Seedling Growth of Three Southern Pine Species Under Long and Short Days

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In the study reported here, loblolly pine (Pinus *taeda* L.) seedlings from southern geographic seed sources made more height growth under long or short days than seedlings from more northern sources. The growth patterns revealed the interaction of a photoperiodic control process and a seasonal rhythmic process. Shortleaf (P. *echinata* MILL.) seedlings grown under short days exhibited a clina! pattern like that of loblolly, but under long days showed significant differences more suggestive of ecotypes. Longleaf (*P. palustris* MILL.) seedlings grew larger under long days than under short, but showed no significant differences attributable to geographic source, perhaps because they represente l a narrower latitudinal range of sources than the other two species.

Experimental Material and Methods

A 9.5-hour photoperiod (short day) of natural daylight was maintained by a clock-controlled mechanism that brought a lightproof cover over the seedlings at 5:15 p. m. and removed it at 7:45 a. m. each day. A 15-hour photoperiod (long day) was attained by adding the light from two 300-watt incandescent bulbs (50-100 foot-candles on the seedlings) to the period of daylight. Seedlings under long and short days were in close proximity in the greenhouse. The minimum temperature was 64° F.

Loblolly pine. — Seeds for the trees used in this study were collected in the fall of 1954 from natural stands of loblolly pine in Florida and Georgia. The four sources represented a latitudinal range of about 4degrees *(Figure 1)*. General habitat conditions for these areas are given in *Tables 1 and* 2.

The seedlings were grown in the Georgia Forestry Commission's Davisboro Nursery in 1955 and shipped to Durham, North Carolina, in December 1955. They were potted in 8-inch metal cans, and remained out-of-doors under normal day length until April 17, 1956. By that time all had broken dormancy.

Eight seedlings of each source were then subjected to a long day and a like number to a short day. Heights were measured biweekly. On March 29, 1957, needles on the long-day seedlings were severely burned by an insecticide, and height measurements on these seedlings were discontinued. Seedlings under short day were enclosed in the lightproof box at the time of the insecticide application and suffered no visible damage; measurements were continued on them until November 1957.

Shortleaf and longleaf *pine.* — The Southern Forest Tree Improvement Committee furnished seeds that had been collected in the fall of 1955 from natural stands of shortleaf and longleaf pine. Seven geographic sources of shortleaf and five sources of longleaf pine were represented *(Figure 1)*.

Table 1. — Annual temperatures and precipitations at the geographic sources of loblolly[1]).

County	Maximum °F	Minimum °F	Mean °F	Precipitat (*Inches*)
St. Johns, Florida	80	61	70	51
Glynn, Georgia	79	60	69	53
Laurens, Georgia	78	54	66	46
Floyd, Georgia	74	50	62	54

[1]) Data from U. S. Weather Bureau.

Table 2. — Time from sunrise through twilight, at the geographic sources of loblolly[1]).

County	Februa-ry	April	June	Au-gust	Octo-ber	Decbr
	Hours *and* minutes					
St. Johns, Florida	11:09	12:53	14:04	13:14	11:28	10:14
Glynn, Georgia	11:07	12:55	14:09	13:17	11:27	10:09
Laurens, Georgia	11:02	12:58	14:16	13:21	11:24	10:02
Floyd, Georgia	10:59	13:01	14:25	13:26	11:21	09:53

[1]) Data from U. S. Weather Bureau.

The shortleaf seed was stratified for two weeks. The longleaf was not stratified. Seeds of both species were sown in flats of moist vermiculite and allowed to germinate under normal day. On December 3, 1956, just before they had shed their seed coats, two shortleaf or five longlesf seedlings were transplanted to one-quart plastic pots. Eight pots of each source were placed under the short-day and eight under the long-day conditions. On January 18, 1957, the shortleaf seedlings were thinned to one per pot and the longleaf to three per pot.

Shortleaf heights were measured periodically. Longleaf did not grow in height. At the end of the experiment, on May 29, 1957, the seedlings were lifted and the roots washed free of soil and cut from the tops. Tops and roots were dried to a constant weight at 70° C. and weighed.

Results and Disrussion

Loblolly pine. — Height growth of the loblolly seedlings is plotted in *Figure* 2. Those under long day averaged 67.6 cm. of growth between April 19, 1956, and March 30, 1957, as compared to 18.7 cm. for short-day trees.

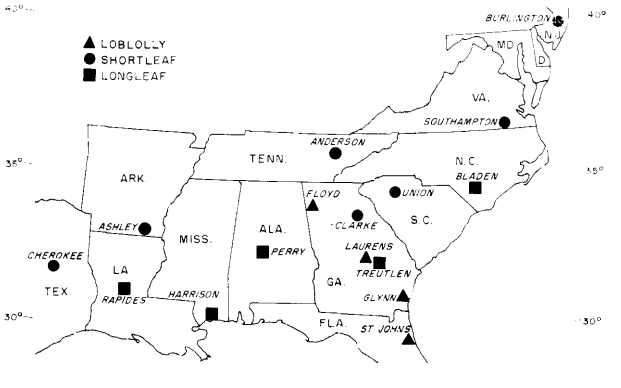

Fig. 1. — Location of seed sources, by State and county.

[1]) U. S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Gulfport, Mississippi.

[2]) Department of Forestry, Clemson Agricultural College, Clemson, South Carolina. With Southeastern Forest Experiment Station, Lake City, Florida, at time of this work.

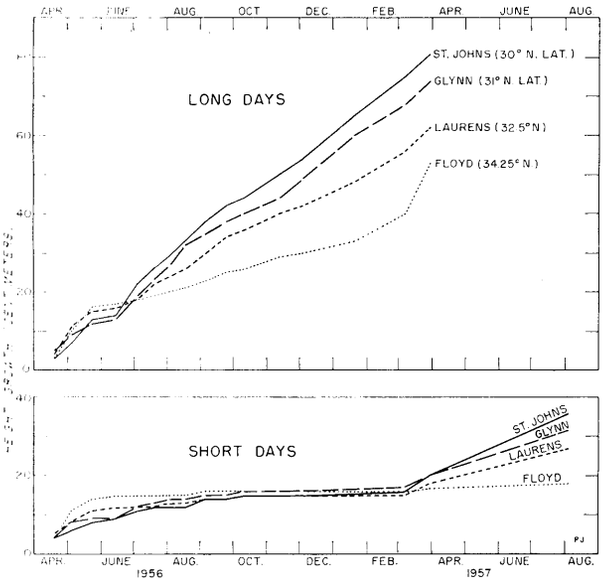

Fig. 2. — Height growth of loblolly pine seedlings under 9.5- and 15-hour days.

Response to long days was not readily apparent until after the spring flush of growth (which began before the seedlings were treated) ended in mid-June; then the St. Johns seedlings (southernmost source) resumed rapid height growth. They continued elongating at this rate throughout the test period, i. e., summer, winter, and spring. Floyd seedlings (northernmost source) grew rapidly during the spring flush of the first year; then throughout the summer and winter they elongated at a markedly slower but uniform rate. In their second spring they again made a growth flush at essentially the same rate as that of the previous spring. The patterns for the Glynn and the Laurens seedlings were intermediate between those of the St. Johns and Floyd trees.

During their first several months, seedlings under short days made almost as much terminal growth as those under long days, probably because they had already broken dormancy when day length was curtailed. However, they made virtually no growth throughout the summer and winter.

About March 6 of the second spring, St. Johns, Glynn, and Laurens sources under short days broke dormancy and started to elongate. In early August they again were dormant. The Floyd seedlings (northernmost source) did not break dormancy in their second spring. It seemed possible that this failure occurred because a cold requirement had not been met. To test this, four Floyd seedlings from short

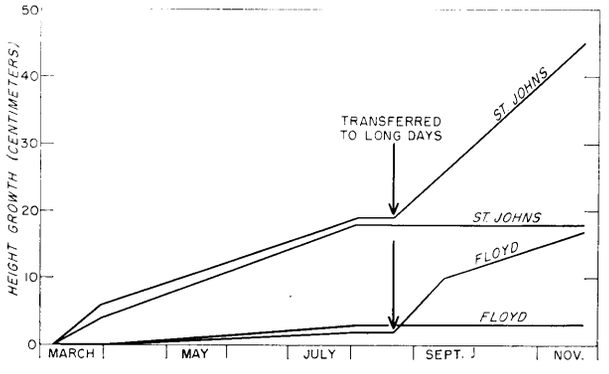

Fig. 3. — Effect of moving loblolly pine seedlings from 9.5- to 15-hour day. St. Johns was the southernmost source, Floyd the northernmost.

day were placed in a dark coldroom at 4° C. from August 4 until August 22, after which 2 were returned to the short day and 2 were placed under the long day. Also on August 22, two of the four seedlings that had been under short day with no cold were placed under long day. The St. Johns seedlings were treated in the same way.

The cold did not cause either the St. Johns or the Floyd seedlings to resume terminal elongation on return to short day. Also, there was no significant growth difference between the seedlings that had been given the cold treatment before being placed under long day and those placed under long day without the cold. With such a small sample, however, rather large differences would have been required to show significance.

Figure 3 shows the effect of moving the seedlings from short to long day on August 22. The values represent the average growth after March 6 of the group of seedlings of each source moved from short day to long day and those kept under short day, irrespective of cold treatment since cold treatment had no effect. Under short day the Floyd and St. Johns seedlings remained dormant from August through November. Both sources broke dormancy shortly after being placed under long day on August 22 and continued elongating until the experiment was terminated in late November.

These results with loblolly pine indicate that at least two processes control dormancy and extension growth. One is photoperiodic control and the other is a rhythm effect that produces a spring growth flush; this may be the endogenous yearly rhythm of Bünning as cited by Wareing (1956).

Photoperiodic control was apparently the dominant process in the seedlings from the southern sources in this experiment, because under long days no rhythm effect was detected. Under short days the rhythm appeared, in the second spring, when seedlings resumed elongation after a long dormant period.

The rhythm effect was more powerful in seedlings from the northern sources than in those from southern sources; this was evident under long day, where a definite flush of elongation in Floyd seedlings occurred in the spring of the second year. The inhibitory effect of short days was apparently much stronger in the Floyd seedlings than in those from the other sources, because the Floyd seedlings did not break dormancy under short day in the second spring.

The nature of the rhythmic process affecting the growth patterns of these seedlings is obscure. An endogenous process may be involved, but we cannot rule out exogenous control, viz. temperature. Although the minimum temperature in the greenhouse never fell below 64° F. there was, of course, an annual cycle above 64° F., and such a cycle could conceivably cause the growth pattern obtained in this experiment.

Shortleaf pine. — The shortleaf seedlings were exposed to the two day lengths for nearly 6 months. Total growth for this entire period is given in *Table 3*. The sources are arranged in north-to-south order.

Average effects of long and short days on the growth of shortleaf pine seedlings were:

	Long day	*Short day*
Height growth per seedling (cm.)	11.7	2.9
Dry weight of top per seedling (gms.)	.67	.21
Dry weight of roots per seedling (gms.)	.32	.17

Table 3. — Height growth of shortleaf pine seedlings from seven geographic sources.

Geographic source	Long day *cm*	Short day *cm*
Burlington Co., New Jersey	9.2	2.1
Southampton Co., Virginia	9.2	2.5
Anderson Co., Tennessee	10.5	2.5
Union Co., South Carolina	15.6	3.4
Clarke Co., Georgia	10.6	3.1
Ashley Co., Arkansas	16.0	2.6
Cherokee Co., Texas	10.6	4.0

At the termination of the experiment all long-day seedlings had fascicled needles, while seedlings under short day had only juvenile foliage.

There was no clinal growth pattern under long day, but the seedlings from Union County, South Carolina, and Ashley County, Arkansas, sources grew significantly more than those from all other sources *(Table 3)*.

Union and Ashley County seedlings probably responded to environmental factors, other than photoperiod, that manifested themselves under long day. Such growth could be obtained if the seedlings from these two sources happened to be better adapted to the potting soil than were the other sources. Of course, some factor other than soil may have been responsible. Such a response indicates the possibility of ecotypes. A somewhat analogous response was reported by VAARTAJA (1960), who obtained differences with seedlings from different altitudinal sources within the same latitude.

Under short day, the seedlings exhibited the same clinal change as found with the loblolly seedlings in that the more northerly sources tended to grow less than the southern sources. The difference between the New Jersey source and the Texas source, the two latitudinal extremes, was highly significant.

Dry weights of roots and tops were highly correlated with the stem elongations given in *Table 3*, but showed no other source differences.

Longleaf pine. — The longleaf seedlings, like the shortleaf, were exposed to the two photoperiods for less than six months.

Those under long day became considerably heavier than those under short day. The average dry weight per top was 1.18 gms. under long day and 0.28 gm. under short day. Roots weighed 0.28 gm. per seedling under long day and 0.16 gm. under short day.

The short period of test, the species dwarf growth habit, and perhaps the lack of latitudinal distribution among sources probably contributed to the absence of any differences attributable to geographic origin.

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Zusammenfassung

Titel der Arbeit: *Sämlingswachstum von drei südlichen Kiefern-Arten unter Lang- und Kurztag-Bedingungen.*

Sämlinge von *Pinus taeda* L. aus Samenherkünften südlicher geographischer Breiten zeigten unter Lang- und auch unter Kurztagbedingungen mehr Höhenwachstum als Sämlinge aus nördlicheren Herkünften. Diese Wachstumseigentümlichkeiten wiesen auf die Interaktion eines photoperiodisch kontrollierten Prozesses mit einer jahreszeitlichen Rhythmik hin. Sämlinge von *Pinus echinata* MILL., die unter kurzem Tag wuchsen, ließen eine klinale Verhaltensweise erkennen, die der der *Pinus taeda* ähnlich war; doch bei langem Tag zeigten sich bei *Pinus echinata* signifikante Unterschiede, die Ökotypen andeuten würden. Sämlinge von *Pinus palustris* MILL. wuchsen im langen Tag schneller als im kurzen Tag, doch zeigten sich hierbei keine signifikanten Unterschiede, die der geographischen Herkunft der Saat zugeschrieben werden könnten, vielleicht deswegen, weil diese Sämlinge nur einen schmaleren Breitengradgürtel von Samenherkünften repräsentierten, als dies bei den beiden anderen Spezies der Fall war.

Résumé

Titre de l'article: *Croissance en jours longs et en jours courts des semis de trois espèces de pin du Sud-Est des Etats-Unis.*

Dans l'étude dont il est rendu compte, des semis de "loblolly pine" *(Pinus taeda* L.) de provenances méridionales ont une croissance en hauteur supérieure en jours longs et en jours courts à celle des semis des provenances plus septentrionales. Le rythme de croissance a montré l'interaction d'un processus photopériodique de contrôle avec le rythme saisonnier. Des semis de "shortleaf pine" *(Pinus echinata* MILL.) ont montré une variation clinale analogue à celle du "loblolly pine", mais en jours courts on a constaté des différences significatives suggérant l'existence d'écotypes. Les semis de "longleaf pine" *(Pinus palustris* MILL.) ont poussé plus vite en jours longs qu'en jours courts, mais n'ont manifesté aucune différence significative attribuable à la provenance, peut-être parce que ces provenances représentaient une gamme de latitudes plus étroite que celle des deux autres espèces.

Literature Cited

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