OUTPLANTING PERFORMANCE IN VIRGINIA OF GENETICALLY IMPROVED VIRGINIA PIEDMONT LOBLOLLY PINE SEEDLINGS PRODUCED IN SOUTH CAROLINA AND VIRGINIA NURSERIES

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Abstract.--This study compared the growth and development of wrenched and non-wrenched Virginia Piedmont loblolly pine (Pinus taeda L.) seedlings produced in Westvaco's South Carolina nursery to those produced by the Virginia State nursery at New Kent, Virginia, correlating seedling characteristics to outplanting performance in Virginia. Wrenching reduced the size of the seedlings in both nurseries. At the time of planting, root starch percent was lowest in the wrenched seedlings from both nurseries. The wrenched seedlings from Virginia grew the best among all treatments. The meaning of these results is discussed.

Additional keywords: wrenching, root starch, loblolly pine.

INTRODUCTION

Growing seedlings in one region for outplanting in another is not uncommon. When an organization has only one nursery it is important to define nursery practices which will ensure good survival and growth at many planting site environments. Situations arise where it is necessary to bring seedlings from a distant nursery because there is a shortage of seedlings to meet a local need. There is always concern about how well seedlings grown in one environment will grow after planting into a different climate.

The ability to grow seedlings in Westvaco's one nursery in South Carolina for outplanting in Virginia is operationally and financially appealing. Westvaco needs to efficiently and consistently produce the highest quality seedlings possible from genetically improved seed. As more genetically improved seed becomes available, producing seedlings in South Carolina which are physiologically adapted to their ultimate planting environments, possibly hundreds of kilometers away, creates higher risks. The biological advantages of growing seedlings near the coast of South Carolina are the mild winters and longer growing season. But the milder winters may not allow the seedlings to physiologically adapt to the same degree they might if grown in Virginia - seedlings might not get enough chilling hours in South Carolina.

Several researchers have reported on the beneficial effects of wrenching and undercutting or root-pruning seedlings (including loblolly pine) to improve survival (Rook, 1971; Tanaka et al., 1976, Dierauf 1984). Rook (1971) found

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that undercutting and wrenching Pinus radiata D. Don seedlings monthly increased the concentrations of reducing and total soluble sugars over those treatments applied every two weeks, weekly, or not at all for three months. Miller et al. (1984) found that wrenched loblolly pine seedlings had lower root starch contents than seedlings not subjected to wrenching.

This study was designed to answer some of the questions concerning how an identical seed lot of Virginia Piedmont loblolly pine will grow in two separate nurseries - one in South Carolina and one in Virginia, how root wrenching affects growth and development and ultimately how seedling characteristics relate to outplanting performance in Virginia.

PROCEDURE

Nursery Phase

Nurseries: Seed from a mixture of improved Virginia Piedmont loblolly pine seed collected from Westvaco's Virginia Piedmont seed orchard located in coastal South Carolina were sown in the Virginia Division of Forestry's nursery in New Kent, Virginia and Westvaco's nursery in Ravenel, South Carolina (Figure 1). With the exception of wrenching, routine nursery practices at each nursery were used.

Sowing: The seeds were hand-sown in early April 1982. Seven rows of seed were sown to a bed to obtain a seedling density of approximately 280 seedlings/m^2 (26 seedlings/ft^2.). In Virginia, 30.5 meters (100 ft.) of bed were sown; 18.3 meters (60 ft.) were sown in South Carolina.

Treatments: Two wrenching treatments were used in each nursery - three wrenches and no wrenching. Wrenched plots were cut once in July, August, and September at a depth of 18 to 20 centimeters (7 to 8 inches). The wrenching was carried out by digging a 30 cm (12 in.) deep trench across the bed so that the undercutting bar could be adjusted to the proper depth. Once the bar was properly positioned, the tractor pulled the bar the distance of the treatment plot.

Plot Size: The treatment plots were laid out along the length of each bed with some allowances made for digging trenches and for lifting the wrenching bar. Plot length was 2.4m (8 ft.) in Virginia. In South Carolina, it was 1.8m (6 ft.).

Measurements: Seedlings were harvested from each plot prior to each wrenching. A final seedling harvest was made in December 1982. A 1.2m (4 ft.) by 15.2cm (6 in.) grid was laid across the bed, and the five center rows were harvested separately. The number of seedlings was counted per row, placed in a labeled plastic bag, and immediately frozen on dry ice. The seedlings within a row were later defrosted, measured for height and caliper, and separated into pooled lots of needles, stems, and roots. These pooled samples were dried in an oven for 48 hours at 65° C and weighed. The total weight of each sample was divided by the number of seedlings to give an average needle, stem, and root dry weight for that row of seedlings. Average height and caliper were also computed. The needles were assayed for N, P, K, Ca, and Mg by the Soils/Analytical Group at the Westvaco Forest Science Laboratory. The roots were analyzed

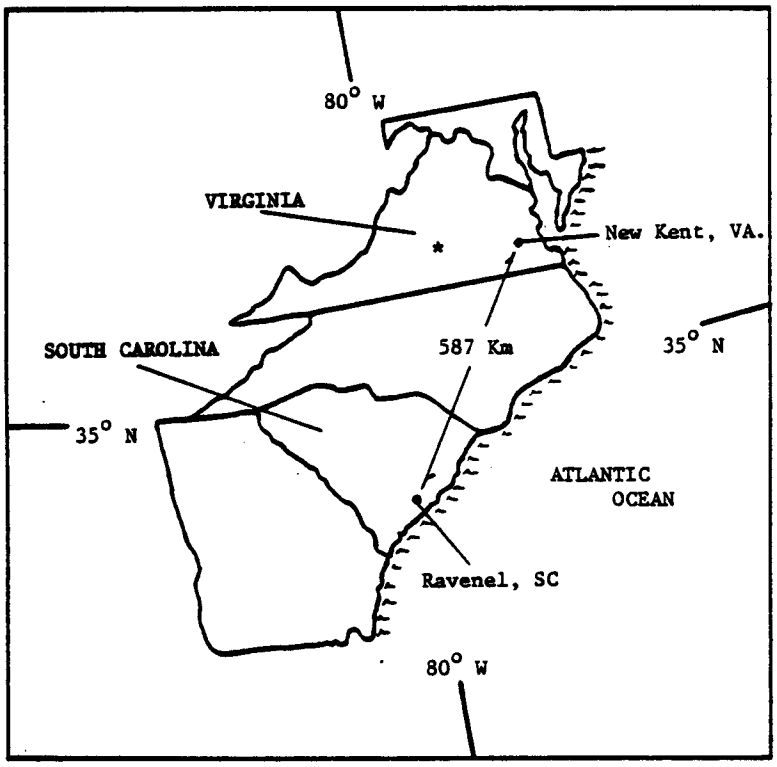

FIGURE 1. LOCATIONS OF THE NEW KENT, VA. AND RAVENEL S.C. NURSERIES. THE PLANTING SITE (*) IS LOCATED AT SPROUSES CORNER, VA.

for percent starch content using a method adapted from Haissig and Dickson (1979).

A harvest was made just before lifting in each nursery. In this case, ten randomly selected seedlings were placed in separate bags and frozen. Each was later separated into needles, stem, and roots, and the same analyses performed.

Prior to planting, an additional harvest was made. A bundle of twenty seedlings from each treatment was frozen in the field and later destructively sampled as previously described. These seedlings were considered indicative of seedling quality at the time of planting.

Design and Statistical Analysis: The experiments in each nursery were designed to be analyzed as one-way analysis of variance models having two treatments. Each was set up to be analyzed separately by month, but with the intention of looking for different trends in seedling growth between the two nurseries. Virginia and South Carolina had four and six replications of each treatment, respectively. The July through December data were analyzed as shown in Table 1. The mean of the five rows per plot was used as a treatment observation. Duncan's New Multiple Range Test was used to test differences between treatments.

Table 1. Analysis of variance model for the nursery data collected between July and December

Source of Variation	df
Treatments	1
Error	6
Total	7

Outplanting Phase

Site: The study was planted on the Hanes Tract in Buckingham County, Virginia, approximately 3.2 kilometers (2 miles) from Sprouses Corner. The hardwood conversion site was chopped and burned prior to planting.

Lifting: At lifting, all of the seedlings within a treatment for each nursery block were pooled together. The seedlings were then sorted into 30 separate bundles, each containing 20 randomly selected seedlings. Each treatment was bagged separately and placed in a cooler to await field planting. The South Carolina seedlings were lifted on January 28, 1983, and the Virginia seedlings were lifted February 23, 1983. The South Carolina seedlings were stored for 30 days while the Virginia seedlings were stored for only 15 days. The South Carolina seedlings were stored in Kraft paper bags with moisture barriers; the Virginia seedlings were stored in sealed plastic bags.

Planting: Field planting was on March 9, 1983. Weather conditions were ideal. Skies were overcast with light rain, and the temperature ranged from 4.4 to 7.2°C (40-45°F). The soil was moist. Velpar Gridballs® were applied to the site 30 days after planting at a rate of 454 grams (1 lb.) a.i./acre. Plant spacing was 1.2 x 3.1m (4 x 10 ft.). Seedling survival was 93% for the entire study.

Measurements: Each seedling was measured for height and caliper in April, July, and September 1983.

Design and Statistical Analysis: The design was a randomized complete block with four treatments per block, and twenty-six blocks. The treatments were Virginia wrenched, Virginia wrenched, South Carolina wrenched, and South Carolina wrenched. Ten trees per treatment were planted per block.

Actual height and caliper were analyzed as a completely randomized block design. Growth was analyzed as a completely randomized block design after subtracting the height and caliper in April from the final height and caliper of each seedling in September.

RESULTS

Wrenching reduced the size of the seedlings in both nurseries. Figure 2 shows the dramatic effect wrenching in July, August, and September 1982 had on seedling dry weight. By December, the wrenched seedlings had lower total dry weights than the non-wrenched seedlings. Figure 3 shows there were very little differences among treatments and between nurseries for root percent starch from July to September 1982. Wrenching reduced height, caliper, stem dry weight, and needle dry weight in both nurseries (Table 2). Wrenching tended to increase root dry weight in both nurseries even though there were no significant differences in South Carolina.

In December, root starch percent was significantly higher in wrenched South Carolina seedlings (8.5% wrenched versus 6.8% non-wrenched), but not in Virginia seedlings (10.8% for both) (Table 2). The South Carolina seedlings had uniform needle nutrient levels. Needle nutrient levels in the Virginia seedlings differed only for calcium between treatments (0.31% wrenched versus 0.27% non-wrenched).

The two nurseries grew physiologically and morphologically different seedlings by December (Table 2). The Virginia seedlings had higher starch levels, nine percent less N, and higher levels of P, Ca, and K than the South Carolina seedlings. Based on nutrient ratios (to nitrogen), the Virginia seedlings had higher proportions of P, Ca, Mg, and K. The South Carolina grown seedlings were larger than the Virginia seedlings (Figure 2).

Seedlings harvested just prior to lifting showed some of the trends apparent in the December seedlings (Table 3). Wrenched seedlings were smaller than non-wrenched in both nurseries. South Carolina seedlings were again larger than Virginia seedlings.

Root percent starch levels in the pre-lifted seedlings were very similar regardless of treatment and nursery (Table 3). At the time of lifting, both treatments showed an increase over December levels in both nurseries. The Virginia wrenched and non-wrenched seedlings increased by 11% and 26%, respectively. The South Carolina wrenched and non-wrenched seedlings increased by 55% and 56%, respectively.

Seedlings sampled just prior to planting do not show the same uniformity in root percent starch levels by treatment for both nurseries (Table 4). Handling and storage did not cause an appreciable change in starch levels for the non-wrenched seedlings. However, starch content dropped in both of the

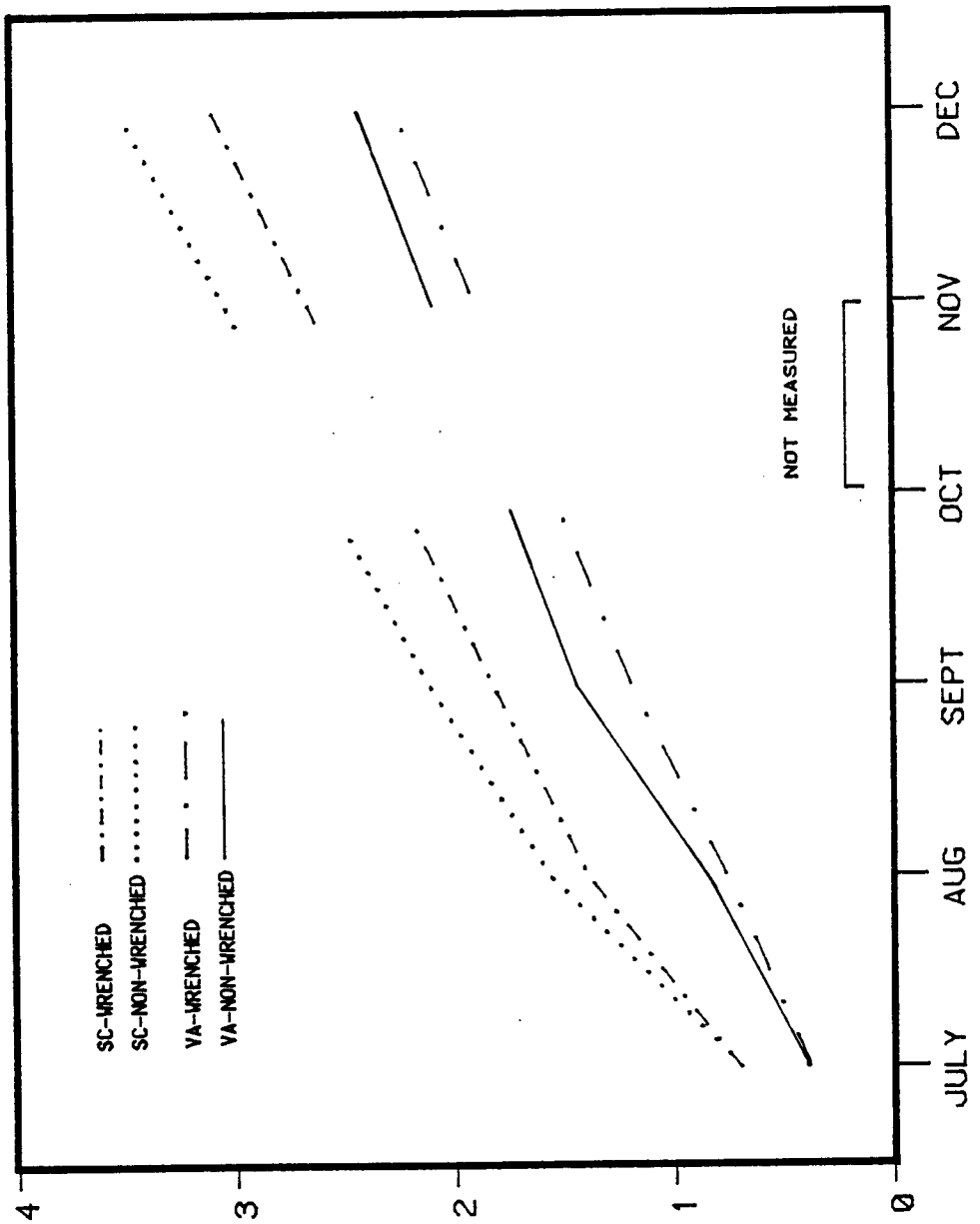

FIGURE 2. TOTAL DRY WEIGHT BY NURSERY AND WRENCHING TREATMENT.

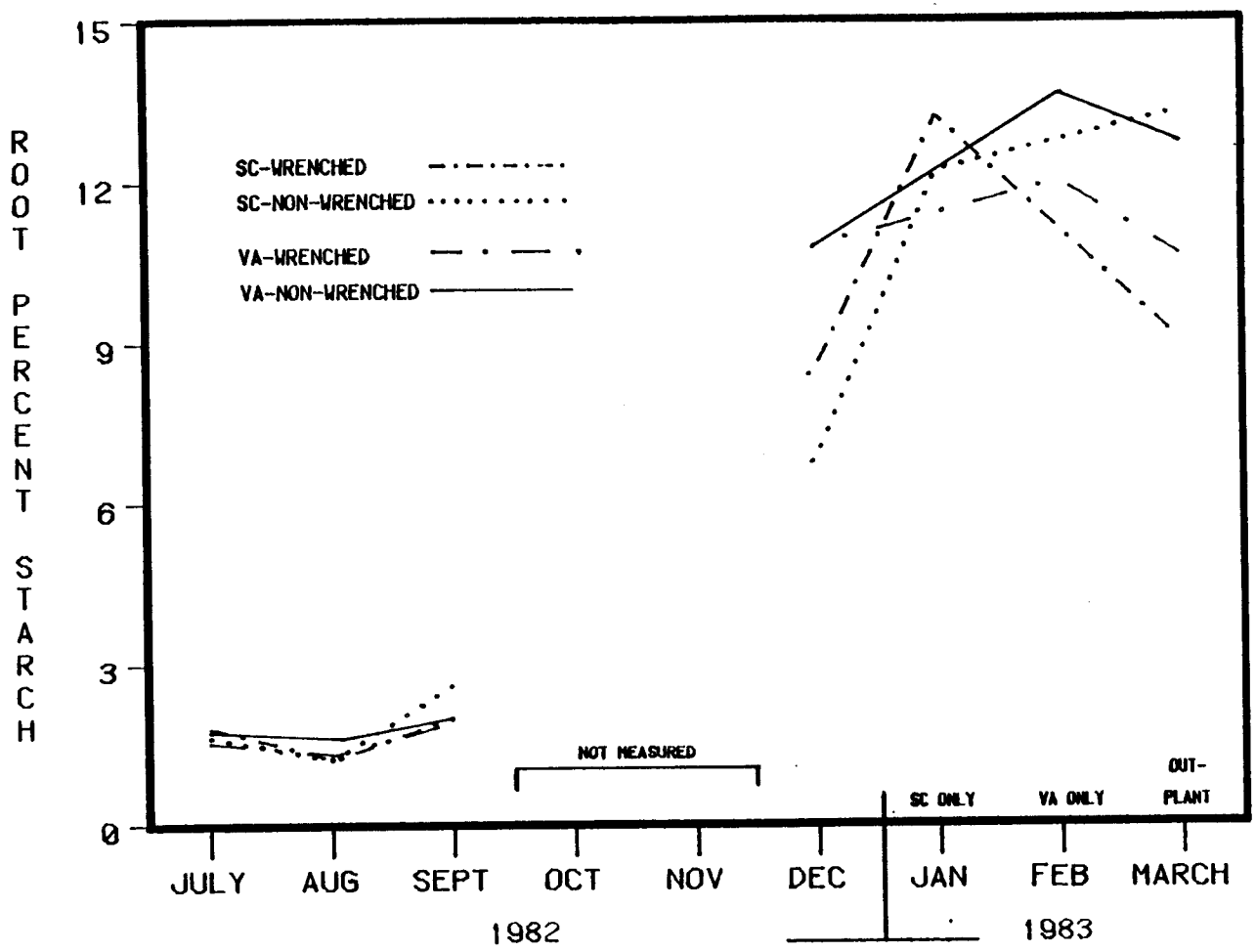

FIGURE 3. ROOT PERCENT STARCH BY NURSERY LOCATION AND TREATMENT FROM JULY 1982 THROUGH OUTPLANTING IN MARCH, 1983.

Table 2. Treatment means of loblolly pine seedlings grown in the Virginia Division of Forestry nursery and Westvaco's South Carolina nursery. Measurements were made in December 1982.

	NURSERY LOCATION					
	Virginia Treatment			South Carolina Treatment		
Variable	Wrenched	Non-Wrenched	Significance	Wrenched	Non-Wrenched	Significance
Seedling Components						
Height (cm)	15.5	19.2	**1/	21.0	24.0	*
Stem Caliper (mm)	3.0	3.4	*	3.9	4.2	NS
Needle Dry Weight (g)	0.97	1.08	NS	1.47	1.71	NS
Stem Dry Weight (g)	0.51	0.73	**	0.82	1.07	*
Root Dry Weight (g)	0.77	0.62	**	0.79	0.73	NS
Shoot/Root Ratio	1.79	2.43	**	2.67	3.42	*
Starch (root%)	10.8	10.8	NS	8.5	6.8	**
Needle Nutrients (to nitrogen)						
Nitrogen (%)	1.25	1.27	NS	1.40	1.39	NS
Phosphorus (%)	0.15	0.16	NS	0.13	0.13	NS
Calcium (%)	0.31	0.27	**	0.25	0.23	NS
Magnesium (%)	0.09	0.09	NS	0.09	0.09	NS
Potassium (%)	0.64	0.63	NS	0.54	0.53	NS
Needle Nutrient Ratios						
Nitrogen	100	100	nc	100	100	nc
Phosphorus	12	13	nc	9	9	nc
Calcium	25	22	nc	18	17	nc
Magnesium	7	7	nc	6	6	nc
Potassium	51	50	nc	39	38	nc

1/** Significant at 99% level.
* Significant at 95% level.
NS Non-significant.
nc Not calculated

Table 3. Treatment means of loblolly pine seedlings at time of lifting in the Virginia Division of Forestry nursery and Westvaco's South Carolina nursery. Virginia seedlings were lifted on February 23, 1983, and South Carolina seedlings were lifted on January 28, 1983.

	NURSERY LOCATION					
	Virginia Treatment			South Carolina Treatment		
	Wrenched	Non-Wrenched	Significance	Wrenched	Non-Wrenched	Significance
Root Dry Weight (g)	0.93	0.95	NS[1/]	1.36	1.98	NS
Stem Dry Weight (g)	0.61	0.91	**	0.96	1.42	NS
Needle Dry Weight (g)	1.05	1.34	**	1.94	2.68	NS
Shoot/root Ratio	1.87	2.51	**	2.16	2.16	NS
Starch (root %)	12.0	13.6	NS	13.2	12.2	NS

1/** Significant at 99% level.
NS Non-significant.

Table 4. Treatment means of loblolly pine seedlings prior to planting in the Virginia Division of Forestry nursery and Westvaco's South Carolina nursery. Seedlings were sampled in March 1983.

	NURSERY LOCATION				
	Virginia Treatment		South Carolina Treatment		
Variable	Wrenched	Non-Wrenched	Wrenched	Non-Wrenched	Treatment Differences
Seedling Components					
Height (cm)	15.0a[1/]	16.0b	20.0c	23.0d	**
Stem Caliper (mm)	3.7ab	4.1b	4.3b	4.5b	**
Needle Dry Weight (g)	1.39	1.69	1.89	2.03	NS
Stem Dry Weight (g)	0.50a	0.77b	0.85b	0.95b	**
Root Dry Weight (g)	0.90a	0.98a	1.33b	1.12ab	**
Shoot/Root Ratio	1.96a	2.54b	2.57b	2.86b	**
Starch (root%)	10.6a	12.7b	9.0a	13.3b	**
Needle Nutrients					
Nitrogen (%)	1.06ab	1.10ab	1.18b	1.19b	**
Phosphorus (%)	0.16a	0.16a	0.13b	0.13b	**
Calcium (%)	0.33a	0.31ab	0.30b	0.28b	**
Magnesium (%)	0.11	0.10	0.10	0.11	NS
Potassium (%)	0.53a	0.51a	0.44b	0.45b	**
Needle Nutrient Ratios					
Nitrogen	100	100	100	100	
Phosphorus	15	14	11	11	
Calcium	32	28	25	23	
Magnesium	10	9	8	9	
Potassium	50	47	37	38	

1/ Treatment means followed by the same letters are not significantly different from each other.

2/ ** significant at the 99% level.
* significant at the 95% level.
NS Non-significant

Differences between treatment means are read across the table.

wrenched treatments. The Virginia wrenched seedlings dropped 12% from 12.0% to 10.6%. The South Carolina wrenched seedlings dropped 32% from 13.2% to 9%. The wrenched seedlings dropped back at planting to starch levels that were very close to their starch levels in December.

The twenty seedlings from each treatment harvested at the time of planting mirror some of the trends found in the seedlings in December. The Virginia seedlings had higher nutrient proportions at the time of planting. The Virginia seedlings were smaller in height and dry weight. The Virginia wrenched seedlings had the smallest shoot:root ratios. However, by planting time, root starch had shifted. Root percent starch fell into two mutually exclusive groups by the March planting date - wrenched versus non-wrenched seedlings (Table 4).

The wrenched seedlings grown in the Virginia nursery significantly outgrew the other treatments after outplanting (Table 5). The South Carolina wrenched seedlings came in a close second for height (Table 5). Figure 4 demonstrates that the South Carolina seedlings maintained their nursery size advantage over the Virginia seedlings. However, the Virginia wrenched seedlings show a steeper upward height growth trend than the other treatments.

DISCUSSION

The data taken on the 20 seedlings of each treatment at the time of planting offered some explanations as to why the Virginia wrenched seedlings performed so much better than the other treatments. Several trends showed up. It is important to realize that no one feature makes a good seedling, but rather a combination of factors which work well together.

First, the seedlings in all treatments had adequate starch levels (9-12%) in their roots as judged by other experiments (Miller, et al. 1984). Total starch contents did not appear to be limiting, though wrenched seedlings had significantly lower starch contents than non-wrenched.

Second, seedling needle nutrient levels were not limiting (Boyer and South, 1984; Miller et al. 1984). The Virginia seedlings had higher nutrient levels and higher nutrient ratios.

Third, the Virginia wrenched seedlings had the lowest shoot:root ratios of any of the treatments.

Seedling performance is dependent on a number of interacting variables which hinder or induce good growth. In this case, the Virginia wrenched seedlings seemed to have the best combination of morphological and physiological characteristics. Their small size, low top-to-root relationship, adequate starch levels, and high nutrient levels gave them a slight advantage over the South Carolina grown seedlings.

The lower root starch percent levels in the wrenched seedlings and the better field growth of wrenched seedlings cannot be explained. The starch levels were low to average as judged by other experiments in the wrenched seedlings. Soluble sugars such as glucose, fructose, and sucrose were not measured and are rapidly transported and usable energy sources. These soluble sugars may have played some role. Why did wrenching reduce starch content at planting

Table 5. Average first year change[1/] in field height (cm) and stem caliper (mm) for loblolly pine seedlings grown in the Virginia Division of Forestry nursery and Westvaco's South Carolina nursery.

	NURSERY LOCATION				
	Virginia Treatment		South Carolina Treatment		
Growth	Wrenched	Non-Wrenched	Wrenched	Non-Wrenched	Significance Level
Height (cm)[2/]	19.64a*	13.89c	17.19b	15.70b	**
Stem Caliper (mm)	2.07a	1.58b	1.60b	1.38b	**

1/ Each mean is the difference between the April and September 1983 measurement.

2/ All treatment means are significantly different at the 99% level. Treatment means followed by the same letters are not significantly different from each other. Differences between treatment means are read across the table.

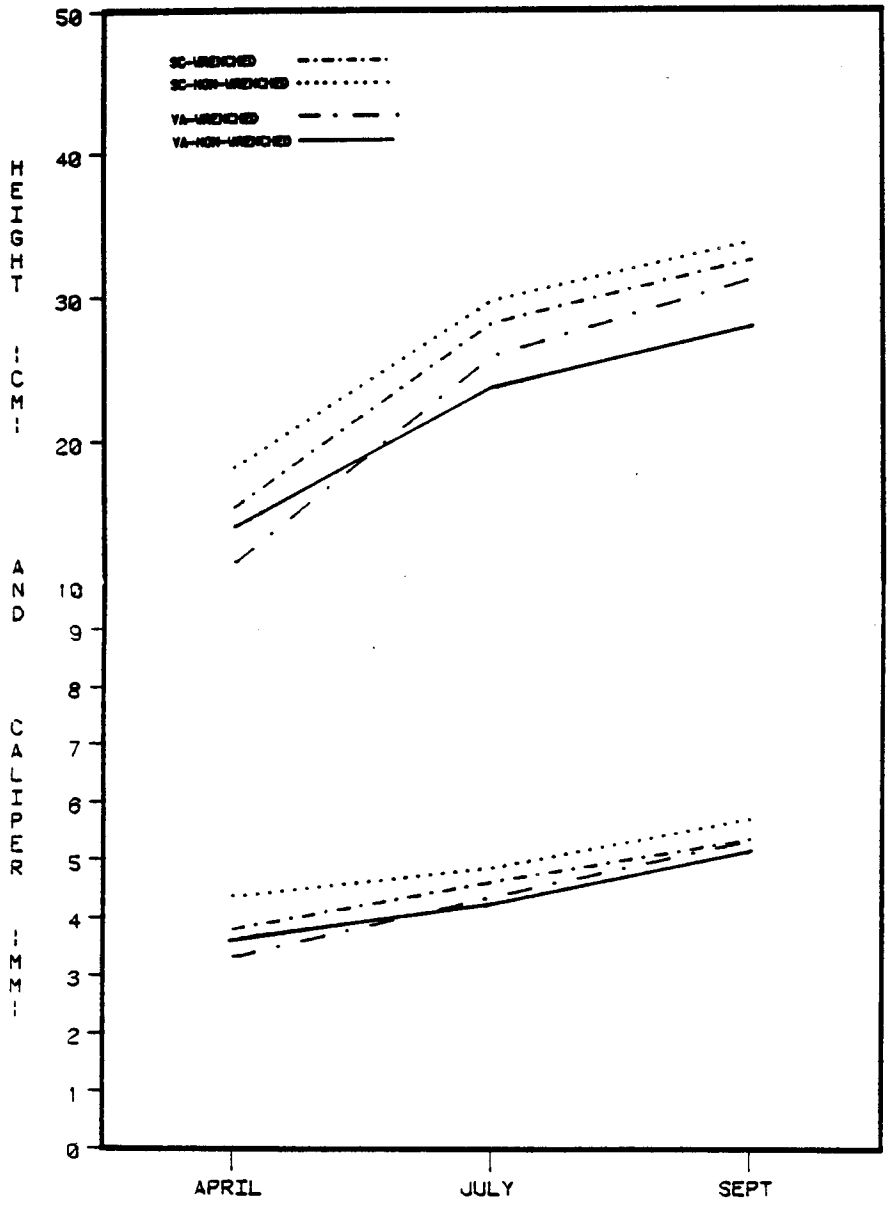

FIGURE 4. SEEDLING HEIGHT(CM) AND CALIPER(MM) AFTER PLANTING BY NURSERY AND WRENCHING TREATMENT.

date? Why should a reduced starch content appear to be an advantage? What interactions exist among plant auxins, starch content, shoot:root ratio, and needle nutrient levels?

The shifts in starch content between December and the planting date in March were most interesting. The sharp rise in starch content between December and lifting for the South Carolina seedlings seems related to extra chilling hours and lower respiration due to the generally colder weather in January. The higher starch levels seem to indicate a shift in seedling metabolism during dormancy. By lifting date, the seedlings all had the same root starch levels; but by planting, the undercut seedlings lost starch. Regardless of size and nursery, the drop in starch indicates a shift in physiological quality during dormancy between the wrenched and non-wrenched seedlings. Neither physical size nor nutrient levels served to explain the shift in starch. The wrenched seedlings underwent some sort of starch conversion (carbon reallocation) and proceeded to grow better than the non-wrenched seedlings after planting in the field. Perhaps the increased number of fine roots on the wrenched seedlings caused a more beneficial distribution of the starch, resulting in greater root initiation.

Approaching these questions from another direction, it is unexplained how the non-wrenched Virginia seedlings can have similar shoot:root ratios, higher nutrient ratios, and higher starch levels than the South Carolina wrenched seedlings and grow the poorest in height of any treatment! The data point toward physiological shifts within the seedlings due to wrenching.

The 93% survival points up other aspects about this experiment. Given an early planting time, good rainfall, and proper handling, South Carolina grown seedlings will survive and grow well in Virginia during the first growing season. The nutrient and starch levels in all of the seedlings were adequate for the conditions encountered. This is all the more interesting when it is fully realized that the South Carolina seedlings were grown in the nursery with cultural techniques other than wrenching designed for outplanting those seedlings in Coastal South Carolina.

These results suggest that it is possible to manipulate seedling physiological and morphological characteristics to a desired level using specifically developed cultural practices and realize improved outplanting performance.

LITERATURE CITED

Boyer, J. N. and D. B. South. 1984. Nutrient content of nursery-grown loblolly pine seedlings. Auburn Univ. So. For. Nursery Management Cooperative. No. 14.

Dierauf, T. A. 1984. Survival of root pruned loblolly pine seedlings after long-term cold storage. Virginia Division of Forestry, Occasional Report 64.

Haissig, B. E. and R. E. Dickson. 1979. Starch measurement in plant tissue using enzymatic hydrolysis. Physiol. Plant. 47:151-157.

Miller, A. E., R. W. Rose, K. F. Ray. 1984. Wrenching and top pruning effects on loblolly pine nursery seedling development. Southern Silviculture Research Conference, Atlanta, GA. Nov. 7-8, 1984.

Rook, D. A. 1971. Effect of undercutting and wrenching on growth of Pinus radiata D. Don seedlings. J. Appl. Ecol. 8:477-490.

Tanaka, Y., J. D. Walstad, and J. E. Borrecco. 1976. The effect of wrenching on morphology and field performance of Douglas fir and loblolly pine seedlings. Can. J. For. Res. 6:453-458.