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Planting Techniques for Establishing Loblolly Pine Seedlings on Two Subsoiled Sites in Arkansas

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Abstract.—The presence of soil compaction and root-restricting layers (e.g., plow pans) resulting from long-term agricultural practices often poses difficulties when converting these sites into loblolly pine plantations. Subsoiling is usually prescribed to alleviate any problems with soil strength. Subsoiling also creates soil conditions that may aid or hinder planting seedlings. The interaction of planting location, either in the furrow or the adjacent 0.3, 0.9 or 1.5 ft, and planting depth on 2 marginal crop lands was assessed in this study. Planting seedlings in the furrow and deep planting (to the terminal bud) resulted in better growth and increased survival after the first growing season compared to planting outside the furrow and shallow to moderately deep planting, respectively.

Key words:—Soil compaction, loblolly pine plantations, subsoiling.

Introduction

Aforestation is proceeding at an accelerated pace throughout the southern United States with roughly 1.2 billion loblolly pine (*Pinus taeda* L.) seedlings planted annually on cutover and reclaimed lands (McKeand et al. 2003). The conversion of marginal agriculture lands in Arkansas to productive pine plantations is continuing at a rapid rate. However, the low survival rate of some recent plantings due to severe droughts in the Western Gulf Coastal Plain has prompted interest in determining whether alternative planting protocols are needed on former agriculture sites.

Many of the abandoned agricultural lands have soil properties that make reforestation challenging. Most land that is being converted tends to be lower quality—low productivity, often wet in the winter and spring, and with root-restricting layers (*i.e.*, plow pans). These layers impede root penetration, reduce drainage, and have been shown to significantly reduce loblolly pine survival and growth (Greacen and Sands 1980, Simmons and Ezell 1982).

Subsoiling (ripping) can greatly improve physical soil properties (Kelting and Allen 2000) and enhance both growth and survival of pine planted on sites with compacted soil layers (Wheeler et al. 2002). Subsoiling utilizes a tractor-mounted, vertically oriented, steel shank to break up root-restricting layers within the soil. Subsoiling further aids plantation establishment by facilitating spacing control and improving the quality of the planting by creating a deep, well-tilled area as the shank is pulled through the soil.

Numerous planting guidelines have been developed over the years for loblolly pine (e.g., Wakeley 1954, Balmer and Williston 1974, USDA Forest Service 1989, Taylor and Murphrey 2002). Appropriately, many recommendations have been modified or changed altogether as better information has become available. For example, suggested planting depth on well-drained soils was traditionally to the root collar (Wakeley 1954), but newer guidebooks have recommended planting pine seedlings 5.0 to 7.6 cm below the level grown in the nursery (USDA Forest Service 1989, Taylor and Murphrey 2002).

Some deviations from the currently accepted planting guidelines have been suggested for extremely dry sites. A major cause of mortality for newly planted seedlings is moisture stress (Dougherty and Gresham 1988). On extremely dry, excessively drained, sandy soils in the Atlantic Coastal Plain, seedlings are sometimes planted to the terminal bud to allow seedlings better access to soil moisture (Brissette and Barnett 1989).

On poorer drained soils, current recommendations state that pines should be planted only 2.54 cm below the root collar (USDA Forest Service 1989), thereby avoiding prolonged exposure to anoxic conditions. Operationally, many of these sites are bedded to improve soil aeration in the local rooting environment. However, on sites that have high clay contents and vertic soil properties (high shrink-swell capacity), planted seedlings can encounter excessively wet and dry conditions in the same year. Especially during summer months, soils with vertic properties can dry and develop large cracks, which further exacerbate moisture loss by exposing more of the soil volume to air. By contrast, soil moisture is often high and surface puddling is common during the winter months. This contrast in the rooting environment makes selecting site preparation treatments difficult.

The objectives of this study were to test the effects of planting depth and planting distance from the subsoil furrow on loblolly pine seedling growth and survival on 2 former agriculture sites. Research on deep planting for sites that are not well drained, especially when combined with intensive site preparation treatments, is limited. While deep planting can be facilitated by planting in the furrow, there is some concern that planted seedlings may wash out during heavy rains, drown if water collects in the furrows during wet periods, or suffer root exposure when seedlings are planted in unsettled furrows (Wakeley 1954), which has led some foresters to suggest planting adjacent to the furrow. When carefully implemented, subsoiling treatments can improve soil conditions at least 65 cm from the furrow (Kelting and Allen 2000). Therefore, seedlings planted adjacent to the furrow should theoretically be able to take advantage of the subsoiling treatment. If results show similar growth and survival rates regardless of planting location (*i.e.*, the subsoiling benefits extend several feet from the furrow), subsoiling can occur at wider spacing, thereby providing a cost-savings.

Materials and Methods

Two sites, both located on the University of Arkansas System Forests, were selected for study. The Hope site was located on the Southwest Research and Extension Center in Hempstead County and was formerly in pasture and row crops. The Pine Tree site was located on the Pine Tree Branch Experiment Station in St. Francis County and was formerly in row crops. At Hope, the soil was characterized as Una silty clay (Fine, mixed, active, acid, thermic Typic Epiaquepts), which is a deep, poorly drained soil with low permeability. The water table during the winter and early spring is near the surface. During dry summers, this soil develops large cracks. At Pine Tree, the soil was characterized as a Loring silt loam (Fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs), which is a moderately well-drained soil with a fragipan and is derived from loessial deposits.

In September 2005, each site was subsoiled, using a parabolic shank without wings when soils were relatively dry, to a depth of 40 cm in rows that were 3.3 m apart. Bareroot 1-0 loblolly pine seedlings from the Arkansas Forestry Commission were hand planted at each site. The 4 planting distances selected were 0, 0.3, 0.9, and 1.5 m out from the center of the subsoil furrow. The 3 planting depths were at the root collar (shallow depth), to one-half the seedling height which was about 7.6 cm below the root collar (moderate depth), and the total seedling except for the terminal bud which was about 18 cm below the root collar (deep depth). Each planting distance and depth combination was repeated 5 times per block (Fig. 1) with 9 and 12 blocks per site at Hope and Pine Tree, respectively.

Competition, which can confound or mask treatment effects, was chemically controlled using herbicides in late spring 2006 and as needed during the growing season. Seedling diameters and heights were measured prior to bud burst. First-year measurements were recorded at the end of August (Hope) and September (Pine Tree) in 2006. Rodent damage precluded the analysis of September data at the Hope site. The growth increment for height and diameter was analyzed to remove initial bias inherent with planting seedlings at different depths. Height and diameter increments were compared among treatments in a factorial arrangement using analysis of variance for each site separately. Main effects were separated by Tukey's honestly significant difference tests. Survival data were averaged by treatment for each block and transformed using an arcsin(survival $\%)^{0.5}$ transformation. All statistics were evaluated at $\alpha = 0.05$.

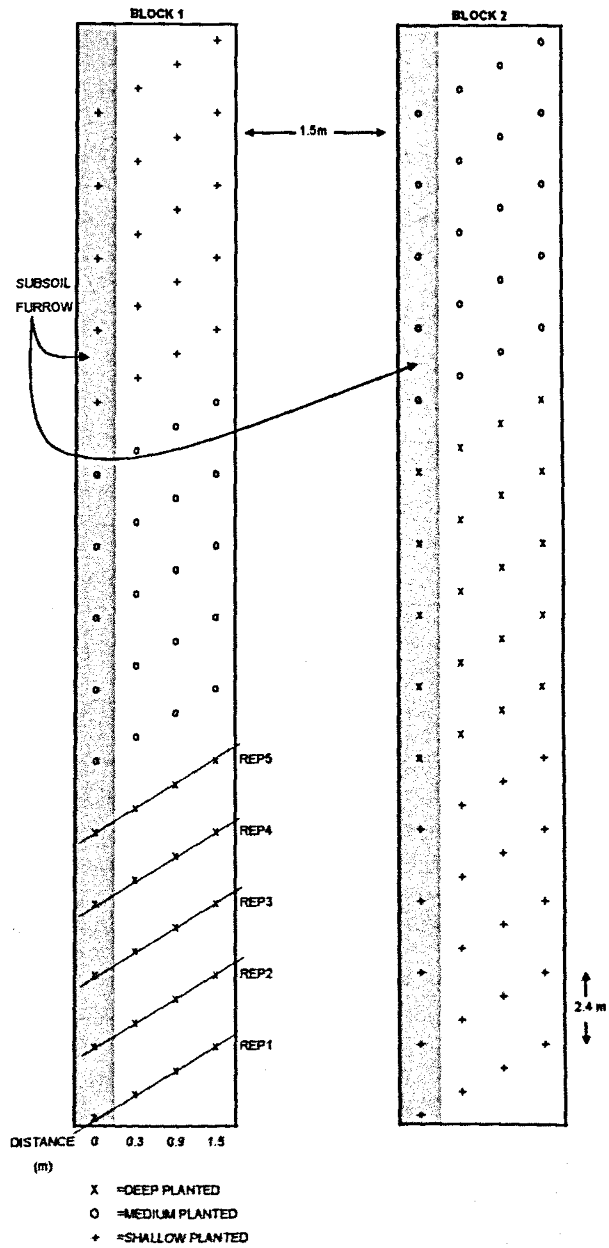

Fig. 1. Experimental layout of treatments illustrating seedling locations and planting depths.

Results

Hope Site.—Seedling survival ranged from 68 to 90 % depending on treatment combination and was strongly affected by distance from the furrow (P = 0.001). Seedlings planted in the furrow had significantly greater survival rates than those planted at 0.3, 0.9, and 1.5 m away (Table 1). Planting depth also influenced survival (P = 0.001). Deep-planted seedlings had

Table 1. The response of loblolly pine seedlings to depth of planting and distance from the subsoil furrow at the Hope site through August of the first growing season.

	Distance (m)				Planting Depth		
	0	0.3	0.9	1.5	Shallow	Mod. Deep	Deep
Height Inc. (cm)	22.9a	19.8b	17.6bc	16.1c	17.1B	18.8B	21.4A
Diameter Inc. (mm)	3.5a	3.3a	2.8b	2.6b	3.1A	2.9A	3.2A
Survival (%)	90.4a	79.8ab	68.1b	68.7b	74.4B	71.1B	84.7A

Means within a row followed by the same letter are not significantly different at $\alpha = 0.05$ using Tukey's HSD test. Lowercase and capital letter are used to distinguish between the distance and depth factors. Survival was analyzed statistically using arcsin $(\text{survival}\%)^{0.5}$ transformation, but back-calculated here for reporting purposes.

Table 2. The response of loblolly pine seedlings to depth of planting and distance from the subsoil furrow at the Pine Tree site through September of the first growing season.

	Distance (m)				Planting Depth		
	0	0.3	0.9	1.5	Shallow	Mod. Deep	Deep
Height Inc. (cm)	22.1a	19.7b	20.0b	21.1ab	17.8C	20.0B	24.7A
Diameter Inc. (mm)	4.9a	4.9a	5.0a	5.0a	5.0A	4.8A	5.0A
Survival (%)	89.7a	88.3a	91.1a	93.4a	84.0B	92.1A	96.4A

Means within a row followed by the same letter are not significantly different at $\alpha=0.05$ using Tukey's HSD test. Lowercase and capital letter are used to distinguish between the distance and depth factors. Survival was analyzed statistically using arcsin$(\text{survival}\%)^{0.5}$ transformation, but back-calculated here for reporting purposes.

greater survivability compared to seedlings planted at moderate and shallow depths (Table 1). No block x treatment interactions were noted for survival or diameter increments.

Height increment followed similar trends to that of survival. As the distance from the furrow increased, so did the height increment ($P < 0.001$). Seedlings planted in furrows grew 3 to 7 cm more than those planted outside the furrow (Table 1). Diameter increment was not sensitive to differences in planting depth, but there was a significant effect of distance ($P < 0.001$). Diameter growth for seedlings planted the 0 and 0.3 m distances was greater than that for seedlings planted at 0.9 and 1.5 m distances. However, these differences amounted to less than 1 mm among the planting distances (Table 1).

Pine Tree Site.—Seedling survival ranged from 88 to 93 % and from 84 to 96 % for distance from furrow and planting depth factors, respectively. Again, no significant block or treatment interactions affecting survival were detected. Depth of planting was the only factor that significantly influenced survival ($P < 0.001$). Seedlings planted to one-half of the stem height and to the terminal bud had about 10% greater survival through September than seedlings planted to the root collar (Table 2).

Height growth varied by planting depth ($P < 0.001$) and distance from the furrow ($P = 0.003$). Deeply planted seedlings grew 5 cm more than seedlings planted at the moderate depth, which in turn, grew only 2 cm more than seedlings planted at a shallow depth. Height increment varied by distance from the furrow, but this trend was not consistent with the results at the Hope site. Here, height increments for seedlings planted in the furrow were not statistically different from seedlings planted at 1.5 m (Table 2), although furrow planted seedlings had greater increments than 0.3 and 0.9 m planted seedlings. Another difference was the presence of block x planting depth ($P < 0.001$) and block x distance from furrow ($P = 0.041$) interactions. However, with the exception of one block, deep-planted seedlings had larger increments than those planted at shallow and moderately deep planting depths.

Diameter increments varied only slightly, from 4.8 to 5.0 mm and from 4.9 to 5.0 mm for planting depth and distance from the furrow, respectively. None of these differences or their interactions was significant (Table 2).

Discussion

One of the most important components of any forestation activity is planting. Current planting protocols suggest planting pine seedlings 5 to 7.6 cm below the root collar (FS 1989, Taylor and Murphrey 2002). Even in the 1950s, information was available that suggested deeper planting on well-drained soils produced as good or better results than planting to the same level as the seedlings were grown in the nursery (Wakeley 1954). This study critically examined this recommendation on 2 sites with root-restricting layers on soils that are not well drained and are frequently saturated during winter months.

Planting depth in this study significantly affected both growth and survival of loblolly pine seedlings during the first growing season. At both sites, deep-planted seedlings had increased survival and height growth compared to shallow- and moderately deep-planted seedlings. Most important was that survival of deep-planted seedlings was at least 10% greater than that of shallow-planted seedlings. The growth and survival of planted seedlings is highly dependent on moisture availability. Since new seedlings are very susceptible to moisture stress (Dougherty and Gresham 1988), improved growth and survival of deep-planted seedlings was likely facilitated by their root systems having better access to soil moisture lower in the soil profile, especially during summer droughts. On intensively prepared sites, herbicide treatments generally reduce the vegetation that shades the soil, while tillage treatments often displace the organic matter that mulches the soil surface leading to additional drying of the upper surface soil. These treatments may predispose more shallowly planted seedlings to drought stress.

One of the challenges to the widespread acceptance of deep planting is the loss of planting productivity. Intuitively, it takes longer to plant a seedling to the terminal bud compared to 2-3 inches. However, in conjunction with subsoiling treatments, deep planting does not appear to greatly reduce planting times (personal observation). Deep planting of seedlings in the furrow was facilitated by the roughly 50 cm of loose soil created by subsoiling. In addition, planting outside the furrow generally reduced growth and survival during the first growing season. Many concerns about planting directly in the furrow (e.g., seedling mortality due to poor aeration) seem unfounded (Tables 1 and 2). In fact, many seedlings at the Hope site were planted in standing water within the furrows without any apparent negative consequences.

Conclusions

This study provides evidence contrary to most guidelines for planting southern pine on subsoiled sites. One can reasonably conclude that deeper planting is better than shallower planting for loblolly pine seedlings. Planting in the furrow, at least at these sites, is the logical location. Seedlings planted in the furrow survived as well as or better than seedlings planted in the other locations, and they have the added benefit of being easier to plant. The only concern not addressed thus far is the effect of prolonged water saturated conditions. This study took place during a relatively dry spring and summer. It is possible that late-season flooding may disproportionately harm the seedlings planted deeper and in the furrow.

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