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Relating the survival and growth of planted longleaf pine seedlings to microsite conditions altered by site preparation treatments

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ABSTRACT

Pine plantations in the southeastern United States are often created using site preparation treatments to alleviate site conditions that may limit survival or growth of planted seedlings. However, little is understood about how site preparations affect longleaf pine (*Pinus palustris* P. Miller) seedlings planted on wet sites. In a 2-year study (2004 and 2005) on poorly drained, sandy soils of Onslow County, North Carolina, we examined the effects of common site preparation treatments on microsite conditions and quantified relationships between microsite conditions and longleaf pine seedling survival and growth. Treatments used in the study included site preparations designed to control competing vegetation (chopping and herbicide) combined with those that alter soil conditions (mounding and bedding). During both years, mounding and bedding treatments reduced the amount of moisture within the top 6 cm of soil and increased soil temperatures when compared to flat planting ($p < 0.001$). Soil moisture was inversely related to seedling mortality in 2004 ($r^2 = 0.405$) and inversely related to root collar diameter in 2005 ($r^2 = 0.334$), while light was positively related to root collar diameter in 2005 ($r^2 = 0.262$). Light availability at the seedling level was highest on treatments that effectively reduced surrounding vegetation. Herbicides were more effective than chopping at controlling vegetation in 2004 ($p < 0.001$) and 2005 ($p = 0.036$). Controlling competing vegetation, especially shrubs, was critical for increasing early longleaf pine seedling growth.

1. Introduction

Restoring the longleaf pine (*Pinus palustris* P. Miller) ecosystem is currently a major focus of land managers throughout the southeastern United States. Widespread reduction since European settlement has left longleaf pine occupying approximately 3% of its original range (Frost, 1993; Landers et al., 1995), largely due to land conversion and fire exclusion. Areas still containing longleaf pine may be maintained successfully with natural regeneration and frequent prescribed fire. However, the majority of the original range no longer contains longleaf pine in the overstory to provide seed and therefore requires artificial regeneration (Barnett, 1999).

Land managers in the southeastern United States frequently use site preparation in conjunction with artificial regeneration of southern pine species. Previous studies have demonstrated the effectiveness of various types of site preparation for increasing early growth of loblolly pine (*Pinus taeda* L.) and/or slash pine (*Pinus elliottii* Engelm.) (e.g. Burger and Pritchett, 1988; Nilsson and Allen, 2003; Rahman and Messina, 2006). For example, Knowe et al. (1992) reported that herbicides and chopping increased loblolly pine height (2.65 m) and diameter (4.47 cm) after 4 years of growth when compared to an untreated control (1.46 m, 1.45 cm, respectively). Moreover, studies have indicated that site preparation intensity is positively related to seedling growth (Nilsson and Allen, 2003). Burger and Pritchett (1988) compared the effects of low intensity site preparation (chopping) and high intensity site preparation (windrowing, disc harrowing, and bedding) on loblolly pine seedling response. After two growing seasons, seedling height and diameter were significantly greater on the high intensity treatment (79.9 cm and 2.33 cm, respectively) than on the low intensity treatment (68.5 cm and 1.41 cm, respectively).

Barnett (1992) identifies well-prepared sites as a critical prerequisite for successful artificial regeneration of longleaf pine. Although limited to only a few studies, previous research has demonstrated the beneficial effects of mechanical treatments on survival and growth of planted longleaf pine seedlings (Croker, 1975; Croker and Boyer, 1975; Boyer, 1988). For instance, Boyer (1988) reported greater seedling survival 3 years after planting on sites treated with two passes of mechanical competition control

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(chop or harrow) (73% survival) when compared to sites with one mechanical pass (58% survival). Additionally, plots treated with herbicides shortly after planting resulted in 77% of seedlings in height growth after 3 years, compared to 58% of seedlings in height growth on untreated plots. The importance of competition control for longleaf pine establishment (Wahlenburg, 1946; Boyer, 1990) has prompted additional studies focused on understanding the effects of using herbicides for seedling release (e.g. Nelson et al., 1985; Creighton et al., 1987; Ramsey et al., 2003; Ramsey and Jose, 2004). Although the type of herbicide and method of application vary across published studies, competition control provided by herbicides typically results in improved seedling establishment. Haywood (2000) found that after 3 years of growth, 59% of surviving seedlings had emerged from the grass stage on plots treated with herbicides and only 17% had emerged on untreated check plots. After 5 years, seedlings out of the grass stage were nearly twice as tall on herbicide plots as those on check plots, indicating potentially long-term benefits for stand production.

Although longleaf pine naturally occurs on a range of site types that includes poorly drained flatwoods (Boyer, 1990), wet sites are often planted with faster growing pine species, and artificial regeneration of longleaf pine is commonly restricted to drier soils. Little is understood about how mechanical site preparation influences longleaf pine seedlings on wet sites. Studies on other southern pines have associated greater growth rates with improved drainage following mechanical treatments (e.g. bedding or mounding) on poorly drained sites (Outcalt, 1984; McKee and Wilhite, 1986; Haywood, 1987). For example, in a study in the flatwoods of Florida, Pritchett (1979) found that slash pines planted on bedded sites averaged 1.25 m taller than those planted on burn-only sites after eight growing seasons and suggested that increased drainage within the root zone was responsible for the growth difference. We would expect that improved drainage on wet sites would also benefit longleaf pine seedlings, although we are aware of no studies designed to evaluate the impact of mechanical treatments that alter soil conditions on longleaf pine seedling response.

The effectiveness of a site preparation treatment, in regard to seedling growth and survival, is typically determined by the magnitude of the target seedling's response; the treatment resulting in a higher growth rate or greater survival is considered the better treatment. However, effects of site preparations on seedling response are complex and vary with specific site, seasonal, and climatic conditions. Therefore, to implement site preparation most efficiently, it is important to understand the underlying mechanisms responsible for improving seedling growth and survival. According to Morris and Lowery (1988), two primary functions of site preparation include (1) manipulation of soil conditions and (2) competition control, and they discuss the benefit of separating the effects of each when evaluating site preparation treatments. However, many types of site preparation, especially mechanical treatments such as bedding and mounding, inherently alter both the immediate soil conditions and the abundance of competing vegetation. Therefore, it is necessary to directly quantify resource availability, soil conditions, and abundance of competing vegetation when identifying primary effects of a site preparation treatment.

This study was designed to investigate the effectiveness of common site preparations for use in longleaf pine regeneration on poorly drained soils by relating seedling response to direct measurements of microsite conditions. Our specific objectives were to: (1) quantify soil conditions (moisture and temperature), abundance of competing vegetation, and light availability following low to medium intensity site preparation treatments, and (2) determine relationships between seedling survival/growth and the measured microsite conditions.

2. Materials and methods

2.1. Study area

The study was conducted on Marine Corps Base Camp Lejeune (34°7′N, 77°4′W), in Onslow County, North Carolina. Camp Lejeune is located within the Atlantic Coastal Flatlands Section of the Outer Coastal Plains Mixed Forest Province (Bailey, 1995). The climate is classified as warm humid temperate with an average annual temperature of 17.4 °C and an average annual precipitation of 145 cm (National Climate Data Center, Hofmann Forest Station, 34°5′N, 77°2′W). Study sites were on Leon fine sand (sandy, siliceous, thermic, Aeric Alaquod), which is characterized by light-gray to white sand within the first 30–60 cm, underlain by a dark B horizon of organic accumulation. The B horizon was sufficiently cemented to form a hardpan of varying thickness (15–25 cm). This soil type is poorly drained, with internal drainage impeded by the hardpan layer (Barnhill, 1992; NRCS, 2005). Natural vegetation on Leon sand in this area is longleaf pine savanna, consisting of longleaf pine overstories with herbaceous ground layers dominated by grasses and sedges, including wiregrass (*Aristida* spp.), bluestems (*Andropogon* spp., *Schizachyrium* spp.), panic grasses (*Panicum* spp., *Dichanthelium* spp.), and beak rushes (*Rhynchospora* spp.) (Frost, 2001). Additionally, the ground layer includes a diverse mix of forbs. With frequent fire, this site type is favorable for rare species such as roughleaf loosestrife (*Lysimachia asperulifolia* Poir.) and Venus flytrap (*Dionaea muscipula* Ellis). Common shrubs include *Ilex glabra* (L.) Gray, *Gaylussacia frondosa* (L.), and *Vaccinium* spp.

2.2. Experimental design and implementation

The study design was a randomized complete block consisting of 8 treatments replicated on 5 blocks, for a total of 40 experimental units. Study treatments were randomly assigned to approximately 0.4 ha experimental units with 15 m buffers between plots to reduce treatment overlap. Prior to site preparation, all blocks were harvested and sheared to remove standing vegetation. Eight experimental treatments were applied in August 2003: a check (no site preparation), six treatments that combined two initial vegetation control treatments (chopping or herbicide) with three planting site conditions (flat [no additional treatment], mounding, or bedding), and a more intense treatment including chopping, herbicide, and bedding. In this paper, the treatments are often referred to by their initials as follows: flat or check (F), chopping and flat (CF), herbicide and flat (HF), chopping and mounding (CM), herbicide and mounding (HM), chopping and bedding (CB), herbicide and bedding (HB), and chopping, herbicide, and bedding (CHB). Details on treatment application are given in Knapp et al. (2006), and all treatments were applied before planting.

Study plots were hand planted in December 2003 with container-grown seedlings from locally collected seed. The average root collar diameter of planted seedlings was 6.6 mm with a standard deviation of 1.2 mm. Planting was done by contracted crews who exhibited a wide range of planting skill, occasionally leaving plugs exposed or buried too deeply in the soil. To avoid problems with planting variability, only seedlings planted with the root collar from one centimeter above the soil to three centimeters beneath the soil (i.e. terminal bud exposed and plug buried) were considered for measurement.

2.3. Data collection

In May 2004, a sub-sample of 45 seedlings was identified in each experimental unit by randomly determining a seedling within