Comparison of containerized Pinus taeda L. seedlings grown outside and in a growth chamber under natural light.

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A comparison between outside- and chamber-grown containerized loblolly pine (Pinus taeda L.) seedlings shows significant morphological differences in development occur between the two groups. After a 90-day growth period, outside-grown seedlings had significantly shorter heights, smaller root collar diameters, and smaller root, stem, foliage, shoot, and total dry weights than the chamber-grown seedlings. The smaller outside-grown seedlings had higher field survival after overwintering than the taller chamber-grown seedlings.

Container-grown forest tree seedlings present opportunities to supplement bare-root seedling production (Raisch 1981). Beneficial features of containerized forest tree seedlings include uniform growth rates, fast crop rotation, extended planting seasons, and favorable field performance (Hahn 1981). Furthermore, some species such as true firs, hemlock, and redwood are easier to grow in containers than in bare-root nurseries.

Container-grown tree seedlings are often produced in greenhouses. The greenhouse provides some control over the environment and some factors can be optimized for growth (Tinus 1974). Generally, it has been assumed that containerized seedlings grown under greenhouse conditions are as suitable as similar seedlings grown outside.

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However, Boyer and South (1984) have shown that container-grown loblolly pine seedlings grown in a greenhouse can be morphologically different from the same seedling stock grown outdoors. They found that seedlings grown indoors tended to be taller and more slender than those grown outdoors. They suggest that producers of containerized loblolly pine seedlings in the Southeast should consider growing seedlings outdoors in full sunlight when weather conditions are favorable in order to produce higher quality seedlings and reduce costs.

The present report further quantifies the morphological differences between chamber- and outside-grown containerized loblolly pine seedlings. In addition, overwinter field survival is reported for seedlings from these two groups.

Materials and Methods

Two groups of 294 loblolly pine seedlings were grown adjacent to one another; one group was grown outside on the ground and the other was grown in a growth chamber having a clear, 0.64 cm thick plexiglass top. Treatments were initiated on June 13 and concluded 90 days later on September 11,1985.

At the beginning of the experiment, seeds from an orchard seed source (S.C. State Forestry Commission) were germinated in flats of builders sand. When their radicles were 1-4 cm long, the seedlings were transplanted into 115 cu. cm Leach-cells (Ray Leach "Cone-tainer" Nursery, Canby, Oregon) containing a 2:2:1 mixture of fine grade

peatmoss (sphagnum), vermiculite (grade #2), and perlite (particle size 1-3 mm). Filled trays were set either outside on the ground or in the growth chamber. Beginning at cotyledon emergence and at 10-day intervals for 90 days, 9 seedlings from each group were randomly selected and their individual total heights, root collar diameters, and root, stem, and foliage dry weights determined.

Daytime temperatures were kept below 27°C inside the growth chamber with a 9100 BTU air conditioner. Ventilation with outside air without temperature control was used at night. Both outside- and chamber-grown seedlings received natural light (up to 2000 uEs-^{1}m-^{2}) and natural photoperiods. However, light intensity was reduced 10% after passing through the plexiglass top of the growth chamber. Irrigation was applied to both groups of containerized seedlings approximately every 3 days throughout the experiment. In addition, the outside seedling group received natural rainfall, while the chamber group did not. On June 14 and 23, July 24, and August 15, seedlings of both groups were irrigated with a 20-20-20 fertilizer (0.5 g/l) solution.

At the end of the 90-days, 10 seedlings from each group were examined for starch content by the enzymatic hydrolysis technique of Haissig and Dickson (1979). An additional 10 seedlings from each group were prepared for a root growth potential (RGP) study. First, the rooting medium was washed away from their roots and then all white root tips were removed. Seedlings prepared in this manner were potted two per pot (one from each group) in sand and grown for 30 days under a 16-hour photoperiod. Light intensity was 35 $^{-1}$ m $^{-2}$ and temperature was maintained at 27°C. At the end of the 30-day period,

sand was washed from the roots and the number of new white root tips

the potential of the seedlings to produce new roots (RGP).

Finally, 100 seedlings per group were outplanted at the end of the 90-day growth period on September 20 and 23, 1985 on a rootraked and windrowed upland Piedmont site. Twenty trees from each group were planted in each of five blocks. On March 24, 1986 seedling survival was recorded.

Results and Discussion

Significant morphological differences between outside-grown and chamber-grown seedlings became apparent 30 to 50 days after study initiation depending on the morphological characteristic considered. For example, separation of total seedling height between the two seedling groups over the 90-day growth period is shown in Figure 1. At the time of the final sample, seedling height, root collar diameter, and root, stem, foliage, shoot, and total dry weights were all significantly lower (Alpha = 0.05) for the outside-grown seedlings than those from the chamber (Table 1).

These data agree with Boyer and South (1984) whose outside-grown loblolly pine seedlings were also shorter than greenhouse-grown seedlings. However, their outside-grown seedlings had a greater root collar diameter than greenhouse-grown seedlings. The reverse was true in our study. The difference in light intensity reduction in the two studies may explain this difference in diameter response between

studies. Light intensity was reduced 75% in the greenhouse (Boyer and South 1984), but only 10% in the growth chamber used in this study.

In our study, the variable and generally higher outside air temperatures and lower humidities coupled with the greater light intensity could have resulted in outside-grown seedlings having greater diurnal water stress. Such stress conditions could cause development of shorter, more hardy stock and explain why seedlings grown outside better survived conditions in the field (Table 2). Barnett (1983), in an experiment with containerized loblolly pine seedlings ranging in size from 8 to 23 cm tall, found no significant correlation between survival and height (all treatments had greater than 95% survival). However, our field survival data suggests that growth conditions affecting factors such as shoot/root ratios can influence field survival of container-grown loblolly pine seedlings.

In this study, starch concentrations (Table 2) were significantly greater in the outside seedlings compared to the chamber seedlings. Because chamber-grown seedlings had more favorable temperatures and less water stress, differences in water relations between the two groups during the experiment period could explain differences in starch concentrations. The outside group had starch while the chamber group was apparently utilizing starch for growth.

RGP, which is a measure of a seedlings ability to produce new roots and therefore indicates its ability to become established in the field (Ritchie and Dunlap 1980), was not significantly different between the outside-grown group and the chamber-grown group (Table 2). However, the average RGP of the outside group was smaller possibly

indicating that RGP is a reflection of seedling size. Lack of difference in RGP could lie in the vigorous physical handling required to remove potting media from roots of container-grown seedlings.

In this study, shorter seedlings with lower shoot/root ratios had higher field survival than chamber-grown seedlings. The difference in morphology may lie in the predisposition to more stressful conditions received by the outside-grown seedlings.

Conclusion

The findings in this study support those of Boyer and South (1984) who recommend that producers of containerized loblolly pine seedlings in the Southeast grow seedlings for fall outplanting outdoors in full sunlight when conditions are favorable during the summer months. Furthermore, results of this study show that overwinter field survival was greater in outside-grown seedlings than in chamber-grown seedlings. However, final measurement of seedling growth in the field at the end of their first growing season should furnish stronger information for evaluating performances of outside-grown containerized seedlings against those grown in controlled environments.

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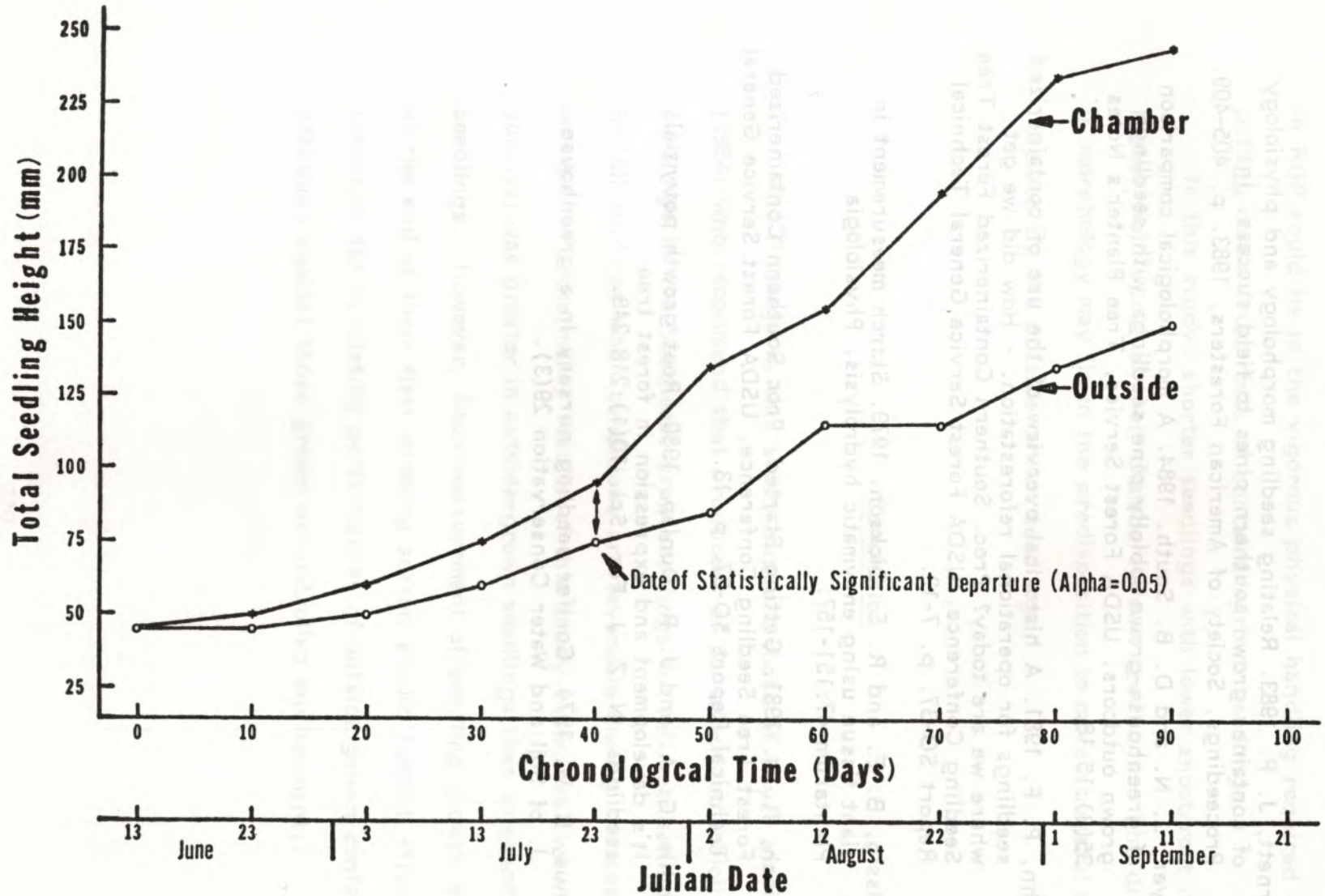

FIGURE 1. TOTAL SEEDLING HEIGHT OF OUTSIDE-GROWN AND CHAMBER-GROWN CONTAINERIZED LOBLOLLY PINE SEEDLINGS OVER THE 90-DAY GROWTH PERIOD.

Table 1. Morphological characteristics of seedlings grown outside and in a growth chamber under natural light for 90 days after cotyledon emergence.

Growth Conditions	Total Height	Root Collar Diameter	Seedling Dry Weight					Shoot/Root Ratio
			Root	Stem	Foliage[1]	Shoot[2]	Total[3]	
	-mm-	-mm-	----------grams----------					
Outside	148 B[4]	2.8 B	0.6 B	0.2 B	0.5 B	0.7 B	1.3 B	1.2 B
Chamber	245 A	4.1 A	1.0 A	0.6 A	1.6 A	2.2 A	3.2 A	2.2 A

[1] Foliage Dry Weight = Dry Weight of Cotyledons + Primary Needles + Secondary Needles.

[2] Shoot Dry Weight = Foliage Dry Weight + Stem Dry Weight.

[3] Total Dry Weight = Root Dry Weight + Shoot Dry Weight.

[4] Means followed by the same letter are not significantly different (Alpha = 0.05).

Table 2. Tissue starch content, root growth potential, and field survival of seedlings grown outside and in a chamber under natural light.

Growth Conditions	Starch Concentration[1] Root	Stem	Foliage	Seedling Root Growth Potential	Outplanting[2] Survival
	----------%----------			-No. of new roots-	-%-
Outside	4.6 A[3]	3.9 A	4.9 A	6.9 A	95 A
Chamber	1.9 B	2.2 B	2.5 B	14.4 A	86 B

[1] Starch concentration as % in a 0.1 gram sample.

[2] Outplanting survival in March 1986 after planting in September 1985.

[3] Means followed by the same letter are not significantly different (Alpha = 0.05).