PHOTOPERIOD CONTROL OF CONTAINER SEEDLINGS

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ABSTRACT: Research at the Pacific Forest Research Centre, Victoria. on the use of photoperiod lighting to grow seedlings of white spruce, Engelmann spruce, white x Engelmann hybrids, mountain hemlock, and amabilis fir in container nurseries is reviewed. Factors investigated were the critical minimum and maximum light intensities required by the above species when using photoperiod lighting; comparisons of natural daylength extension and cyclic lighting (interruption of the darkness); the effect of photoperiod lighting failure on tree seedling growth; and the influence that photoperiod lighting in the nursery has on tree seedling growth in the following year.

INTRODUCTION

The effect of photoperiod on the growth of tree seedlings has been known for some time and has been reviewed by Arnott and Mitchell (1981). The objective of this presentation is to highlight some of the results of research conducted at the Pacific Forest Research Centre (PFRC) to provide operational guidelines for container nursery growers in British Columbia (B.C.) using photoperiod lighting to grow tree seedlings.

Throughout this report, photometric units (lux) will be used to define light intensity levels (1 ft-candle = 10.8 lux). However, lux is not a measure of radiation received by plants but a measure of visible radiant energy that has spectral sensitivity (i.e., 200 lux from an incandescent source is not equivalent to 200 lux from a high pressure sodium (HPS) source). Therefore, when applying results from these and other studies, the reader must consider the source of lighting used.

EXTENDED DAYLENGTH VERSUS CYCLIC LIGHTING

In the coastal region of southwestern B.C. the long growing season is advantageously used to produce northern provenances of white spruce (*Picea glauca* [Moench] Voss), and highaltitude species such as Engelmann spruce (*Picea engelmannii* [Parry]), mountain hemlock (*Tsuga mertensiana* (Bong.] Carr.), and amabilis fir (*Abies amabilis* [Dougl.] Forbes). However, north-latitude and high-altitude ecotypes have long critical daylengths (Habjdrg 1972; Heide 1974). Unless seedlings of these species growing in southern B.C. nurseries are provided with an extended photoperiod, they prematurely form terminal buds, cease shoot growth early in the season, and do not achieve the desired height (Arnott 1974, 1979).

Trees can be kept in a state of indeterminate growth by extending the daylength with low-intensity artificial light or by interrupting the dark period with light of low intensities (cyclic lighting). Experiments at PFRC determined the duration of dark period interruption required in cyclic lighting to maintain growth of the four species listed above and compared such treatments with the growth response obtained using extended daylengths in an outdoor container nursery at Victoria, B.C. (lat. 48'28'N). Details have been published elsewhere (Arnott 1974), and have been presented at a meeting of this Nursery Council (Arnott 1976). Height growth of all four species was significantly greater under the extended daylength and cyclic lighting treatments than in the control where seedlings started forming terminal buds as early as mid-May. Supplemental photoperiodic light prevented early terminal bud formation. Cyclic lighting of 2 minutes every 30 minutes of darkness produced seedlings of white spruce. Engelmann spruce, and mountain hemlock that were significantly taller than those grown under the 18-h extended photoperiod. Amabilis fir seedlings grown under the 18-h regime were taller than those grown under cyclic lighting.

LIGHT INTENSITIES FOR EXTENDED PHOTOPERIOD

Critical Minimum

Most nursery growers are interested in knowing what the critical minimum light intensities are for species that require daylength extension. Critical minimum is defined as the minimum intensity of supplemental photoperiodic lighting required to produce seedling shoot lengths that are significantly larger than seedlings grown under natural photoperiods. These intensities were determined

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for white spruce, Engelmann spruce, mountain hemlock, and amabilis fir (Arnott 1979). The experiment was conducted in situ at the Koksilah tree nursery (latitude 48°47'N) at Duncan, B.C., to provide some answers for local nurserymen. A 400-watt, high-pressure sodium (HPS) lamp was chosen as the supplemental light source for extending the photoperiod to 24 h. The treatment stations were positioned along the length of the shadehouse nursery at 20-foot (6-m) intervals in a direct line away from the light source to provide the following light intensities.

Distance from Light Source (ft)	(m)	Supplemental Light Intensity (lux)
20	6	220
40	12	80
60	18	40
80	24	20
100	30	12
120	36	8
140	42	5
–	–	0

Terminal resting buds were noted and seedling height was recorded biweekly throughout the experiment until October 30, when a destructive sample was taken for shoot and root dry weight.

Extending the photoperiod and increasing the light intensity had highly significant effects on seedling shoot growth of all four species (fig. 1). Shoot length and weight declined as the light intensity decreased. The effect of extended photoperiod and increasing light intensity on root weight was usually negative, although the differences were significant only in two spruce seedlots. The greatest shoot length response to light intensity was attained at the highest level (220 lux). The critical minimum intensity varied by species as follows.

Species	Critical minimum for HPS source (lux)
White spruce	80
Engelmann spruce/ White-Engelmann hybrid	40
Engelmann spruce	20
Amabilis fir	20
Mountain hemlock	80

The trend in shoot weight was somewhat different. Minimum light intensity levels usually had to be one treatment level higher to produce a response significantly different from that of the controls. The smaller average shoot length and weight at the lower light intensities is a result of many of the seedlings forming terminal resting buds and ceasing shoot growth before the lights were turned off on September 7.

Species differ in their response to light intensities used to extend the photoperiod. Amabilis fir did not respond dramatically to the various levels of light intensity. This confirms earlier work where that species showed a small but significant response to extended photoperiodic treatment; in that case, using a light intensity of 1600 lux from an incandescent source (Arnott 1976). Mountain hemlock and the spruces made large gains in shoot growth at the higher light intensities.

Critical Maximum

Having determined the minimum light intensities in the above experiments, the next step in the research program was to establish what the critical maximum light levels were for each species. We have defined critical maximum as the light intensity level above which no further significant increase in shoot length occurs when seedlings are grown under extended daylengths using supplemental light (Arnott and Macey (1984). White spruce, Engelmann spruce, and mountain hemlock were chosen for this experiment at PFRC. Again, a 400-watt lamp was used as the supplemental light source from May 6 - August 16, 1982. The seedlings were grown in an unheated shelterhouse at varying horizontal distances from a HPS lamp so that they received the following light intensities during the extended portion (beyond sunset) of a 19-hour photoperiod regime.

Distance From Light Source (ft)	(m)	Supplemental Light Intensity (lux)
4.8	1.45	1600
10.7	3.25	800
18.0	5.45	400
28.7	8.70	200
37.1	11.25	100
–	–	0(control)

Results of this experiment will soon be published (Arnott and Macey 1984) and are summarized here as follows.

As in previous experiments, an extended photoperiod produced large significant increases in seedling shoot length of all three species. The critical maximum light intensities were species-dependent. For white spruce, Engelmann spruce, and mountain hemlock, the figures were 800, 100, and 400 lux, respectively. With light intensities approaching the critical maximum levels as they did in this experiment, there were no significant responses in shoot weight, root weight, or root collar diameter to increased light intensi

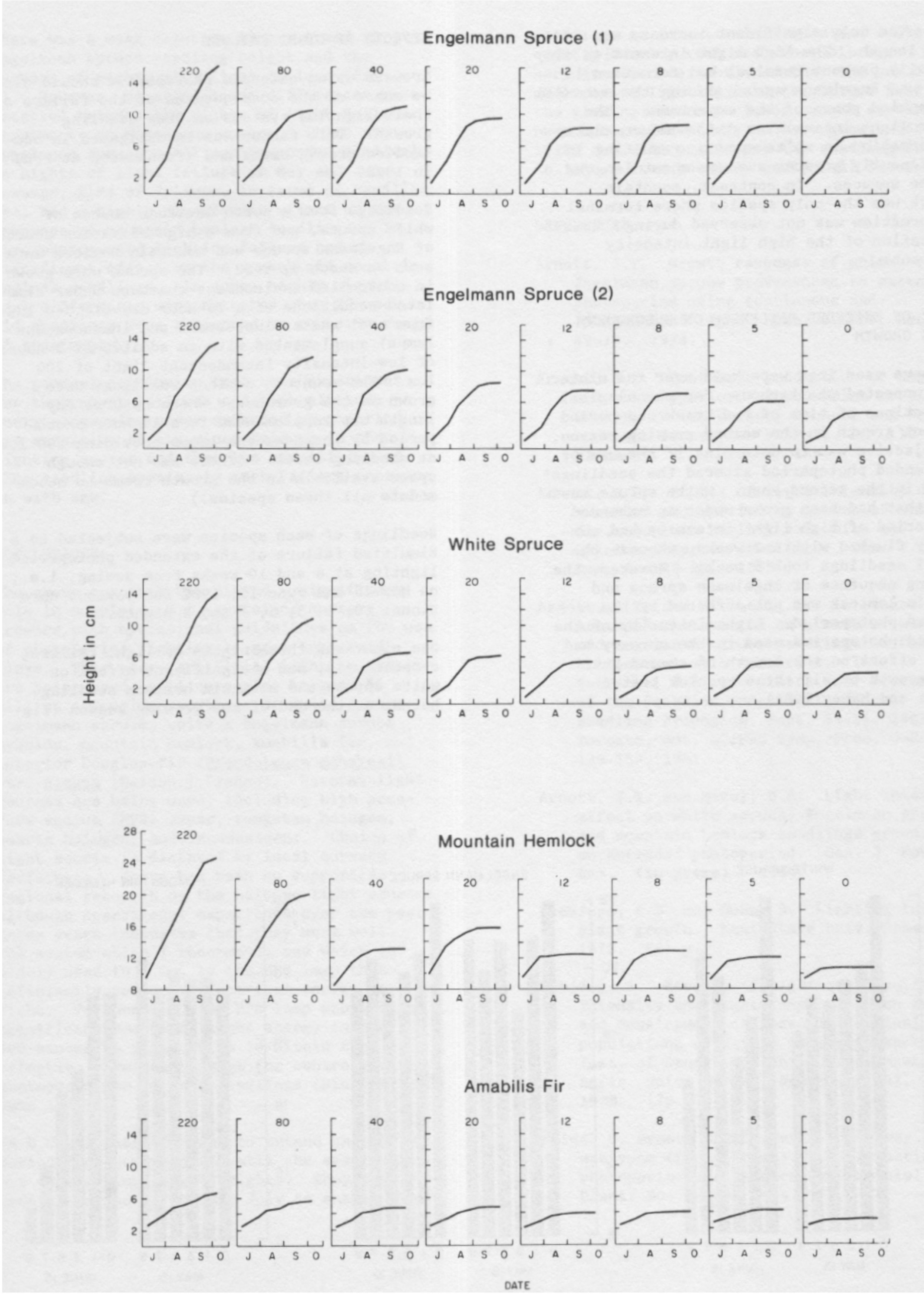

Figure 1.--Height growth of Engelmann spruce, white spruce, mountain hemlock, and amabilis fir seedlings grown in a shadehouse nursery using eight intensities (lux) of supplemental lighting from a HPS lamp (from Arnott 1979).

ties. The only significant increase was in shoot length. The high light intensities did not fully prevent terminal bud formation in white and Engelmann spruce during the extended photoperiod phase of the experiment. The higher light intensities did, however, delay bud formation in white spruce, resulting in significantly greater average shoot lengths for the spruces. In contrast, mountain hemlock was the only species where terminal bud formation was not observed during application of the high light intensity treatments.

EFFECT OF EXTENDED DAYLENGTH ON SUBSEQUENT YEAR'S GROWTH

The above seedlings were held over the winter in an unheated shelterhouse for phenological observations of time of bud break and period of shoot growth in the second growing season. The objective was to determine if the use of an extended photoperiod altered the seedlings' growth in the second year. White spruce seedlings that had been grown under an extended photoperiod of high light intensity had completely flushed within 2 weeks, whereas the control seedlings took 5 weeks. However, the flushing sequence of Engelmann spruce and mountain hemlock was not affected by the extended photoperiod. Light intensity of the extended photoperiod used in the nursery had little effect on the length of second-year shoot growth of all three species tested (Arnott and Macey 1984).

EFFECTS OF LIGHT FAILURE

Growers using extended photoperiod should also be aware of the consequences of the failure of their lighting systems on tree seedling growth. This factor was investigated in controlled growth rooms and greenhouses at PFRC in 1982.

Seedlings from a north-latitude source of white spruce, and from a high-elevation source of Engelmann spruce and mountain hemlock were sown on March 3, 1982. The spruce were grown in controlled environment chambers under simulated conditions of a 16-hour day (16,340 lux from cool white fluorescent and incandescent lamps) supplemented with an additional 3 hours of low-intensity incandescent light of 200 lux. The mountain hemlock seedlings were grown in the greenhouse where natural daylength was supplemented to a 19-hour photoperiod by incandescent lamps providing 200 lux at seedling level. (There was not enough space available in the growth rooms to accommodate all three species.)

Seedlings of each species were subjected to a simulated failure of the extended photoperiod lighting at 6 and 10 weeks from sowing, i.e., on May 15 and June 15, 1982 for various durations: 0, 1, 3, 5, 7 and 9 nights.

One night and three nights of light failure, respectively, had a significant effect on white spruce and mountain hemlock seedling height at the end of the growing season (fig. 2).

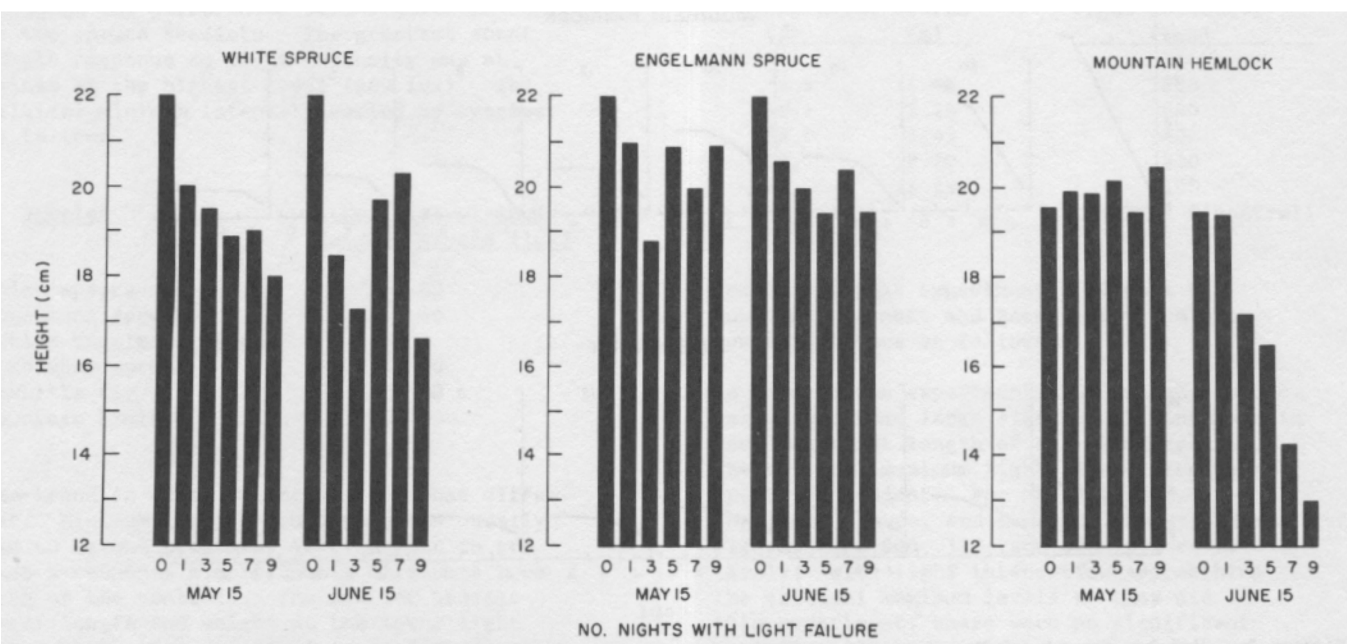

Figure 2.--Effect of 0-9 nights of simulated light failure at two different times in the growing season on white spruce, Engelmann spruce, and mountain hemlock seedlings.

There was a weak negative linear trend of Engelmann spruce seedling height and the numbers of nights with light failure (fig. 2). However, no significant differences were detected between the nights of light failure treatments on Engelmann spruce. White and Engelmann spruce seedlings responded similarly to nights of light failure in May and June. However, time of failure, in terms of seedling age, had a highly significant effect on the response of mountain hemlock seedlings. In May, photoperiod lighting failure had no significant effect on the 6-week-old mountain hemlock seedlings. In June, highly significant differences were detected when 10-weekold seedlings were subjected to the same range of treatments.

The general conclusion from this experiment was that north-latitude and high-altitude ecotypes growing under extended photoperiod are sensitive to any minor failure in the lighting system and that the sensitivity of some seedling species to such failure increases with age.

CONCLUSIONS

The above research has played a significant role in supplying B.C. container nursery growers with operational guidelines on the use of photoperiod lighting to grow tree seedlings. This year, artificial lighting systems are being used in 16 nurseries to grow 56 million styroplug seedlings of white spruce, Engelmann spruce, white x Engelmann spruce hybrids, mountain hemlock, amabilis fir, and Interior Douglas-fir (*Pseudotsuga menziesii* var.*glauca* [Beissn.] Franco). Several light sources are being used, including high pressure sodium (HPS) vapor, tungsten halogen, quartz halogen, and incandescent. Choice of light source is dictated by local nursery preference. There has been no supportive regional research on the halogen light sources although operational experience over the past three years indicates that they work well. The system which I recommend, and which is widely used in B.C., is the HPS lamp that efficiently converts electrical energy to light. Furthermore, the HPS lamp provides a significant amount of light energy in the 600-nanometre range which is within the effective wavelength range for controlling photoperiodism in tree seedlings (Bickford and Dunn 1972).

In B.C., lights are used to extend the photoperiod from sowing date until the seedlings are approaching target heights. They are usually turned off by mid-July to enable the seedlings to form terminal buds and subsequently develop root and shoot biomass. Nursery growers are cautioned that the use of photoperiod lighting into the latter half of the growing season to favor height growth will have a negative effect on root growth (Arnott 1979) and will predispose the seedling shoots to injury from possible early fall frosts.

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