ELEVEN-YEAR LOBLOLLY PINE GROWTH IN RESPONSE TO SITE PREPARATION AND SEEDLING TYPE IN NORTH LOUISIANA

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Abstract—On a well-drained site in northwest Louisiana, effects of seedling type (container, bareroot) and herbicide site preparation (hexazinone, hexazinone + sulfometuron, imazapyr + metsulfuron) on loblolly pine growth and survival have been tested for 11 years. All possible combinations of these treatments were applied to loblolly pine planted at 302 trees acre^{-1}, and these treatments were compared to a special control treatment planted at a spacing of 605 trees acre^{-1} to test tree density effects on yields. Results indicate container seedlings may be preferable to bareroot seedlings as planting stock for a well-drained site, and herbicide site preparation mixtures that provide broad-spectrum control are most effective in producing long-term growth benefits. Further research will be necessary to ascertain the effects of planting density on yields and product classes, but results thus far suggest container seedlings planted at a wide spacing are a viable management option for this type of site.

INTRODUCTION

Well-drained soils are among the most problematic soils on which to establish and profitably manage loblolly pine (*Pinus taeda* L.) plantations in the Western Gulf region. Such soils are associated with relatively poor loblolly pine survival and growth due to inadequate moisture and nutrient supply and retention (Pritchett and Fisher 1987). Management practices that promote the allocation of moisture and nutrients to crop trees can increase the feasibility of managing loblolly pine plantations on such sites.

Inter-specific competition for moisture and nutrients from herbaceous and woody vegetation can be effectively suppressed with herbicides (Cain and Barnett 2002, Dixon and Clay 2004, Zutter and others 1999), particularly when using herbicide combinations that provide broad-spectrum control of understory vegetation (Yeiser and others 2004). Intra-specific competition for moisture and nutrients can be reduced on adverse sites early in the rotation by planting at lower densities (Schultz 1997). However, it is common for forest managers to plant at relatively high densities on inferior sites due to perceived survival problems. This tendency to plant “extra” trees to compensate for initial seedling mortality can negatively impact revenue over the course of the rotation by raising planting costs and reducing average diameter growth, resulting in fewer trees in the more valuable product classes (Dean and Chang 2002).

With their relatively higher root densities, container seedlings are superior to bareroot seedlings in their ability to gather moisture and nutrients immediately after planting. Consequently, early-rotation survival and growth is often significantly greater for container seedlings than for bareroot seedlings (Haywood and Barnett 1994, McDonald 1991). The survival and growth advantages of container seedlings are most pronounced on drought-prone sites (Barnett and Brissette 1986, South and Barnett 1986). However, container seedlings are as much as twice the cost of bareroot seedlings.

A combination of inter- and intra-specific competition control and seedling type selection may yield the best means by which loblolly pine plantations can be established and profitably managed on droughty soils. However, there is a relative lack of long-term studies on how these silvicultural treatments act in concert on such sites. The objective of this study was to observe the survival and growth of loblolly pine in response to seedling type, a variety of herbicide site preparation treatments, and planting density on a well-drained soil in northern Louisiana.

METHODS

In 1993, a loblolly pine plantation was planted at the Louisiana State University AgCenter Hill Farm Research Station in northwest Louisiana (32° 44’N, 93° 03’ W) on a gravelly, fine sandy loam Darley-Sacul soil (an association of a fine, kaolinitic, thermic Hapludult and a fine, mixed, active, thermic Aquic Hapludult). This well-drained soil type is common in upland forests of northwestern Louisiana, southwestern Arkansas, and eastern Texas (USDA SCS 1989). Drought conditions are common in the region because late summer precipitation is typically substantially below potential evapotranspiration during the same period (fig. 1).

The effects of seedling type were tested by comparing growth and survival of container seedlings to that of bareroot seedlings. All container and bareroot seedlings were of the same loblolly pine family; the family was selected due to its good growth potential on well-drained soils. The effects of the herbicide formulation and timing used for chemical site preparation on loblolly pine growth and survival were assessed with four treatments listed in table 1. Herbicides were band-applied around seedlings on a 6-foot-wide swath using backpack sprayers. Seedlings receiving all possible combinations of these seedling type/herbicide treatments were planted on a 6 foot x 24 foot spacing (302 trees acre^{-1}). This seedling density is nearly half that conventionally planted on similar sites.

A special control (CONV) treatment was also established to compare the effects of the seedling type × herbicide treatments on widely spaced loblolly pine survival and growth to

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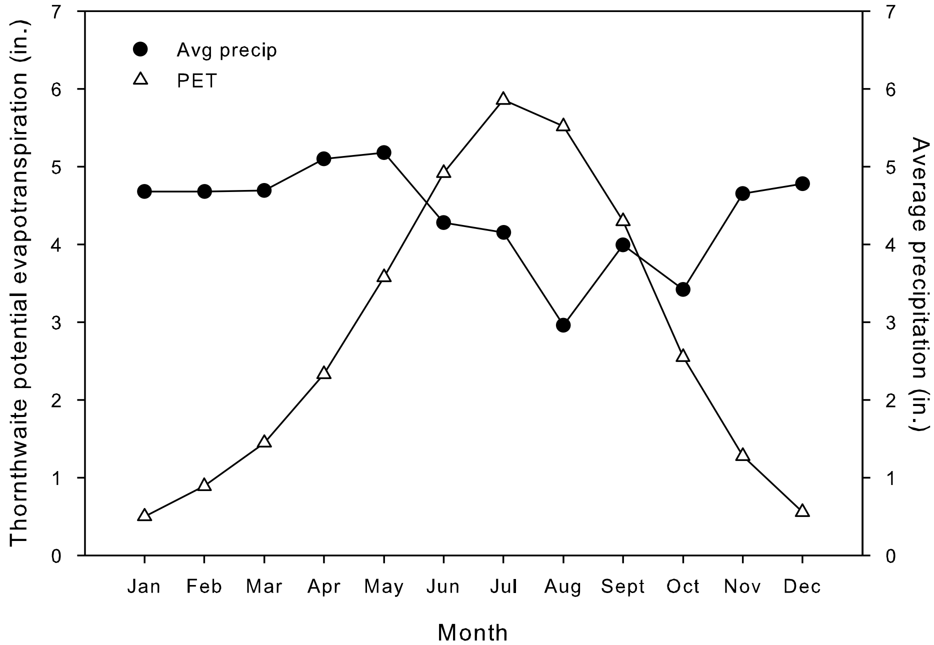

Figure 1—Average annual precipitation (Avg precip) and potential evapotranspiration (PET) for Claiborne Parish, LA.

Table 1—Herbicide treatments applied to a loblolly pine plantation on a well-drained soil in north Louisiana

Treatment	Herbicides	Application rate	Application date
		lb acre^{-1}	
LOHEX	Hexazinone	1.50	Spring pre-plant
HIHEX	Hexazinone	4.00	Summer post-plant
HEXSULF	Hexazinone,	1.50	Spring pre-plant
	Sulfometuron methyl	0.13	Summer post-plant
IMAZMET[a]	Imazapyr,	0.75	Summer post-plant
	Metsulfuron methyl	0.04	Summer post-plant

[a] Imazapyr and metsulfuron methyl were tank-mixed.

that associated with a more conventional combination of seedling type, herbicide, and planting spacing. The CONV treatment consisted of bareroot seedlings planted on a 6 foot x 12 foot spacing (605 trees acre^{-1}) with a pre-plant application of 1.5 pounds hexazinone acre^{-1} and post-plant application of 1 ounce sulfometuron methyl acre^{-1} used for site preparation. This study design was thus comprised of a 2 x 4 treatment structure plus a control arranged in a randomized complete block design, with slope as a blocking factor. All seedling type x herbicide treatment combinations and the control treatment were replicated three times and applied to 0.10-acre plots.

In 1994, survival of seedlings after the first growing season was measured. In 2003, survival, height, and d.b.h. of all trees were measured. The height and d.b.h. measurements were used to estimate total outside-bark tree volume using the model developed by Van Deusen and others (1981).

Analyses of the seedling type x herbicide treatments applied to the widely spaced trees were conducted by analysis of variance (ANOVA) using the MIXED procedure of the SAS System (SAS Institute, Inc., Cary, NC). Because no significant seedling type x herbicide interactions were found, when an ANOVA indicated significant ($P < 0.05$) treatment effects, treatment means were calculated and separated by the DIFF option of the LSMEANS procedure. The DIFF option provided multiple comparisons of treatment means by invoking t-tests to determine significant differences between all possible treatment combinations. CONTRAST statements were used to evaluate treatment differences between the seedling type × herbicide treatments applied to the widely spaced trees and the CONV treatment.

RESULTS AND DISCUSSION

Barnett and McGilvray (1993) found that survival differences between container and bareroot loblolly pine seedlings were most pronounced under stressful environmental conditions in the first growing season. In our study, survival of loblolly pines of container origin also significantly exceeded that of the bareroot seedlings planted at both wide and conventional spacings in 1994 and 2003 (table 2). These findings suggest a long-term survival advantage to planting container seedlings on edaphically and/or environmentally adverse sites. Haywood and Barnett (1994) similarly found greater survival through age 15 of loblolly pine of container origin relative to that of bareroot origin on a silt loam soil in central Louisiana. However, the magnitude of difference between the survival of container and bareroot trees at our site was nearly three times that observed in that study, which suggests a greater advantage to planting container seedlings on well-drained sites.

Among trees planted at the wide spacing, there were no significant differences in survival attributable to the herbicide treatments in either 1994 or 2003 (table 3). However, survival associated with the CONV treatment was significantly lower than that of the HEXSULF treatment in 1994 and 2003. Furthermore, survival of the CONV treatment was moderately ($0.05 < P < 0.10$) lower than that of the LOHEX, HIHEX, and IMAZMET treatments in 2003. Short-term survival and growth benefits of hexazinone and sulfometuron methyl mixtures have been well-documented (Miller and others 1994, Zutter and others 1987), and such mixtures have consequently become an industry standard (Muir and Zutter 1999, Yeiser and others 2004).

Individual-tree volume of the container trees in 2003 was significantly greater than that of bareroot seedlings planted at the wide and conventional spacings (table 2). This finding contrasts with that of Haywood and Barnett (1994), in which volume per tree was comparable between 15-year-old container and bareroot trees on a silt loam soil. The lack of difference in volume per tree among the bareroot seedlings planted at the conventional and low densities may indicate that intraspecific competition for site resources has not begun by age 11 even at the higher stand density.

Among the trees planted at the wide spacing, the HEXSULF and IMAZMET herbicide treatments produced the highest volumes per tree (table 3), which underscores the growth advantages conferred by broad-spectrum chemical site preparation on this well-drained site. The LOHEX treatment produced the lowest volumes per tree; the hexazinone rate of the LOHEX treatment was well below the optimum rate for hexazinone applied alone (Yeiser and others 2004) and likely did not adequately suppress understory vegetation. The HEXSULF treatment consisted of a hexazinone rate and timing identical to that of the LOHEX treatment, and its significantly greater volume per tree may indicate that the suite of

Table 2—Effects of a conventional planting practice relative to bareroot and container seedlings planted at low density on loblolly pine survival and growth on a well-drained site in north Louisiana[a]

Seedling type[b]	1994 survival	2003 survival	Tree volume	Stand volume	Stand BA[c]
	%	*%*	*ft^3*	*$ft^3\ ac^{-1}$*	*$ft^2\ ac^{-1}$*
CONV	84b	66b	1.76b	808.4a	84.3a
BARE	85b	73b	1.69b	368.5c	38.7c
CONT	95a	89a	2.12a	565.2b	55.2b

[a] Means within columns followed by different letters differ significantly at $P < 0.05$.
[b] CONV = conventional planting practice (bareroot seedlings planted at 605 trees per acre); BARE = bareroot seedlings planted at 302 trees per acre; CONT = container seedlings planted at 302 trees per acre.
[c] BA = basal area.

Table 3—Effects of a conventional planting practice relative to diverse chemical site preparation treatments applied to a low-density loblolly pine plantation on loblolly pine survival and growth on a well-drained site in north Louisiana[a]

Seedling type[b]	1994 survival	2003 survival	Tree volume	Stand volume	Stand BA[c]
	%	*%*	*ft^3*	*$ft^3\ ac^{-1}$*	*$ft^2\ ac^{-1}$*
CONV	84 b	66 b	1.76 b	808.4 a	84.3 a
LOHEX	89 ab	77 ab	1.68 c	407.7 c	42.3 c
HIHEX	88 ab	77 ab	1.88 b	447.4 c	44.9 c
HEXSULF	92 a	83 a	2.08 a	528.7 b	50.9 b
IMAZMET	87 ab	77 ab	1.97 ab	483.6 bc	47.7 bc

[a] Means within columns followed by different letters differ significantly at $P < 0.05$.
[b] CONV = conventional planting practice (605 seedlings planted per acre, pre-plant application of 1.5 pounds hexazinone, post-plant application of 0.13 pound sulfometuron acre-1); LOHEX = 302 seedlings planted per acre, pre-plant application of 1.5 pounds hexazinone per acre; HIHEX = 302 seedling planted per acre, post-plant application of 4.0 pounds hexazinone per acre; HEXSULF = 302 seedlings planted per acre, pre-plant application of 1.5 pounds hexazinone per acre, post-plant application of 0.13 pound sulfometuron per acre; IMAZMET = 302 seedlings planted per acre, post-plant application of 0.75 pound imazapyr + 0.04 pound metsulfuron per acre.
[c] BA = basal area.

vegetation controlled by sulfometuron on this site was a substantial competitor for site resources. Volume per tree associated with the CONV treatment was significantly lower than that of the HEXSULF treatment.

When compared to all seedling type x herbicide treatments, the CONV treatment had the highest stand volume and basal area due to its higher tree density (tables 2 and 3). Between the seedling types planted at the wider spacing, the container trees had significantly higher stand volume due to higher survival and individual-tree volumes. Among the herbicide treatments applied to widely spaced trees, the LOHEX treatment produced stand volumes significantly lower than that of all other treatments. Stand density may influence the product class of logs cut in intermediate harvests (Dean and Chang 2002). Stand basal area is currently much higher in plots receiving the CONV treatment, so thinning likely must occur sooner in those plots to stave off competition-induced mortality. Given the lower volumes per tree, it is likely that most material harvested in the first thinning will be in the relatively low-value pulpwood product class. As a result of the lower stand basal area and relatively high volumes per tree currently observed in the container treatments, thinning will likely occur later and more logs harvested in the first thinning may be of the higher-value chip-n-saw product class. Such a phenomenon would markedly increase the rate of return associated with planting container seedlings at 302 trees acre^{-1} at this site. However, the larger crowns and branch diameters commonly associated trees planted at the wider spacing may be detrimental to product quality as well (Huang and others 2005), but the wider spacing would facilitate traffic of equipment used for pruning. Due to the low stand basal area and volumes per tree currently observed in the plots planted with bareroot seedlings at 302 trees acre^{-1}, there will likely be less material harvested in the first thinning relative to the container plots. If so, the return rates for planting bareroot material at wide spacing may be lower than that of planting container seedlings at the same spacing.

CONCLUSIONS

On this well-drained site, planting container seedlings dramatically increased pine growth relative to planting bareroot seedlings. The long-term survival and growth benefits of container seedlings highlight the importance of planting seedlings with a good ability to gather moisture and nutrients on an adverse site. As such, planting container seedlings may be preferable to planting bareroot seedlings on a well-drained site.

Using herbicide mixtures that provided broad-spectrum control also produced lasting survival and growth benefits on this site, which underscores the value of reallocating moisture and nutrients to crop trees with herbicides on such sites. The hexazinone + sulfometuron and imazapyr + metsulfuron mixtures used in this study have become an industry standard for site preparation since this study's establishment. In fact, pre-mixed granular blends of hexazinone and sulfometuron (which produced the best survival and tree growth in this study) are now available.

The effects of planting density on the productivity and profitability of managing a pine plantation on this site are less clear at this stage of the study, but a more thorough exploration of product quality issues will be pursued as this study progresses.

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