Effects of Lift Date, Storage, and Family on Early Survival and Root Growth Potential of Shortleaf Pine[1]

S. W. Hallgren and C. G. Tauer [2]

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Abstract.--High survival and RGP can be expected for seedlings planted from December through February even when a severe spring drought occurs. Seedling performance is only slightly reduced by storage, is positively related to number of primary lateral roots, negatively related to presence of secondary needles, and not related to the presence of a terminal bud.

INTRODUCTION

Shortleaf pine (Pinus echinata Mill.) is the most widespread of the southern pines. It is an important timber species, and is widely planted by the U.S. Forest Service and private industry. Current nursery practices and regeneration techniques that work well for loblolly pine are apparently inappropriate for shortleaf pine which shows very poor survival in plantations in the Ozark and Ouachita Mountains. Contributing to these poor results is the lack of specific information about artificial regeneration of shortleaf pine (Barnett et al. 1986).

Previous research has led to the recommendation that southern pine seedling quality be assessed by grading seedlings for planting. Results vary somewhat, but in general best performance can be expected from seedlings that are large and have an appropriate root/shoot ratio, that have a woody stem, secondary needles and a terminal bud (Wakely 1954, Phares et al. 1960, Grigsby 1975, Barnett 1984, Barnett et al. 1985). Shortleaf pine seedlings grown in southwest Arkansas showed high field survival when lifted and planted immediately during December through February. Only seedlings lifted in December retained high survival rates after cold storage for 30 days (Venator 1985).

The capacity of a seedling to rapidly produce new roots when transplanted into the field is critical for survival and growth. A frequently used measure of this capacity is root growth potential (RGP) which is considered a valuable tool for assessing seedling quality (Ritchie and Dunlap 1980). RGP can be measured by growing seedlings in a controlled environment for 4 weeks and counting the number of new roots greater than 1 cm long. Factors known to affect RGP are genotype, nursery environment, lifting dates, and storage (Ritchie and Dunlap 1980, Jenkinson and Nelson 1978, Carlson 1985), but very little is known about RGP in shortleaf pine.

This study was undertaken to develop improved techniques for artificial regeneration of shortleaf pine. Since there is considerable interest in managing seedlings by family we decided to evaluate the genetic variability in effects of lift date and storage on survival and growth. In order to better understand treatment response, seedlings were also measured for size, number of primary lateral roots, root growth potential and presence of secondary needles and a terminal bud.

MATERIALS AND METHODS

Shortleaf pine seedlings of 12 open-pollinated families from Oklahoma and Arkansas were grown for one season under operational procedures at the Weyerhauser Company Nursery at Fort Towson, Oklahoma. Seedlings were grown in 3 replicates in a randomized complete block design. They were operationally undercut at a depth of 15 cm in November 1986.

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[2]S. W. Hallgren is Assistant Professor and C. G. Tauer is Professor of Forestry at Oklahoma State University, Stillwater.

Starting December 1, 1986, one fifth of the seedlings in each replicate were hand-lifted every 28 days for 5 lifts until March 23, 1987 (Table i).

Table 1.--Schedule of Lift and Plant Activities

Lift	Not Stored	Plant Stored
Dec. 1	Dec. 2	Dec. 30
Dec. 29	Dec. 30	Jan. 27
Jan. 26	Jan. 27	Feb. 24
Feb. 23	Feb. 24	Mar. 24
Mar. 23	Mar. 24	Apr. 21

Following each lift seedlings were graded according to operational standards and divided into two equal groups, one for immediate testing and one to be stored for 28 days and then tested. Each group was divided a second time, 80 seedlings per family going to the field planting and 24 to the RGP test. The integrity of nursery replicates was maintained throughout the study.

The field test was planted at the Kiamichi Forest Research Station near Idabel, Oklahoma. Seedlings were planted one day after lifting or upon removal from 28 days of storage. The experimental design was a 12 x 5 x 2 (family x lift date x storage) factorial with 10 replicates laid out in randomized complete block design. Each treatment combination was represented by an 8-tree row plot in each replicate. A total of 9600 trees were planted at a spacing of 0.5 m and the entire experiment was surrounded by a border row of similar shortleaf pine seedlings. Immediately after the last planting, all the seedlings were measured for survival, diameter and height.

Weeds were controlled by herbicides and manual methods. No irrigation was applied. Temperature and precipitation were monitored at a weather station on the center. Early survival was counted on June 22, 1987. The experiment will be monitored for survival and growth for two years.

Seedlings for the RGP test were kept in cold storage until the test began 3 days after lifting or the end of the cold storage treatment. Prior to commencement of the RGP test seedlings were measured for height, diameter, number of primary lateral roots, root volume and presence of secondary needles and a terminal bud.

Three seedlings of a family were planted into 1 1 milk carton pots filled with a 1:1 peat-vermiculite mixture (on the first test date, 2 1 cartons were used). The pots were arranged in a randomized complete block design with 8 replicates. The test was conducted in a controlled environment chamber set for a 16 hour photoperiod and a 25° C day/15° C night. After 28 days the seedlings were removed from the chamber and placed in cold storage until the roots could be washed and the new root tips longer than 1 cm counted. RGP measurement was complete within 2 to 3 days.

The data were subjected to analysis of variance to determine the significance of family, lift date and storage on RGP and seedling survival. Phenotypic correlations between survival and the various seedling traits were calculated.

RESULTS AND DISCUSSION

Lift date, storage and family all showed a significant effect ($P < 0.05$) on survival and RGP of shortleaf pine (Table 2).

Table 2.--Analysis of Variance Results

		Probability > F	
Source	DF	Survival	RGP
Date (D)	4	<0.0001	<0.0001
Storage (S)	1	<0.0001	0.0465
Family (F)	11	<0.0001	<0.0001
D x S	4	<0.0001	<0.0001
D x F	44	0.2765	<0.0001
S x F	11	0.77.04	0.4405
D x S x F	44	0.0323	0.2512
Error	1071/833		

A significant interaction of lift date with storage suggested that seedling performance after storage is dependent in part on lifting date. The lack of an interaction between family and lift date and family and storage treatment for survival indicates that in general the families respond in a similar manner to lift date and storage. However, a significant three-way interaction between lift date, family and storage treatment suggests the survival response is complex. In general, the families showed a dissimilar RGP response to different lift dates but a similar RGP response to storage treatment.

These results correspond well with previous work in pines that has shown lift date to affect survival and RGP (Jenkinson 1975, Jenkinson and Nelson 1978). Lift date is also known to determine the response of seedlings to storage (Stone and Jenkinson 1971, Venator 1985). The pattern of changes in RGP and survival with time of lift as well as the magnitude of RGP at a given date have been shown to be under strong genetic control (Jenkinson 1975, Nambiar 1982, Carlson 1985 and 1986).

Overall, survival was high, over 90 percent, for seedlings planted from early December to late February whether they were stored or not (Figure 1). Survival fell after February and the late March planting showed survival of 80 and 85 percent for freshly lifted and stored seedlings. Only stored seedlings were planted in late April and survival was poor, less than 50 percent.

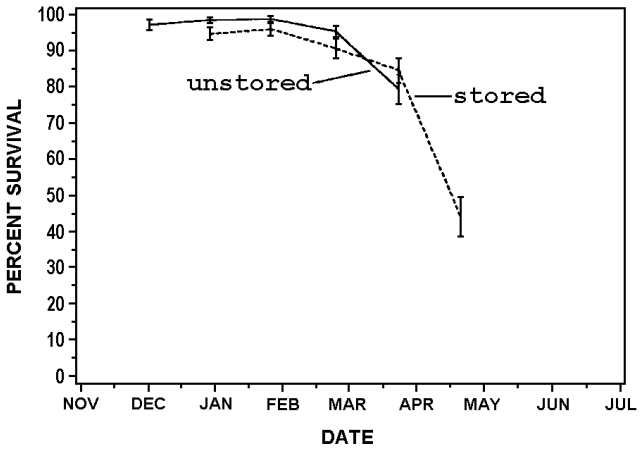

Figure 1. Effect of lift date and storage on June 22 survival of shortleaf pine seedlings by planting date. Points represent values averaged across 12 families and bars represent plus and minus the standard error of the mean.

The late season drop in survival can be at least partially explained by the weather at the planting site. Temperatures were mild and precipitation adequate from November 1986 through March 1987. The weekly maximum temperatures never exceeded 30oC and monthly rainfall ranged from 45 mm in December to 164 mm in March. April and early May were much hotter and drier with weekly maximum temperatures constantly above 33°C and rainfall of only 9 mm from March 30 until May 15. Temperatures remained high and precipitation returned to higher levels for the last 2 weeks of May (154 mm) and the first 3 weeks of June (40 mm).

Survival for a specific planting date was generally reduced only 5 percent by storage (Figure 1). Seedlings lifted on a given date showed a reduction in survival due to storage of only 2 percent in December, 8 to 10 percent in January and February and 36 percent in March. The March lifted seedlings planted in April showed poor survival partly due to the spring drought.

RGP followed a seasonal pattern somewhat similar to that for survival, showing high values of 80 to 110 new roots for seedlings lifted in December, stored and unstored, and in January, unstored (Figure 2). RGP fell to 50 to 75 new roots for stored seedlings lifted in January and all seedlings lifted after January whether stored or unstored. The stored seedlings tested in April showed a higher RGP than seedlings tested in March and yet they showed much lower survival in

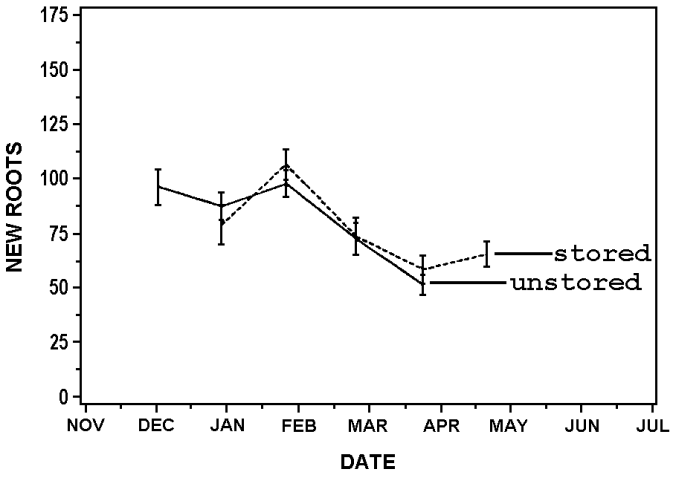

Figure 2. Effect of lift date and storage on root growth potential of shortleaf pine seedlings by date tested. Points represent values averaged across 12 families and bars represent plus and minus the standard error of the mean.

the field. Apparently the higher RGP did not prevent severe mortality for seedlings planted in the middle of the spring drought. It is worth noting that in general RGP declined for seedlings lifted in February and lat6r at the same time that risk of mortality from drought and high temperature was increasing. The effects of storage on RGP were generally small and inconsistent from one lift date to the next.

Comparison of survival across all dates for families showing the highest (Family 5) and lowest (Family 6) survival reveals small differences for unstored

seedlings, usually less than 10 percent, and much larger differences for stored seedlings, usually 20 percent or greater (Figure 3). These families showed similar seasonal changes in survival and maintained their respective ranks regardless of storage treatment.

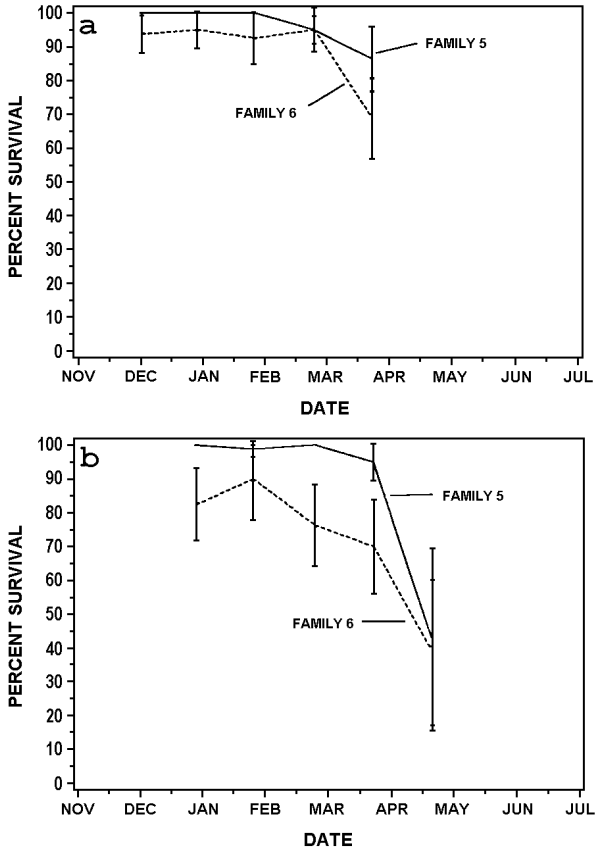

Figure 3. Effect of lift date and storage on June 22 survival of shortleaf pine families showing the highest (Family 5) and lowest (Family 6) overall survival. Data are plotted by date planted for unstored (a) and stored (b) seedlings. Bars represent plus and minus the standard error of the mean.

RGP showed a good relationship to field survival, as high survival for Family 5 was associated with high RGP and low survival of Family 6 was associated with low RGP across all dates regardless of storage treatment (Figure 4). Unstored seedlings showed a peak RGP in early December for Family 5 and late January for Family 6. Stored seedlings showed a peak RGP for both families in late January.

Survival was significantly correlated to RGP and number of primary lateral roots

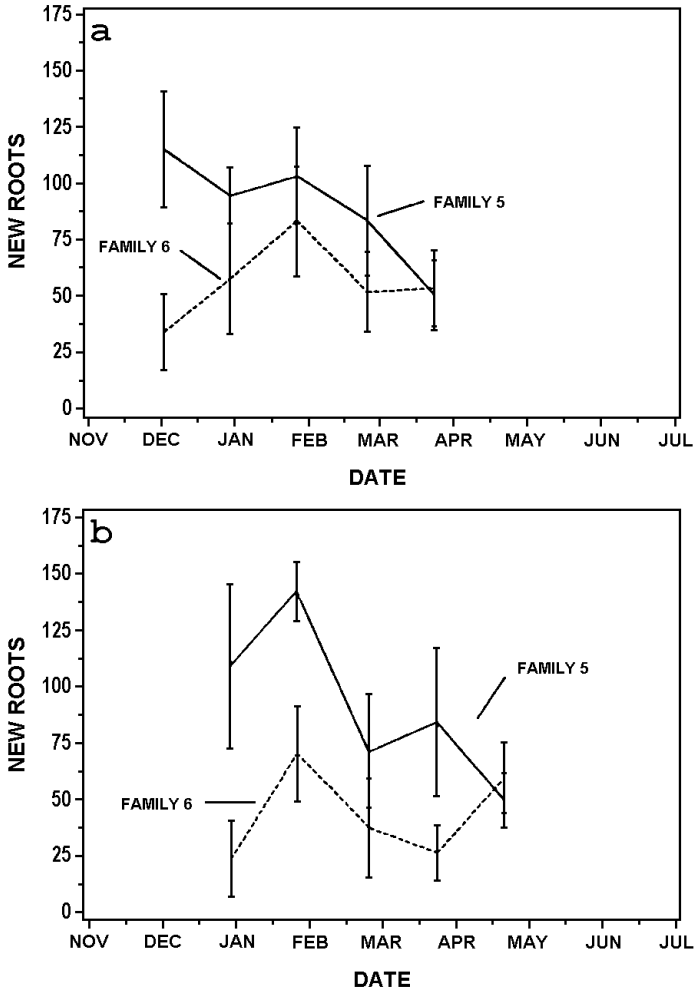

Figure 4. Effect of lift date and storage on root growth potential of shortleaf pine families showing highest (Family 5) and lowest (Family 6) overall survival. Data are plotted by date tested for unstored (a) and stored (b) seedlings. Bars represent plus and minus the standard error of the mean.

(Table 3). Previous research has often shown a close relationship between RGP and survival (Ritchie and Dunlap 1980, Nambiar et al. 1982, Larsen et al. 1986). Other root characteristics such as root weight and shoot/root ratio may be correlated with survival (Larsen et al. 1986), and the importance of primary laterals in development of RGP has been noted (Nambiar et al. 1982). The current study clearly shows the close relation between number of primary laterals and survival. In fact, it was a better predictor of survival than RGP. Number of primary laterals is easier to measure than RGP and should be given consideration as a measure of seedling quality.

Survival showed no correlation with root volume, diameter and height (Table 3). We observed that root volume appeared to be largely determined by the tap root size which was reflected in seedling diameter, hence the close relation between

Table 3.--Phenotypic Correlations for Survival and Various Seedling Traits

	RGP	ROOT	ROOT VOL.	DIA	HGT	BUD	SECONDARY NEEDLES
SURVIVAL	.657*	.709*	.109	-.173	-.093	-.263	-.661*
RGP		.900**	.527	.216	.126	-.268	-.299
ROOT			.624*	.290	.223	-.140	-.278
ROOT VOL.				.842**	.327	.353	.384
DIA.					.614*	.600*	.620*
HEIGHT						.384	.246
BUD							.707**

* Significant at 5% level
**Significant at 1% level

root volume and diameter. Apparently, the number of primary lateral roots is more important in determining survival than tap root size.

Surprising was the fact that survival was not related to the presence of a bud and was negatively related to the presence of secondary needles. The presence of both a terminal bud and secondary needles has been suggested as important to seedling quality (Wakely 1954, Barnett et al. 1986). The data from this study indicates that this recommendation should be reevaluated, at least for shortleaf pine. Very little attention has been paid to this species and it appears that regeneration techniques developed for other southern pines are not well suited to it.

RGP was, not surprisingly, strongly correlated to number of primary lateral roots. This again reinforces the suggestion that number of primary laterals be considered as a measure of seedling quality. RGP was not related to any of the other seedling traits.

CONCLUSIONS

Early results show survival is high for seedlings lifted from early December through the end of February and planted without storage. Seedlings lifted in December and January can be stored for 28 days with only a slight reduction in survival. Seedlings planted in March and April are subject to greater mortality. High RGP and number of primary lateral roots are associated with high survival. The presence of a terminal bud shows no relation to survival, and the presence of secondary needles appears to be negatively related to survival. Family differences in performance indicate a significant opportunity to improve regeneration techniques through management of seedlings by family.

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