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M. Victor Bilan
Stephen F. Austin State University

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M. Victor Bilan^{2/}

Abstract.--Loblolly pine seedlings were lifted from a nursery bed in two-week intervals (November 4-April 21) and were immediately planted in an open field. Each planting included seedlings planted at the root collar (A), one-half of shoot buried (B) and most of the shoot buried except for the one-inch terminal (C). Average mortality during the first year was 10%, 13% and 16% for the A, B and C planting depths, respectively; the corresponding values for the second year mortality were 2%, 3% and 5%. Average first year mortality by the planting periods ranged 7% - 24% with the highest values for April plantings. Deep (C) planting produced most height growth during the first growing season and least during the second and third growing seasons.

INTRODUCTION

This study was initiated in 1958, during the period of intensified interest in survival of outplanted southern pine seedlings and in the successful establishment of pine plantations. Review of then available literature (Ferguson and Stephenson, 1955) concluded that some attempts have been made to rationalize the results in view of weather conditions and morphological development of planting stock. Slocum (1951) and Slocum and Maki (1956) reported that deep planting had some positive effect on growth of loblolly pine seedlings, but no literature was available dealing with the season of planting.

Preliminary experiments conducted by the author revealed that in East Texas roots of the pine seedlings were actively growing in the winter, so he had concluded that early planting would enable seedlings to develop sufficient root systems before the occurrence of the late spring and summer droughts. It was, however, necessary to determine the time in the autumn when seedlings in a nursery were "hardened" enough to be transplanted in a field without sustaining high mortality. It was also postulated that, other factors being equal, pine seedlings with well-developed deep-reaching root systems have a much better chance of surviving prolonged drought than the seedlings with superficial shallow root systems. This study was designed to plant seedlings in two-week intervals from November till April by using three different depths of plantings.

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^{2/} Professor of Forestry, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas 75962.

EXPERIMENTAL PROCEDURES

The study was established on a Woden sandy loam soil of old field in Nacogdoches County, Texas. The field was plowed and disked six weeks before the establishment of the experiment and then it was subdivided into three blocks, each 164 feet by 108 feet. Each block consisted of 41 rows, each 108 feet long and four feet apart. Two edge rows served as isolation strips, while the remaining 39 rows represented randomly assigned 13 different dates of planting at the three different depths. The plantings were made in two-week intervals beginning November 4, 1958 and ending April 21, 1959. Each row in a block contained 27 seedlings spaced four feet apart and planted on the same date and at the same depth. Two edge seedlings were considered as isolation.

The depths of planting were as follows: (A) root collar at the ground level, (B) one-half of the shoot buried, (C) most of the shoot buried except for the upper one-inch of terminal. Standard planting bar was used for regular (A) planting, while 18-inch bar was used for B and C planting depths. All roots were trimmed to the length of seven inches.

Statistically, this study consisted of 13 planting dates and three depths of planting, each represented by three replications of 25 seedlings. All data were analyzed by two-way analysis of variance.

RESULTS

Mortality

Periodic survey of experimental planting revealed that by March 19, 1959, attrition due gophers and weather damage was 6 percent, 4 percent and 2 percent in A, B and C planting depths, respectively (Table 1). Mortality was

particularly very high in November 18 planting, amounting to 22 percent in A and 16 percent in B depth of planting. It is important to notice that this planting was made just two days before the first freeze of the season. The loss due to inclement weather was four times as high as was the loss due to the obvious damage by gophers.

Average annual mortality for 1959 amounted to 10 percent, 13 percent and 16 percent in the planting depths A, B, and C, respectively (Table 2). Both April plantings suffered very high mortality in all depths of planting, averaging 19 percent, 21 percent and 33 percent in A, B and C, respectively. The highest mortality in A (25%) and B (27%) depths of planting occurred in planting made on November 18, while the highest mortality in C (36%) depth of planting occurred in April 21 planting.

Average mortality during 1960 growing season was 2 percent in A, 3 percent in B and 5 percent in C depth of planting, and no particular pattern was noticed in respect to the season of planting.

Seasonal Height Growth

Average seasonal height growth in 1959 was significantly different for each depth of planting, amounting to 9 inches in A, 11 inches in B and 13 inches in C planting (Table 3). Seedlings planted on November 4 grew most, while those planted in March and April grew least, regardless of the depth of planting.

In 1960 and 1961, average height growth of A and B plantings was significantly higher than that of C plantings (Table 4), but in 1962 growth was identical in all depths of planting. Height growth of all April plantings continued to lag behind all others through 1960 and 1961 growing seasons.

Total Height

Average height of all A plantings was greater than was the height of either B or C plantings from 1959 through 1962 (Table 5 and Table 6), while average height of all C plantings was significantly smaller than that of average B plantings. Average height superiority of November 4 planting was maintained in A plantings 1959 through 1961 and in B plantings 1959 through 1960. During four years of study, average height of trees planted in March and April was shorter than the height of trees planted in November-February in all depths of planting.

DISCUSSION

Deep planting by burying shoot to one inch terminal reduced survival during the first two years and resulted in less height growth during the second and third year. The increased height growth during the first year did not compensate for less growth during the second and third year. Burying one-half of the shoot reduced survival and

increased height growth during the first year only. Deep planted trees were shorter than the conventionally planted trees during four following years.

Slocum (1951) and Slocum and Maki (1956) reported that deep planting on well-drained clay did not effect survival and it increased height growth of loblolly pine seedlings through the second growing season, but the authors warned that similar results might not be expected elsewhere. Deep planting reduced survival of loblolly pine on droughty sandy loam (Ursic 1963) and poorly drained silt and clay soils (Switzer 1960) in Mississippi as well as on sandy loams in East Texas (Koshi, 1960).

The highest mortality in this study occurred in the seedlings lifted and planted before the first freeze in the fall or after broken shoot dormancy in April. It seems that high mortality in November 18 planting was caused by the first cold spell of the season, while root disturbance of the seedlings during the onset of shoot elongation was responsible for high mortality in the April plantings. Low temperature as the cause of high mortality in November 18 planting is supported by the fact that mortality was relatively low in the C depth of planting where only tips of the shoots were exposed to freezing atmosphere.

Poor survival of loblolly pine seedlings lifted prior to dormancy was reported by Venator and Barnett (1984), and Brissette and Roberts (1984) found less root regeneration potential in seedlings lifted in November. Bilan and Ferguson (1985) reported that all seedlings survived when they were lifted and outplanted in a field in two-week intervals December 1 through March 2.

Reduction of height growth in all March and April plantings during the first growing season resulted probably from the interruption of spring shoot elongation. Poor survival of loblolly pine seedlings lifted and planted during late spring was reported by Dierauf (1978) and Venator (1985). The author (Bilan and Ferguson 1985) found that loblolly pine seedlings lifted and planted in March grew less in height by early May than did seedlings lifted and planted December 1 - January 12.

The author concludes that loblolly pine seedlings have their highest survival and early growth potential when they are lifted and outplanted during their dormancy, but the actual survival and growth in the field may be to a great degree affected by the climatic conditions following outplanting.

Table 1. Average Attrition of Seedlings Due to Gophers and Weather by Time and Depth of Planting by March 19, 1959.

DATE PLANTED	Planting Depth A			Planting Depth B			Planting Depth C		
	GOPHER	DEAD	TOTAL	GOPHER	DEAD	TOTAL	GOPHER	DEAD	TOTAL
	P E R C E N T								
NOV. 4	1.3	11.7	13.0	1.3	3.9	5.2	1.3	1.3	2.6
18	3.9	18.2	22.1	2.6	13.0	15.6	1.3	0	1.3
DEC. 2	3.9	6.5	10.4	1.3	2.6	3.9	1.3	0	1.3
16	1.3	1.3	2.6	1.3	0	1.3	2.6	2.6	5.2
30	1.3	3.9	5.2	1.3	2.6	3.9	1.3	1.3	2.6
JAN. 13	0	1.3	1.3	0	1.3	1.3	0	0	0
27	0	1.3	1.3	0	0	0	1.3	0	1.3
FEB. 10	0	1.3	1.3	0	0	0	1.3	0	1.3
14	0	0	0	0	0	0	0	0	0
AVERAGE	1.3	5.1	6.4	0.9	2.6	3.5	1.2	0.6	1.8

Table 2. Average Annual Mortality of Loblolly Pine Seedlings by Time and Depth of Planting During 1959 and 1960.

DATE PLANTED	Planting Depth			Planting Depth			
	A	B	C	A	B	C	
	1959						1960
	P E R C E N T						
NOV. 4	7.4c ^{1/}	16.0b	12.3b	2.5	2.5	5.0	
18	24.7a	27.2a	9.9b	0	3.7	2.5	
DEC. 2	9.9bc	4.9c	9.9b	0	1.3	5.0	
16	6.2c	4.9c	14.8b	0	4.9	2.5	
30	7.4c	13.6bc	17.3b	2.5	0	7.4	
JAN. 13	2.5c	9.9c	14.8b	3.7	3.7	2.5	
27	4.9c	4.9c	9.9b	1.3	1.3	2.5	
FEB. 10	4.9c	7.4c	7.4b	6.2	7.4	8.6	
24	11.1bc	8.6c	9.9b	1.3	2.5	7.4	
MAR. 10	2.6c	21.0ab	18.5b	3.7	7.4	3.7	
24	7.4c	11.1c	13.6b	1.3	3.7	0	
APR. 7	21.0ab	22.2ab	30.9a	0	0	11.1	
21	17.3ab	19.8ab	35.8a	2.5	2.5	3.7	
AVERAGE FOR PLANTING DEPTH	10.3a ^{2/}	13.2b	15.8c	1.9a	3.2ab	4.8b	

^{1/} Values in individual columns for year 1959 followed by the same letters are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

^{2/} Average values for planting depth for 1959 and 1960 followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

Table 3. Average Annual Height Growth of Loblolly Pine Seedlings by Time and Depth of Planting for 1959 and 1960.

DATE PLANTED	Planting Depth			Planting Depth			
	A	B	C	A	B	C	
		1959				1960	
		I N C H E S					
NOV. 4	14.4 a ^{1/}	16.8a	16.7a	31.6a	31.0a	28.8a	
18	9.8b	12.3b	14.4a	28.4a	30.3a	29.4a	
DEC. 2	10.7b	12.1b	14.5a	30.8a	29.6a	29.1a	
16	10.6b	12.8b	14.5a	29.8a	30.4a	28.4a	
30	9.1b	12.2b	13.8b	29.8a	31.4a	29.7a	
JAN. 13	12.3a	14.1b	15.3a	30.6a	32.1a	29.6a	
27	10.2b	12.5b	15.2a	29.9a	30.5a	30.1a	
FEB. 10	10.5b	13.1b	13.2b	32.8a	30.5a	29.9a	
24	7.9bc	11.7b	10.6c	29.2a	27.6b	28.1a	
MAR. 10	5.5c	7.9c	10.3c	28.0a	24.7b	27.1a	
24	6.7c	8.3c	10.2c	29.2a	29.7a	28.8a	
APR. 7	4.7c	7.6c	9.0c	26.3b	26.3b	23.8b	
21	6.4c	6.9c	8.7c	25.2b	25.3b	25.9b	
AVERAGE FOR PLANTING DEPTH	9.1c ^{2/}	11.4b	12.8a	29.3a	29.2a	28.1b	

1/ Values in individual columns followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

2/ Average values for planting depth within years filler by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

Table 4. Average Annual Height Growth of Loblolly Pine Seedlings By Time and Depth of Planting for 1961 and 1963.

DATE PLANTED	Planting Depth			Planting Depth			
	A	B	C	A	B	C	
		1961				1962	
		I N C H E S					
NOV. 4	50.0a ^{1/}	49.9a	46.5a	48.5a	49.0a	52.0a	
18	45.8a	49.4a	46.8a	50.5a	51.3a	47.2ab	
DEC. 2	47.0a	46.9a	48.3a	49.6a	51.9a	50.4ab	
16	45.8a	47.1a	47.1a	48.4a	51.0a	51.0a	
30	46.4a	46.6a	47.3a	50.7a	53.2a	51.1a	
JAN. 13	48.0a	50.4a	44.8b	49.6a	50.8a	46.7b	
27	49.8a	47.0a	49.2a	50.9a	51.1a	50.6ab	
FEB. 10	46.9a	48.0a	45.5a	50.6a	52.5a	52.1a	
24	46.2ab	49.2a	43.1c	50.1a	51.2a	48.7ab	
MAR. 10	44.7b	40.8b	43.9b	49.8a	47.7a	49.2ab	
24	47.7a	47.6a	43.5c	50.7a	49.2a	50.1ab	
APR. 7	43.5b	43.5b	42.0c	47.6a	46.5b	47.8ab	
21	43.9b	43.4b	39.9c	50.3a	45.9b	46.9b	
AVERAGE FOR PLANTING DEPTH	46.6a ^{2/}	46.7a	45.2b	49.9a	50.1a	49.5a	

1/ Values in individual columns followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

2/ Average values for planting depth within years followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

Table 5. Mean total height of loblolly pine seedlings by time and depth of planting in 1959 and 1960.

DATE PLANTED	Planting Depth 1959			Planting Depth 1960		
	A	B	C	A	B	C
	-	-	I N C H E S	-	-	-
NOV. 4	24.4a	21.8a	17.7a	56.0a	52.8a	46.5a
18	19.8b	17.3b	15.4a	48.2b	47.6b	44.8a
DEC. 2	20.7b	17.1b	15.5a	51.5b	46.7b	44.6a
16	20.6b	17.8b	15.5a	50.4b	48.2b	43.9a
30	19.4b	17.2b	14.8a	49.2b	48.6b	44.5a
JAN. 13	22.3ab	19.1b	16.3a	52.9b	51.2b	46.4a
27	20.2b	17.5b	16.2a	50.1b	48.0b	46.3a
FEB. 10	20.5b	18.1b	14.2a	53.3b	48.6b	44.1a
24	17.9bc	16.7b	11.6c	47.1bc	44.3bc	39.7b
MAR. 10	15.5c	12.9c	11.3b	43.5c	37.6c	38.4b
24	16.7c	13.3c	11.2b	45.9c	43.0bc	40.0b
APR. 7	14.7c	12.6c	10.0b	41.0c	38.9c	33.8b
21	16.4c	11.9c	9.7b	41.6c	37.2c	35.6b
AVERAGE BY PLANTING DEPTH	19.2 ^{2/} a	16.4b	13.8c	48.5a	45.6b	42.2c

1/ Values in individual columns followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

2/ Average values for planting depth within years followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

Table 6. Mean Total Height of Loblolly Pine Seedlings by Time and Depth of Planting in 1961 and 1962.

DATE PLANTED	Planting Depth			Planting Depth		
	A	B	C	A	B	C
	-	-	I N C H E S	-	-	-
NOV. 4	106.0a	99.7a	93.0a	154.5a	148.7a	145.0a
18	94.0b	97.0a	91.6a	144.5b	148.3a	138.8ab
DEC. 2	98.5b	93.6a	92.9a	148.1b	145.5a	143.3a
16	96.2b	95.3a	91.0a	144.6b	146.3a	142.0a
30	95.6b	95.2a	91.8a	146.3b	148.4a	142.9a
JAN. 13	100.9b	101.6a	91.2a	150.5a	152.4a	137.9ab
27	99.9b	95.0a	95.5a	150.8a	146.1a	146.1a
FEB. 10	100.2b	96.6a	89.6a	150.8a	149.1a	141.7a
24	93.3bc	93.5a	82.8b	143.4b	144.7a	131.5b
MAR. 10	88.2c	78.4c	82.3b	138.0c	125.1b	131.5b
24	93.6bc	90.6b	83.5b	144.3b	139.8b	133.6b
APR. 7	84.5c	82.4c	75.8c	132.1c	128.9b	123.6c
21	85.5c	80.6c	75.5c	135.8c	126.5b	122.4c
AVERAGE FOR PLANTING DEPTH	95.1 ^{2/} a	92.3b	87.4c	144.9a	142.3b	137.0c

1/ Values in individual columns followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

2/ Average values for planting depth within years followed by the same letter are not statistically different at the 95 percent confidence level by Duncan's multiple range test.

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