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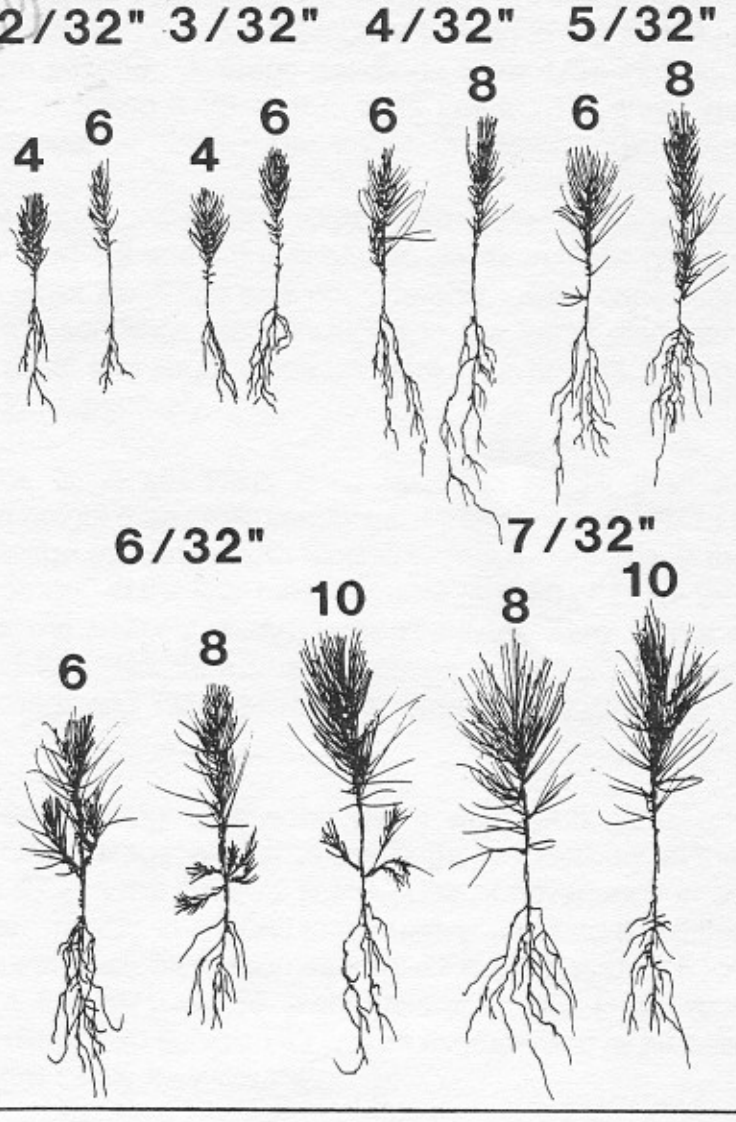

Virginia Department of Forestry

LOBLOLLY PINE SEEDLING GRADE--EFFECT ON SURVIVAL AND GROWTH THROUGH 20 YEARS

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ABSTRACT

Survival and growth through approximately 20 years were compared for seedlings of small, average, and large initial root collar diameter. The same study was installed in 1969-70 and 1971-72, with field plots established on eight different tracts in each year. Small diameter seedlings included both 2 and 3/32-inch seedlings in the first study, and only 3/32-inch seedlings in the second. Average seedlings were 4/32 inch and large seedlings were a combination of 5 and 6/32 inch in both years. The three diameter classes were planted on three different dates: December 15, March 15, and April 15.

In both years, large seedlings survived only slightly better than average seedlings: differences after two seasons were 1.2 and 1.8 percentage points in 1969-70 and 1971-72, respectively. Survival of small seedlings was considerably lower, especially in the 1969-70 study, when 2/32 inch seedlings were included in the small diameter class. Survival differences between small and large seedlings were 18.8 and 11.0 percentage points in 1969-70 and 1971-72, respectively.

For the first few years, large seedlings grew faster in height than average seedlings, which grew faster in height than small seedlings. Differences stabilized by age 5, and after that small and average seedlings both tended to make up some of the early height advantage of large seedlings. At the final measurement (age 20 or 21 for the 1969-70 study and age 18 or 19 for the 1971-72 study), large seedlings were .1 foot shorter than average seedlings and 1.1 foot taller than small seedlings in the 1969-70 study, and .4 feet taller than average seedlings and 1.0 foot taller than small seedlings in the 1971-72 study.

At the final measurement, average pulpwood yields were 24.0, 33.0, and 33.8 standard cords per acre for small, average, and large seedlings, respectively, in the 1969-70 study; and 20.7, 25.5, and 27.2 in the 1971-72 study. Use of covariance analysis to adjust final volume yields for differences in second year survival reduced the differences between diameter classes. Average adjusted volumes were 27.6, 31.5, and 31.6 for 1969-70, and 22.1, 25.0, and 26.4 for 1971-72, for small, average, and large seedlings, respectively. Even if small seedlings had survived as well as average and large seedlings, they would have produced significantly less volume.

INTRODUCTION

This paper reports the results of two seedling grade studies planted during the 1969-70 and 1971-72 planting seasons. Results of two earlier seedling grade studies, planted in 1966 and 1967, were reported in Occasional Report No. 40. The 1966 and 1967 studies involved seedlings of different root collar diameters and top lengths, with and without terminal buds, which were planted in March, usually the safest time to plant seedlings in Virginia. In the two studies reported here, seedlings of small, average, and large root collar diameters were planted in December, March, and April.

LIFTING THE SEEDLINGS

1969-70 Study

Eight field plots were installed, four each in the Piedmont and Coastal Plain (Figure 1). The seedlings for each field plot came from a different seedbed at our New Kent nursery. Eight of the nine seedbeds of a single 600-foot section were used. For the December planting, three samples, each 6 inches wide across the seedbed, were lifted at random distances within each seedbed. For the March and April plantings, 6-inch samples were lifted on either side of the initial 6-inch samples. The seedlings to be planted in April were lifted in March and placed in cold storage for a month.

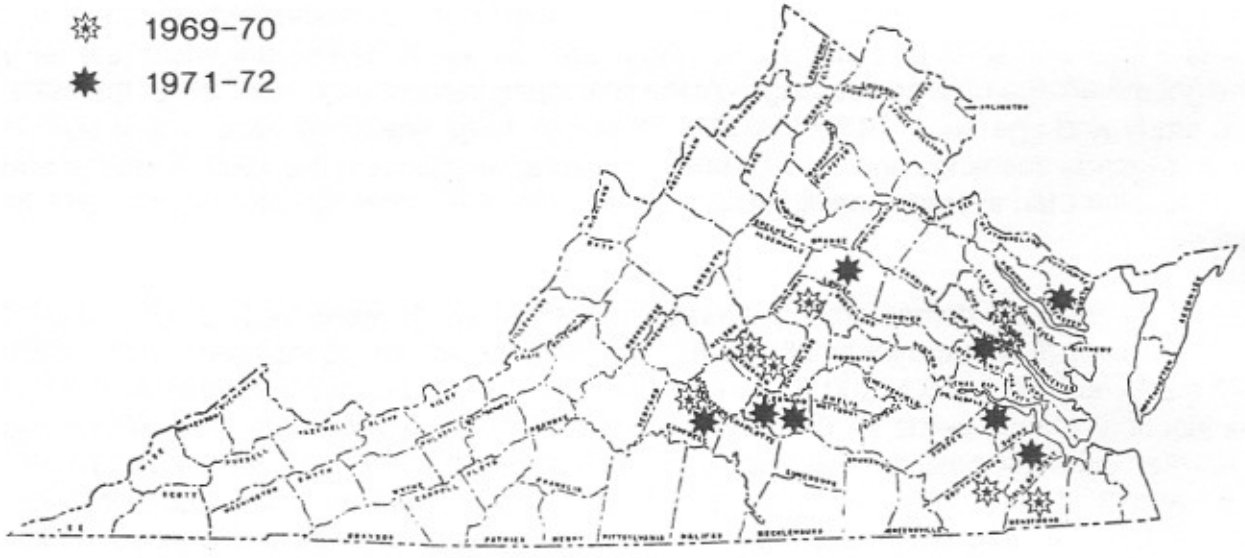

Figure 1. Location of field plots.

All seedlings in each 6-inch sample were separated into three root-collar diameter classes:

1. 2/32 and 3/32 inch
2. 4/32 inch
3. 5/32 and 6/32 inch

The very few seedlings smaller than 1.5 or greater than 6.5/32 inch were not used. From each 6-inch sample, 20 seedlings were randomly selected from each of the three diameter classes for 20 seedling rows in the field. Thus, each row in the field came from a different 6-inch sample in the seedbed. Top length was sampled by measuring every fifth seedling in each 20-seedling row package. Therefore, a total of 12 seedlings were measured for top length in each of the 9 field treatments (3 diameter classes x 3 planting dates). The same 12 seedlings were classified as to having set a terminal bud or not. In some cases, usually for the large seedlings, seedlings had set a terminal bud and later resumed growth; such seedlings were still tallied as having set terminal buds.

1971-72 Study

This study also involved eight field plots, four each in the Piedmont and Coastal Plain (Figure 1). Seedlings for this study came from two adjacent seedbeds about 400 feet long. Two locations were selected in each seedbed, and all seedlings came from these four locations. One location was picked to represent short, stocky seedlings, two to represent seedlings that were about average, and one to represent tall, spindly seedlings. Seedlings for a pair of field plots, one Coastal Plain and one Piedmont, were selected from each seedbed location. In contrast, the field plots in the 1969-70 study were not paired, and each came from a different seedbed. For the December planting, two samples were lifted at each of the four locations. Each sample was 18 inches wide across the seedbed. For the March and April plantings, four additional 18-inch wide samples were lifted from the same four seedbed locations. Each individual sample was evaluated separately and carried through to one field plot installation.

All seedlings in each sample were measured and separated into three root collar diameter classes:

1. 3/32 inch
2. 4/32 inch
3. 5/32 and 6/32 inch

The very few seedlings smaller than 2.5 or greater than 6.5/32 inch were not used. Every third seedling was measured for top length and classified as to having set a terminal bud or not. Enough seedlings were randomly taken from each of the three size classes for three 20-seedling rows. In this study, all three rows of each treatment (seedling size x

planting date) came from a single seedbed location, whereas in the 1969-70 study, the three rows of each treatment came from three different seedbed locations.

Extra seedlings not needed for field planting were cut at the root collar and weighed to calculate shoot to root ratios. Seedlings were weighed fresh, not oven-dried. For the December lifting, diameter classes were not kept separate, but for the March lifting, at which time seedlings were also lifted for April, seedlings were weighed separately by root-collar diameter class.

SEEDLING CHARACTERISTICS

Seedbed densities were very high, higher than for the nursery as a whole, averaging 52 seedlings per square foot in both years. These high densities resulted in many small diameter seedlings. Table 1 shows the percent of seedlings in each diameter class for both years. The average diameter in both years was 4/32 inch. Table 2 shows the average top length and average percent of seedlings that set buds, by diameter class. Table 3 shows bed density, top length, percent of seedlings that set buds, and shoot/root ratios for the seedlings used to establish each field plot in each year.

Table 1. Percent of seedlings by diameter class for the 72 and 24 samples lifted in 1969-70 and 1971-72, respectively.

Diameter Class	1969-70	1971-72
<1.5/32	.3	1.5
2/32	29.5	11.3
3/32		23.2
4/32	46.5	29.6
5&6/32	22.5	30.3
>6.5/32	1.1	4.1

Table 2. Average top length (inches) and percent of seedlings that set buds, by root collar diameter class, for the 72 and 24 samples lifted in 1969-70 and 1971-72, respectively.

Year	Diameter Class	Top Length	% That Set Buds
1969-70	2&3/32	6.2	52
	4/32	7.7	75
	5&6/32	8.9	97
1971-72	3/32	6.6	62
	4/32	7.9	70
	5&6/32	9.2	73

Table 3. **Average bed density, top length, percent of seedlings that set buds, and shoot to root ratio (1971-72 only) for the seedlings lifted for each of the eight field plots in each year.**

Year	Seedbed Location		Seedbed Density	Top Length	% Set Buds	Shoot/ Root Ratio	Province	Region	Field County	Plot Location Tract
1969-70	Sect. BB/Bed	1	60.4	8.1	85	-	C.P.	1	Southampton	Gardner
		2	49.1	7.8	81	-	C.P.	2	King William	Sutton & Hazelwood
		3	53.4	7.9	79	-	Piedmont	3	Fluvanna	Walton
		4	46.1	7.5	71	-	Piedmont	4	Buckingham	Carter
		5	47.1	7.0	66	-	Piedmont	5	Campbell	Carter
		6	54.9	7.7	78	-	C.P.	8	Nansemond	Rawls
		7	48.4	6.7	65	-	C.P.	9	King & Queen	Walton
		8	56.2	8.2	74	-	Piedmont	SF	Buckingham	State Forest
		Means	52.0	7.6	75					
1971-72	Sect. MM/Bed	1, 230'	48.8	10.1	56	5.08	C.P.	1	Surry	Gwaltney
		1, 230'	52.5	10.1	56	4.84	Piedmont	5	Campbell	Carter
		1, 60'	53.3	8.3	70	4.30	C.P.	2	New Kent	Mountcastle
		1, 60'	56.7	8.2	72	4.17	Piedmont	SF	Prince Edward	State Forest
	Bed	2, 294'	53.0	7.3	75	3.57	C.P.	8	Isle of Wight	Jones
		2, 294'	52.7	7.6	71	3.35	Piedmont	4	Prince Edward	Waddell
		2, 354'	50.4	6.2	75	2.87	C.P.	9	Lancaster	Dann
		2, 354'	47.9	6.5	77	2.90	Piedmont	3	Louisa	Atkins
		Means	51.9	8.0	69	3.88				

In 1971-72, a total of 1540 seedlings were weighed to calculate shoot to root ratios, 385 from the December lifting and 615 and 540 seedlings from the March lifting for the March and April plantings, respectively. There was no relationship between shoot to root ratio and root collar diameter. The average shoot to root ratios, over all four seedbed sampling locations, for 4/32, 5/32, and 6/32 inch seedlings were 3.61, 3.57, and 3.53, respectively. At one of the four seedbed locations we did not have enough extra 3/32 inch seedlings to obtain a good estimate of average shoot to root ratio, but for the other three locations, the average shoot to root ratios for 3/32, 4/32, 5/32, and 6/32 inch seedlings were 3.36, 3.23, 3.22, and 3.26, respectively.

Because there was no relationship between shoot to root ratio and root collar diameter, shoot to root ratios for the December lifting, in which shoot to root ratios were not calculated separately by root collar diameter class, and the March lifting, in which root collar diameter classes were kept separate, can be compared. Shoot to root ratios improved considerably between the December and March lifting, from 4.73 to 3.52. The main reason for the improvement was that root systems became heavier through the winter, as was the case in another of our studies.[1] Average seedling root weight increased 44 percent, from an average of .99 grams to 1.43 grams between the December and March liftings.

There was a considerable range in shoot to root ratios among the four seedbed locations from which seedlings were lifted. Average shoot to root ratios, combining both lifting dates, for the four seedbed locations were 4.96, 4.23, 3.46, and 2.88.

FIELD PLOT INSTALLATION AND MEASUREMENT

Field plots were installed on upland sites in the Coastal Plain and central Piedmont of Virginia (Figure 1). Seedling spacing was 6.6 feet within rows and 8 feet between rows for the 1969-70 study, and 6.6 feet within rows and 10 feet between rows for the 1971-72 study.

For the 1969-70 study, treatments were not replicated at each field location. The three planted rows for each treatment were planted side by side, in case larger seedlings suppressed smaller seedlings where they were planted side by side. If this did occur, the center rows could safely be used for comparing size classes. For the 1971-72 study, where the row spacing was increased from 8 to 10 feet, treatments were replicated in each field installation, randomly assigning a single row of each treatment to each of three blocks.

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[1]Occasional Report No. 50, July 1976, *Changes in Loblolly Pine Seedling Dry Weight and Top to Root Ratio Between October and March.*

Release from hardwood sprout competition was carried out on 6 of the 16 plots. Five plots were operationally released by aerial spraying, and one was released by hand chopping.

All plots were measured annually for the first five years, again at age 10, and finally at age 20 or 21 for the 1969-70 study, and at age 18 or 19 for the 1971-72 study. For the first five years, only seedling height was measured. At age 10 we measured DBH of each tree on all plots to the nearest inch, but had time to measure total heights on only 5 plots in the 1969-70 study and none of the plots in the 1971-72 study. Between the 10-year measurement and the final measurement, we lost two of the 1969-70 plots to thinning and one of the 1971-72 plots to development. At the final measurement, we measured both DBH and total height of all trees. Diameters were measured to the nearest one inch class, and heights were measured to the nearest foot, noting which trees were dominant or codominant.

Analyses of variance were performed on plot (i.e., tract) means for survival, height, DBH, basal area, and volume in standard cords. Survival percents were first transformed to arc sine. The means for all 3 rows (combined), for each of the 9 treatments, on each of the 8 tracts, provided 9 x 8 - 1 = 71 degrees of freedom. Covariance analysis was used to adjust DBH, basal area, and volume at the final measurement for differences in survival at age 2.

SURVIVAL

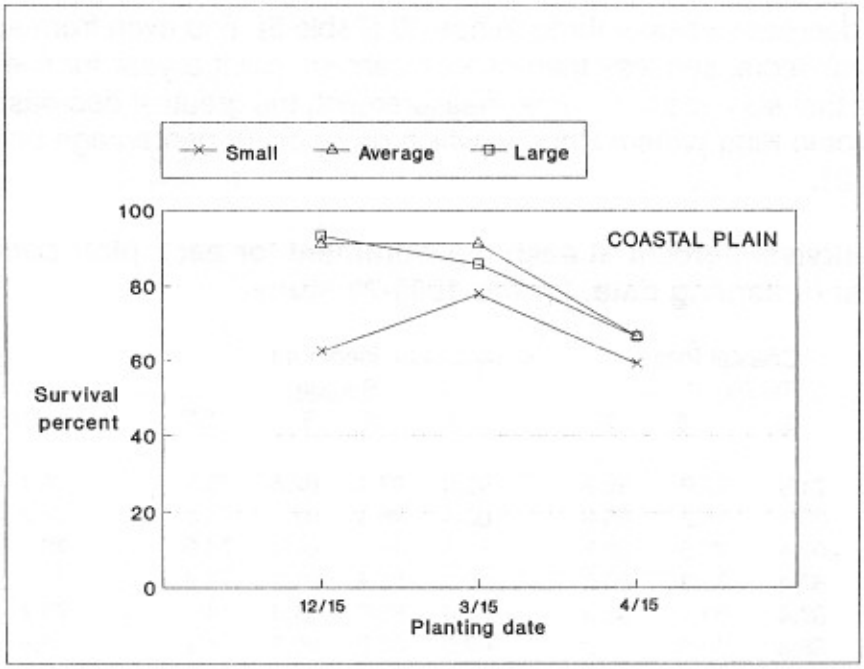
1969-70 Study

Survival after the second season in the field is presented in Table 4 and Figure 2. There was little difference in survival between average and large seedlings, but survival of small seedlings was considerably lower. Combining the three planting dates and all eight field plots, average survival for small, average, and large seedlings was 64.8, 82.4, and 83.6, respectively. Survival of large seedlings was not significantly better than average seedlings (probability of a larger $F=.71$), but the average of average and large seedlings was significantly better than small seedlings (probability of a larger $F=6.8 \times 10^{-8}$).

The best overall survival was obtained with March planting, when survival was similar in the Coastal Plain and Piedmont. Survival for December and April planting, however, was different in the Coastal Plain and Piedmont. In the Coastal Plain, December planting was considerably better than April planting, with the reverse true in the Piedmont. Survival for December 15 and April 15 planting was not significantly different (probability of a larger $F=.35$), but March 15 planting had significantly higher survival than the average of December 15 and April 15 (probability of a larger $F=2.2 \times 10^{-6}$).

Table 4. Second year survival percent by root collar diameter and planting date for each plot, for the 1969-70 study.

Root Collar	Planting	Coastal Plain Region				Piedmont Region				Means		
Dia.	**Date**	**1**	**2**	**8**	**9**	**3**	**4**	**5**	**SF**	**CP**	**Pied.**	**Combined**
2&3/32	Dec.	56.7	43.3	73.3	76.7	25.0	58.3	56.7	28.3	62.5	42.1	52.3
	Mar.	88.3	76.7	66.7	80.0	73.7	88.3	80.0	81.7	77.9	80.9	79.4
	Apr.	53.3	55.0	53.3	75.0	42.1	78.3	81.7	61.7	59.2	65.9	62.6
4/32	Dec.	96.7	83.3	93.3	91.7	56.7	80.0	90.0	55.0	91.2	70.4	80.8
	Mar.	95.0	81.7	95.0	93.3	91.2	100	93.3	91.7	91.2	94.1	92.6
	Apr.	61.7	65.0	56.7	83.3	59.6	95.0	75.0	93.3	66.7	80.7	73.7
5&6/32	Dec.	95.0	85.0	98.3	95.0	76.7	88.3	83.3	66.7	93.3	78.8	86.0
	Mar.	91.7	78.3	81.7	91.7	96.5	95.0	96.7	96.7	85.8	96.2	91.0
	Apr.	60.0	53.3	58.3	95.0	49.1	93.3	81.7	98.3	66.6	80.6	73.6
	Means	77.6	69.1	75.2	86.9	63.4	86.3	82.0	74.8	77.2	76.6	76.9



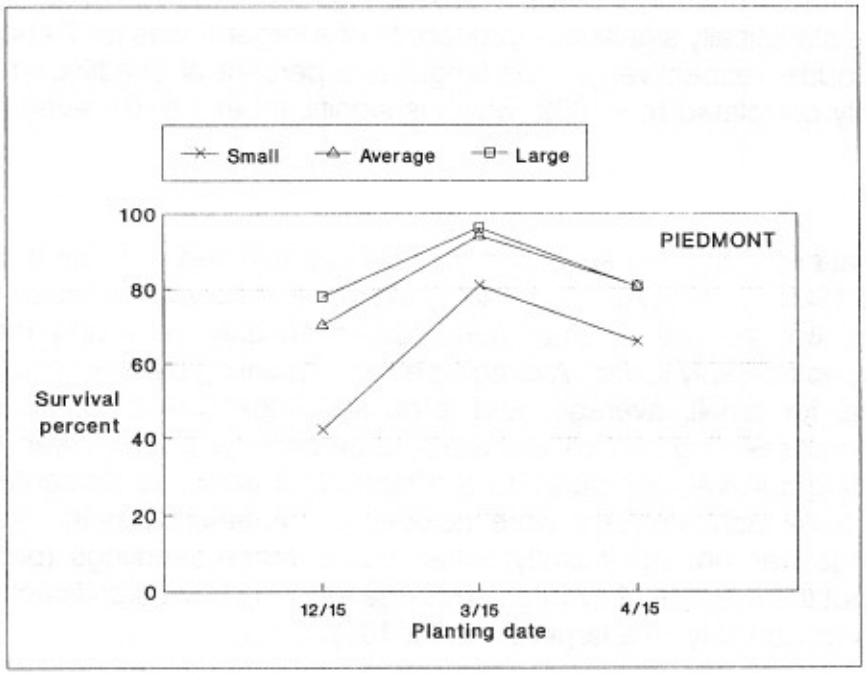


Figure 2. Average second year survival for Coastal Plain and Piedmont plots, for the 1969-70 study.

Survival decreased slowly through age 10 (Table 5), and even from age 10 to age 20 or 21, survival decreased less than one percentage point a year for five of six plots. For the six plots that survived to the final measurement, the greatest decrease was for the Coastal Plain plot in King William County, which dropped 18 percentage points between age 1 and age 21.

Table 5. Average survival percent at each measurement for each plot, combining root collar diameter and planting date, for the 1969-70 study.

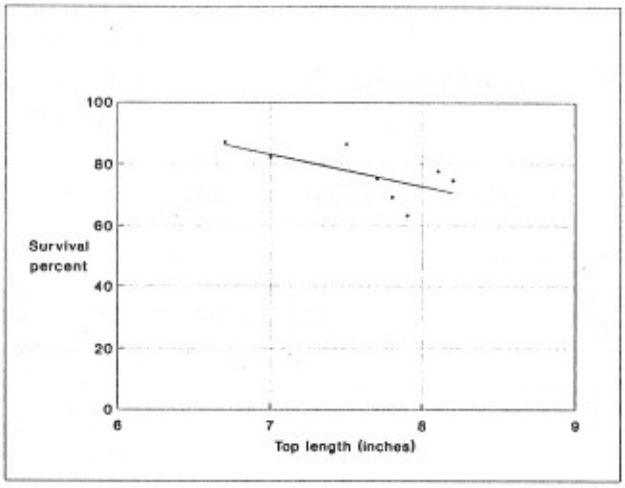
Measurement	Coastal Plain Region				Piedmont Region				Means		
Age	**1**	**2**	**8**	**9**	**3**	**4**	**5**	**SF**	**CP**	**Pied.**	**Combined**
1	78.7	71.9	77.0	88.9	63.6	87.4	82.6	75.9	79.1	77.4	78.2
2	77.6	69.1	75.2	86.9	63.4	86.3	82.0	74.8	77.2	76.6	76.9
3	76.9	67.4	73.5	86.7	63.4	85.6	81.9	74.6	76.1	76.4	76.2
4	76.1	67.4	73.3	86.5	63.0	85.4	81.3	74.4	75.8	76.0	75.9
5	76.1	67.4	73.0	86.3	62.8	85.2	81.3	74.1	75.7	75.9	75.8
10	71.0	66.8	70.9	85.2	62.5	83.9	80.9	74.1	73.5	75.4	74.4
20 or 21		53.9		77.8	59.0	79.6	77.2	70.7		71.6	

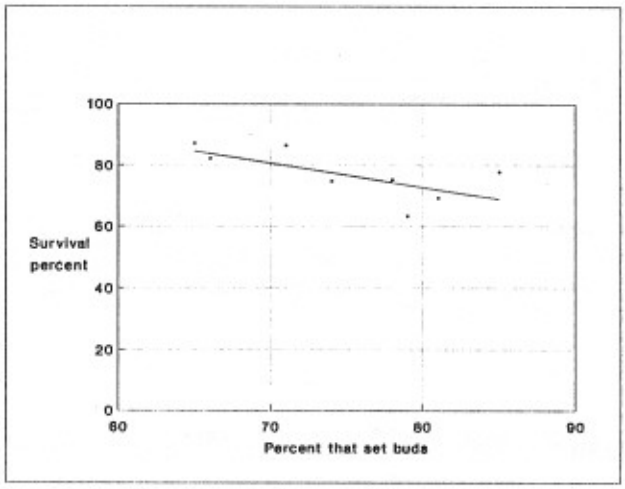
Average second year survival for each of the eight plots can be compared to average top length and average percent of seedlings that set buds (Figure 3). Neither relationship was statistically significant (probability of a larger F was .077 and .060 for top length and set buds, respectively). Top length and percent of seedlings that set buds were significantly correlated ($r = .833$, which is significant at the .01 level).

1971-72 Study

Survival after the second season in the field is presented in Table 6 and Figure 4. Again, as in the 1969-70 study, there was little difference in survival between average and large seedlings, but survival of small seedlings, even after removing the 2/32 inch seedlings, was considerably lower. Averaging all three planting dates over all eight tracts, average survival for small, average, and large seedlings was 81.6, 90.9, and 92.7, respectively. Small seedling survival averaged 10 percentage points lower than average and large seedling survival, compared to a difference of about 18 percentage points in 1969-70, when 2/32 inch seedlings were included in the small diameter class. Survival of large seedlings was not significantly better than average seedlings (probability of a larger $F = .31$), but the average of average and large seedlings was significantly better than small seedlings (probability of a larger $F = 2.8 \times 10^{-7}$).

Unlike 1969-70, survival was similar in the Coastal Plain and Piedmont, and there was practically no difference among the three planting dates, except, as in 1969-70, survival of small seedlings was poorest for December planting.





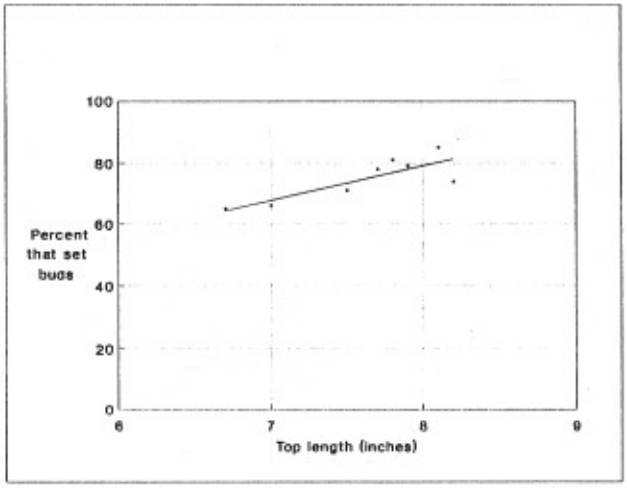
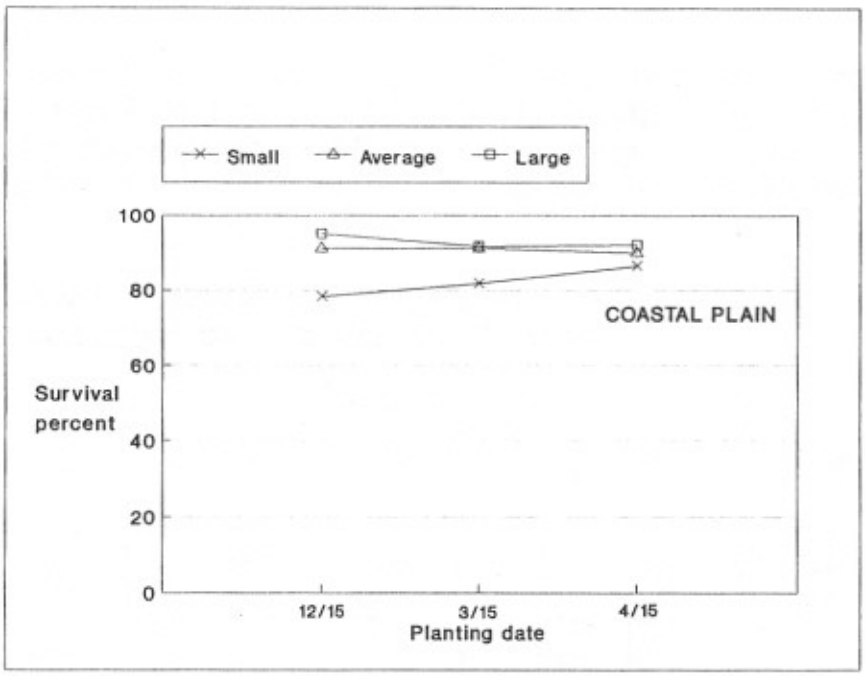


Figure 3. Relationships between second year survival, top length, and percent of seedlings that set buds, for the 1969-70 study.



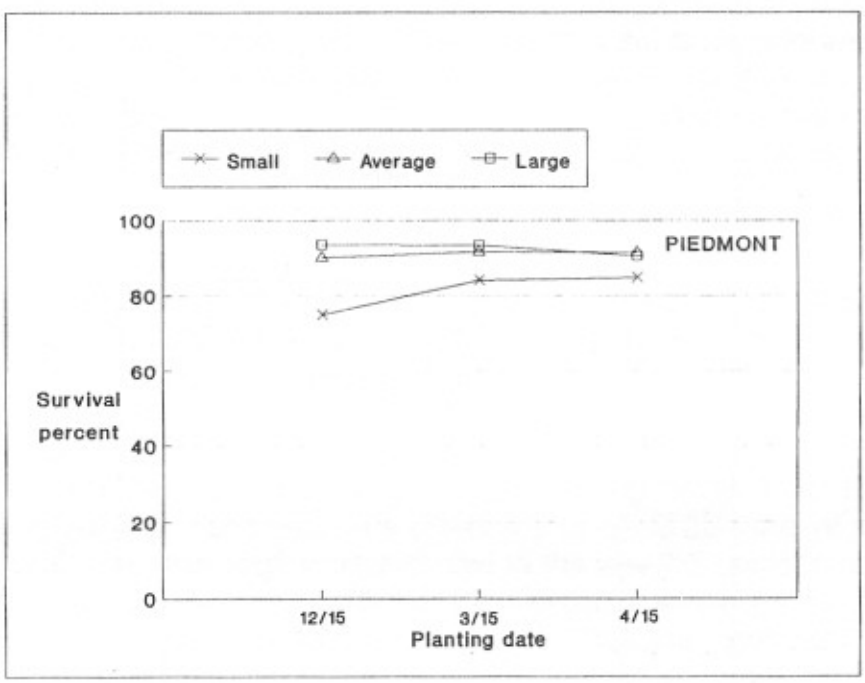


Figure 4. Average second year survival for Coastal Plain and Piedmont plots, for the 1971-72 study.

Table 6. Second year survival percent by root collar diameter and planting date for each plot, for the 1971-72 study.

Root Collar	Planting	Coastal Plain Region				Piedmont Region				Means		
Dia.	**Date**	**1**	**2**	**8**	**9**	**3**	**4**	**5**	**SF**	**CP**	**Piedmont**	**Combined**
3	Dec.	58.3	80.0	81.7	93.3	98.3	70.0	46.7	85.0	78.3	75.0	76.7
	Mar.	57.2	93.3	84.1	91.7	98.3	86.7	60.8	90.0	81.6	84.0	82.8
	Apr.	70.9	96.7	89.5	88.3	93.3	86.2	73.8	85.0	86.4	84.6	85.5
4	Dec.	85.0	90.0	89.9	100	98.3	86.7	78.3	96.7	91.2	90.0	90.6
	Mar.	83.3	96.7	98.3	86.7	98.3	86.7	83.3	98.3	91.2	91.6	91.4
	Apr.	78.3	91.7	92.9	96.7	96.7	95.0	86.7	86.7	89.9	91.3	90.6
5&6	Dec.	91.7	93.3	96.7	98.3	96.7	91.7	86.7	98.3	95.0	93.4	94.2
	Mar.	81.7	96.7	98.3	90.0	100	85.6	90.0	98.3	91.7	93.5	92.6
	Apr.	85.0	93.3	94.7	95.0	96.7	96.7	93.3	75.0	92.0	90.4	91.2
	Means	76.8	92.4	91.8	93.3	97.4	87.3	77.7	90.4	88.6	88.2	88.4

Again, survival decreased slowly through age 10 (Table 7), and even through age 18 or 19. For the seven plots that survived to the final measurement, the greatest decrease was for the Coastal Plain plot in Isle of Wight County, which dropped 14 percentage points between age 1 and age 19.

Table 7. Average survival percent at each measurement for each plot, combining root collar diameter and planting date, for the 1971-72 study.

		Coastal Plain				Piedmont						
	1,230'	1,60'	2,294'	2,354'	1,230'	1,60'	2,294'	2,354'		Means		
		Region				Region						
Year	**1**	**2**	**8**	**9**	**3**	**4**	**5**	**SF**	**CP**	**Pied.**	**Combined**	
1	78.8	93.3	93.5	96.5	99.1	90.7	78.5	91.5	90.5	89.9	90.2	
2	76.8	92.4	91.8	93.3	97.4	87.3	77.7	90.4	88.6	88.2	88.4	
3	76.3	92.4	91.0	93.1	97.0	87.3	77.7	90.4	88.2	88.1	88.2	
4	75.2	92.2	89.7	92.6	96.3	86.9	77.4	90.4	87.4	87.8	87.6	
5	75.2	92.2	89.5	92.6	96.3	86.9	77.4	90.4	87.4	87.8	87.6	
10	72.3	90.7	88.7	91.3	95.0	86.5	77.1	90.2	85.8	87.2	86.5	
18 or 19		82.6	79.4	84.4	93.7	84.4	74.1	87.6		85.0		

Average second year survival for each of the eight plots can be compared to average top length, average percent of seedlings that set buds, and average shoot to root ratio (Figure 5). All three relationships were highly significant, (probability of a larger F was .002, .0001, and .012 for top length, percent that set buds, and shoot to root ratio, respectively). The relationship between survival and percent of seedlings that set buds is positive, whereas the relationship was negative in the 1969-70 study (compare Figures 3 and 5). Notice that the percent of seedlings that set buds was positively related to top length in the 1969-70 study but negatively related to top length in the 1971-72 study. In two earlier seedling grade studies, seedlings that either did or did not set buds survived equally well, when seedlings of the same diameter and top length were compared.[2] The simple correlations among these three seedling traits were highly significant ($r = -.950$ for percent that set buds compared to top length, $r = .974$ for shoot to root ratio compared to top length, and $r = -.885$ for percent that set buds compared to shoot to root ratio, all significant above the .01 level).

There were big differences in survival between seedlings from the four nursery locations. A pair of plots, one Coastal Plain and one Piedmont, were planted with seedlings from each of the four nursery locations, and survival was similar for the Coastal Plain and Piedmont plots from each nursery location (Table 6). The differences are strongly correlated with average top length and shoot to root ratio for these four locations (Table 8). In Table 8, survival of 3/32 inch seedlings is compared with the average of 4/32 and 5&6/32 inch seedlings, combining both field plots for each nursery location. The nursery locations in Table 8 are listed as in Table 3, in order of decreasing top length and shoot to root ratio. Survival generally improves with decreasing top length and shoot to root ratio for all sizes, but the amount of improvement is greater for small seedlings. The difference in survival between small versus average plus large seedlings decreases from 24.0 percentage points for the tallest (and therefore spindliest) seedlings to only 2.2 percentage points for the shortest (and therefore stockiest) seedlings.

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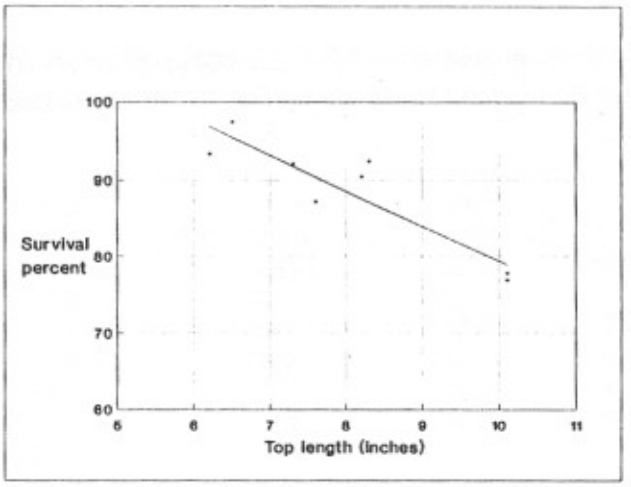
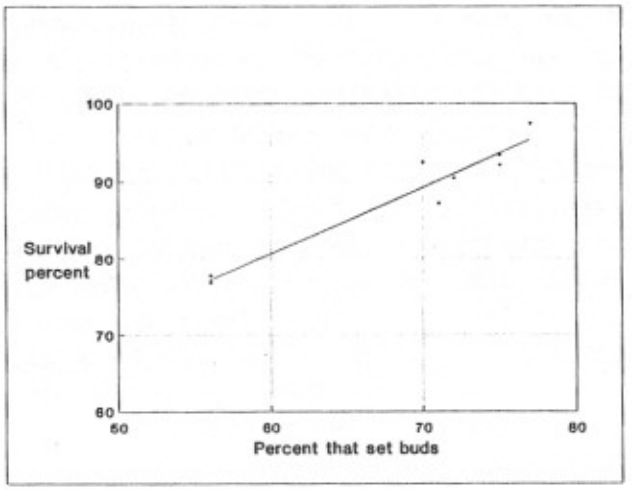
[2]Occasional Report No. 40, April 1973, *Loblolly Pine Seedling Grade, Growth and Survival.*





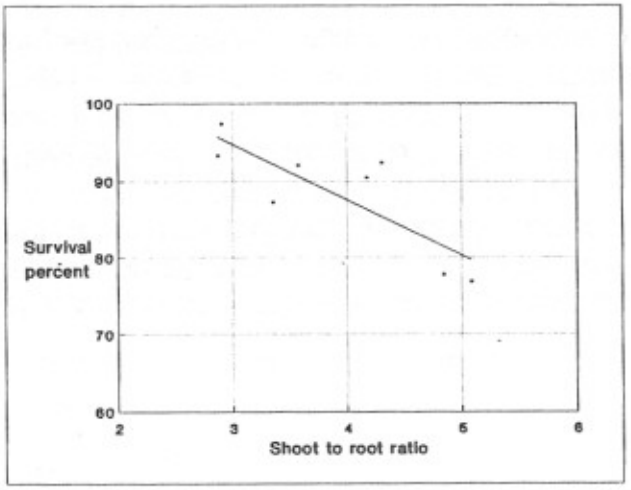


Figure 5. Relationships between second year survival, top length, percent of seedlings that set buds, and shoot to root ratio, for the 1971-72 study.

Table 8. Second year survival of 3/32 compared to average of 4 plus 5&6/32 seedlings, by nursery location, planting dates combined, for 1971-72 study.

Nursery Location	Region	Mean Top Length	Mean Shoot/Root Ratio	Mean Survival Small	Average & Large	Difference
Bed 1,230'	1 & 5	10.1	4.96	61.3	85.3	24.0
Bed 1,60'	2 & SF	8.3	4.23	88.3	92.9	4.6
Bed 2,294'	8 & 4	7.5	3.46	83.1	92.8	9.7
Bed 2,354'	9 & 3	6.3	2.88	93.9	96.1	2.2

HEIGHT GROWTH

For the final measurement of the 1969-70 study, average height for all three rows of each treatment was compared with average height for just the center row. If the larger seedlings had suppressed the height growth of the smaller seedlings, then the center rows of small seedlings, on the average, ought to be taller than the average for all three rows. This is because the odds are 6 out of 8 that an outside row of small seedlings will be adjacent to a row of either average or large seedlings, rather than another row of small seedlings. For the six studies that survived until the final measurement, center rows averaged .06 feet shorter (than all three rows) for small seedlings, .41 feet taller for average seedlings, and .02 taller for large seedlings. Consequently, all comparisons and discussions that follow, including those for diameter, basal area, and volume, are based on all three rows.

Large seedlings grew faster in height than average and small seedlings for the first five years (Table 9). After that, small seedlings grew somewhat faster than large seedlings and made up some of the difference present at age 5. Large seedlings were 45 percent taller than small seedlings after one season, but only 2 percent taller after 20 or 21 seasons. Average seedlings made up all of the difference present at age 5, and were actually taller than large seedlings at age 20 or 21 (Table 9). Average seedlings grew faster than small seedlings, through the final measurement. Average seedlings were 28 percent taller than small seedlings after one season and 3 percent taller after 20 or 21 seasons. Table 9 is based on the six plots that survived to the final measurement, and averages the three planting dates. At age 20 or 21, small seedlings were still significantly shorter than the average of average and large seedlings (probability of a larger $F = .005$).

Table 9. Average height by year for small, average, and large seedlings for the six plots that survived to the final measurement, for the 1969-70 study.

	Average height in feet				Differences	
Age	2&3	4	5&6	4 minus 2&3	5&6 minus 2&3	5&6 minus 4
1	.76	.97	1.10	.21	.34	.13
2	2.11	2.52	2.76	.41	.65	.24
3	4.33	5.02	5.42	.69	1.09	.40
4	6.73	7.61	8.05	.88	1.32	.44
5	9.65	10.69	11.14	1.04	1.49	.45
20 or 21	45.69	46.87	46.80	1.18	1.11	-.07

The 1971-72 study was similar to the 1969-70 study. Large seedlings grew faster than average and small seedlings for about the first 5 years (Table 10). After that, small seedlings grew slightly faster than both average and large seedlings, and made up some of the differences present at age 5. Large seedlings were 41 percent taller than small seedlings after one season, but only 2 percent taller after 18 or 19 seasons. Average seedlings were 21 percent taller than small seedlings after one season, and 2 percent taller after 18 or 19. Average seedlings also grew somewhat faster than large seedlings after age 5. Large seedlings were 16 percent taller than average seedlings after one season, but only 1 percent taller after 18 or 19 (Table 10). Table 10 is based on the seven plots that survived to the final measurement, and averages the three planting dates. At age 18 or 19, average and large seedlings were not significantly different (probability of a larger F=.147), but small seedlings were significantly shorter than the average of average and large seedlings (probability of a larger F=.00062).

Table 10. Average height by year for small, average, and large seedlings for the seven plots that survived to the final measurement, for the 1971-72 study.

	Average height in feet				Differences	
Age	3	4	5&6	4 minus 3	5&6 minus 3	5&6 minus 4
1	.76	.92	1.07	.16	.31	.15
2	1.93	2.21	2.43	.28	.50	.22
3	3.84	4.37	4.71	.51	.85	.34
4	5.95	6.55	6.95	.60	1.00	.40
5	8.39	9.07	9.46	.68	1.07	.39
18 or 19	41.36	41.99	42.37	.63	1.01	.38

DIAMETER GROWTH

For the 1969-70 study, diameters were measured at age 10 and at the final measurement at age 20 or 21. Table 11 presents average diameters for the six tracts that survived to the final measurement. Average seedlings had the largest average DBH at both age 10 and age 20 or 21. Large seedlings were larger than small seedlings at both measurements, but the difference at age 20 or 21 was not as large as at age 10.

Table 11. Average diameter at age 10 and age 20 or 21, by diameter class, for the 1969-70 study.

Root Collar Diameter	Age 10 DBH	Age 10 Difference	Age 20 or 21 DBH	Age 20 or 21 Difference
2&3	4.34		6.59	
		.24		.15
4	4.58		6.74	
		-.01		-.13
5&6	4.57		6.61	

Where seedlings died, surviving neighbors had more growing space, and were able to grow faster in diameter. Consequently, diameter growth was affected by initial survival, tending to increase with decreasing survival (Figure 6). The three linear regression lines in Figure 6 were fitted separately to small, average, and large seedlings. Each of the 54 points plotted in Figure 6 is the mean of three rows of each of nine treatments for six different tracts. Small seedlings are larger in diameter, on the average, than they would have been had their survival been as good as average and large seedlings. Conversely, average and large seedlings are smaller, on the average, than they would have been if their survival had been as low as the small seedlings.

It is interesting to speculate what the average diameters might have been had survival been equal for the three diameter classes. Covariance analysis was used to adjust average diameters to the overall, average survival at age 2 (Table 12). After adjusting average DBH for differences in age 2 survival, there was no statistically significant difference between average and large seedlings (probability of a larger $F = .370$), but average and large seedlings combined were significantly larger than small seedlings (probability of a larger $F = .008$).

Table 12. Comparison of actual diameters with diameters adjusted by covariance analysis for initial survival differences, for the 1969-70 study.

Root Collar Diameter	Unadjusted Survival %	Unadjusted DBH	Adjusted Survival %	Adjusted DBH
2&3	64.6	6.59	77.1	6.40
4	82.2	6.74	77.1	6.82
5&6	84.5	6.61	77.1	6.72

For the 1971-72 study, diameters were also measured at age 10 and at the final measurement at age 18 or 19. Table 13 presents average diameters for the seven tracts that survived to the final measurement. Large seedlings grew faster in diameter than average seedlings, which in turn grew faster than small seedlings, but the differences at age 18 or 19 were not as great as at age 10.

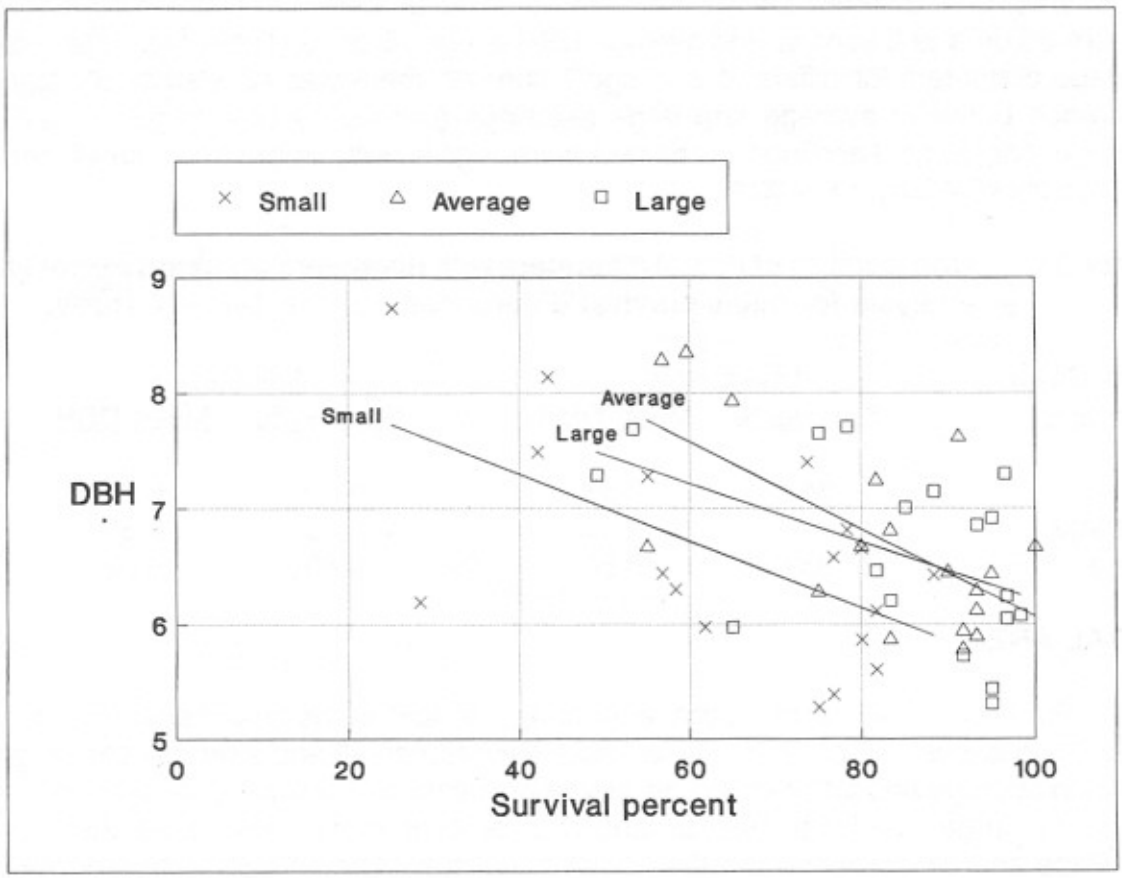


Figure 6. Relationship between average DBH at age 20 or 21 and second year survival, for the six tracts that survived to the final measurement, for the 1969-70 study.

Table 13. Average diameter at age 10 and age 18 or 19, by diameter class, for the 1971-72 study.

Root Collar Diameter	Age 10 DBH	Age 10 Difference	Age 18 or 19 DBH	Age 18 or 19 Difference
3	4.02		6.33	
		.23		.19
4	4.25		6.52	
		.13		.08
5&6	4.38		6.60	

Diameter growth was again related to initial survival, but the relationship was not as strong as in 1969-70, partly because overall survival was better in 1971-72 (Figure 7). The three linear regression lines in Figure 7 were fitted separately to small, average, and large seedlings, and each of the 63 points plotted is the mean of 3 rows of each of 9 treatments for 7 different tracts. An analysis of covariance for randomized blocks was performed on age 2 survival and average DBH at age 18 or 19 (Table 14). After adjusting average diameters for differences in age 2 survival, there was no statistically significant difference between average and large seedlings (probability of a larger F=.274), but average and large seedlings combined were significantly larger than small seedlings (probability of a larger F=.001).

Table 14. Comparison of actual diameters with diameters adjusted by covariance analysis for initial survival differences, for the 1971-72 study.

Root Collar Diameter	Unadjusted Survival %	Unadjusted Mean DBH	Adjusted Survival %	Adjusted Mean DBH
Small	84.4	6.33	90.0	6.29
Average	92.1	6.52	90.0	6.53
Large	93.6	6.60	90.0	6.62

BASAL AREA

For the 1969-70 study, basal area at age 10 and at the final measurement at age 20 or 21 is shown in Table 15. Differences between small and average seedlings, and between average and large seedlings, increased between the two measurements. At age 20 or 21, large seedlings had produced 3 percent more basal area than average seedlings and 37 percent more than small seedlings. The difference between average and large seedlings was not significant (probability of a larger F=.56), but the difference between small seedlings and the average of average and large seedlings was significant (probability of a larger $F=1.0 \times 10^{-7}$).

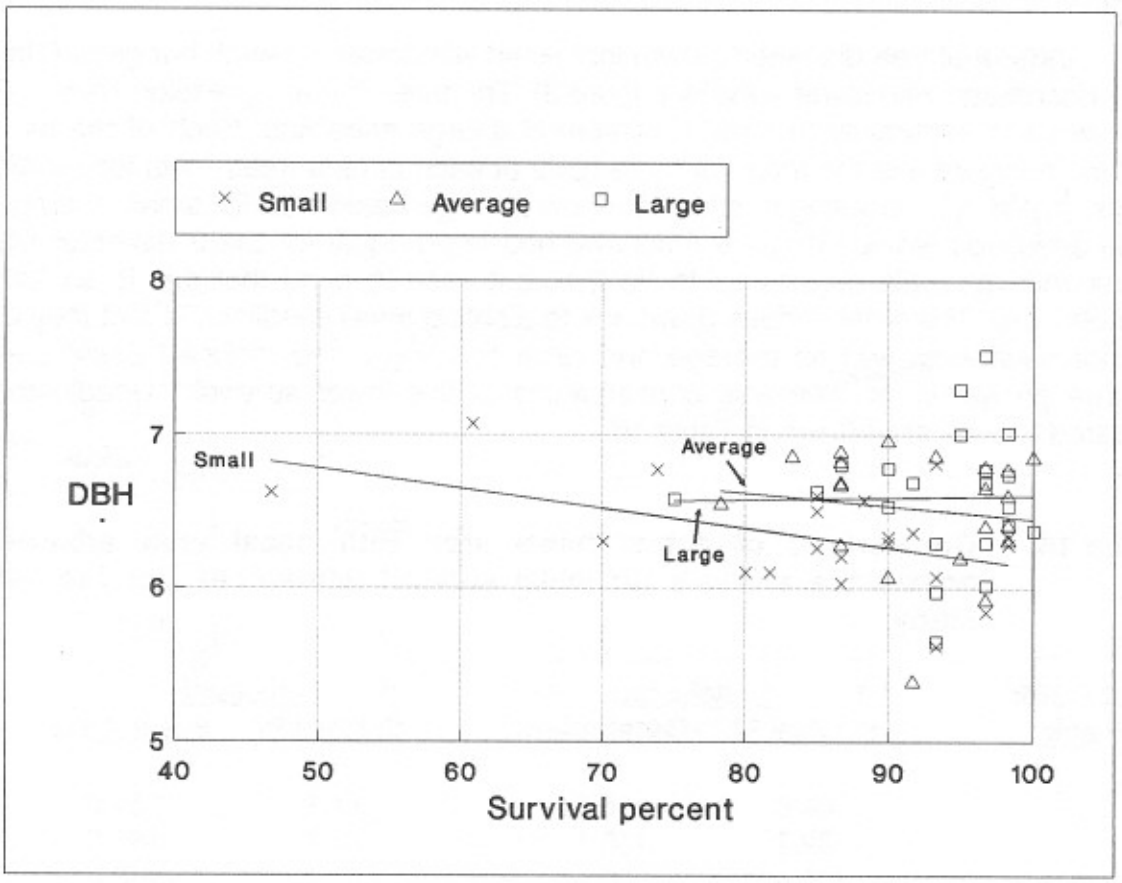


Figure 7. Relationship between average DBH at age 18 or 19 and second year survival, for the seven tracts that survived to the final measurement, for the 1971-72 study.

Table 15. Average basal area, on a per-acre basis, at age 10 and at age 20 or 21, by diameter class, for the 1969-70 study.

Seedling Diameter	Age 10 Basal Area	Age 10 Difference	Age 20 or 21 Basal Area	Age 20 or 21 Difference
Small	56.8		116.1	
		23.1		39.0
Average	79.9		155.1	
		2.1		4.3
Large	82.0		159.4	

Individual tree diameter growth increased with lower survival, but growth in basal area decreased with lower survival (Figure 8). The three linear regression lines in Figure 8 were fitted separately to small, average, and large seedlings. Each of the 54 points plotted in Figure 8 is the mean of three rows of each of nine treatments for six different tracts. Again, it is tempting to speculate how average basal area for small, average, and large seedlings would compare if survival had been equal for the 3 diameter classes. Covariance analysis permits us to do this, but keep in mind that this is an "artificial" comparison. The most serious drawback to planting small seedlings is that they usually do not survive as well as average and large seedlings, and reduced basal area and volume growth is an inevitable consequence of this lower survival. Unadjusted and adjusted means are shown in Table 16.

Table 16. Comparison of actual basal area with basal area adjusted by covariance analysis for initial survival differences, for the 1969-70 study.

Root Collar Diameter	Unadjusted Survival %	Unadjusted Basal Area	Adjusted Survival %	Adjusted Basal Area
3	64.6	116.1	77.1	134.0
4	82.2	155.1	77.1	147.8
5&6	84.5	159.4	77.1	148.8

Adjustment for second-year survival reduced the difference between small and average seedlings by 65 percent, and the difference between small and large seedlings by 66 percent. Even if they had survived as well, small seedlings would still not have produced as much basal area as average and large seedlings (probability of a larger $F = .026$).

For the 1971-72 study, basal area at age 10 and at the final measurement at age 18 or 19 is shown in Table 17. Again, differences between small and average seedlings, and between average and large seedlings, increased between the two measurements. At age 18 or 19, large seedlings had produced 6 percent more basal area than average seedlings and 26 percent more than small seedlings. The difference between average and large seedlings is almost significant (probability of a larger F=.052), and between average and small seedlings is highly significant (probability of a larger $F=5.5 \times 10^{-7}$).[3]

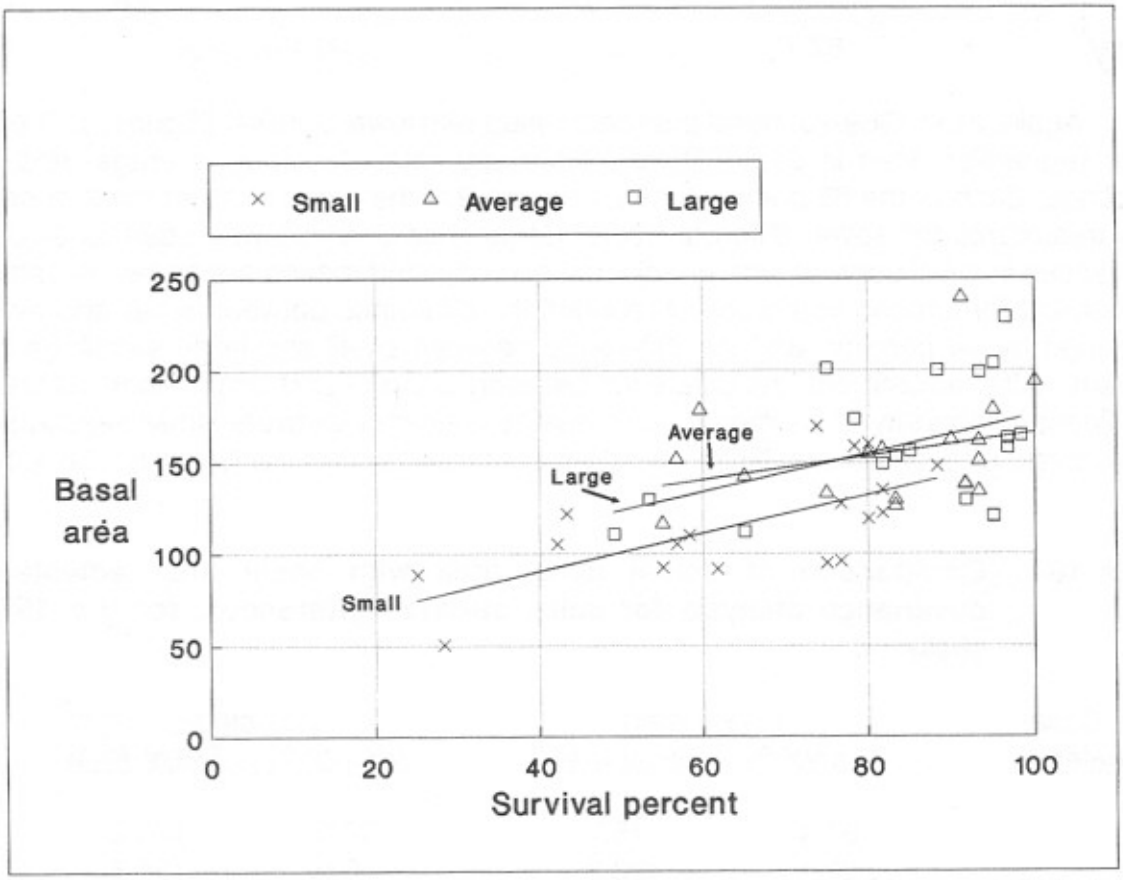


Figure 8. Relationship between basal area at age 20 or 21 and second year survival, for the six tracts that survived to the final measurement, for the 1969-70 study.

[3] Caution should be used in evaluating the statistical significance of these two comparisons because they are not independent.

Table 17. Average basal area at age 10 and at age 18 or 19, by diameter class, for the 1971-72 study.

Seedling Diameter	Age 10 Basal Area	Age 10 Difference	Age 18 or 19 Basal Area	Age 18 or 19 Difference
Small	51.7		115.7	
		11.3		22.6
Average	63.0		138.3	
		4.7		7.8
Large	67.7		146.1	

Again, as in 1969-70, basal area decreased with lower survival (Figure 9). The three linear regression lines in Figure 9 were fitted separately to small, average, and large seedlings. Each of the 63 points plotted in Figure 9 is the mean of three rows of each of nine treatments for seven different tracts. Covariance analysis was used to adjust for differences in initial survival, and unadjusted and adjusted means are shown in Table 18. Adjustment for second year survival reduced the difference between small and average seedlings by 44 percent, and the difference between small and large seedlings by 39 percent. After adjustment, the difference between average and large seedlings was not significant (probability of a larger $F = .51$), but the difference between small seedlings and the average of average and large was significant (probability of a larger $F = 3.6 \times 10^{-6}$).

Table 18. Comparison of actual basal area with basal area adjusted by covariance analysis for initial survival differences, for the 1971-72 study.

Root Collar Diameter	Unadjusted Survival %	Unadjusted Basal Area	Adjusted Survival %	Adjusted Basal Area
3	84.4	115.7	90.0	123.0
4	92.1	138.3	90.0	135.6
5&6	93.6	146.1	90.0	141.5

STANDARD CORDS

For the 1969-70 study, at age 20 or 21, large seedlings had produced .8 cords (2 percent) more than average seedlings, and 9.8 cords (41 percent) more than small seedlings. The difference between average and large seedlings was not significant (probability of a larger $F = .68$), but small seedlings produced significantly less volume than the average of average and large seedlings (probability of a larger $F = 1.1 \times 10^{-6}$). Volume growth was also adversely affected by lower survival (Figure 10), but the relationship was not as strong as for basal area growth (Figure 8). The three linear regression lines in

Figure 10 were fitted separately to small, average, and large seedlings, and each of the 54 points plotted is the mean of 3 rows of each of 9 treatments for 6 different tracts. Again, it is interesting to speculate what the volume differences would be if initial survival of the three diameter classes had been equal. An analysis of covariance for randomized blocks was performed on age 2 survival and cordwood yields at age 20 or 21. Unadjusted and adjusted means are shown in Table 19. Adjustment for second-year survival reduced the difference between small and average seedlings by 57 percent, and the difference between small and large seedlings by 59 percent. After adjustment, the difference between average and large seedlings was not significant (probability of a larger F=.94), but the difference between small seedlings and the average of average and large seedlings was significant (probability of a larger F=.041).

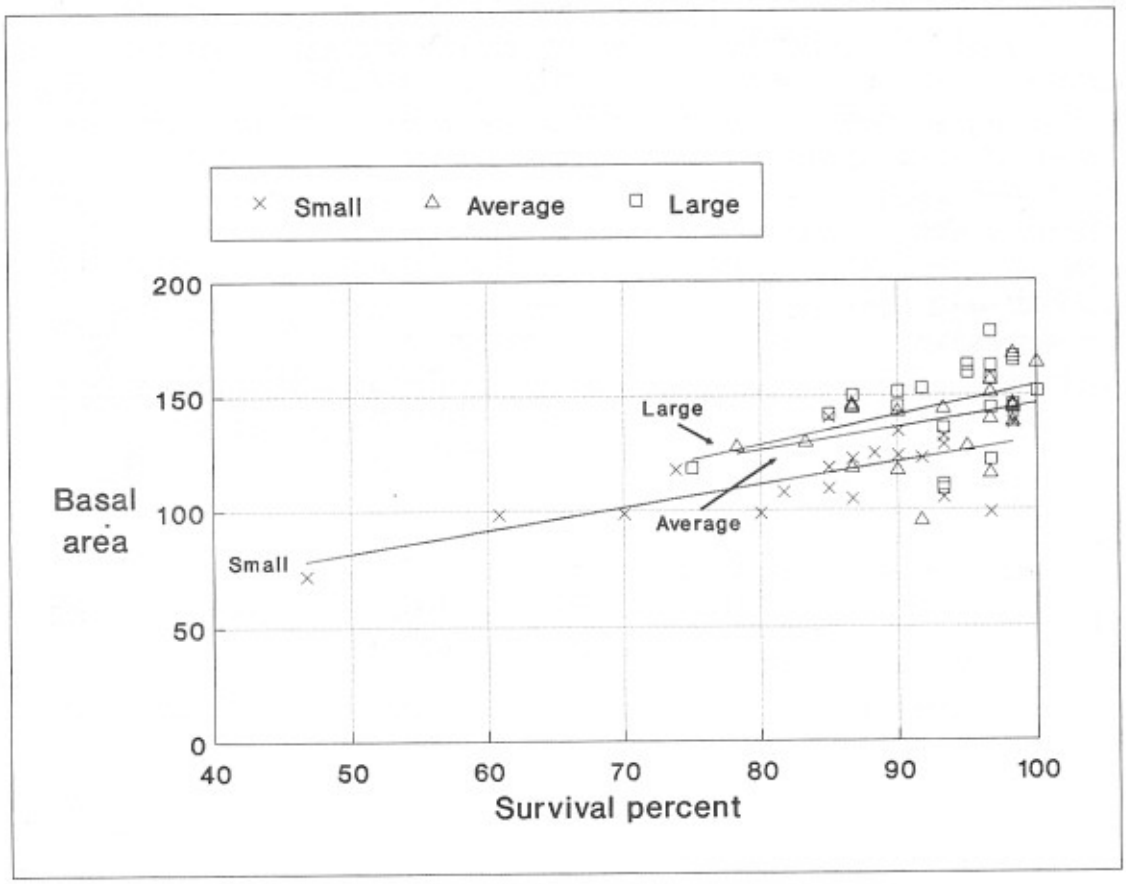


Figure 9. Relationship between basal area at age 18 or 19 and second-year survival, for the seven tracts that survived to the final measurement, for the 1971-72 study.

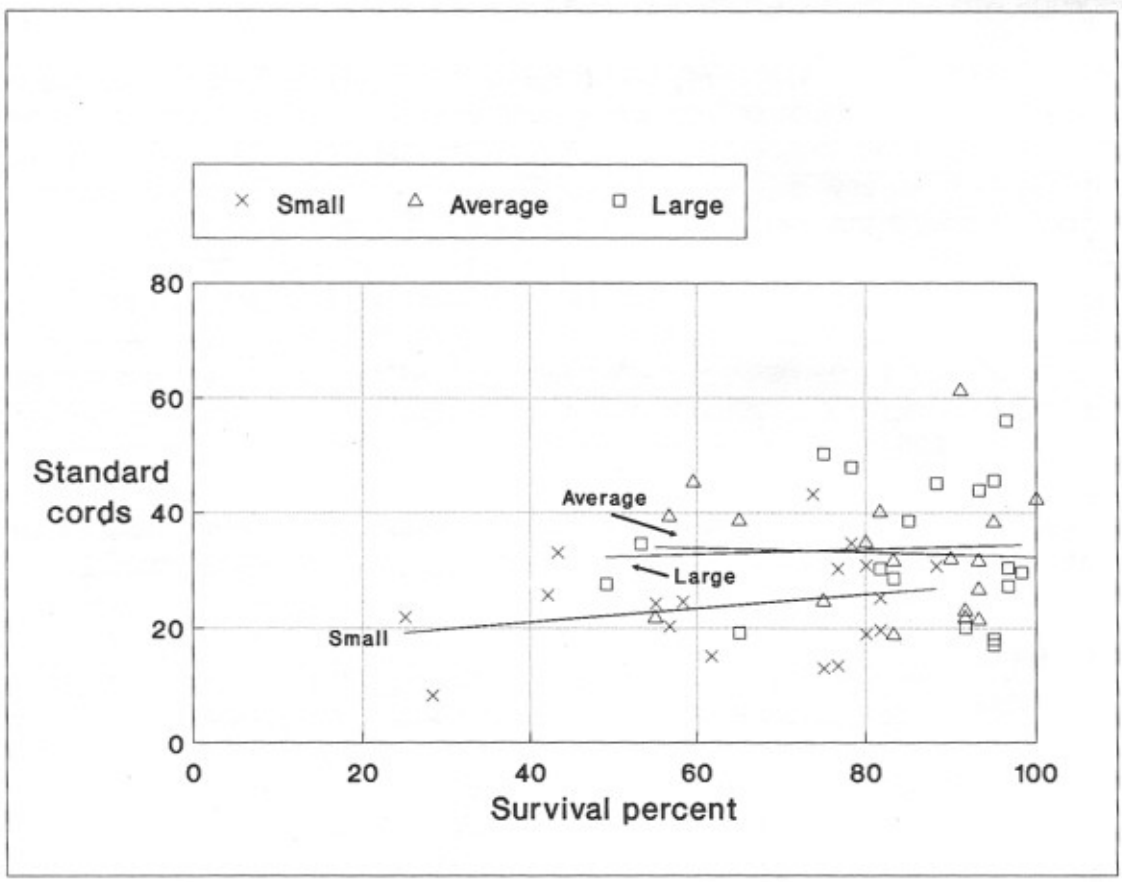


Figure 10. Relationship between standard cord yields at age 20 or 21 and second year survival, for the six tracts that survived to the final measurement, for the 1969-70 study.

Table 19. Comparison of actual volume with volume adjusted by covariance analysis for initial survival differences, for the 1969-70 study.

Root Collar Diameter	Unadjusted		Adjusted	
	Survival %	Cords	Survival %	Cords
Small	64.6	24.0	77.1	27.6
Average	82.2	33.0	77.1	31.5
Large	84.5	33.8	77.1	31.6

For the 1971-72 study, at age 18 or 19, large seedlings had produced 1.7 cords (7 percent) more than average seedlings, and 6.5 cords (31 percent) more than small seedlings. The difference between average and large seedlings was significant (probability of a larger $F=.049$), and the difference between small and average seedlings was highly significant (probability of a larger $F=2.3 \times 10^{-6}$).[4] The relationship between cordwood yields and second year survival is shown in Figure 11. The three linear regression lines in Figure 11 were fitted separately to small, average, and large seedlings, and each of the 63 points plotted is the mean of three rows of each of 9 treatments for 7 different tracts. An analysis of covariance for randomized blocks was performed on age 2 survival and cordwood yields at age 18 or 19. Unadjusted and adjusted means are shown in Table 20. Adjustment for second year survival reduced the difference between small and average seedlings by 40 percent, and the difference between small and large seedlings by 34 percent. After adjustment, the difference between average and large seedlings was not significant (probability of a larger $F=.057$), but the difference between small seedlings and the average of average and large seedlings was significant (probability of a larger $F=2.1 \times 10^{-5}$).

[4] Caution should be used in evaluating the statistical significance of these two comparisons because they are not independent.

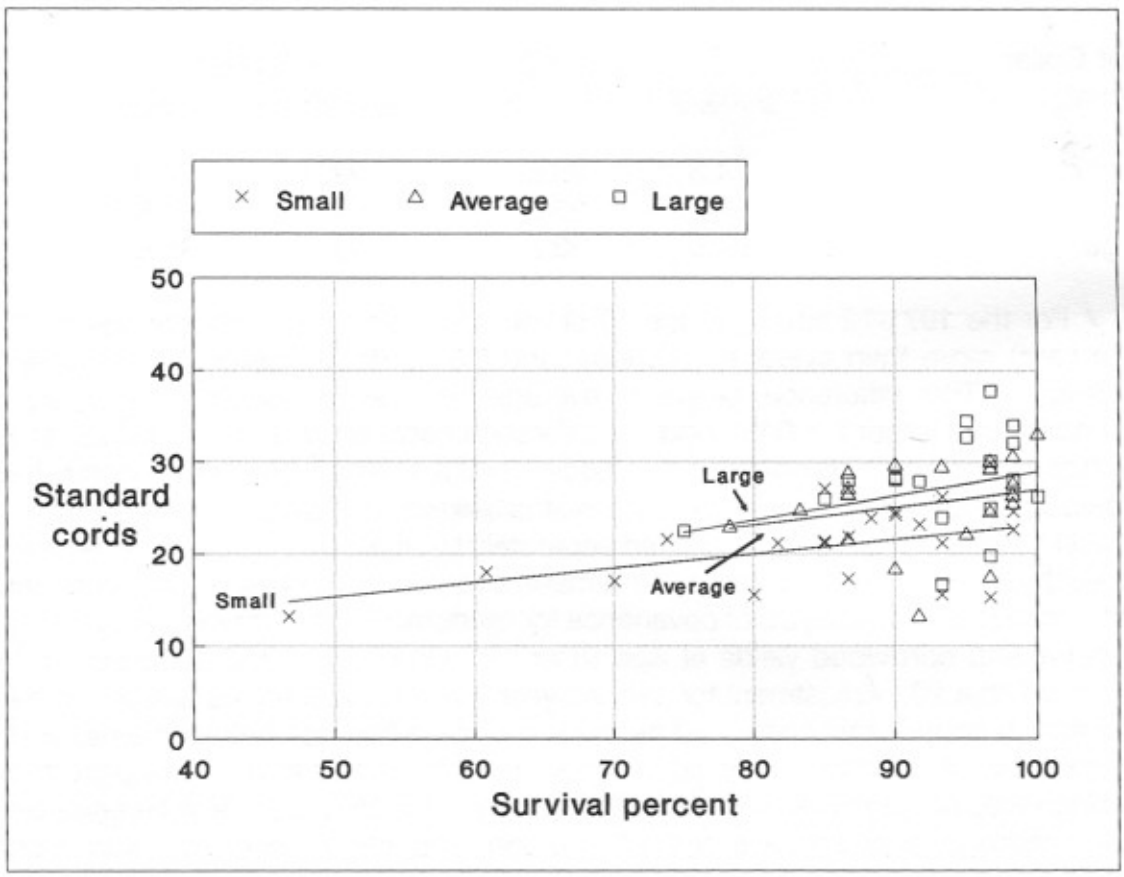


Figure 11. Relationship between standard cord yields at age 18 or 19 and second year survival, for the seven tracts that survived to the final measurement, for the 1971-72 study.

Table 20. Comparison of actual volume with volume adjusted by covariance analysis for initial survival differences, for the 1971-72 study.

Root Collar Diameter	Unadjusted		Adjusted	
	Survival %	Cords	Survival %	Cords
Small	84.4	20.7	90.0	22.1
Average	92.1	25.5	90.0	25.0
Large	93.6	27.2	90.0	26.4

CONCLUSIONS AND DISCUSSION

Initial seedling diameter can influence performance in the field in two ways: by affecting initial survival and by affecting the subsequent growth of surviving seedlings. Both effects occurred in these studies.

Initial Survival

Small diameter seedlings did not survive nearly as well as average and large seedlings, even after eliminating the 2/32 inch seedlings in the 1971-72 study. Survival of small seedlings planted in December was especially poor. Winters are cold in Virginia, and seedlings planted in December have to "tough it out," essentially "stored in place" on the planting site until March, when soils warm up enough for new root growth to occur. Small seedlings don't do this very well. Our nurseries used to sell 2/32-inch seedlings, and the high bed densities that were standard 20 years ago resulted in the production of many 2/32 inch seedlings. Since then, bed densities have been greatly reduced. Our present target density is about 27 or 28 seedlings per square foot, which eliminates most of the 2/32 and 3/32 inch seedlings. Also, our grading standard, for a number of years now, has been to remove all seedlings less than 3.5/32, so that only seedlings in the 4/32 inch class and larger are sold.

Average diameter seedlings survived almost as well as large seedlings. Overall average differences were 1.0 percentage points in 1969-70 and 1.7 points in 1971-72.

There was a negative relationship between survival and top length in both years. The high bed densities in these studies caused tall seedlings to be spindly as well. Reducing seedbed densities in recent years, as well as adding several top clippings to our cultural practices, has resulted in much stockier seedlings.

A two-year study is not nearly long enough to determine the average effect of planting date on survival. In Virginia, late February and March is usually the safest time to plant loblolly seedlings. This conclusion is the result of many different studies extending over about 30 years. Early planting, in December and January, and late planting, in April and May, involve greater risk, and may be expected to reduce average survival about 10 to 15 percentage points below March planting. Survival in the 1971-72 study was unusual because December and April planting was as good as March, with the exception of small seedlings planted in December. Combining diameter classes over all eight tracts, average survival at age 2 was 87.2, 88.9, and 89.1 for December, March, and April planting respectively. In the 1969-70 study, the trends were more typical (March better than both December and April), but the differences were perhaps greater than usual (72.9, 87.5, and 70.0 for December, March, and April respectively, combining diameter classes over all eight tracts).

Subsequent Growth

The tendency of small diameter seedlings to make up some of the early difference in height growth was unexpected. A possible explanation is that taller trees provide a sheltering effect that favors height growth of shorter trees that are able to maintain a codominant or intermediate position in the canopy. Taller neighboring trees provide some protection from wind, and perhaps also from top breakage from ice and snow. This raises the question of whether block plots of uniformly sized seedlings, where there would not be a sheltering effect, might give different results. Our results should, however, be applicable to the kind of operational planting done on private land in Virginia, where seedlings of varying sizes are randomly intermixed when planting.

The performance of 4/32 compared to 5&6/32 inch seedlings surprised us. They not only survived as well, but grew as fast in height, and also grew almost as fast in diameter, so that basal area and volume growth were almost as good as for 5&6/32 inch seedlings.

APPENDIX

Individual tract data at ages 1, 2, 3, 4, 5, 10, and the final measurement at ages 18, 19, 20, or 21.

1969-70, Gardner, Southampton County, Region 1

Planting Date	Root Collar Diameter	Survival at Age						Height (feet) at Age					DBH (inches) at Age	Basal Area at Age
		1	2	3	4	5	10	1	2	3	4	5	10	10
Dec. 15	2, 3	58	57	57	57	57	47	.9	2.7	5.5	8.6	11.8	4.9	56
Dec. 15	4	97	97	97	97	97	80	1.4	3.7	7.0	10.5	13.8	5.3	107
Dec. 15	5, 6	97	95	95	95	95	92	1.6	3.9	7.3	11.2	14.6	5.2	117
March 15	2, 3	88	88	88	87	87	80	1.1	3.1	6.1	9.6	13.1	4.9	94
March 15	4	97	95	93	92	92	90	1.3	3.3	6.7	10.5	14.5	5.1	109
March 15	5,6	95	92	88	88	88	83	1.5	3.6	6.9	10.6	14.1	5.3	109
April 15	2, 3	53	53	52	50	50	50	.8	2.3	4.7	8.0	11.1	4.3	50
April 15	4	63	62	62	62	62	62	1.2	3.1	6.2	9.7	13.5	4.9	74
April 15	5, 6	60	60	60	58	58	55	1.1	2.8	5.7	9.4	12.7	5.2	76

1969-70, Sutton and Hazelwood, King William County, Region 2

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	21	1	2	3	4	5	21	10	21	10	21	21
Dec. 15	2, 3	43	43	42	42	42	42	38	.8	2.0	4.0	7.2	11.2	56.9	5.4	8.1	59	122	32.9
Dec. 15	4	83	83	83	83	83	80	60	1.0	2.7	5.6	9.2	13.0	53.3	5.0	6.8	93	130	31.6
Dec. 15	5, 6	87	85	85	85	85	83	68	1.1	2.9	5.8	9.3	13.0	53.5	5.1	7.0	100	156	38.4
March 15	2, 3	83	77	77	77	77	75	62	1.0	2.6	5.1	8.4	12.1	51.7	4.8	6.6	81	127	30.1
March 15	4	87	82	80	80	80	80	63	1.0	2.4	4.8	8.0	11.8	54.5	5.1	7.2	98	157	40.1
March 15	5, 6	82	78	75	75	75	75	62	1.0	2.4	5.1	8.3	12.2	58.0	5.1	7.7	93	173	47.8
April 15	2, 3	60	55	52	52	52	52	37	.6	1.6	3.7	6.5	10.1	55.9	4.6	7.3	54	92	24.1
April 15	4	65	65	62	62	62	62	48	.9	2.1	4.4	7.3	10.9	57.7	5.0	7.9	76	143	38.7
April 15	5, 6	57	53	52	52	52	52	47	.9	2.3	4.9	8.1	11.9	56.1	5.5	7.7	72	130	34.4

1969-70, Rawls, Nansemond County, Region 8

Planting Date	Root Collar Diameter	Survival at Age						Height (feet) at Age						DBH (inches) at Age	Basal Area at Age
		1	2	3	4	5	10	1	2	3	4	5	10	10	10
Dec. 15	2, 3	77	73	67	67	67	65	1.0	2.3	4.7	7.6	10.5	25.3	4.8	71
Dec. 15	4	98	93	90	90	90	85	1.2	2.8	5.4	8.5	11.7	27.4	5.1	102
Dec. 15	5, 6	98	98	98	98	98	98	1.3	3.1	5.8	8.9	12.1	25.9	4.6	101
March 15	2, 3	67	67	67	67	67	65	.8	2.0	3.8	6.4	9.0	21.6	3.9	51
March 15	4	97	95	95	93	93	93	1.1	2.4	4.8	7.9	10.8	25.2	4.4	84
March 15	5, 6	82	82	82	82	78	77	1.2	2.7	5.3	8.3	11.4	25.1	4.6	77
April 15	2, 3	58	53	52	52	52	48	.8	2.1	3.8	6.5	9.3	23.4	4.1	42
April 15	4	58	57	55	55	55	55	1.0	2.3	4.6	7.4	10.2	23.9	4.5	52
April 15	5, 6	58	58	57	57	57	52	1.1	2.5	4.9	7.8	11.0	26.5	4.8	57

1969-70, Walton, King and Queen County, Region 9

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age							DBH (inches) atAge		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	21	1	2	3	4	5	10	21	10	21	10	21	21
Dec. 15	2, 3	80	77	77	77	77	77	67	.6	1.9	3.9	6.3	8.7	20.2	35.0	3.5	5.4	47	95	13.4
Dec. 15	4	95	92	90	90	90	90	82	.8	2.6	4.6	6.9	9.8	22.4	38.5	3.9	5.9	68	138	21.8
Dec. 15	5, 6	98	95	95	95	95	95	88	1.0	2.6	4.9	7.2	9.9	21.0	36.0	3.5	5.3	58	121	17.0
March 15	2, 3	83	80	80	78	78	77	72	.7	2.2	4.1	6.5	9.1	22.1	38.4	3.8	5.9	55	119	18.9
March 15	4	93	93	93	93	93	88	82	.9	2.6	4.8	7.2	9.9	22.9	39.3	3.8	5.9	63	134	21.4
March 15	5, 6	93	92	92	92	92	92	83	1.1	2.9	5.3	8.0	10.7	22.9	38.8	4.0	5.7	71	129	20.0
April 15	2, 3	77	75	75	75	75	73	68	.6	1.9	3.7	5.8	8.0	19.7	35.3	3.4	5.3	44	94	13.0
April 15	4	83	83	83	83	83	83	77	.9	2.5	4.7	7.3	10.1	22.5	37.5	4.0	5.9	64	127	18.9
April 15	5, 6	97	95	95	95	93	92	82	1.1	2.9	5.1	7.5	10.2	22.1	37.5	3.7	5.4	64	120	18.0

1969-70, Walton, Fluvanna County, Region 3

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age							DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	21	1	2	3	4	5	10	21	10	21	10	21	21
Dec. 15	2, 3	25	25	25	25	25	25	25	.6	2.1	4.5	7.5	11.1	28.5	53.5	5.7	8.7	38	88	21.8
Dec. 15	4	57	57	57	55	53	53	48	.9	2.4	5.0	7.9	11.9	29.2	56.1	5.2	8.3	69	152	39.3
Dec. 15	5, 6	78	77	77	77	77	75	73	1.2	3.1	6.1	9.1	13.4	30.5	54.4	5.4	7.6	103	200	50.1
March 15	2, 3	74	74	74	72	72	72	67	1.0	2.7	5.5	8.2	12.3	28.9	55.2	5.0	7.4	84	169	43.1
March 15	4	91	91	91	91	91	91	88	1.1	2.9	5.9	8.5	12.5	29.6	54.6	5.4	7.6	122	239	61.3
March 15	5, 6	96	96	96	96	96	96	91	1.3	3.2	6.2	8.8	12.7	29.7	53.1	5.2	7.3	121	228	55.9
April 15	2, 3	42	42	42	42	42	42	40	.8	2.3	4.8	7.2	11.0	28.2	53.0	5.1	7.5	51	105	25.5
April 15	4	60	60	60	60	60	60	54	1.1	2.9	5.9	8.5	12.4	28.3	54.0	5.6	8.4	87	178	45.4
April 15	5, 6	49	49	49	49	49	47	44	.9	2.5	5.4	7.8	11.2	28.4	54.1	4.7	7.3	52	110	27.4

1969-70, Carter, Buckingham County, Region 4

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age							DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	20	1	2	3	4	5	10	20	10	20	10	20	10
Dec. 15	2, 3	60	58	58	58	58	58	55	.6	1.5	3.4	5.2	7.5	23.9	45.8	4.0	6.3	49	110	24.4
Dec. 15	4	82	80	80	80	80	77	72	.8	2.2	4.6	7.1	9.7	26.8	48.2	4.6	6.7	80	155	34.8
Dec. 15	5, 6	92	88	88	88	88	88	83	1.1	2.6	5.2	7.8	10.3	26.6	48.9	4.7	7.1	92	200	45.0
March 15	2, 3	90	88	88	88	88	85	75	.8	1.9	4.3	6.6	9.0	25.2	47.6	4.3	6.4	78	148	30.6
March 15	4	100	100	98	97	97	97	90	1.1	2.5	5.2	7.7	10.3	26.7	47.7	4.6	6.7	99	194	42.4
March 15	5, 6	95	95	93	93	93	92	92	1.3	2.9	6.0	8.7	11.4	29.4	49.5	4.8	6.9	97	203	45.5
April 15	2, 3	78	78	77	77	75	72	70	.8	1.8	4.0	6.3	8.7	25.1	47.3	4.5	6.8	72	159	34.6
April 15	4	97	95	93	93	93	93	90	1.0	2.3	4.8	7.2	9.8	27.2	47.9	4.6	6.4	93	179	38.3
April 15	5, 6	93	93	93	93	93	93	90	1.2	2.8	5.8	8.5	11.5	28.6	47.9	4.9	6.9	105	199	43.8

1969-70, Carter, Campbell County, Region 5

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	21	1	2	3	4	5	21	10	21	10	21	10
Dec. 15	2, 3	57	57	57	57	57	57	53	1.0	2.6	5.0	6.9	8.5	43.6	4.2	6.4	48	105	20.2
Dec. 15	4	90	90	90	88	88	86	82	1.1	3.0	5.5	7.6	9.3	43.8	4.3	6.4	75	163	31.9
Dec. 15	5, 6	83	83	83	83	83	83	83	1.2	3.0	5.6	7.6	9.3	42.7	4.3	6.2	74	153	28.4
March 15	2, 3	82	80	80	80	80	80	77	1.1	3.2	5.9	7.9	9.6	43.2	4.6	6.7	80	160	30.7
March 15	4	93	93	93	93	93	92	87	1.3	3.2	5.8	7.9	9.3	43.8	4.3	6.3	81	162	31.5
March 15	5, 6	97	97	95	92	92	92	90	1.4	3.2	5.8	7.8	9.7	43.7	4.3	6.2	79	163	30.2
April 15	2, 3	82	82	82	82	82	82	75	1.0	2.4	4.8	6.6	8.3	43.0	4.0	6.1	62	135	25.1
April 15	4	78	75	75	75	75	75	72	1.0	2.7	5.1	7.0	8.7	43.2	4.2	6.3	63	133	24.6
April 15	5, 6	82	82	82	82	82	82	77	1.3	3.2	5.9	8.0	9.7	45.2	4.3	6.5	73	149	30.1

1969-70, State Forest, Buckingham County

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age							DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	20	1	2	3	4	5	10	20	10	20	10	20	20
Dec. 15	2, 3	28	28	28	28	28	28	27	.5	1.5	3.3	5.3	8.5	19.8	38.3	3.6	6.2	19	50	8.2
Dec. 15	4	57	55	55	55	55	55	55	.6	1.8	4.0	6.7	10.2	23.8	41.9	4.5	6.7	54	117	21.7
Dec. 15	5, 6	68	67	67	67	67	67	63	.7	1.7	3.6	5.9	9.4	21.2	39.1	3.8	6.0	47	112	19.1
March 15	2, 3	83	82	82	82	82	82	80	.7	1.9	4.1	6.8	10.6	23.8	39.3	4.0	5.6	65	122	19.5
March 15	4	92	92	90	90	90	90	85	.9	2.3	4.9	7.7	11.7	24.7	39.2	4.2	5.8	76	139	23.0
March 15	5, 6	97	97	97	97	95	95	92	1.0	2.7	5.4	8.1	12.2	25.6	41.9	4.3	6.0	83	158	27.1
April 15	2, 3	63	62	62	60	60	60	53	.7	1.8	3.8	6.0	9.4	20.2	39.8	3.5	6.0	39	91	15.1
April 15	4	97	93	93	93	92	92	87	.9	2.2	4.6	7.2	11.2	24.5	42.3	4.3	6.1	79	151	26.6
April 15	5, 6	98	98	98	98	98	98	95	1.0	2.5	5.2	8.2	12.1	25.6	42.1	4.5	6.1	91	164	29.4

1971-72, Gwaltney, Surry County, Region 1

Planting Date	Root Collar Diameter	Survival at Age						Height (feet) at Age					DBH (inches) at Age	Basal Area at Age
		1	2	3	4	5	10	1	2	3	4	5	10	10
Dec. 15	3	60	58	55	53	53	48	.9	2.0	4.4	6.4	8.3	3.2	22
Dec. 15	4	87	85	85	83	83	83	1.1	2.6	4.8	6.9	9.0	3.4	38
Dec. 15	5, 6	93	92	92	92	92	87	1.4	2.9	5.6	7.6	9.7	3.6	45
March 15	3	62	57	57	57	57	55	.7	1.8	3.6	5.4	7.1	2.7	17
March 15	4	85	83	82	80	80	77	.8	1.9	3.6	5.2	6.8	2.5	23
March 15	5, 6	83	82	82	80	80	80	.9	1.9	3.8	5.6	7.6	2.7	25
April 15	3	71	71	71	68	68	62	.8	1.9	3.6	5.2	6.8	2.7	21
April 15	4	82	78	78	78	78	73	.8	1.9	3.7	5.4	7.3	2.9	27
April 15	5, 6	87	85	85	85	85	85	.9	2.0	3.9	5.8	7.6	2.8	28

1971-72, Mountcastle, New Kent County, Region 2

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	80	80	80	80	80	78	70	1.1	2.6	5.0	7.4	9.6	38.0	3.8	6.1	45	98	15.5
Dec. 15	4	90	90	90	90	90	90	83	1.3	3.0	5.8	8.1	10.3	37.7	4.1	6.1	59	117	18.3
Dec. 15	5, 6	95	93	93	93	93	90	80	1.4	3.2	5.8	8.1	10.1	37.5	3.9	6.0	53	109	16.6
March 15	3	93	93	93	93	93	92	85	.9	2.2	4.5	6.7	8.9	36.7	3.7	5.6	49	105	15.5
March 15	4	98	97	97	97	97	97	88	1.0	2.5	5.2	7.3	9.6	37.8	3.7	5.9	52	116	17.4
March 15	5, 6	97	97	97	97	97	93	88	1.1	2.6	5.5	7.8	10.2	38.1	4.2	6.0	62	122	19.7
April 15	3	97	97	97	97	97	93	75	.8	2.2	4.1	6.7	8.7	37.8	3.5	5.8	47	99	15.2
April 15	4	93	92	92	90	90	90	85	.8	2.0	4.4	6.4	8.6	35.8	3.6	5.4	44	95	13.2
April 15	5, 6	97	93	93	93	93	93	88	1.0	2.5	5.1	7.4	9.6	36.7	3.8	5.6	54	111	16.5

1971-72, Jones, Isle of Wight County, Region 8

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	85	82	82	82	82	82	72	.9	2.3	3.8	4.9	7.1	44.3	3.7	6.1	47	108	21.1
Dec. 15	4	93	90	88	88	88	88	76	1.2	2.9	4.8	5.8	8.4	46.2	4.0	7.0	58	143	29.6
Dec. 15	5, 6	97	97	95	91	91	90	84	1.3	3.0	5.2	6.4	9.0	47.2	4.6	7.5	76	177	37.7
March 15	3	86	84	84	79	79	77	69	.8	2.0	3.5	4.6	7.0	44.1	3.8	6.5	44	109	21.3
March 15	4	98	98	98	97	97	95	83	.9	2.2	3.9	4.9	7.2	44.5	4.0	6.6	59	138	27.6
March 15	5, 6	98	98	98	98	98	98	88	1.1	2.5	4.3	5.3	7.6	44.8	3.8	6.5	57	144	28.0
April 15	3	93	90	90	90	90	88	81	.6	1.8	3.2	4.4	7.0	45.6	3.9	6.3	52	123	24.5
April 15	4	93	93	91	91	91	91	81	.8	2.1	3.9	5.2	7.9	46.3	4.1	6.9	61	144	29.4
April 15	5, 6	98	95	93	91	89	89	81	1.0	2.5	4.4	5.4	8.1	46.6	4.5	7.3	70	163	34.4

1971-72, Dann, Lancaster County, Region 9

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	97	93	93	93	93	87	75	1.0	2.8	5.8	7.9	10.9	44.4	4.8	6.8	77	132	26.1
Dec. 15	4	100	100	100	100	100	100	93	1.0	3.0	6.1	8.3	11.4	45.3	5.0	6.8	92	164	33.0
Dec. 15	5, 6	100	98	98	97	97	97	90	1.4	3.6	6.8	8.8	11.9	45.8	5.2	7.0	98	165	33.9
March 15	3	93	92	92	92	92	92	80	.8	2.3	4.9	7.0	10.0	43.2	4.5	6.4	71	122	23.1
March 15	4	92	87	87	87	87	87	83	1.0	2.9	5.8	7.8	11.1	44.7	5.0	6.8	81	144	28.8
March 15	5, 6	95	90	90	90	90	90	90	1.1	3.2	6.2	8.2	11.2	43.9	5.1	6.5	85	145	28.0
April 15	3	97	88	87	87	87	85	77	.8	2.4	4.8	6.8	10.0	43.5	4.6	6.6	68	125	23.8
April 15	4	98	97	97	97	97	93	87	1.0	2.6	5.3	7.0	10.2	43.6	4.9	6.8	84	151	29.2
April 15	5, 6	97	95	95	92	92	92	85	1.0	2.9	5.7	7.9	11.1	44.8	5.0	7.0	86	159	32.6

1971-72, Atkins, Louisa County, Region 3

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	98	98	97	97	97	95	92	.7	1.6	3.2	5.5	7.9	40.3	3.8	6.3	53	139	24.5
Dec. 15	4	100	98	98	98	98	98	97	.8	1.7	3.4	5.8	8.2	40.6	4.0	6.3	59	146	25.4
Dec. 15	5, 6	97	97	97	95	95	93	93	1.0	2.0	3.7	6.1	8.6	40.7	4.2	6.8	62	162	29.3
March 15	3	98	98	97	92	92	90	88	.5	1.3	2.4	4.4	6.5	37.5	3.5	6.3	43	137	22.6
March 15	4	100	98	98	98	98	95	95	.8	1.8	3.4	5.8	8.1	40.8	4.0	6.8	58	168	30.6
March 15	5, 6	100	100	100	100	100	100	100	.9	1.7	3.4	5.8	8.2	40.8	4.0	6.4	59	151	26.1
April 15	3	100	93	93	93	93	92	92	.5	1.4	2.5	4.5	6.7	39.1	3.4	6.1	42	128	21.1
April 15	4	100	97	97	97	97	95	90	.6	1.4	2.8	5.0	7.2	41.1	3.7	6.4	52	140	24.5
April 15	5, 6	98	97	97	97	97	97	97	.9	1.7	3.2	5.6	7.9	40.9	4.0	6.3	57	144	24.9

1971-72, Waddell, Prince Edward County, Region 4

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	73	70	70	70	70	68	67	.6	1.4	3.0	5.2	7.5	40.1	3.8	6.3	37	98	16.9
Dec. 15	4	90	87	87	87	87	87	85	.8	1.7	3.5	6.0	8.3	41.2	4.1	6.7	54	145	26.5
Dec. 15	5, 6	97	92	92	92	92	92	92	1.0	1.8	3.6	6.1	8.4	41.7	4.2	6.7	60	153	27.8
March 15	3	90	87	87	85	85	85	83	.6	1.3	2.6	4.8	7.0	41.5	3.8	6.2	47	122	21.8
March 15	4	88	87	87	87	87	85	83	.8	1.6	3.3	5.7	8.0	42.2	4.1	6.9	54	146	27.1
March 15	5, 6	91	86	86	86	86	86	86	1.0	1.8	3.5	5.9	8.1	42.6	4.0	6.6	51	141	25.9
April 15	3	90	86	86	86	86	86	83	.6	1.3	2.7	4.8	6.9	40.6	3.4	5.8	37	105	17.2
April 15	4	98	95	95	93	93	93	88	.7	1.4	2.9	5.1	7.4	40.5	3.8	6.2	51	128	22.1
April 15	5, 6	98	97	97	97	97	97	93	.8	1.6	3.4	5.7	8.0	43.5	3.9	6.7	55	157	30.0

1971-72, Carter, Campbell County, Region 5

Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	19	1	2	3	4	5	19	10	19	10	19	19
Dec. 15	3	47	47	47	47	47	47	43	1.0	2.4	4.8	7.2	9.4	41.7	4.3	6.6	34	72	13.1
Dec. 15	4	82	78	78	78	78	78	78	1.3	3.1	5.8	8.5	10.6	41.4	4.7	6.6	64	128	22.9
Dec. 15	5, 6	87	87	87	85	85	85	85	1.4	3.3	6.3	9.2	11.3	41.6	4.8	6.8	74	150	27.9
March 15	3	61	61	61	61	61	59	53	.8	2.1	4.4	7.1	9.2	41.8	4.5	7.1	48	98	17.9
March 15	4	85	83	83	82	82	82	73	1.0	2.5	5.0	7.7	9.9	42.4	4.5	6.9	64	130	24.7
March 15	5, 6	92	90	90	90	90	90	88	1.1	2.8	5.7	8.3	10.6	42.7	4.8	6.8	77	151	28.2
April 15	3	74	74	74	74	74	74	69	.8	2.0	4.5	7.0	9.5	42.1	4.5	6.8	58	117	21.5
April 15	4	87	87	87	87	87	87	87	.9	2.4	5.0	7.7	10.1	42.0	4.6	6.7	69	145	26.4
April 15	5, 6	93	93	93	93	93	93	90	1.0	2.5	5.2	7.8	10.1	40.8	4.5	6.3	72	135	23.8

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Planting Date	Root Collar Diameter	Survival at Age							Height (feet) at Age						DBH (inches) at Age		Basal Area at Age		Cords at Age
		1	2	3	4	5	10	18	1	2	3	4	5	18	10	18	10	18	18
Dec. 15	3	87	85	85	85	85	85	85	.8	1.9	4.2	6.9	9.9	43.1	4.5	6.6	67	140	27.0
Dec. 15	4	98	97	97	97	97	97	93	1.0	2.2	4.5	7.3	10.2	43.5	4.6	6.6	78	156	30.0
Dec. 15	5, 6	100	98	98	98	98	98	98	1.0	2.1	4.5	7.3	10.2	43.6	4.8	6.7	83	166	32.0
March 15	3	92	90	90	90	90	90	90	.7	1.6	3.3	5.8	8.5	41.8	4.3	6.3	62	134	24.2
March 15	4	98	98	98	98	98	98	93	.8	1.8	3.6	6.2	8.9	42.1	4.4	6.4	70	145	26.3
March 15	5, 6	98	98	98	98	98	98	95	1.0	1.9	4.0	6.5	9.2	42.2	4.3	6.4	70	146	26.3
April 15	3	85	85	85	85	85	85	80	.7	1.4	2.9	5.4	8.0	41.5	4.2	6.3	56	118	21.1
April 15	4	90	87	87	87	87	85	80	.8	1.5	3.4	6.0	8.8	42.0	4.3	6.3	59	118	21.5
April 15	5, 6	75	75	75	75	75	75	73	.9	1.9	3.7	6.4	9.2	43.4	4.6	6.6	60	118	22.4