Ramsey and others (2003) also found no relationship between survival and RCD, and found that competition may be just as important as RCD for emergence from the grass stage.

One key to maximizing seedling survival is proper planting depth (Boyer 1988, Burns 1974, Larson 2002). Soil should cover the top of the plug to prevent moisture loss from the nursery media but not the seedling bud. Erosion should not uncover the plug, and air pockets from poorly packed soil can damage or kill containerized seedlings (Larson 2002). On well-drained Lakeland sand, Burns (1974) found a corresponding increase in longleaf mortality with each increase in planting depth, and deep planting negatively affected growth. Not until age 3 years, however, did the deepest plantings show the highest mortality. Deep planting may have protected the seedling from desiccation by the wind and sun, delaying the mortality associated with deep planting that other researchers reported.

Routine mechanical site preparation can improve microsites for seedlings (Burger and Pritchett 1988). While mounding and bedding improve drainage and aeration, treatments (like chopping and herbicides) that reduce competition increase moisture available to seedlings (Spittlehouse and Childs 1990). Bedding has become commonplace (Thomas and others 2004), but mounding is not used extensively in the Southeast.

Mounding as a site preparation technique has been used for centuries and currently is used in the uplands of Scandinavia and Canada; it is becoming more prevalent in the Upper Great Lake States (Londo 2001, Sutton 1993). Mounding involves scooping up soil and inverting it on the forest floor to create a double organic layer to provide nutrients and water for seedlings. Mounding can increase the volume of aerated soil on wet sites, reduce excessive soil moisture, increase the rooting zone (Londo 2001, Sutton 1993), and control competition. Runoff water flows into the pits by each mound. By increasing decomposition, mounds increase nutrient availability (Londo 2001).

Many species of northern conifers planted on mounds show mixed results for both survival and growth rates (Londo 2001); however, long-term evaluation is lacking. In the Southeast, only slash pine (*P. elliottii* Englem.) has been studied and reported on in the literature (Sutton 1993). Studying slash pine on silt-loam soils in Louisiana, Haywood (1987) found greater survival and accelerated growth due to mounding. The discontinued nature of mounds permitted natural surface drainage, and during the winter when the water table was highest, mounding provided additional rooting. Rates of settling, erosion, and regrowth of competing vegetation in mounding have received little to no attention (Sutton 1993).

Chemical treatments can also help establish longleaf pine. Ramsey and others (2003) examined longleaf survival from a well-drained old field where they applied herbicides and fertilizers at different times postplanting. The herbicide treatment plots had the greatest survival after 1 year, but in the second year, the control and herbicide-only treatment plots had similar survivorship. They attributed the additional 4 to 6 percent second-year mortality to natural causes and not to treatment effects. Additionally, the second-year leveling off of mortality indicated the seedlings had well-established root systems. The fertilizer treatment was detrimental to seedling survival by accelerating the growth of competing understory vegetation (Ramsey and others 2003).

The majority of seedling mortality occurs primarily in the first growing season (Boyer 1988, Ramsey and others 2003), and our objective was to determine if applied treatments affected seedling survivorship. This research reports longleaf pine seedling survival 1 year after planting. This research is part

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of an ongoing project designed to evaluate site preparation methods for optimal tree survival and growth and for effects on the understory community.

MATERIALS AND METHODS

The project is based at Marine Corps Base, Camp Lejeune, in Onslow County, NC. Camp Lejeune is in the Atlantic Coastal Flatlands section of the Outer Coastal Plains Mixed Forest Province (Bailey 1995). Study sites have Leon soils (sandy, siliceous, thermic Aeric Alaquod), a poorly drained fine sand with a cemented spodic horizon. Despite their poor drainage, spodosols have a low water-holding capacity due to a sandy nature, low organic matter content, and macroporosity of surface horizons (Barnhill 1992). The previous stands of slash and loblolly pines (*Pinus taeda* L.), ranging in age from 10 to 40 years, were sheared 6 months to 2 years prior to treatment installation.

The research design was a split-plot with eight treatments replicated on six blocks. Each 0.6-ha treatment plot had a 0.4-ha measurement plot and a 15-m buffer. The treatments began in different stages from August to December, 2003. A single-pass chop or herbicide application preceded burning, followed by either flat planting, mounding and planting, or bedding and planting. Each block had a control treatment (burned and flat planted) and a combination treatment (herbicide and chop prior to bedding).

The chop treatment was done with a 2.4-m Lucas drum chopper pulled by a TD15 dresser crawler tractor. The herbicide treatment, a combination of Chopper® (2.8 liter ha^{-1}) and Garlon 4® (1.4 liter ha^{-1}), was broadcast-applied prior to burning as an alternative to chopping. A Rome six-disc bedding harrow (three on each side), pulled with a TD15 dresser crawler tractor, created 2.1- to 2.4-m beds. Mounding was done with a New Forest Technology™ custom mounding bucket mounted on a Caterpillar 320BL excavator. Mounds (1.2 m wide) were installed in rows as opposed to an irregular pattern that is usually employed.

In December 2003, we hand-planted container-grown longleaf pine seedlings on 4.5- by 2-m spacing. The seeds were sown in Rotak multipots (6-45), in a vermiculite-peat moss-perlite (2:2:1) planting medium and fertilized with Osmocote control-release fertilizer (3.5 kg Osmocote/m^3 of planting medium). Seedlings were kept on outdoor benches and watered with an automatic sprinkler. The minimum requirement for culls was > 0.5-cm RCD and abundant secondary needles > 10 cm in length.

We surveyed measurement plots for seedling survival 6 months and 1 year after planting. In flat-planted plots, seedlings were located and marked with pin flags. The pin flags were counted prior to marking the seedlings. Flags marking dead seedlings were pulled, counted, and subtracted from the live total. In bedded and mounded plots, we established the boundaries of measurement plots and counted the number of rows. We walked rows to tally the number of live seedlings; seedlings were marked as alive if any portion of the foliage was green. To detect significant differences for survival among treatments, we performed analysis of variance with a split-plot design (Proc GLM; SAS Institute 2002). The effects on seedling survival due to chopping vs. herbicides and mounding and planting vs. bedding and planting vs. flat planting, as well as any interaction, were tested as a 2 x 3 factorial. Since the control and chop-herbicide-bed do not fit into a factorial, we omitted them from this portion of the analysis. We considered differences significant at $p \le 0.05$.

RESULTS AND CONCLUSIONS

Six months after planting, all treatments had > 85 percent seedling survival with the control being the highest (95 percent) and the chop-mound being the lowest (85 percent; table 1). The treatments chop-bed ($p = 0.02$), chop-mound (0.008), and herbicide-mound (0.015) differed significantly from the control. Factorial results detected no significant difference on seedling survival from a chop or an herbicide application ($p = 0.52$). However, there was a significant difference ($p = 0.007$) for survival between flat planting and mounding (table 2). We detected no significant interaction between herbicide or chop and mounding, bedding, or flat planting.

Table 1—Mean seedling survival percentage at 6 months and 1 year after planting (standard deviation given in parenthesis)

Treatment	Mean survival	
	6 months	1 year
	percent	
CB	88.4^a (± 7.4)	66.5 (± 15.9)
CF	93.4^{ab} (± 2.6)	71.5 (± 13.4)
CHB	91.3^{ab} (± 4.7)	66.0 (± 9.8)
CM	85.0^a (± 7.9)	70.9 (± 13.6)
HB	89.6^{ab} (± 6.4)	68.8 (± 16.7)
HF	92.3^{ab} (± 4.3)	70.8 (± 16.6)
HM	87.1^a (± 3.8)	66.3 (± 9.4)
CTL	95.4^b (± 1.8)	74.0 (± 17.7)

C = chop; B = bed; F = flat planted; H = herbicide; M = mound; CTL = control.
Within a column, values not sharing a letter are significantly different ($p \ge 0.05$).

Table 2—Mean seedling survival percentage from the 3 x 2 factorial at 6 months and 1 year after planting

Treatment	Mean survival	
	6 months	1 year
	percent	
Planting method		
Bed	88.5^{ab}	67.8
Mound	86.5^b	69.5
Flat	92.5^a	70.8
Pr > F	0.008	0.8
Site preparation		
Herbicide	89.6	68.7
Chop	88.7	70.1
Pr > F	0.5	0.7

Within a column, treatments followed by letters are significantly different ($p \ge 0.05$).

After 1 year, no significant differences appeared among treatments for survival ($p = 0.7$). The control had the highest percentage survival (74 percent), and the chop-herbicide-bed treatment had the lowest survival (65 percent). First-year survival had greater variation within treatments relative to 6-month survival as indicated by the standard deviations (table 1, fig. 1). Seedling survival showed no significant differences between herbicides and chopping, or among bedding, mounding, and flat planting (table 2).

Treatment differences at 6 months were no longer evident at 1 year; however, the control treatment continued to have the highest survival. Because the majority of seedlings die in the first growing season (Boyer 1988, Ramsey and others 2003), we expect that differences in mortality will not re-emerge over time. Poor survival is attributed to the quality of nursery stock, quality of planting, or unsatisfactory field conditions during planting and through the first year (Boyer 1988, Larson 2002). Assuming equal seedling quality, planting quality and field conditions remain as reasons for the early 6-month differences; however, even these differences do not remain significant after 1 year.

The variation within treatment plots increased dramatically from 6 months to 1 year. Within individual treatment plots, we frequently observed that the majority of seedlings in a row were dead or chlorotic, while the majority in the adjacent row exhibited vigor, suggesting that planting quality varied with individual planters. The individual planters moved down rows as a group, and the same planter almost never planted adjacent rows. The planters' varying skill probably yielded the high variation in seedling survival. Because the same crew planted the entire research area, quality was equal among beds, mounds, and flat areas. Mechanical treatments had no effect on survivorship, and no differences emerged between methods of competition control (chopping and herbicides) or planting area (bed, mound, or flat). While survivorship continues to be monitored, treatments will be evaluated for effect on emergence from the grass stage and growth.

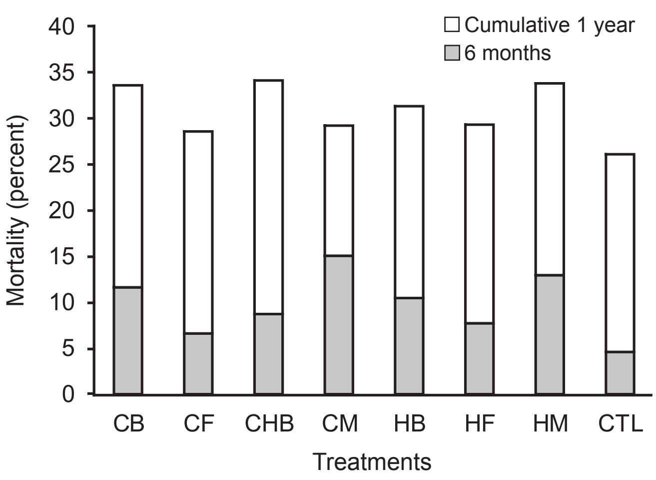

Figure 1—Cumulative mean seedling mortality over 1 year by treatment. CTL = control, C = chop, H = herbicide, M = mound, B = bed, and F = flat planted.

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LITERATURE CITED

Bailey, R.G. 1995. Description of the ecoregions of the United States, 2d ed. Misc. Pub. No. 1391. Washington, DC: U.S. Department of Agriculture, Forest Service. 108 p.

Barnhill, W.L. 1992. Soil survey of Onslow County, North Carolina. National cooperative soil survey. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 139 p.

Boyer, W.D. 1988. Effects of site preparation and release on the survival and growth of planted bare-root and container grown longleaf pine. Georgia Forest Research Paper 76. [Place of publication unknown]: Georgia Forestry Commission, Research Division: 1-7.

Burger, J.A.; Pritchett, W.L. 1988. Site preparation effects on soil moisture and available nutrients in a pine plantation in the Florida flatwoods. Forest Science. 34: 77-87.

Burns, R.M. 1974. Deep planting detrimental to longleaf pines on droughty acid sands. Tree Planter's Notes. 25(4): 28-29.

Haywood, J.D. 1987. Response of slash pine planted on mounds in central and southwestern Louisiana. New Forests. 4: 291-300.

Larson, D.R. 2002. Field planting containerized longleaf pine seedlings. In: Barnett, J.P.; Dumroese, R.K.; Moorhead, D.J., eds. Proceedings of workshops on growing longleaf pine in containers: 1999 and 2001. Gen. Tech. Rep. SRS-56. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 62-63.

Lauer, D.K. 1987. Seedling size influences early growth of longleaf pine. Tree Planter's Notes. 38 (3): 16-17.

Londo, A.J. 2001. Bucket mounding as a mechanical site preparation technique in wetlands. Northern Journal of Applied Forestry. 18 (1): 7-13.

Ramsey, C.L.; Jose, S.; Brecke, B.J.; Merritt, S. 2003. Growth response of longleaf pine (*Pinus palustris* Mill.) seedlings to fertilization and herbaceous weed control in an old field in southern USA. Forest Ecology and Management. 172: 281-289.

SAS Institute. 2002. Release 9.1. Cary, NC: SAS Institute. [Not paged].

Spittlehouse, D.L.; Childs, S.W. 1990. Evaluating the seedling moisture environment after site preparation. In: Gessel, S.P.; Lacate, D.S.; Weetman, G.F.; Powers, R.F., eds. Sustained productivity of forest soils. Proceedings of the seventh North American forest soils conference. Vancouver, BC: University of British Columbia, Faculty of Forestry Publication: 432-450.

Sutton, R.F. 1993. Mounding site preparation: a review of European and North American experience. New Forests. 7: 151-192.

Thomas, R.F.; Jokela, E.J.; Allen, H.L. 2004. The evolution of pine plantation silviculture in the southern United States. In: Rauscher, H.M.; Johnsen, K., eds. Southern forest science: past, present, and future. Gen. Tech. Rep. SRS-75. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 63-82.