Effects of Stock Type and Fall Fertilization on Survival of Longleaf Pine Seedlings Planted in Lignite Minespoil

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EFFECTS OF STOCK TYPE AND FALL FERTILIZATION ON SURVIVAL OF LONGLEAF PINE SEEDLINGS PLANTED IN LIGNITE MINESPOIL

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Abstract—One-year-old longleaf pine (*Pinus palustris* Mill.) seedlings were hand-planted in January 1996 on an east Texas minespoil site. Effects of two seedling stock types and four levels of preplanting fall fertilization on seedling survival were evaluated. Fertilizer treatments consisting of a single application of ammonium nitrate (73 kilograms per hectare N), phosphorus (81 kilograms per hectare P), diammonium phosphate (73 kilograms per hectare N, 81 kilograms per hectare P), or control (no fertilizer) were applied to bare-root and container seedlings in November 1995. Root growth potential, the ability of a seedling to initiate and elongate new roots when placed into a favorable environment, was measured at time of planting. Field survival was surveyed monthly beginning in April 1996. Data were examined using analysis of variance. Container seedlings had significantly higher root growth potential and survival than bare-root. Fertilizer treatment effects, while not significant, tended to decrease both root growth potential and early survival for bare-root seedlings, and to increase root growth potential and decrease survival for container seedlings. Drought conditions during the 1996 growing season probably had a negative effect on survival of both bare-root and container seedlings. Only 2 percent of bare-root and 56 percent of container seedlings survived through the growing season, suggesting that only container stock should be used for reforestation of longleaf on minespoil sites. However, in years with normal precipitation, stock type effects on survival may not be significant and planting bare-root seedlings may be a viable option.

INTRODUCTION

It is estimated that between 1 and 2 million acres of land will eventually be disturbed by surface mining of lignite coal in Texas. Much of this mining will occur in the pineywoods region of east Texas (Hossner and others 1980). The Federal Surface Mine Control and Reclamation Act of 1977 requires restoration of vegetation on these lands for the primary purposes of limiting erosion and controlling flow and quality of water. Establishment of vegetation may be difficult on these sites due to physical properties, chemical toxicities, and nutrient deficiencies of the spoil material.

Reclamation of spoil banks on surface lignite mines in Texas has traditionally been accomplished using pasture grasses, even though many of these sites were forested prior to mining. Pasture grasses are relatively easy to establish, and offer immediate erosion control. However, pastures require long-term maintenance, including weed control and fertilization. On the other hand, establishment of forests is more difficult, but may provide more long-term benefits. Once established, forests require less maintenance than pastures. Forests provide wildlife habitat and recreational and economic opportunities as well as excellent control of erosion and water quality.

Texas Utilities Mining Company (TUMCO) operates several surface coal mines in east Texas, including the Beckville Mine in Panola County, which supplies fuel for the Martin Lake generating plant. In the early 1980's, TUMCO reclamation managers recognized the potential economic and environmental benefits of establishing forests on mined lands, and commenced with a program of intensive tree planting. To date, about 7 million seedlings have been planted on the Beckville Mine, consisting of approximately 85 percent improved loblolly pine (*Pinus taeda* L.) and 15 percent various hardwood species. These seedlings have been planted on both established pastures and recently graded spoil material.

TUMCO is interested in using longleaf pine (*P. palustris* Mill.) in its reclamation program in east Texas because the Beckville Mine site lies within the historical range of longleaf pine (Landers and others 1995). However, establishment of longleaf pine seedlings is more difficult than other southern pines for several reasons. First, bare-root longleaf seedlings are sensitive to handling and do not tolerate long periods of cold storage (Dennington and Farrar 1983, Dougherty and Duryea 1991). When weather delays planting, storage limitations can result in severe seedling mortality. Also, planting depth is critical because longleaf seedlings have no stems. If seedlings are planted too deep, the apical bud is smothered; if planted too shallow, the root collar is exposed and desiccation occurs. Movement of soil onto or away from seedlings after planting can have the same effect as incorrect planting depth. Finally, longleaf seedlings are very intolerant of woody competition (Dennington and Farrar 1983).

Many planting problems may be overcome when using container seedlings. Handling stress and storage are minimized. Container seedlings also perform better than bare-root in droughty conditions, and have an extended planting season. However, container seedlings have disadvantages. Compared to bare-root seedlings, they require more attention while growing, are more expensive to produce, are bulky to handle and transport, and are often smaller (Barnett and others 1989).

Obtaining quality nursery stock is an important factor in planting success. According to Duryea (1985), a high-quality seedling is one that meets defined levels of survival and growth on a given planting site. Late fall nursery

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fertilization has been used to improve the nutrient reserves of seedlings with the intent of improving survival and growth after outplanting. Previous research has shown varying effects of late-season nursery application of fertilizer. Hinesley and Maki (1980) found that fall nursery fertilization increased longleaf seedling dry weight, root collar diameter, and root:shoot ratio over controls. Field survival was not significantly affected, but height growth commenced sooner in fertilized seedlings. Anderson and Gessel (1966) found that late-season nitrogen application in the nursery significantly increased survival and height growth of outplanted Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco]. However, Ursic (1956) found a detrimental effect on field survival when loblolly seedlings were fertilized with nitrogen and potassium in the nursery in January. Shoulders (1959) found that fall nitrogen fertilization improved field survival of longleaf, loblolly, and slash pine (*P. elliotii* Engelm.) from one nursery, while survival of longleaf and loblolly from another nursery was depressed by fertilization.

This study attempts to assess effects of stock type and fall nursery fertilization treatments on survival of longleaf pine seedlings planted at the Beckville Mine.

METHODS

Seedling Treatments

Stock type treatments consisted of bare-root and container seedlings. Bare-root seedlings were commercially grown at the Texas Forest Service nursery located at Alto, TX, using seed obtained from a wild collection in east Texas. Ammonium nitrate was applied to bare-root seedlings weekly from April to August for a total growing-season application of 180 kilograms per hectare of nitrogen. Container seedlings were grown outdoors at the Arthur Temple College of Forestry greenhouse facilities located on the campus of Stephen F. Austin State University in Nacogdoches, TX. Seeds from the same east Texas source were sown in April 1995 in a commercial peat-pinebark-vermiculite growing medium in 144 cubic cm plastic cone containers. Seedlings were fertilized weekly from April to October with a commercial 30-10-10 liquid formula for a total growing-season application of 840 kilograms per hectare of nitrogen.

Four levels of mineral fertilizer treatment were applied to bare-root and container seedlings in November 1995. Treatments consisted of a single application of ammonium nitrate (73 kilograms per hectare N), phosphorus (81 kilograms per hectare P), diammonium phosphate (73 kilograms per hectare N, 81 kilograms per hectare P), or control (no fertilizer). Commercial grade fertilizer was applied to bare-root seedlings using a tractor-drawn agricultural spreader. High-purity ACS grade minerals were applied in liquid form by measured dose to each container seedling.

Design of Experiment

The study was conducted using a randomized block split plot 2 by 4 factorial design with five replications. Stock types were the whole units and fertilizer treatments were the subunits. Data were examined by analysis of variance using Statistical Analysis System procedures (SAS Institute, Inc. 1989). Results are reported as significant at the 5 percent probability level.

Bare-root and container seedlings were hand planted at the Beckville Mine in January 1996. Bare-root seedlings were lifted 1 day before planting and placed in plastic bags. Roots were sprayed with Terrasorb super-absorbent gel, bags were sealed, and seedlings were stored at 3 °C overnight. Container seedlings were watered thoroughly the day before planting. A total of 600 seedlings (15 seedlings per treatment combination per replication) were planted on 3-meters by 3-meters spacing. Field survival counts were made monthly from April to October.

The planting site was located in an area scheduled for machine-planting of loblolly seedlings. Mining operations were completed, the site was graded, and hay mulch was applied for stabilization during the summer of 1995. Winter wheat was sown in September 1995 to further stabilize the site. Seedlings were planted in spoil consisting of mixed overburden material with a silty clay texture and average pH of 6.9. At the time of planting, soil moisture content averaged 30 percent (dry weight basis) and winter wheat was about 10 cm tall.

Root growth potential (RGP) was measured at planting time on a sample of four seedlings per treatment combination per replication, using a hydroponic method modified from Ritchie (1985). RGP is defined as the ability of a seedling to initiate and elongate new roots when placed into an environment favorable for root growth. A seedling with high RGP is expected to have high potential for survival and growth after outplanting (Ritchie 1985). The experiment was conducted in a growth chamber with photoperiod controlled at 16 hours, day temperature controlled at 26 °C and night temperature controlled at 20 °C. After 28 days in the growth chamber, seedlings were removed and root counts conducted. RGP was determined as the number of new roots initiated greater than 1 cm in length.

RESULTS AND DISCUSSION

Root Growth Potential

Stock type had a significant effect on RGP. Mean RGP was 39 for bare-root seedlings and 61 for container seedlings. Of 80 bare-root seedlings tested, 25 initiated no new roots and were dead at the end of the experiment. There was no mortality among container seedlings. We expected container seedlings to have higher RGP than bare-root seedlings. Container seedlings have a fibrous root system consisting of a taproot and many higher order laterals that provide many potential initiation points for new root growth. In comparison, bare-root seedlings have a root system consisting of a large taproot and a few primary and secondary laterals, providing fewer potential initiation points. Also, bare-root seedling root systems are damaged in the lifting process; many fibrous roots are removed and stress may be induced. However, we did not expect mortality among either stock type in the RGP experiment.

Fertilizer treatments did not have a significant effect on RGP (P>0.42). Interaction effect between stock type and fertilizer was also not significant (P>0.14), but tendencies were strong, as shown in figure 1. Fertilizer treatments tended to improve RGP for container seedlings and depress RGP for bare-root seedlings. Control (unfertilized) bare-root seedlings had a higher average of RGP (68) than control container seedlings (50), but fertilized bare-root seedlings performed worse than all other treatment combinations. Container seedlings are often subject to nutrient deficiencies because soil-less growing media provide few mineral ions, container volume is small, and frequent irrigation leaches nutrients (Landis 1989). Therefore, fall fertilization was expected to improve container seedling quality and performance. Fertilizer treatments were not expected to be detrimental to bare-root seedlings, and reasons for this effect are not apparent.

Field Survival

Stock type had a significant effect on survival for all monthly counts. RGP results indicated an expected initial mortality of at least 30 percent for bare-root seedlings. No mortality was noticed in a visual inspection in February, but bare-root seedlings appeared stressed and unhealthy. Precipitation in February was less than 25 percent of normal and soil moisture was low. Drought conditions persisted throughout the growing season. Cumulative precipitation and survival count results are depicted in figure 2. In April, 56 percent of bare-root seedlings were dead, while more than 99 percent of container seedlings

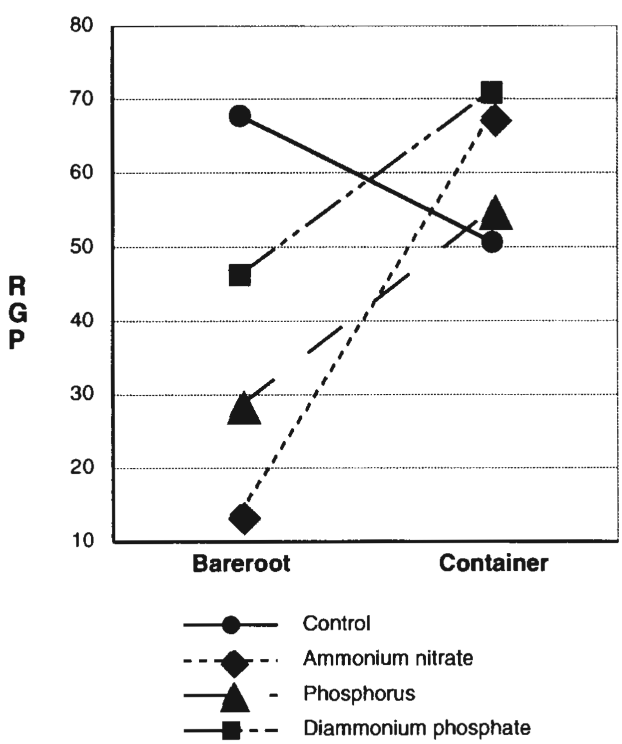

Figure 1—Interaction effect of stock type and fertilizer treatments on root growth potential of bare-root and container longleaf pine seedlings.

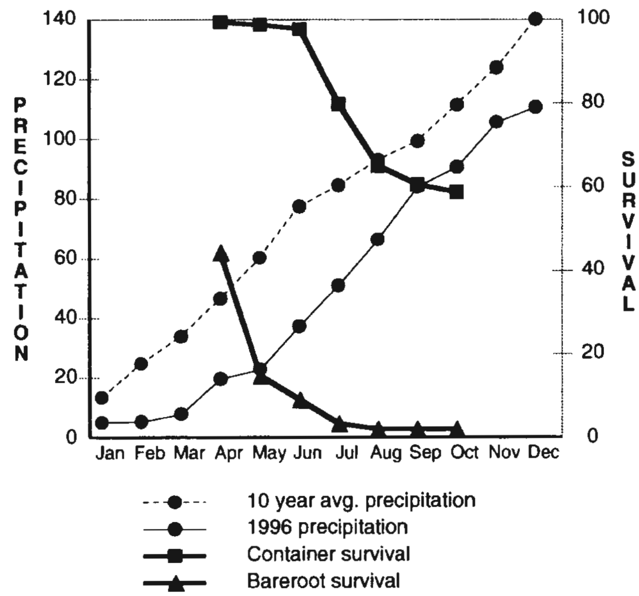

Figure 2—Cumulative 10-year average and 1996 precipitation in centimeters, and percent survival of bare-root and container longleaf pine seedlings planted on a lignite minespoil site in Panola County, TX.

remained alive. All living seedlings appeared stressed and competition from winter wheat and hairy vetch was intense. Herbicide was sprayed in a 1-meter radius around each living seedling in May to control competition. By June, 91 percent of bare-root seedlings were dead, but container survival was still high at 98 percent. New growth was visible on most living seedlings, but young needles were only 6 to 8 centimeters long. Herbaceous vegetation on the entire site was brown and dry, so effects of herbicide were not obvious. Container survival declined sharply to 75 percent in July, and only 3 percent of bare-root seedlings remained alive. By October, bare-root survival was 2 percent, and container survival had stabilized at 56 percent. Young needles on surviving seedlings had elongated to only 20 to 25 cm.

Container seedlings were expected to survive and perform better than bare-root in this study, but effects of the drought probably intensified this phenomenon. Fibrous root systems of container seedlings have a larger absorptive surface than bare-root root systems and therefore have a greater ability to extract water from the surrounding soil and tolerate drought. However, we believe that both container and bare-root seedlings were negatively affected by the poor soil moisture conditions.

Fertilizer treatments had no significant effect on seedling survival. However, bare-root seedlings fertilized with ammonium nitrate tended to die sooner than those receiving other treatment combinations. Survival of container seedlings also tended to be lower for nitrogen fertilizer treatments for all monthly counts. Perhaps the effects of fertilizer treatments would have been greater if mortality had not been as rapid and severe.

Visual inspection of seedlings in March 1997 indicated no additional over-winter mortality, and new growth was noticeable on most seedlings. Effects of herbicide treatment were obvious; a patch of bare ground surrounded each seedling. Intense winter rainstorms had caused sheet erosion to remove up to 4 centimeters of soil from around the roots of some seedlings. Effects of this soil removal on seedling survival remain to be seen.

CONCLUSIONS

Container seedlings had significantly higher overall RGP and survival than bare-root seedlings. High mortality of bare-root seedlings suggests that only container seedlings should be used for longleaf reforestation on east Texas lignite minespoil sites. However, effects of stock type on survival may not be as noticeable when growing season precipitation is closer to normal. Results of this study indicate that fall fertilization may be detrimental to both RGP and survival of bare-root seedlings, although effects were not statistically significant. Fertilizer effects on container seedlings were also not significant. However, fall fertilization tended to improve RGP of container seedlings; in contrast, survival of container seedlings tended to be depressed by fertilizer treatments. Additional study of the effects of fall fertilization on both stock types is needed before recommendations can be made.

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