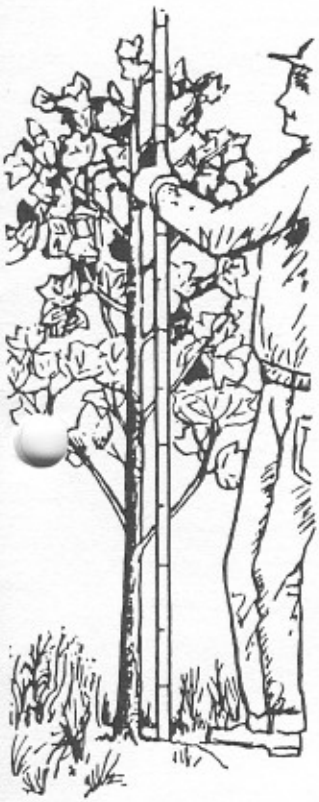

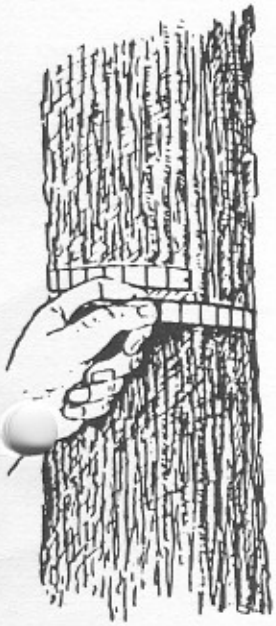

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ADDITIONAL TESTS OF ROOT PRUNING LOBLOLLY PINE SEEDLINGS IN THE SEEDBED

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Abstract

Five separate undercutting studies that involved varying the frequency, timing, and depth of undercutting were installed in 1988, 89, 90, and 91. Lateral root pruning was done each time undercutting was done. The studies were installed at our New Kent and Sussex nurseries.

Survival of unpruned control seedlings was high in all of the studies, ranging from 94 to 97 percent, leaving little room for improvement from root pruning. Root pruning, combining treatments and years, improved survival by only about 1 percentage point. There was also a slight improvement in height growth from root pruning, averaging about 0.2 foot after 3 years in the field.

Introduction

Earlier studies were installed at our New Kent nursery in 1977 and 1982, and the results of these studies were reported in Occasional Report #58 and #72. These two earlier studies were similar: a control treatment was compared to 6 different undercutting treatments which involved either 1, 2, or 3 undercuttings on 3 different dates. In both studies, the undercutting treatments had no effect on survival.

After we developed a second loblolly pine nursery in Sussex County, we decided to look at root pruning again. Studies were installed in 1988, 1989, and 1990 in which identical treatments were applied at both the New Kent and Sussex nurseries. In 1991, a smaller study was installed just at the Sussex nursery. The soils at both nurseries have a deep, sandy, top soil containing 90 percent or more sand.

1988 Study

Procedure

Seedlings were undercut 4 times on the following dates:

Sussex	New Kent
July 27	August 1
August 19	August 22
September 16	September 12
October 5	October 5

Undercutting was applied to a 20-foot-long section of seedbed in four widely separated seedbeds at each nursery. We used a homemade, stationary blade for the undercuttings. The target depth was 5½ inches for all undercutting. The last 3 feet of each 20-foot-long undercut plot was laterally pruned using a flat-blade spade to cut straight down midway between each drill row. Lateral pruning was done just before undercutting. All plots were irrigated for an hour before pruning and again for 1 to 2 hours after pruning to prevent, or at least minimize, wilting.

Seedlings were lifted on March 6 at New Kent and March 13 at Sussex. We lifted a 1½-foot-wide sample across the bed, from the center of each 3-foot plot that was both undercut and laterally pruned. The sample was taken from drill rows 2 through 7. A short distance past the undercutting plot, we lifted a comparable sample of unpruned check seedlings.

We sorted through the seedlings from each sample (2 treatments from each of 8 seedbeds) and picked out all seedlings between $^{4.5}/_{32}$- and $^{6.5}/_{32}$-inch root collar diameter. Then we counted these into piles of 10 seedlings each and randomly selected 2 piles of 10 to combine for a 20-seedling row in the field. The seedlings were planted on March 22 on the Appomattox-Buckingham State Forest in the central Piedmont of Virginia. They were planted by seedbed location, with the 2 treatments from each seedbed location (check and root pruned) randomly assigned to each of 8 blocks.

Results

Survival was tallied and heights measured for 3 years following planting (Table 1). Survival didn't change between age 1 and age 3, and root pruned seedlings survived 2.5 percentage points better than unpruned seedlings and were .27 feet taller at age 3. The survival difference was not statistically significant, but the height difference at age 3

resulted in the probability of a larger F = 0.173 and 0.032 respectively.

Table 1. Average survival at age 1, 2, and 3 and average height at age 3 for the 1988 Study.

	Survival			Height
	Age 1	Age 2	Age 3	Age 3
Check	95.6	95.6	95.6	5.12
Pruned	98.1	98.1	98.1	5.39

1989 Study

In 1989, we installed two studies, a main study and a pilot study at both nurseries, using a recently purchased Summit undercutter. This undercutter was more accurate in depth control and produced a cleaner cut.

Main Study

Procedure

Seedlings were undercut once, twice, or 4 times, and for the 2- and 4-cut treatments, we undercut at either a constant or increasing depth, giving a total of 7 treatments:

1. Undercut once, in July, at 3-inch depth
2. Undercut once, in October, at 5-inch depth
3. Undercut twice, in July and September, at 3- and 5-inch depths
4. Undercut twice, in July and September, at 5-inch depths
5. Undercut 4 times; in July, August, September, and October; at 3-, 4-, 5-, and 5-inch depths
6. Undercut 4 times; in July, August, September, and October; at 5-inch depths
7. Check, not undercut

The actual undercutting dates were:

Sussex	New Kent
July 24	July 26
August 15	August 16
September 13	September 14
October 10	October 12

Undercutting treatments were randomly applied to entire beds, using the 7 interior beds of two 9-bed sections at Sussex and one 9-bed section at New Kent. These 3 sections provided 3 replications of the 7 treatments.

Lateral pruning was done by hand right after the undercutting, using a flat-blade spade pushed straight down midway between the drill rows and outside the outer drill rows. Lateral pruning was done in 3 plots, each 2 feet long, within each undercut bed.

Seedbeds were irrigated before and after undercutting. Our intention was to prevent wilting, and we were generally successful, although we had some slight wilting at times.

We lifted the seedlings at Sussex on December 5, lifting a 4-square-foot sample (1 foot wide across the bed) from each of the 3 lateral pruning plots in each seedbed. The seedlings were kept in cold storage until December 21, when they were separated by root collar diameter. Small seedlings (below $^{4}/_{32}$) were discarded, and proportional numbers of seedlings from each diameter class from each of the 3 samples were selected for four 20-seedling rows in the field. This was done separately for each of the 7 treatments of each of the 2 seedbed replications.

The seedlings at New Kent could not be lifted until January 8, because the seedbeds had been frozen continuously since early in December. We measured and selected the seedlings for planting the same day, following the same procedures in lifting, measuring, and selecting seedlings as we did at Sussex.

The seedlings were planted on the Appomattox-Buckingham State Forest on January 9. We installed 4 randomized blocks, with a 20-seedling row of each of the 7 treatments from each of the 3 seedbed replications in each block, for a total of 1,680 seedlings.

Seedbed Results

Root pruning decreased diameter growth slightly, as shown in Table 2. The single

pruning in October had the smallest effect on diameter growth, followed by the single pruning in July. There was no difference between pruning 2 or 4 times, but pruning at a constant depth did not reduce diameter as much as pruning at an increasing depth.[1] Average seedbed densities for the 7 treatments ranged from 25.4 to 27.9 per square foot (including undersized seedlings that were discarded).

Table 2. Average root collar diameter when lifted (in 32^{nds} inch).

Treatment	Diameter
1. July, 3"	5.07
2. October, 5"	5.27
3. July & September, 3" & 5"	4.79
4. July & September, 5"	5.04
5. July, August, September, October; 3, 4, 5, & 5"	4.82
6. July, August, September, October; 5"	5.03
7. Check	5.63

Root pruning had a striking effect on root morphology (Figure 1); the more frequent the pruning, the greater the effect. Seedlings pruned 4 times had many more fine roots and mycorrhizae; and tended to have diffuse, multiple tap roots (somewhat resembling a soft brush). It was possible to locate where each undercutting occurred on many of the seedlings undercut at increasing depths, because 2 or more new "sinker roots" often formed after each cut.

Field Results

After one season in the field, average survival among the 6 root pruning treatments ranged from 97.1 to 98.8 percent while survival of unpruned check seedlings was 96.2 percent (Table 3). After three seasons, survival ranged from 94.5 to 96.7 among root pruned treatments and was 91.2 for check seedlings. Between the first and third season, cronartium fusiform killed 26 seedlings, 1.5 percent, and this mortality was

[1]Mean root-collar diameters for the 7 treatments and 3 seedbed replications were subjected to an analysis of variance with orthogonal comparisons. Check seedlings were significantly larger than the average of all pruning treatments (probability of a larger F = 0.0004). Seedlings pruned once were significantly larger than the average of seedlings pruned 2 or 4 times (probability of a larger F = 0.033). For seedlings pruned 2 or 4 times, those pruned at a constant depth were almost significantly larger than those pruned at an increasing depth (probability of a larger F = 0.085).

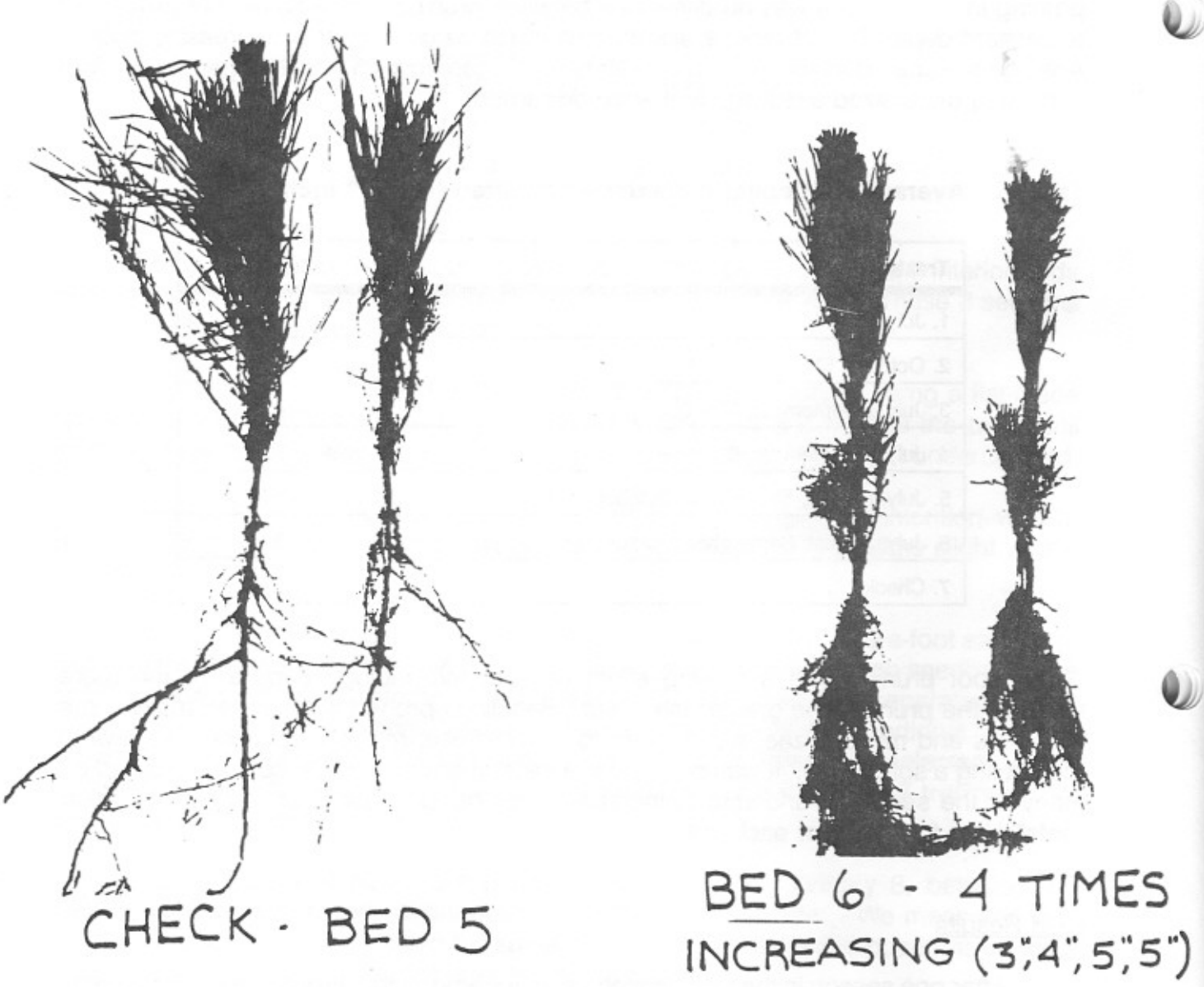

Figure 1. Representative check seedlings on left and seedlings pruned 4 times at increasing depths on right.

not evenly distributed over the 7 treatments (Table 3). Treatments involving 4 prunings and the check treatment suffered the most mortality from fusiform, which should be coincidental and not related to treatments.

An analysis of variance was performed on average survival percent at age 3, after transforming to arc sine percent. The main effects of root pruning and seedbed location, and their interaction, were not significant (probability of a larger F = 0.37, 0.08, and 0.51 respectively). Orthogonal comparisons were made among root pruning treatments, and none were significant. The comparison of the check with the average of the 6 root pruning treatments came close (probability of a larger F = 0.053). Considering the uneven mortality from rust after age 1, comparisons of survival at age 1 may be more meaningful. After one season, the improvement from root pruning is considerably less, 1.7 versus 4.3 percentage points (Table 3).

Table 3. Average survival at age 1 and 3, mortality caused by Fusiform rust between age 1 and 3, and average height at age 3.

	Survival Percent		Mortality from Fusiform	Height
Treatment	Age 1	Age 3		Age 3
1. July, 3"	97.5	94.6	1.7	5.8
2. October, 5"	97.9	96.7	0.8	5.8
3. July & September, 3 & 5"	98.3	95.4	1.2	5.6
4. July & September, 5"	98.8	96.2	0.4	5.6
5. July, August, September, October; 3, 4, 5, & 5"	97.9	95.8	2.1	5.8
6. July, August, September, October; 5"	97.1	94.5	2.1	5.6
7. Check	96.2	91.2	2.5	5.6

Height growth was improved slightly by root pruning. At age 3, the overall average height for all 6 root pruning treatments was 5.69 feet, compared to 5.56 feet for unpruned check seedlings (Table 3). An analysis of variance was performed and orthagonal comparisons were made among root pruning treatments. Only the 0.16 foot difference between seedlings pruned at an increasing or constant depth was significant (probability of a larger F = 0.044)

PILOT STUDY

Procedure

We installed some small plots to see what might happen if we started undercutting in late June, when the seedlings were only 2 or 3 inches tall. We undercut a 20-foot section of seedbed at Sussex at a depth of about 1.5 inches on June 20. Undercutting was repeated on July 26 at 4 inches, August 15 at 5 inches, September 13 at 4.5 inches, and finally a fifth undercutting was done on October 11, at 5 inches. A small plot was lateral pruned by hand as in the main study.

We undercut a 20-foot section in each of 2 seedbeds, side by side, at New Kent, on June 26 at a depth of 3 inches. One bed was undercut a total of 5 times and the other 3 times. Small lateral pruning plots were installed. Pruning dates and depths were July 26 at 4 inches, August 16 at 5 inches, September 14 at 5 inches, and October 12 at 5 inches. Lateral pruning was done immediately before undercutting.

Samples were lifted on the same dates and seedlings were selected for planting following the same procedures as for the main study. The seedlings were planted on January 12 adjacent to the main study, in 3 randomized blocks, planting a 20-seedling row of both pruned and unpruned seedlings from each seedbed, for a total of 18 rows.

Results

Survival after one and three seasons and average height after three seasons are shown in Table 4. Survival of root pruned seedlings was exceptional, all 180 seedlings (9 rows) survived. An analysis of variance was performed on average survival percent at age 3, after transforming to arc sine percent[2]. The average difference of 5.6 percentage points was highly significant (probability of a larger F = 0.00001).

Root pruned seedlings also grew faster. At age 3, they averaged 0.21 foot taller than check seedlings, and in an analysis of variance, this difference was significant (probability of a larger F = 0.040).

[2]This may not be meaningful when all 9 rows of root pruned seedlings had 100 percent survival.

Table 4. Average survival percent at age 1 and 3 and average height (in feet) at age 3.

	Survival Percent		Height
Nursery Treatment	Age 1	Age 3	Age 3
Sussex, 5 cuts starting at 1½"	100	100	5.8
Sussex, Check	100	95.0	5.7
New Kent, 5 cuts starting at 3"	100	100	5.7
New Kent, Check	91.7	91.7	5.6
New Kent, 3 cuts starting at 3"	100	100	5.9
New Kent, Check	96.7	96.7	5.4

Compared to the main study, unpruned control seedlings survived about the same in both studies (94.4 percent in the pilot study versus 96.2 or 91.2 in the main study after 1 or 3 years). However, the root pruned seedlings survived better in the pilot study, 100 percent versus 97.9 or 95.5 in the main study after 1 or 3 years. This suggests that starting undercutting about a month earlier than normally done, when the seedlings are still very small, might improve survival. There would be risks in starting this early, because root systems have not yet grown enough to hold the soil together, and the beds could break up badly.

1990 Study

Procedure

In addition to the Summit undercutter that we purchased and used for the 1989 study, we purchased a wrenching attachment for the undercutter and a Summit lateral pruner. We used all of these in the 1990 study. Identical studies were installed at New Kent and Sussex:

1. Undercut twice, in early August and late September, at 3- and 4.5-inch depths
2. Undercut twice, in early August and late September, both times at 4.5-inch depths
3. Undercut once, in early August, at 4.5-inch depth and then wrenched in late September at 4.5 inches
4. Undercut 4 times; in early August, late August, late September, and late October; at 3-, 4-, 4.5-, and 4.5-inch depths

5. Undercut 4 times; in early August, late August, late September, and late October; at 4.5-inch depths
6. Undercut once, in early August, at 4.5-inch depth and then wrenched three times in late August, late September, and late October at 4.5 inches
7. Check, not undercut

The actual undercutting dates were:

Sussex		New Kent	
2 Times	**4 Times**	**2 Times**	**4 Times**
August 1 & 3	August 1 & 3	August 7 & 8	August 7 & 8
---	August 29	---	August 30
September 26	September 26	September 27	September 27
---	October 24	---	October 26

All root pruning treatments included lateral pruning, done just after undercutting or wrenching. Beds were irrigated before (if necessary) and after pruning to avoid (or at least minimize) wilting. Treatments were applied to full-length beds in 3 different sections at both New Kent and Sussex, 42 beds in all, counting the control beds.

Seedlings were lifted on December 3 and 4 at New Kent and December 10 at Sussex. We lifted 3 samples from each seedbed, each sample 3 inches wide across the bed for a 1-square-foot sample. The total number of samples lifted was 126: 3 samples/seedbed times 7 treatment beds/section times 6 sections.

Seedlings were separated by root collar diameter, keeping each sample separate. The New Kent seedlings were measured on December 4 and the Sussex seedlings on December 11. Seedlings smaller than $^{3.5}/_{32}$ were discarded. From the remaining seedlings, proportional numbers of seedlings were randomly taken from each diameter class from each of the 9 samples (3 samples from each of 3 sections) to obtain 80 seedlings (enough for four 20-seedling rows) from each undercutting treatment from each nursery. To prevent roots from drying while all this measuring and counting was done, we misted the roots with water frequently and kept them covered with plastic.

The seedlings were planted on December 13 on the Appomattox-Buckingham State Forest. We installed 4 randomized blocks, with a 20-seedling row of each treatment from each nursery in each block, for a total of 1,120 seedlings.

Seedbed Results

Root pruning again reduced diameter slightly (Table 5). Pruning 4 times reduced diameter slightly more than pruning twice.

Table 5. Average root collar diameter (32^{nds} inch) by treatment and nursery (including seedlings less than $^{3.5}/_{32}$ inch) and average seedbed density (seedlings per square foot).

	New Kent		Sussex		
Treatment	**Diameter**	**Density**	**Diameter**	**Density**	**Average Diameter**
1. Undercut 2 times, increasing	5.40	31.8	5.32	24.8	5.36
2. Undercut 2 times, constant	5.26	35.1	5.58	24.3	5.42
3. Undercut 2 times, wrenched	5.49	32.8	5.37	23.7	5.43
4. Undercut 4 times, increasing	5.34	33.3	5.13	25.0	5.24
5. Undercut 4 times, constant	5.07	36.3	5.34	24.3	5.20
6. Undercut 4 times, wrenched	5.06	32.3	5.10	24.2	5.08
7. Control	5.61	32.7	5.80	26.0	5.70

Field Results

Survival changed very little between age 1 and age 3 (Table 6). Only 2 seedlings in the entire study died during the second season, and 1 seedling during the third season. An analysis of variance was performed on average survival at age 3, after transforming to arc sine percent. The main effects of root pruning and nursery, and their interaction, were not significant (probability of a larger F = 0.99, 0.34, and 0.89, respectively). Orthogonal comparisons were made among treatments and none were significant.

Root pruning did improve height growth slightly, primarily for Sussex seedlings (Table 6). The average difference between pruned (all 6 treatments combined) and control seedlings at age 3 was 6.97 versus 6.89 for a difference of .08 feet at New Kent and 7.38 versus 7.00 for difference of 0.38 feet at Sussex. An analysis of variance was performed on average heights at age 3. The main effect of root pruning was not significant (probability of a larger F = 0.35), but the main effect of nursery was (probability of a larger F = 0.003). The interaction of root pruning and nursery was not significant (probability of a larger F = 0.58). Orthogonal comparisons were made among treatments, and the only significant one was again the overall comparison of New Kent

and Sussex seedlings (probability of a larger F = 0.003).

Table 6. Average survival at age 1 and 3 and average height at age 3.

	New Kent			Sussex		
	Survival		Height	Survival		Height
Treatment	Age 1	Age 3	Age 3	Age 1	Age 3	Age 3
1. Pruned 2 times, increasing	91.2	91.2	7.0	95.0	95.0	7.2
2. Pruned 2 times, constant	92.5	92.5	7.2	96.0	94.8	7.2
3. Pruned 2 times, wrenched	93.8	92.5	7.2	93.8	93.8	7.7
4. Pruned 4 times, increasing	90.0	90.0	6.9	96.2	96.2	7.4
5. Pruned 4 times, constant	90.0	90.0	6.7	96.2	96.2	7.3
6. Pruned 4 times, wrenched	95.0	95.0	6.9	95.0	95.0	7.5
7. Control	93.5	93.5	6.9	95.0	93.8	7.0
Means	**92.3**	**92.1**	**7.0**	**95.3**	**95.0**	**7.3**

1991 Study

Procedure

This was a comparison of operationally root pruned and unpruned seedlings at the Sussex Nursery. Four sections were involved, and 8 of the 9 beds in each section were undercut and lateral pruned on August 21 and October 21. The center bed of each section was left unpruned as a check. The seedbeds were irrigated before and after pruning to avoid wilting.

Samples were lifted on January 2, 1992. We lifted a total of 16 samples, each sample 6 inches wide across the bed for 2 square feet per sample. In each of the 4 sections, we lifted 2 samples from the unpruned center bed and a single sample from each of the pruned beds on either side. Check and pruned samples were paired.

Seedlings for a 20-seedling row in the field were randomly selected from each of the 16 samples. The seedlings from each paired sample, a pruned and a check, were used to plant a replication in the field, for a total of 8 replications. The seedlings were planted on January 6 on the Appomattox-Buckingham State Forest.

When the samples were lifted, they were counted into 2 piles, by drill row, as they

were lifted. Half of the seedlings were used for the field planting, and half were separated by root collar diameter on January 30. Average diameter and seedbed density was $^{4.70}/_{32}$ inches and 35.9 per square foot for pruned seedlings; and $^{4.82}/_{32}$ inches and 37.9 per square foot for check seedlings.

Results

Survival after one and three seasons in the field and average height after three seasons is presented in Table 7. Analyses of variance were performed on third year survival percents (after transforming to arc sine percent) and third year heights. The difference in survival at age 3 was not significant (probability of a larger F = 0.291), but the difference in average height at age 3 was significant (probability of a larger F = 0.027).

Table 7. Average survival at age 1 and 2 and average height (in feet) at age 3.

	Survival Percent		Height
	Age 1	Age 3	Age 3
Pruned	96.2	94.4	6.79
Check	98.1	96.2	6.55

Discussion

Survival improvement from root pruning was slight, with the exception of the 1989 pilot study when undercutting was started much earlier than is normally done. Improvement in height was also slight. Overall average improvements in survival and height are summarized in Table 8, along with the results of the analyses of variance.

Table 8. Survival and height differences, root pruned minus check.

Study	Survival	Height
1988	+2 (N.S.)	+.27 (.032)
1989, Main	+2 (N.S.)	+.13 (N.S.)
1990	0 (N.S.)	+.24 (N.S.)
1991	-2 (N.S.)	+.24 (.027)

The excellent survival of unpruned check seedlings (96, 96, 94, and 96 in 1988, 1989, 1990, and 1991 respectively) made it difficult for root pruning to improve survival substantially. Survival from operational planting is seldom as good as survival on research plots where seedlings are stored and handled carefully and planted properly. It is possible that root pruning might provide more improvement with operational planting.

Frequent root pruning greatly changed root morphology (Figure 1), resulting in more compact root systems with many more fine roots and many more mycorrhizae. These root systems resembled a soft paint brush, and were more difficult to place properly in the planting slit made by a standard planting bar. Roots tended to hang up on the sides of the hole, making it more difficult to get the roots deep and straight. Unpruned seedlings with straight, stiff taproots are easier to plant.

If root pruning does not significantly improve survival and growth in the field, it is hard to justify. Root pruning reduces top growth in the seedbed, but it reduces growth of all seedlings, large and small. Top-clipping, on the other hand, only slows the top growth of seedlings that are growing too fast, and top-clipping is an easier and cheaper operation than root pruning.