AN EVALUATION OF SEEDLING QUALITY AT GEORGE 0. WHITE STATE FOREST NURSERY

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Introduction

Seedling quality has been the subject of foresters' attention even before 1928 when morphological grading systems were established (Wakeley 1948). In the past, morphological systems, those based on seedling shape and size, adequately distinguished seedlings with a greater capacity for survival and growth after outplanting (Clark and Phares 1961; Pawsey 1972; Mullin and Christl 1981). Since the sharp increase in planting in the 1930's, however, the relationship between morphologically-based prediction and actual field performance dissolved (Wakeley 1948). This prompted researchers to investigate whether a judgement of quality based on seedling morphology is invalidated by physiological changes that occur during seedling processing.

One objective of this study was to determine the effect of exposure during seedling processing on subsequent survival and growth. A second objective was to evaluate the ability of a morphological grading system based on root size to distinguish differences in seedling quality.

Materials and Methods

The study was conducted at the George 0. White State Forest Nursery at Licking, Missouri (Texas County; 91° 54' West longitude, 37° 33' North latitude; elevation 360 meters). Shortleaf pine (*Pinus echinata* L.) seedlings (1-0) were lifted December 17, 1986, February 4 and April 8, 1987. Following lifting, the seedlings were subjected to a short-exposure period (6 minutes), a long-exposure period (14 minutes) or no exposure period (0 minutes) in the seedbed. After lifting, all seedlings were processed according to normal handling procedures.

To evaluate the effects of seedling processing and the capacity of a morphological grading system based on root size to predict outplanting performance, the seedlings were grown in pots for one season. Before planting, a high or low rootgrade was assigned to each seedling. High rootgrade seedlings had 9 primary lateral roots greater than 4.2 cm in length and 0.58 mm in diameter whereas low rootgrade seedlings had 5 roots.

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Seedlings were planted between April 25 and May 7, 1987 and grown until July 14 under irrigated conditions in a shadehouse at the Ashland Wildlife Area in central Missouri (southeastern portion of Boone County; 92° 12' West longitude, 38° 48' North latitude). The pots were 30.48 cm tall X 25.40 cm in diameter and filled with a silty clay loam soil. A randomized complete block design with four replications and three seedlings per replication per treatment was used. Beginning July 15, half of the seedlings in each treatment were droughted. The remaining seedlings were watered as a control treatment. Water was withheld from the droughted seedlings until September 16. All seedlings were harvested the week beginning October 4, 1987. Survival before and after the drought was recorded. Weights of roots and shoots were measured after drying for 48 hours at 77°C. Also, height and diameter increment for the growing season and the number of first-order lateral roots (of the size used to establish rootgrades) present at the end of the season were recorded.

Statistical Analysis

Categorical Modeling Analysis (Log-linear Model) was used to analyze for treatment differences with regard to survival before or after the drought (SAS Institute 1985). Analysis of Variance was used to determine whether experiment-wise treatment differences existed for growth and dry weight parameters taken after seedling harvest. The Least Significant Difference test was used to evaluate differences among individual treatment means (SAS Institute 1985). In the following text, means that are different at the p=0.05 and p=0.01 level are referred to as significant and highly significant differences, respectively.

Results

Survival after the period of growth under irrigated conditions was 93 percent. Mortality among December-lifted seedlings (14) was significantly greater than that observed for the February (5) or April (1) lifting dates. Mortality between February-and April-lifted seedlings, however, was not significantly different. There were also no significant differences in mortality between high (5) and low (15) rootgrade seedlings or between seedlings exposed for a short (8) or long (12) period after lifting.

Growth Increment After One Growing Season

Effect of Lifting Date Neither height nor diameter increment of shortleaf pine from three lifting dates was significantly different after one growing season (Table 1). The number of lateral roots present at the end of the season was the only growth variable to exhibit a significant difference among lifting dates. Shortleaf pine seedlings lifted in December and February had a similar number of roots, whereas April-lifted seedlings had significantly fewer lateral roots at the end of one growing season.

TABLE 1
HEIGHT AND DIAMETER INCREMENTS AND NUMBER OF ROOTS FOR SHORTLEAF PINE FROM THREE LIFTING DATES

	Growth Parameter		
Lifting Date	Height (cm)	Diameter (mm)	Roots (#)
December 1986	11.21 a[1]	1.83 a	6.40 a
February 1987	11.75 a	1.87 a	6.93 a
April 1987	9.62 a	1.58 a	5.42 b

[1] Means within a column followed by a different letter are significantly different at p=0.05.

Effect of Rootqrade High root-grade seedlings did not perform better than low rootgrade seedlings with regard to height or diameter increments, or the number of roots present at harvest (Table 2).

Effect of Watering Regime As expected, the watering regime resulted in significant differences in the amount of growth realized between May and October (Table 2). Shortleaf pine seedlings that were watered regularly exhibited 29 and 120 percent greater height and diameter increments, respectively, and 58 percent more first-order lateral roots than did the droughted seedlings.

Effect of Exposure Period Neither height increment nor the number of roots was significantly different between short- and long-exposure seedlings after one growing season (Table 2). In contrast, diameter growth of short-exposure seedlings was significantly greater than that of seedlings exposed for the long period, and this difference was observed only in the well-watered seedlings (Table 3). Mean diameter growth of droughted seedlings exposed for the long period was not significantly different from that of short-exposure seedlings.

TABLE 2
SHORTLEAF PINE HEIGHT AND DIAMETER INCREMENTS AND NUMBER OF ROOTS WITHIN TWO ROOTGRADES, WATERING REGIMES AND EXPOSURE PERIODS

Treatment	Height (cm)	Diameter (mm)	Roots (#)
Rootgrade			
Low	11.01 a[1]	1.83 a	6.05 a
High	10.71 a	1.70 a	6.46 a
Watering Regime			
Watered	12.25 a	2.42 a	7.67 a
Droughted	9.47 b	1.10 b	4.84 b
Exposure			
Short	11.67 a	1.99 a	6.35 a
Long	10.05 a	1.54 b	6.16 a

[1]Means within a treatment class are not significantly different (p=0.05) for the specified growth measurement when followed by the same letter.

TABLE 3
EFFECT OF EXPOSURE PERIOD ON DIAMETER INCREMENT (mm) OF SHORTLEAF PINE WITHIN TWO WATERING REGIMES

Exposure Period	Watering Regime: Watered	Watering Regime: Droughted
	diameter increment (mm)	
Short	2.90 a[1]	1.08 a
Long	1.94 b	1.13 a

[1]Means within a watering treatment are not significantly different at p=0.05 when followed by the same letter.

Dry Weight and Root-to-Shoot Ratio

Effect of Lifting Date Root dry weights of shortleaf pine lifted in December and February were not significantly different, nor were root dry weights of February- and April-lifted seedlings also were not significantly different (Table 4). Shoot dry weight was lowest for seedlings lifted in April, although not significantly different from that of December-lifted seedlings.

The reduction in dry weights for April-lifted seedlings did not occur in both watering treatments, however. A highly significant interaction between the effects of lifting date and watering regime resulted in significantly lower root and shoot dry weights only for April-lifted seedlings within the well-watered treatment (Table 5).

Root-to-shoot ratio was not significantly different between December- and April-lifted shortleaf pine, but root-to-shoot ratio of February-lifted seedlings was lower than those for the other two lifting dates (Table 4).

TABLE 4
DRY WEIGHT (g) AND ROOT-TO-SHOOT RATIO
OF SHORTLEAF PINE FROM THREE LIFTING DATES

Plant Tissue	Lifting Date: December	February	April
	(g)		
Root	1.59 a[1]	1.58 ab	1.22 b
Shoot	3.89 ab	4.44 a	2.96 b
		(g dry weight)	
Root-to-Shoot Ratio	0.45 a	0.37 b	0.44 a

'Means within a row are significantly different (p=0.05) when followed by a different letter.

TABLE 5
ROOT & SHOOT DRY WEIGHTS (g)
OF WELL-WATERED SHORTLEAF PINE
FROM THREE LIFTING DATES

Plant Tissue	Lifting Date December	February	April
	Dry Weight (g)		
Root	2.18 a[1]	2.33 a	1.43 b
Shoot	5.16 a	6.33 a	3.64 b

[1]Means within a row are not significantly different (p=0.05) when followed by the same letter.

Effect of Rootgrade The effect of rootgrade on root and shoot dry weights, and root-to-shoot ratio, was not significant (Table 6). There was, however, a significant interaction between rootgrade and watering regime which resulted in significantly greater root dry weight for high rootgrade seedlings when watered throughout the growing season (Table 7).

Rootgrade and exposure period also interacted significantly such that high rootgrade seedlings had a significantly greater root dry weight and shoot dry weight if exposed for a short period during lifting (Table 8). The difference in dry weights between rootgrades within the long-exposure treatment was not significant.

Effect of Watering Regime As expected, root and shoot dry weights of shortleaf pine were significantly lower for droughted seedlings (Table 6). Despite this difference, root-to-shoot ratio was unaffected by the drought treatment.

Effect of Exposure Period A long-exposure period during lifting resulted in significantly reduced root and shoot dry weights (Table 6). The adverse effects of a long exposure period, however, only occurred in high rootgrade (Table 8) or well-watered seedlings (Table 9).

Root-to-shoot ratio was unaffected by the exposure treatment (Table 5). Ratios of short- and long-exposure seedlings were 0.41 and 0.43, respectively.

TABLE 6
DRY WEIGHT (g) AND ROOT-TO-SHOOT RATIO
OF SHORTLEAF PINE WITHIN TWO ROOTGRADES,
WATERING REGIMES AND EXPOSURE PERIODS

	Plant Tissue		
Treatment	Root	Shoot	Root: Shoot
	Dry weight (g)		
Rootgrade			
Low	1.37	3.55	0.43
High	1.56	3.98	0.41
Watering Regime			
Watered	1.98	5.04	0.43
Droughted	0.94 *	2.49 *	0.41
Exposure			
Short	1.63	4.28	0.41
Long	1.30 *	3.25 *	0.43

[1]Means within a treatment class are significantly different (p=0.05) for the specific plant tissue when marked by an asterisk (*).

TABLE 7
ROOT DRY WEIGHT OF WELL-WATERED
SHORTLEAF PINE FROM TWO ROOTGRADES

Rootgrade	Root Dry Weight (g)
Low	1.74
High	2.23 *

'Means within a watering regime are significantly different (p=0.05) when marked with an asterisk (*).

TABLE 8
ROOT & SHOOT DRY WEIGHTS OF SHORTLEAF PINE
FROM TWO ROOTGRADES AND EXPOSURE PERIODS

Exposure Period	Rootgrade Low	Rootgrade High
	Root Dry Weight (g)	
Short	1.40[a]	1.87[b]
Long	1.35[a]	1.25[a] *
	Shoot Dry Weight (g)	
Short	3.67[a]	4.89[b]
Long	3.43[a]	3.07[a] *

[1]Means within a rootgrade are significantly (p=0.05) different for the specific plant tissue when marked with an asterisk (*). Means within an exposure period are significantly (p=0.05) different for the specific plant tissue when followed by a different letter.

TABLE 9
ROOT & SHOOT DRY WEIGHTS OF WELL-WATERED
SHORTLEAF PINE FROM TWO EXPOSURE PERIODS

Exposure Period	Plant Tissue Root	Plant Tissue Shoot
	Dry Weight (g)	
Short	2.31	5.97
Long	1.66 *	4.11*

[1]Means within a column are significantly (p=0.05) different when marked with an asterisk (*).

Discussion

It is often unknown whether low rates of survival and growth after outplanting are attributable to damage incurred by seedlings at the nursery or during and after shipping. In the present study, a 14-minute exposure period during lifting did not significantly reduce survival, height increment or the number of roots present at the end of the growing season. In contrast, the long-exposure period proved to be critical for diameter increment and dry weight growth of well-watered or high rootgrade seedlings. High rootgrade seedlings were probably more sensitive to exposure duration because they were significantly larger than low rootgrade seedlings and, hence, probably had greater rates of transpiration, respiration and greater levels of water stress.

Seedling quality was also affected by lifting date. Seedlings lifted in December were stored the longest (18 weeks) and had the greatest pre-drought mortality. This may be associated with the level of starch reserves available when seedlings were planted since root starch reserves, determined with an I_2KI stain, decreased with longer periods of storage (Smith 1989). Survival of Jeffrey pine (Pinus ieffreyi Grey. and Balf) seedlings also has been shown to be directly related to the level of starch reserves remaining after cold storage (Hellmers 1962).

Lifting in April also diminished seedling quality because these seedlings had fewer roots and lower tissue dry weights. This detrimental effect may result from lifting at a time not within the "lifting window" for shortleaf pine seedlings. When seedlings are lifted after the last date of the lifting window, new root growth that is lost during lifting may not be replaced because after outplanting rapid shoot development is a stronger sink for carbohydrates (Krugman and Stone 1966; Ritchie and Dunlap 1980). This may explain the low rate of root initiation and elongation observed by Stone and Schubert (1959) for ponderosa pine (P. ponderosa Dougl. ex Laws) seedlings lifted in April.

Another problem with lifting too late is that the negative effects of exposure to harsh conditions, whether they be exposure during lifting or cold storage, may be greatest when seedlings are in a post-dormant stage of rest (Lavender 1964; Kramer and Kozlowski 1979; Coutts 1981). Other conifers have shown decreased survival and growth with less than 10 minutes exposure during lifting in March (Hermann 1967; Feret et al. 1985), or 5 minutes exposure in April (Cummings 1942) or May (Hermann 1962).

The rootgrading system, contrary to predictions, was not a strong indicator of seedling quality. High rootgrade seedlings did not have superior survival, height or diameter increment, or a greater number of roots at the end of the season. These seedlings, however, had greater dry weight if exposure during lifting was brief or soil moisture stress during the growing season was low. As mentioned earlier, high rootgrade seedlings were significantly larger than low rootgrade seedlings and this may have predisposed them to greater water stress during lifting and droughting. Other investigators also have found that seedling quality differences were nullified by stressful conditions after outplanting (Daniels 1978; Ritchie and Stevens 1979).

Conclusions

It is apparent that if high rootgrade seedlings are to attain superior growth, exposure during lifting should not exceed 6 minutes. This, however is impractical in many situations. Therefore, accomodations should be made to spray seedlings during lifting or as soon as possible, thereafter.

In addition, shortleaf pine seedlings should not be lifted as early as mid-December if they are not scheduled for shipment until April. Seedlings also should be lifted before April to avoid exposure to stressful conditions at a time when seedlings are not physiologically dormant and, hence, less resistant to injury.

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