Regulation of Seedling Height in Container-Grown Spruce Using Photoperiod Control[1]

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Abstract.--In 1989, container-grown white x Sitka spruce (Sxs) seedlings were subjected to a 15h day, either static or dynamic method of blackout treatment, for four weeks to promote budset and regulate height. The blackout treated seedlings were shorter, and had less shoot mass compared to controls without any effect on stem diameter. Control seedlings acquired cold-hardiness slower than blackout treated seedlings, and the dynamic method acquired cold-hardiness slower than the static method. Under controlled conditions, days to budbreak in spring was three days earlier for blackout treated seedlings compared to controls. In 1988, a larger experiment with six seedlots and 12 blackout treatments, applied using dynamic method, was conducted which included the same seedlot as in 1989 and results are compared. All seedlings were lifted and frozen stored. In May 1989, all treatments for all seedlots were outplanted in nursery beds and four seedlots were also planted in their respective regions. First year field assessments indicated a reduction in height growth with 13 h daylength for Engelmann spruce, but not for white x Sitka spruce seedlings. Blackout treatments had little or no effect on phenology.

INTRODUCTION

In British Columbia we produce Container-grown seedlings of white (*Picea glauca* (Moench), Englemann (*P. engelmannii* Parry), and Sitka spruce (*P. sitchensis* (Bong.) Carr.) and commonly we are dealing with naturally occurring hybrids of these three species. Regulating height growth at the end of the season is a common problem for nurserymen, particularly in nurseries located in northern latitudes with naturally long days during the growing season.

Nurserymen use both drought and nutrient stress to regulate seedling height (Macey & Arnott 1986). Both of these stresses appear to regulate height by slowing growth rather than promoting early budset. Shortened daylengths imposed by blackout systems promote early budset to regulate seedling height (Dormling et al. 1968). The advantages of using blackout over drought and nutrient stressing are:

1) seedlings are not stressed,
2) crop response is uniform, and
3) it is easier to impose.

Research on the use of blackout culture to promote budset and regulate height in spruce seedling production began in 1987 at the B.C. Ministry of Forests, Red Rock Research Station (RRRS), Prince George, B.C. Results from the 1987 growth chamber study (Hawkins and Hooge 1988) and preliminary results from 1988 (Hawkins and Draper 1988) were presented at the Combined Meeting of the Western Forest Nursery

[1]Paper presented at Western Forest Council 1990 Conference, Roseburg, Oregon, August 13-17, 1990.

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Associations held August 8-11, 1988 in Vernon, B.C. This paper presents some of the results from experiments conducted during 1988 and 1989, including first year field performance of blackout cultured seedlings.

OBJECTIVE

Experiments were conducted at RRRS, a northern latitude research facility (lat. 530 45'N; long. 1220 41'W), to determine the effect of short day treatments on height growth of spruce seedlings in order to provide nurserymen with operational guidelines for length of day (hours) and duration (weeks) of blackout treatment. The effects of blackout culture on cold-hardiness, dormancy, and field performance were also investigated.

MATERIALS AND METHODS

Spruce seeds (Sxs) of 5L3958 (Lat. 55° OO'N, Long. 128° 45'W; Elevation 400 m) from the Prince Rupert Region were stratified at 2°C for three weeks prior to sowing March 16, 1989 in BC/CFS 313 styroblocks using a 2:1 peat:vermiculite (v/v) growing mix. The styroblocks were placed in a research polyhouse at the Red Rock Research Station, Prince George, B.C. and grown using the culture described by Hawkins and Draper, 1988. Seedlings were grown under a 23h photoperiod until blackout treatments began on June 28, 1989.

The blackout treatments were ambient (control), and a 15h daylength for four weeks applied using either the static or the dynamic method of imposing short days (fig. 1). The static method is simply a constant night length for a given period of time and is the standard method used in crop production. The dynamic method parallels the natural declining day length over the treatment period so that the daylength gradually shortens during the weeks of treatment, offset from the ambient daylength by a predetermined, constant number of hours.

Following treatment, seedlings were grown in the polyhouse under ambient conditions until lift. The lift date (Nov. 24, 1989) for all seedlings was based on the results of freezer tests conducted every one to two weeks starting Sept. 15, 1989.

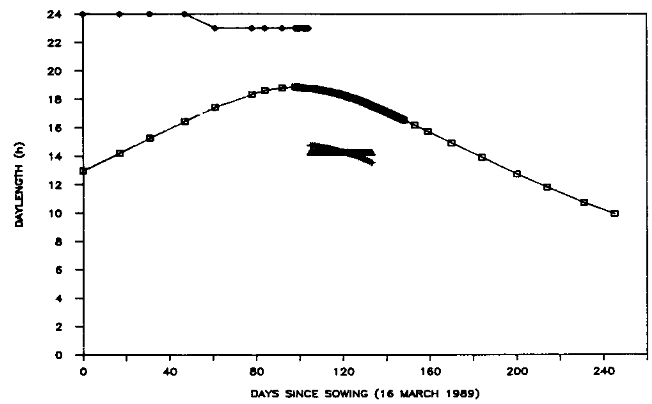

Figure 1. --The natural daylength (includes civil twilight) at RRRS (□), showing the daylengths imposed by the static (△) and dynamic (+) blackout treatments for four weeks from June 28 to July 27, 1989.

Ten seedlings per treatment were selected at random and exposed to three or four preset temperatures during each test with a constant 5°C h^{-1} ramp and 5 min soak at each plateau temperature. The temperatures used on each date were decreased gradually as seedlings acquired cold hardiness. Following freezing, 5 seedlings from each treatment were potted into 1-gal nursery pots for a total of two pots per treatment. Seedlings were placed in controlled environment growth chambers and assessed one week later for percent foliage browning. At lift, 150 seedlings per treatment were systematically selected and measured for height, stem diameter, shoot dry weight, and root dry weight. As well, 15 blocks for each treatment were assessed for percent of seedlings reflushing. Following lift, seedlings were stored at -2°C until spring 1990.

Twenty seedlings per treatment were selected at random from storage in May 1990, potted with five seedlings per pot and placed in controlled environment chambers for determination of days to budbreak (DBB) and root growth capacity (RGC). Two pots were placed in a chamber with day/night temperatures of 25°C/20°C, and two in a chamber with 15°C/5°C.

In 1988, spruce seedlings from six seedlots were exposed to four blackout daylengths, each applied for three durations as described by Hawkins and Draper, 1990. All seedlings were lifted and frozen stored.

On May 13, 1989, 99 seedlings per treatment were outplanted at RRRS and terminal bud phenology assessed using the codes in Table 1. End of season height and stem diameter increment were determined on 54 seedlings per treatment.

Table l.--Phenology coding and description of each code used during the first field season following outplanting of blackout treated spruce seedlings.

Code	Description
0	resting spring terminal bud
1	bud swell
2	bud flush/shoot elongation
3	lateral buds forming
4	terminal buds forming
5	resting fall terminal bud

As well, four seedlots were outplanted in their respective regions through the cooperation of the Regional Forest Science staff. This paper reports the terminal bud phenology, and seedling height and stem diameter increment after the first year in the field for Engelmann spruce seedlot 4311 (Lat 50° 55', Long. 120° 05'; Elevation 1435 m) from the Kamloops Region. Twenty-five seedlings per each of the seven original blackout treatments were planted May 30, 1990, at McGillivray Lake in the ESSFdc2[1] elevation 1480 m; aspect SE; logged 1987 and blade scarified.

RESULTS

Static vs Dynamic 1989

The 15h for four week blackout treatments resulted in spruce seedlings that were shorter and had lower shoot dry weight compared to untreated seedlings (table 2). Stem diameter and root dry weight appeared unaffected by treatment, but the shoot:root ratio was lower for treated seedlings due to the decrease in shoot dry weight. The control seedlings, if graded using the B.C. stock specifications[1], would have been overheight (maximum = 300 mm) and culled for low root dry weight (cull = 0.5g).

Seedlings subjected to the static blackout treatment (constant 15h day) were significantly shorter with greater stem diameter, compared to those subjected to the dynamic blackout treatment (table 2). With both methods of applying blackout, reflushing occurred in 26-30% of the seedlings for static and dynamic respectively. The static treatment tended to have greater root dry weight and shoot dry weight but not significantly different from the dynamic treatment.

Cold-hardiness was acquired earlier in the growing season by blackout treated seedlings (fig. 2), and the static method appeared to accelerate the acquisition compared to the dynamic method. By Nov. 17, 1989 (just prior to lifting) 55% of the foliage on control seedlings was killed by a test temperature of -18°C compared to only 35% for the dynamic treatment, and 4% for the static treatment. Eleven days later (Nov. 28) the percent injury was down to only 18% for both control seedlings and those subjected to the dynamic blackout, and the seedlings from the static treatment remained at 3-4%.

After six months of frozen storage, the DBB for control seedlings was three days longer than for blackout treated seedlings (table 3) under warm temperature conditions (25°C/20°C D/N). With the cooler temperature regime of 15°C day and 5°C night, the treatment differences in DBB disappeared (table 3), and with either regime there was no difference between static and dynamic.

First year field performance

First year field height growth and stem diameter increment appeared to be unaffected by the blackout treatments they received during the nursery culture

[1]B.C. Ministry of Forests Biogeoclimatic Zones Classification System.

[1]B.C. Ministry of Forests, Silviculture Branch 1989 Stock Specifications for Sitka spruce crosses stock type PSB313A/B.

Table 2.---End of season seedling height, stem diameter, shoot dry weight (SDW), root dry weight (RDW) and root:shoot ratio following a 15 hour day blackout treatment for four weeks starting June 28, 1989 for SL3958.

Blackout Treatment	Height (mm)	Stem dia. (mm)	SDW (mg)	RDW (mg)	Ratio S:R
Control	386 ± 5.5[1]	3.2 ± 0.05	2489 ± 85	494 ± 22	5.0
Dynamic	283 ± 6.3	3.2 ± 0.06	2011 ± 77	508 ± 23	4.0
Static	265 ± 6.0	3.4 ± 0.06	2030 ± 80	546 ± 23	3.7

[1]Mean ± SE, n = 150.

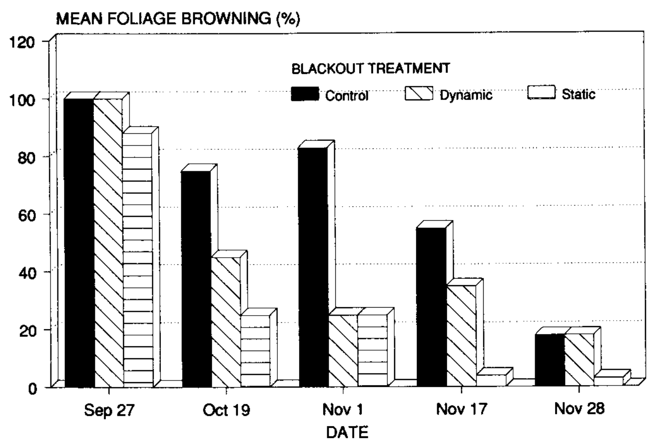

Figure 2.--Development of cold hardiness expressed as percent mean foliage browning assessed one week after frost hardiness tests for control and blackout treated spruce seedlings, SL3958. Test temperature on Sept. 27 and Oct. 19 was -13°C, on Nov. 1 was -17°C, and on Nov. 17 and Nov. 28 was -18°C.

for Engelmann spruce seedlings SL4311 (table 4). The trend for Sitka x white spruce seedlings showed an increase in first year height growth with both 13h and 15h photoperiods compared to 17h and controls. Averaging over treatment duration (weeks), the 13h photoperiod increased 149 mm in height and the 15h increased 146 mm compared to 116 mm and 91 mm for 17h and control, respectively (table 4). Stem diameter increment remained unaffected by blackout treatment.

Table 3.--Days to budbreak of spruce seedlings (SL 3958) in spring 1990 following frozen storage for control, dynamic, and static blackout treatments with the tests conducted at two temperatures (day/night)

Blackout Treatment	Days to budbreak 25°C/20°C	15°C/5°C
Control	10 ± 1.0[1]	11 ± 0.5
Dynamic	7 ± 0.4	11 ± 0.4
Static	7 ± 0.5	10 ± 0.5

[1]Mean ± SE, rep = 5 seedlings, n=2

The opposite effect was observed for SL4311 when planted in a regeneration site (table 5). The height growth for the 13h photoperiod was 111 mm (2 wk + 6 wk) compared to 130, 140, and 128 mm for 15h, 17h, and control treatments, respectively. Again, there appeared to be no effect on stem diameter growth due to blackout treatment during the nursery culture year.

Terminal bud phenology during the first year in the field was not affected by nursery blackout treatments for Engelmann spruce seedlings (table 6). On June 12, 1990 100% of all treated seedlings had flushed and 80% of the controls. However, within the next six days all the controls had flushed as well. By Aug. 22, 1990, all seedlings in all treatments had set bud with the

Table 4.—Seedling height increment and stem diameter increment following first year in the nursery bed at Red Rock Research Station for two seedlots 4311 and 3958, Engelmann spruce and sitka x white hybrid spruce, respectively.[1]

Treatment day (h)	weeks	Height increment (mm) SL 4311	SL 3958	Diameter increment (mm) SL 4311	SL 3958
13	2	123 ± 6[2]	138 ± 15	3.6 ± 0.6	2.5 ± 0.5
	4	140 ± 21	166 ± 18	4.4 ± 0.4	3.5 ± 0.3
	6	126 ± 10	144 ± 14	4.2 ± 0.3	3.9 ± 0.2
15	2	148 ± 4	129 ± 5	3.5 ± 0.2	3.2 ± 0.4
	4	132 ± 11	157 ± 9	3.8 ± 0.4	3.1 ± 0.3
	6	163 ± 10	153 ± 8	3.9 ± 0.1	4.0 ± 0.4
17	2	135 ± 5	97 ± 4	3.3 ± 0.2	3.4 ± 0.1
	4	126 ± 4	115 ± 1	3.1 ± 0.4	3.6 ± 0.4
	6	152 ± 12	135 ± 6	4.0 ± 0.3	3.1 ± 0.2
19	2	138 ± 4	81 ± 13	3.7 ± 0.3	2.7 ± 0.2
	4	151 ± 3	95 ± 1	3.8 ± 0.2	3.3 ± 0.1
	6	135 ± 5	98 ± 4	3.2 ± 0.6	2.6 ± 0.5

[1]Hawkins and Draper, 1990
[2]Mean ± SE, rep = 18 seedlings, n = 3

Table 5.--Mean seedling height increment and stem diameter increment following first year outplanting in Kamloops Region for Engelmann spruce SL4311

Treatment day (h)	weeks	Height inc. (mm)	Diameter inc. (mm)
13	2	115 ± 7[1]	1.4 ± 0.06
	6	107 ± 2	1.7 ± 0.05
15	2	135 ± 6	1.4 ± 0.04
	6	125 ± 5	1.7 ± 0.07
17	2	140 ± 5	1.4 ± 0.08
	6	140 ± 5	1.5 ± 0.04
Control		128 ± 5	1.4 ± 0.08

[1]Mean ± SE, rep = 5 tree row, n=5.

exception of the 13h 2 wk treatment which had 5% of the seedlings without a resting terminal bud. Within one week 100% of the 13h 2 wk treatment seedlings had a final terminal bud, and no reflushing occurred during the rest of the growing season.

In the nursery bed at RRRS, the same seedlot showed the same phenology at budflush, i.e., no treatment effect (table 7). Terminal bud scale formation began nine weeks after planting (mid-July), and resting terminal buds developed in mid-August, 14 weeks after planting. However, in mid-August, reflushing was observed on seedlings from both the 13h, and 15h, for 2 wk and 6 wk treatments (table 7). This resulted in as much as a 14 day delay in final budset in the 13h photoperiod for the longest duration (6 wks).

The Sitka x white hybrid seedlings SL3958 continued to elongate longer into the growing season and did not start the final budset stage (stage 5) until mid-Sept. for control seedlings, and even later in Sept. and Oct. for treated seedlings (table 8). Seedlings from the 13h photoperiod appeared to set bud even later than either the 15h or 17h photoperiods.

DISCUSSION

A complete report of the 1988 experiment which included SL3958 and

Table 6.--Spruce seedling terminal bud modal phenology class during the first year in the field in Kamloops Region. Seedlings were produced in 1988 at RRRS using four daylengths and two durations of blackout culture.

Treatment day	Blackout weeks	Phenology Code[1]								
13 h	2 wk	0	2	2	2	3	3	4	5	5
	6 wk	0	2	2	2	3	3	4	5	5
15 h	2 wk	0	2	2	2	3	3	4	5	5
	6 wk	0	2	2	2	3	3	4	5	5
17 h	2 wk	0	2	2	2	3	3	4	5	5
	6 wk	0	2	2	2	3	3	4	5	5
Control		0	2	2	2	3	3	4	5	5
Julian Day		150	163	170	182	194	205	220	234	248
Month		May	June		July			Aug.		Sept.
		1989 field growing season								

[1]Codes as described in Table 1.

Table 7.--Spruce seedling terminal bud modal phenology class during the first year in the nursery bed at RRRS for SL4311. Seedlings were produced in 1988 using four daylengths and three duration of blackout culture[1].

Blackout Treatment day	weeks	Phenology Code[2]											
13 h	2 wk	0	1	1	2	2	3	4	4	(4)	3	4	5
	4 wk	0	1	2	2	2	3	3	4	4	5	5	5
	6 wk	0	1	2	2	2	3	3	4	(4)	(5)	4	5
15 h	2 wk	0	1	1	2	2	3	4	4	(4)	4	5	5
	4 wk	0	1	1	2	2	3	3	4	4	4	5	5
	6 wk	0	1	1	2	3	3	3	4	(4)	5	5	5
17 h	2 wk	0	1	1	2	2	3	3	4	4	5	5	5
	4 wk	0	1	1	2	2	3	3	4	4	4	5	5
	6 wk	0	1	1	2	2	3	3	4	4	5	5	5
19 h	2 wk	0	1	1	2	2	3	3	5	5	5	5	5
	4 wk	0	1	1	2	2	3	4	4	4	5	5	5
	6 wk	0	1	1	2	2	3	4	4	4	5	5	5
Julian Day		133	139	149	157	171	180	194	209	223	235	249	275
Month		May			June			July		August		September	
		1989 field growing season											

[1]Adapted from Hawkins and Draper, 1990.
[2]Codes described in table 1.
[3]Brackets indicate >20% terminal bud flushing.

Table 8.--Spruce seedling terminal bud modal phenology class during the first year in the nursery bed at RRRS for SL3958. Seedlings were produced in 1988 using four daylengths and three durations of blackout culture[1].

Blackout Treatment day	weeks	Phenology Code[2]											
13 h	2 wk	0	1	2	2	2	3	3	3	3	3	4	5
	4 wk	0	1	2	2	2	3	3	3	3	3	4	4
	6 wk	0	1	2	2	2	3	3	3	3	3	4	4
15 h	2 wk	0	1	1	2	2	2	3	3	3	4	4	5
	4 wk	0	1	2	2	2	3	3	3	3	4	4	5
	6 wk	0	1	1	2	2	3	3	3	3	3	4	4
17 h	2 wk	0	1	1	2	2	2	3	4	4	4	4	5
	4 wk	0	1	2	2	2	2	3	3	3	4	4	5
	6 wk	0	1	2	2	2	2	3	3	3	3	4	4
19 h	2 wk	0	1	1	2	2	2	3	4	4	4	5	5
	4 wk	0	1	1	2	2	2	3	3	3	3	4	5
	6 wk	0	1	1	2	2	2	3	3	4	4	4	5
Julian Day		133	139	149	157	171	180	194	209	223	235	249	275
Month			May			June		July		August		September	
		1989 field growing season											

[1]Adapted from Hawkins and Draper,1990.

[2]Codes as described in Table 1.

SL4311 can be found in Hawkins and Draper (1990). The response of the vigorous Sitka x white hybrid spruce seedlings (SL3958) to a four week, 15h day blackout treatment varied in 1989 from the response in 1988 in both root dry weight and percent reflushing. The difference in mean root dry weight between controls and treated was 180 mg in 1988, but only 14 mg in 1989. Hawkins and Draper (1990) reported only 2% reflushing in this seedlot and these were lateral buds on seedlings in the 13h daylength treatment. This is minimal reflushing compared with the 26-30% recorded in 1989 which included terminal bud reflushing as well. The two growing seasons did differ as control seedlings in 1989 were 77mm taller than those in 1988, and had 12% less root dry weight.

Hawkins and Draper (1990) have given many reasons for using the dynamic method for applying blackout and one possible positive feature is that this method may give adequate height regulation without negatively impacting on seedling physiology. Cold hardiness development was accelerated by blackout treatments in both years, however in 1989, the dynamic method produced seedlings that behaved more like the control seedlings (figure 2).

Days to budbreak for SL3958 were 10 days in 1989 compared to seven days in 1990. Hawkins and Draper (1990) reported that DBB decreased with decreasing daylength and increasing duration. However, there was only five days difference between controls (12 days) and the severist blackout treatment (13h for 6 weeks=7 days). They observed the same trend in white and Engelmann spruce though the difference was only two days for the same comparison.

In the nursery bed there was little or no treatment effect on budflush or budset except with the 13h daylength. For SL4311 on the regeneration site, all treatments were at 100% budset by August 22, 1990 except the 13h for two week blackout treatment which was at 95%. This is in contrast to the results for black spruce in Ontario where short day seedlings remained actively growing for three to six weeks longer than untreated (Odlum and Columbo, 1988). The difference in response between nursery bed and field in our study was the reflushing that was recorded in the nursery bed. This may be related to the fertilization and irrigation practiced in the nursery compared with the drier regional site.

First year after planting terminal height growth was unaffected by the previous blackout treatments for 5L4311 in nursery beds. Results from the outplanting in the region showed a reduction in height increment for seedlings receiving the 13h daylength compared to all other treatments. This same trend was observed in the three other regional outplantings (data not presented). The difference in height increment between nursery and field again may be due to the watering, fertilizing, and weeding that occurred in the nursery.

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