

Effects of Extended Photoperiod on Southern Rocky Mountain Engelmann Spruce and Douglas-fir

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Four sources of Engelmann spruce and two of Douglas-fir were grown under eight different extended photoperiod regimes. Incandescent light 1 minute of every 15 at night at 270 lux was more effective than continuous incandescent at 1200 lux or intermittent fluorescent at 950 lux at preventing bud dormancy and maintaining continuous height growth.

Low levels of light at night are regularly used to extend the photoperiod in greenhouse container nurseries to prevent dormancy and promote continuous height growth (8). However, the degree of response varies greatly between species and between seed origins within species (10). In some species, seeds from low latitude sources respond less strongly to photoperiod than seeds from high latitude sources (9). The objective of this study was to examine the response of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* Beissn. Franco) and Engelmann spruce (*Picea engelmannii* Parry) from the Southern Rocky Mountains to photoperiod extended using continuous or intermittent light.

Materials and Methods

Styro-8 blocks were cut into 48 16-cavity units and filled with a peat-vermiculite growing medium. Each unit was sown with seeds from one of the six sources (table 1), 8 units per source. The blocks were placed in a standard glass greenhouse, where heat was well controlled, but cooling and humidity were not (table 2) during the 20-week experiment.

The blocks were placed on a greenhouse bench equipped with a device that closed automatically in the evening to divide the bench into eight light-tight compartments and that opened again in the morning. One block (16 seedlings) of each seed source was placed in each compartment, which was given a different light treatment by means of a single bulb in each compartment 80 centimeters above the containers (table 3).

Table 1.—Seed sources of Engelmann spruce and Douglas-fir

National Forest	Elevation	Nearest town	Latitude
	Meters		° N.
Engelmann spruce			
Lincoln	2,900	Mayhill, N. Mex.	32.8
Apache- Sitgreaves	2,800+	McNary, Ariz.	33.6
Carson	2,940	Taos, N. Mex.	36.1
Bighorn	2,800	Sheridan, Wyo.	44.8
Douglas-fir			
Lincoln	2,600	Cloudcroft, N. Mex.	32.8
Carson	2,940	Taos, N. Mex.	36.1

Table 2.—Average temperature and humidity during growth

Month	Maximum	Daytime	Nighttime	Minimum	Relative humidity
	°C				Percent
June	32	28	20	18	55 to 71
July	38	32	23	21	45 to 61
August	32	28	22	18	55 to 73
September	25	23	20	19	80 to 85
October	25	23	20	19	56 to 62

Table 3.—*Source, intensity, and duration of added light at night*

Treatment code	Bulb type	Intensity	Duration
		<i>Lux</i>	
0	None	0	None
75	Tungsten incandescent	75	1 minute every 15 throughout the night (24-hour day-intermittent)
160	do	160	do
270	do	270	do
1,200I	do	1,200	do
950F	Cool-white fluorescent	950	do
24C	Tungsten incandescent	1,200	Continuous all night (24-hour day)
21C	do	do	Continuous during night except for 3 hours (21-hour day)

Each compartment was attached to an air exhaust blower to minimize temperature differences between compartments at night. The positions of the various treatments on the bench were rearranged at random monthly to reduce the position effect caused by uneven daylight and temperature in the greenhouse. The compartment opening and closing was synchronized with the natural day. It was closed and the photoperiod treatments operating whenever it was dark, but the natural day was not allowed to exceed 16 hours.

After the seedcoats were shed, the seedlings were watered as needed with a modified Hoagland's solution. The seedlings were grown until

the average spruce height in the best treatment was 120 millimeters or more. Height, root collar to bud or apical meristem, was measured. Response to photoperiod was calculated as the mean height in a given treatment divided by the mean height with no light at night.

Results and Discussion

All seed sources of both species grew taller under intermittent incandescent light intensities greater than 75 lux (table 4). Maximum response was obtained with intermittent light at 1,200 lux, but response was not significantly less at 270 lux, except for the Carson source of Douglas-fir. Continuous light

was not as effective as intermittent. In fact, if only continuous light had been used, it would have been concluded that the Bighorn source was photoperiod sensitive, the Carson source was barely sensitive, and the other two southern sources of Engelmann spruce were not (compare the 24-hour values with the zero-light values).

Several pine species and blue spruce behave similarly (3, 7). Previous investigations using continuous light found that seedlings grew larger under a 21-hour day than under a 24-hour day (10). This was true of the Carson source of Douglas-fir, but made no difference to the Lincoln source. The Lincoln and Apache-Sitgreaves sources of Engelmann spruce also grew larger under a 21-hour day than under a 24-hour day, but the Carson and Bighorn sources responded equally to both 21- and 24-hour days. Neither the 24- nor 21-hour day with continuous incandescent light was as effective as 1 minute of light out of 15, at the same intensity, for any of the six seed sources.

Intermittent fluorescent light at 950 lux was less effective than intermittent incandescent light at 1,200 lux, and very much less effective for the Bighorn source of Engelmann spruce. Fluorescent light has previously been found to be less effective than

Table 4.—Mean height (mm) of seedlings¹

Photoperiod treatment ²	Species and seed source					
	Engelmann spruce				Douglas-fir	
	Lincoln	Apache-Sitgreaves	Carson	Bighorn	Lincoln	Carson
24C	64d	77e	75de	40b	122b	93d
21C	89ab	94cd	81cd	44b	117b	121bc
950E	82bc	111ab	91bc	31a	118b	118c
1,2001	99a	123a	112a	79a	152a	149a
2701	96a	111ab	94bc	70a	145a	125b
1601	86b	103bc	96ab	40b	114bc	124b
751	82bc	88de	66ef	19d	103cd	84de
01	75c	77e	61f	12e	95d	77e

¹Within columns, numbers followed by the same letter are not significantly different (P=.05, Student-Newman-Keuls Test).

²See table 3 for explanation of photoperiod treatment codes.

incandescent (1), but not universally so. Whether the differences in behavior are inherent in the species or whether they are related to differences in experimental conditions between investigations, such as light intensity or temperature, is not known (10). If inherent in the species, the behavior is probably determined by differences in sensitivity of the two processes involved. Red light prevents bud dormancy, but also inhibits stem elongation, although the latter has been demonstrated only for herbaceous species (6, 2). Far red light, present in-incandescent but absent from fluorescent, reverses the effect of red light. Maximum growth should be obtained when sufficient red light is pro-

vided to prevent dormancy, but not enough to inhibit stem elongation.

Ecotypes from northern latitudes tend to be more sensitive to day length and require longer days to maintain growth (5), but close correlations between latitude of origin and growth response under controlled environment are available for only a few species (4, 11). In this study, response to photoperiod extension for each seed source is defined as the mean height in a given treatment divided by the mean height obtained with no added light. Although a linear relationship between the logarithm of maximum photoperiod response and latitude of Engelmann spruce seed origin was found, more data points are

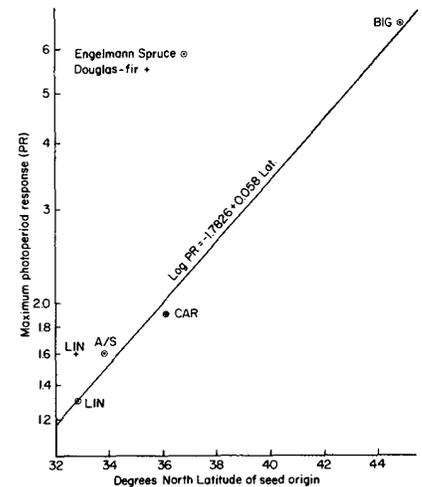


Figure 1.—Relationship between height increase and latitude of seed origin using extended photoperiod.

needed to make the relation convincing (fig. 1). Corresponding points for the two sources of Douglas-fir are also plotted, and maximum photoperiod response is approximately the same as for Engelmann spruce at the same latitude.

Intermittent incandescent light appears to be more effective than continuous incandescent or intermittent fluorescent light at the intensities tested to maintain height growth of Engelmann spruce and Douglas-fir. It is worthwhile to use light to improve growth of seed from even the southernmost of the Rocky Mountain sources tested.

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