A Morphological Comparison of Greenhouse-Grown Loblolly Pine Seedlings With Seedlings Grown Outdoors

James N. Boyer and David B. South
Research Associate and Assistant Professor, Alabama Agricultural Experiment Station, Auburn University Southern Forest Nursery Management Cooperative, Auburn, Ala.

Loblolly pine (Pinus taeda *L.) seedlings grown in a greenhouse were found to be taller, more slender, and less branched than those grown outside. These morphological differences apparently were caused by a shift of light wavelengths and protection from disturbance by wind in the greenhouse.*

Growing tree seedlings in an artificial environment such as a greenhouse causes them to be morphologically different from their counterparts grown outdoors. Generally, seedlings grown indoors tend to be taller and more slender than those grown outdoors. The list of factors that may lead to such differences includes: (1) intensity, quality (wavelength), and duration (photoperiod) of light; (2) physical disturbance, mainly wind, to which outdoor-grown seedlings are exposed; (3) relative humidity; and (4) temperature.

A greenhouse, especially when covered with shade cloth to reduce temperature, blocks out radiation. This not only reduces light intensity, but it also shifts the light spectrum to the right-away from ultraviolet and toward far-red (4, 11). Pine seedlings and other intolerant trees generally increase in relative elongation when shaded. If the photoperiod (light duration in a 24-hour cycle) is extended artificially, height growth may be increased even more. Daylength may not only affect height growth, but also radial growth and the dormancy period (7). The type of artificial lighting used in a greenhouse may also significantly affect seedling growth.

Plants growing in a greenhouse or growth chamber are not disturbed by wind, which has been shown to have a significant effect on the growth habit of many plants. Many plants respond to mechanical stimulation by elongating more slowly and increasing their radial growth. Wind may be considered a stress, and plants respond to it by growing stockier and sturdier (S). Mechanical disturbance has also been shown to induce dormancy in sweetgum *(Liquidambar styraciflua* L.) trees (10).

Changes in relative humidity and temperature can affect photosynthetic rate, growth, and other physiological processes in the plant. Hammer and others (4) implicated a higher relative humidity and a lack of temperature extremes as causes of "greenhouse lushness." Furthermore, while seedlings of many species in a greenhouse or growth-chamber may be induced to enter dormancy by shortening the photoperiod, most species require exposure to near-freezing temperatures in order to break dormancy and resume normal growth (8). Mexal and others (9) suggest that containerized seedlings outplanted in the fall should be exposed to low temperatures before lifting in order to induce cold-hardening.

Materials and Methods

As part of a study on chilling requirements for breaking dormancy in loblolly pine, two seed sources were grown both outside and in a greenhouse. One source of seeds was southeastern Virginia; the other was southeastern Georgia. Seeds were sown in May 1983. In order to avoid washing of containers by heavy rain, seedlings to be grown outside were started in the greenhouse and moved outdoors approximately 2 weeks after sowing.

Seedlings at both locations (inside and outside) were grown in 164-cubic-centimeter Leach-cells (Ray Leach "Cone-tainer" Nursery, Canby, Oreg.). A 2:2:1 mixture of peat moss, vermiculite, and perlite with 3.5 kilograms per cubic meter of 18-7-10 Sierrablen time-release fertilizer (Sierra Chemical Co., Milpitas, Calif.) added was used as a growth medium. In the greenhouse, the photoperiod was extended to 16 hours with artificial lighting (300-watt incandescent lamps). Seedlings outside grew under natural daylengths (approximately 14 hours from May to August). The greenhouse was covered with shade cloth to reduce temperatures. Tempera-

tures inside the greenhouse were further reduced by means of air pulled across wet cooling pads. Light intensity in the greenhouse at midday was approximately 350 $\mu E\ s^{-1}\ m^{-2}$ with full sunlight, compared to 1,550 $\mu E\ s^{-1}\ m^{-2}$ just outside the greenhouse.

Twelve weeks after sowing, 100 greenhouse- and 100 outdoor-grown seedlings from each seed source were measured for epicotyl length (that portion of the stem above the cotyledons), ground-level diameter, and number of lateral branches. Epicotyl length was measured rather than total height because much of the hypocotyl of the outdoor-grown seedlings (that portion of the stem below the cotyledons) was developed in the greenhouse.

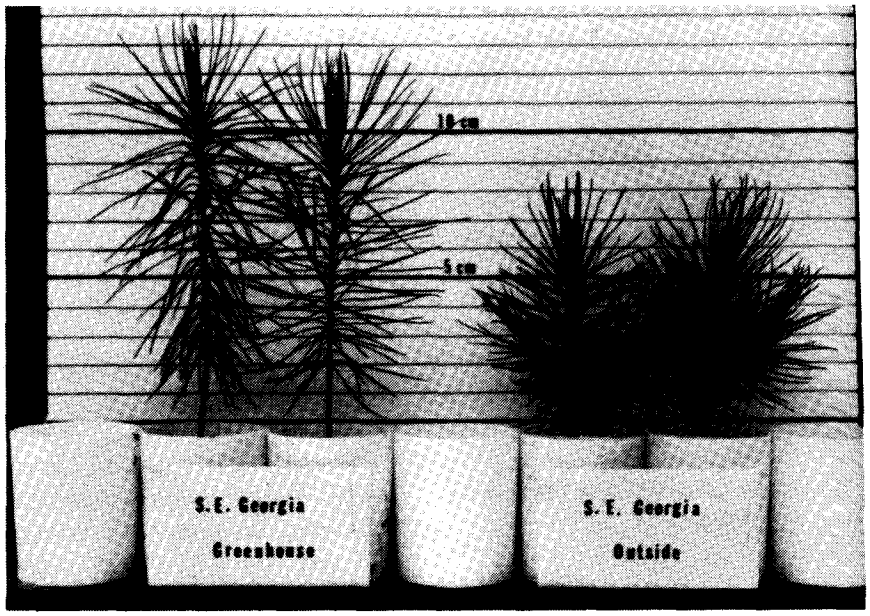

Figure 1—*Comparison of morphology of 12-week-old southeastern Georgia seedlings grown in a greenhouse and outside.*

Results and Discussion

Morphological differences between seedlings grown outside and in the greenhouse were striking (figs. 1 and 2). Seedlings grown inside were taller, more slender, and less branched than those grown outside. Differences in height, diameter, height-diameter ratio, and the number of lateral branches were all very highly significant (table 1). Seedlings in the greenhouse probably grew taller and more spindly through a combination of differences in light quality and quantity and a lack of mechanical stimulation. At present, one can only speculate on the rel-

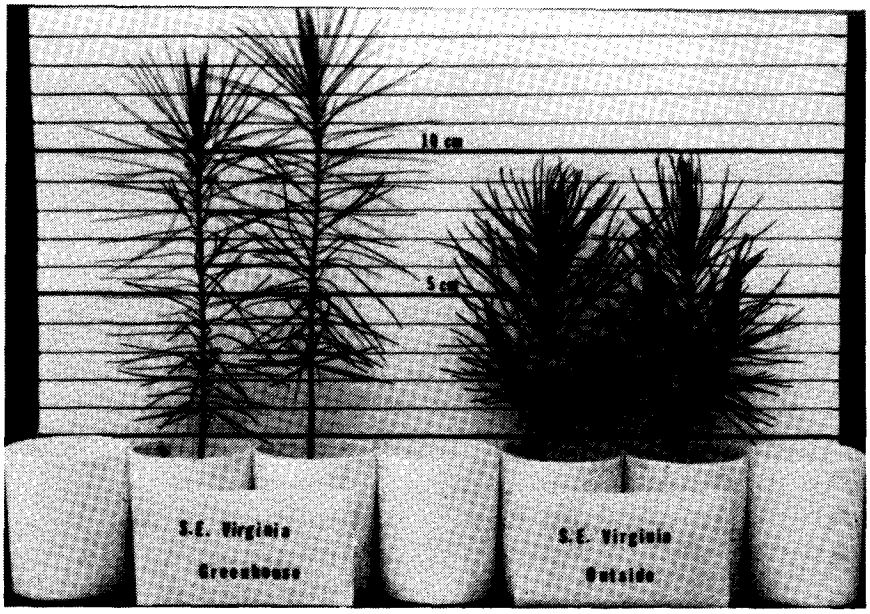

Figure 2—*Comparison of morphology of 12-week-old southeastern Virginia seedlings grown in a greenhouse and outside.*

Table 1—*Morphological characteristics of seedlings from two seed sources grown outside and in a greenhouse (12 weeks after sowing)*[1]

Seed source	Stem length	Stem diameter	Length to diameter ratio	Lateral branches
	mm	*mm*	*mm/mm*	*No./tree*
Southeastern Georgia				
Inside	69.8 ± 2.0	1.42 ± 0.02	49.0 ± 1.2	0.23 ± 0.05
Outside	37.4 ± 0.9	1.78 ± 0.02	21.0 ± 0.5	2.62 ± 0.11
Southeastern Virginia				
Inside	73.7 ± 1.8	1.48 ± 0.02	49.7 ± 1.1	0.11 ± 0.04
Outside	41.7 ± 1.2	1.85 ± 0.02	22.5 ± 0.6	2.80 ± 0.11

[1] Each number represents the mean of 100 seedlings and is followed by its standard error. All differences between locations are significant at $P < 0.0001$.

ative importance of these factors.

Light intensity may not have been as critical as light quality. Because of their leaf arrangement and leaf anatomy, loblolly pine seedlings with foliage composed mainly of juvenile needles are more adapted to lower light intensities than are 1-to 2-year-old seedlings (7). Photoperiod was probably not an important factor, either. The photoperiod in the greenhouse (16 hours) was not very different from that outside (approximately 14 hours from sunrise to sunset plus twilight).

The quality of the supplemental light, however, may have played an important role in seedling morphogenesis. Incandescent lamps emit strongly in the far-red part of the spectrum, while fluorescent lamps emit strongly in the red. Plants receiving far-red light grow significantly taller than plants receiving red light, which inhibits elongation (2). The red-far-red effect depends strongly upon the type of light plants receive last -- just before the onset of the dark period. Furthermore, the intensity of the light does not have to be great to cause an effect. Many kinds of plants elongate markedly when irradiated briefly with far-red light following each daily period of high-intensity light (2). Loblolly pine, among other tree species, shows significant increases in growth with incandescent as opposed to fluorescent supplemental lighting (3). The fact that the greenhouse-grown seedlings in this study received exclusively incandescent light for an hour before each dark period could, in part, explain the taller plants produced.

With the seedlings grown outdoors, the effects of light quality may have been coupled with a response to mechanical stimulation by wind. Specifically, wind stress may have triggered hormone reactions that induced more radial growth and lateral branching and less elongation. Telewski and Jaffe (72) fund that loblolly pine seedlings receiving daily mechanical disturbance in a greenhouse (brushing with a wooden rod) were significantly shorter than undisturbed control plants growing alongside them. Kellogg and Steucek (6) observed that shaking young Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees growing in a greenhouse had a marked influence on leader growth. They suggested, however, that when comparing greenhouse-grown trees with trees grown outside, temperature and humidity may be major factors contributing to the growth of outside-grown trees rather than a response only to mechanical disturbance by wind. Trees grown outside in this study were exposed to higher temperatures and lower humidities than those in the greenhouse. This placed outside-grown trees under greater water stress. Thus, at least a portion of the growth differences recorded may be attributable to temperature, humidity, and plant water status.

Currently, producers of containerized loblolly pine seedlings in the South usually grow the trees in a greenhouse or lath-house. There may be instances where they should consider simply growing the seedlings outdoors in full sunlight in order to produce higher quality trees and reduce costs, such as when seedlings are grown

during the summer to be outplanted in the fall. A possible concern about this approach would be washing of containers by heavy rains. The authors, however, found that, once the growth medium was initially settled, washing did not occur, even with very heavy rains. Finally, growers who conduct progeny tests in a greenhouse should be aware that morphology attained in these tests is likely to be quite different from that attained outdoors. Different families may even respond differently to greenhouse conditions versus outside conditions.

Literature Cited

1. Bormann, F. H. Ecological implications of changes in the photosynthetic response of *Pinus taeda* seedlings during ontogeny. Ecol. 37: 70-75; 1956.
2. Downs, R. J. Photocontrol of growth and dormancy in woody plants. In: Kozlowski, T. T., ed. Tree growth. New York: Ronald Press; 1962: 133-148.
3. Downs, R. J.; Piringer, A. A. Effects of photoperiod and kind of supplemental light on vegetative growth of pines. For. Sci. 4: 185-195; 1958.
4. Hammer, P. A.; Mitchell, C. A.; Weiler, T. C. Height control in greenhouse chrysanthemum by mechanical stress. Hortsci. 9: 474-475; 1974.
5. Jaffe, M. J. The sense of touch in plants. In: Salisbury, F. B.; Ross, C. W., eds. Plant physiology. 2d ed. Belmont, CA: Wadsworth Publishing Co., Inc.; 1978: 286.
6. Kellogg, R. M.; Steucek, G. L. Motion-induced growth effects in Douglas-fir. Can. J. For. Res. 7: 94-99; 1977.
7. Kramer, P. J.; Kozlowski, T. T. Physiology of woody plants. New York; Academic Press; 1979. 811 p.
8. Lavender, D. P. Environment and shoot growth of woody plants. Res. Pap. 45. Corvallis, OR: Oregon State University, Forest Research Laboratory; 1981. 47 p.
9. Mexal, J. G.; Timmis, R.; Morris, W. G. Cold-hardiness of containerized lob-lolly pine seedlings. South. J. Appl. For. 3: 15-19; 1979.
10. Neel, P.L.; Harris, R.W. Motion-induced inhibition of elongation and induction of dormancy in *Liquidambar. S*ci. 173: 58-59; 1971.
11. Salisbury, F. B.; Ross, C. W. Plant physiology. 2d ed. Belmont, CA: Wads worth Publishing Co., Inc.; 1978. 422 p.
12. Telewski, F. W.; Jaffe, M. J. Thigmo-morphogenesis: changes in the morphology and chemical composition in-duced by mechanical perturbation in 6-month-old *Pinus taeda* seedlings. Can. J. For. Res. 11: 380-387; 1981.