Height Control of Interior Spruce by Means of Photoperiodic Induction[1]

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Abstract.--Four blackout periods were each applied for 3 durations to control height in interior spruce species at Red Rock Research Station (RRRS). In all six seedlots tested, height control could be achieved without significantly impacting end of season root collar diameter (caliper) or root mass. This finding is contrary to current nursery dogma. Evidence of physiological changes within treatment will be the basis for further studies at RRRS.

INTRODUCTION

In northern latitude nurseries the need to induce apical budset to limit height growth of spruce to desired standards is a recognized cultural challenge (Van Eerden, pers. comm. IX/87~). Often drought or nutrient stressing techniques (D'Aoust and Cameron 1981; Matthews 1981; Johnson 1985) are used, with the former the most common. However, drought stressing can have negative biological implications (Johnson 1985; MacDonald and Owens 1988), and height control through nutrient stress is not well understood in conifer crops.

An alternative to drought stressing may lie in blackout (photoperiodic induction of budset: Arnott and Mitchell 1981; Arnott 1982). In blackout treatments, the natural day length is artificially shortened prior to normal budset, thus simulating a later time in the growing season. This can result in cessation of height growth, apical budset and the initiation of frost hardiness/dormancy induction processes (Colombo et al. 1981).

The conventional photoperiod treatment in southern B.C. nurseries is to place seedlings in constant 8 h day 16 h night regimes on about 01 July for 4 weeks (Matthews 1983; MacDonald and Owens 1988). This results in budset but at the loss of potential photosynthate, especially at more northern latitudes. Another consequence of this treatment regime is the substantial difference between treatment and ambient day length experienced by the plant upon removal from blackout. There can be as much as an 8 h increase to ambient day length

An alternative approach to constant night length for a given period of time is to develop photoperiod (PP) treatments which parallel the natural ephemeris at a particular nursery latitude. Thus while photoperiod is offset in terms of actual night hours, the treatment ratio of day to night length would parallel over time that of the ambient ephemeris (Figure 1). At RRRS, with treatment beginning on 06 July (114 days after sowing), this results in dynamically increasing night lengths, rather than conventional static night length over the blackout treatment periods. The experimental advantages to this dynamic treatment approach are; constant difference between a given blackout treatment and ambient day length at the conclusion of all treatment durations, increased use of northern latitude long days, and inclusion of ambient ephemeris conditions as a formal 'control' level in treatment comparisons.

This study reports on the use of dynamic blackout regimes for height control of interior spruce.

METHODS

Six spruce seedlots (Table 1) were sown on 14 March 1988 into BCFS/CFS 313" polystyro blocks (764 cavities m^{-1}-) containing a 2 parts peat, 1

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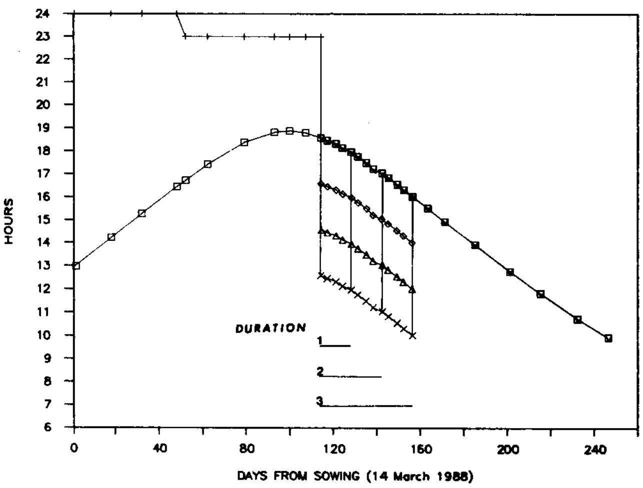

Figure 1.--The ephemeris (natural day length + civil twilight) at RRRS (latitude 53°45` N, longitude 122°41'W, showing the blackout treatment regimes tested. Photoperiod applied to crop prior to blackout treatment, (+); 17h, 15h, and 13h photoperiods during 2, 4 or 6 weeks of blackout D1, D2 or D3, respectively; and ambient photoperiod during and after blackout application (S,).

part vermiculite growing media. Gypsum and 12 mesh lime were added to the media at rates of 1.0 and 0.9 kg m^{-3}, respectively. Germination was carried out in Harnois" greenhouses as described by Hawkins and Draper (1988) equiped with a reflective outer cloth (Enershade" LS11, 95% blockage) and an inner black absorbent cloth (EnershadeF° 100 S/B, 100% blockage) blackout system'. Thermal regimes were 20° C for 5 days and then 20/11° C for 13/11 h, day/night for 4 weeks. Five weeks after sowing a 20-8-20[6] fertilizer regime modified from Draper and Hawkins (1988) was applied to the crop at a rate of 60 ppm N'. Heating setpointsO were changed to 19/13° C for 16/8 h, day/night at this time. All greenhouse and blackout systems were controlled

R: mention of a trademark name, proprietary product or firm does not imply recommendation by the B.C. Forest Service to the exclusion of others in the market place.

I Supplied by Van Rijn Enterprises Ltd., Stoney Creek, ON, LGE 4C3 Canada

[6] 20-8-20 "Forest Seedling Special" supplemented with "Plant-Prod" Chelated Trace Element Mix (both from Plant Products Fertilizer Ltd., Bramalea, Ont., L6T I66),solubor and $CuSo_4$ at rates of 40.0, 1.2, 0.08 and 0.02 g 1-' of stock solution, respectively.

' N application increased to 90 ppm in early July and gradually reduced to 30 ppm by early October.

' This setpoint maintained until 20 July when setpoints were gradually lowered, to assist in frost hardiness / dormancy induction processes, reaching 9/1° C for 11/13 h day/night on 26 Oct.

with an ESC 2000' computer system.

All stock was grown under continuous photoperiod until 6 May, then it was grown under a 23 h photoperiod until blackout treatments were initiated on 6 July 1988. Four blackout treatments were chosen (Figure 1), ambient (nominal 19 h) nominal 17 h, 15 h, and 13 h photoperiods. Each was applied for 2, 4 and 6 weeks duration. Times of blackout were changed daily and curtains were closed at the desired evening time, opened after civil sunset, closed again prior to civil sunrise, and opened at the desired time in the morning. The extra opening was to facilitate humidity regulation. At the end of each blackout treatment, stock was returned to ambient photoperiod and grown under it until lifting and storage in early November.

Analyses that have been or will be carried out on these treatments"' include seasonal serial height determinations; seedling morphology (height, caliper, root and shoot masses) over the season; timing of frost hardiness and dormancy induction processes; developmental anatomy of buds for all treatments in one seedlot; post-cold storage phenology including LT¢„" assessments; mitotic indices; farm-field outplantings; and planting of all seedlots back in location of origin.

RESULTS

Due to the complexity of this trial (72 treatments) and because similar treatment

Table 1.--Seedlot (SL), species (SPP), and approximate elevation (ELEV), latitude (LAT) and longitude (LONG) of origin of the stock.

SL[1]	SPP[2]	ELEV m	LAT °N	LONG °W
5261	Se	1650	49°20	119°30'
4311	Se	1435	50°50	120°30'
8482	Se	1140	52°15	120°30'
599[3]	Sw	760	54°20	125°30'
8779	Sw	1067	55°45'	122°30'
3958	Sxs	400	55°00'	128°45'

1 British Columbia Forest Service (BCFS) registered seedlot number.

2 Species abbreviations: Se, Picea engelmannii Parry; Sw, P. glauca (Moench) Voss; Sxs, P. glauca and its naturally occurring hybrid with P. sitchensis (Bong.) Carr.

3 Courtesy of G. Kiss of the BCFS interior spruce tree improvement programme.

9 Energrated System Consultants Ltd., Surrey, BC V3W 8V3 Canada.

10 4 photoperiods X 3 durations X 6 seedlots = 72 treatments.

11 Temperature required to damage 50% of the seedlings in a given phenological class.

responses were observed for all seedlots, results (one month prior to lifting) are presented for one seedlot (3958).

Serial height increments are presented for all photoperiods (PP) at 2, 4 and 6 weeks duration (Figure 2). Only the 13 h PP was effective for height control after 2 weeks of application (Figure 2a), whereas both 13 and 15 h treatments were effective after 4 and 6 weeks application.

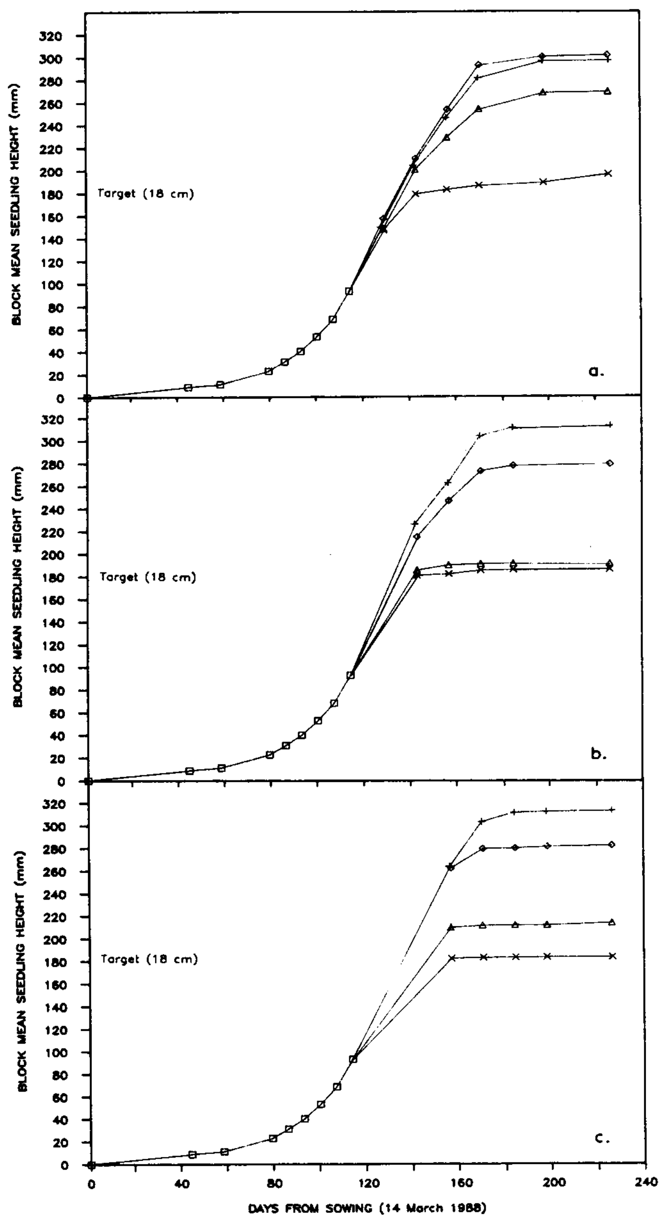

Figure 2.--Cummulative mean seedling block height (based on a serial sample of 10 seedlings from each of six blocks) for seedlot 3958.
a) all PP applied for 2 weeks (D1);
b) all PP applied for 4 weeks (D2); and
c) all PP applied for 6 weeks (D3).
Pre-blackout ambient , nominal 19 h, 17h, 15h, and 13h photoperiod treatments.

Table 2.--Seedlot 3958 (Sxs) treatment (P D) mean' and standard error (SE) of caliper (root collar diameter), shoot (SDW) and root (RDW) dry weights, and shoot to root ratio (S:R) six weeks after removal of the longest durations from blackout.

P[2]	D weeks		Caliper mm	SDW mg	RDW mg	S:R
13	2		3.52	1593	572	2.78
		SE	0.115	126.4	28.6	nc[3]
13	4		3.33	1450	620	2.34
		SE	0.156	139.7	91.8	nc
13	6		2.56	1270	560	2.27
		SE	0.115	93.3	76.3	nc
15	2		3.29	1989	445	4.47
		SE	0.212	261.4	79.3	nc
15	4		2.95	1361	485	2.81
		SE	0.222	129.4	26.8	nc
15	6		3.01	1528	567	2.69
		SE	0.173	110.4	64.0	nc
17	2		3.33	2236	492	4.54
		SE	0.112	187.0	59.4	nc
17	4		3.04	1681	366	4.59
		SE	0.198	118.8	44.4	nc
17	6		3.38	2080	503	4.14
		SE	0.146	167.7	39.0	nc
19	2		3.31	2084	503	4.14
		SE	0.179	172.0	63.5	nc
19	4		3.28	2023	385	5.25
		SE	0.154	187.5	40.3	nc
19	6		3.15	1918	392	4.89
		SE	0.107	142.3	55.8	nc

I Each mean is from a random sample of 18 seedlings.

2 Photoperiods (P): nominal 13 h, P1; nominal 15 h, P2; nominal 17 h, P3; and nominal 19 h (ambient), P4. Durations (D): 2 weeks, D1; 4 weeks, D2; and 6 weeks, D3. All blackout periods were followed by a common ambient light regime.

3 nc, not calculated.

Seedling caliper was reduced by 13 h PP applied for 6 weeks (Table 2). Root dry weight was similar between photoperiod treatments but shoot dry weight was reduced by shorter photoperiods (Table 2). Shoot to root ratios varied but generally were largest in the longer photoperiod treatments (Table 2).

Foliage frost hardiness occurred soonest in the shortest photoperiod applied for the longest duration[12]. Seedlot was also important in

12 Assessed using the -18° C test. Stock is held at +3° C for 1 h, cooled to -18° C at 6° C h-', held at -18° C for 1 h, ramped to 3° C at 6° C h-', held at 3° C for 1 h, and then placed in a standard environment (30/25° C, 16/8 h, day/night, RH 75%, and light intensity of 500 mumols) for 1 week and then evaluated.

determining frost tolerance because the more northerly the origin of the seedlot, the sooner it achieved frost hardiness (not presented). The Sxs seedlot was the last to attain foliage frost hardiness.

DISCUSSION

For this vigorous hybrid seedlot, little or no height control was achieved with longer PP treatments, regardless of the duration of their application (Figure 2). However, adequate height control was achieved with minimal impact on the other variables using the shorter, but still relatively long, PP treatments.

Two weeks of nominal 13 h PP treatment resulted in control about target heights, with associated good caliper and plant mass relationships (Figure 2a, Table 2). This treatment however, produced considerable lateral lammas growth in September (not presented) indicating that it is not a suitable treatment at this latitude.

Application of blackout for four weeks at nominal 13 h or 15 h PP resulted in good control of height about desired targets, with acceptable caliper and plant mass relationships (Figure 2b, Table 2). Based on this preliminary data, it appears that four weeks of nominal 13 h PP resulted in better quality nursery stock. There was no lammas growth with either of these treatments. The 13 h PP stock also achieved frost hardiness earlier than did the 15 h PP stock. The longest application of blackout for the nominal 13 h or 15 h PP also achieved the desired control of height but caliper was much reduced for stock from the shortest PP treatment (Figure 2c, Table 2). Again, there was no lammas growth.

As blackout installation is expensive, there often is a desire by nurserymen to get more than one crop rotation through a blackout equipped house. Therefore, the shortest duration which achieves the desired nursery results is the most attractive. In this case, it is probably four weeks of 13 h PP.

The greater root masses observed under the longer blackout treatments (Table 2) are a result of a rapid and major shift in carbon allocation to the roots, about two weeks after the onset of blackout (not presented). This presumedly occurs because of the changes in plant growth substance concentrations associated with the induction of terminal budset. There is a slowing in the rate of root mass increase for stock from the shorter PP treatments as frost hardiness increases. This is probably a result of decreased rates of photosynthesis during the period of increasing frost hardiness in spruce (Hawkins et al. pers. comm. III/87'"). Based on projections at this time, there will be little difference in root mass between treatments at the time of lifting and storage, while the large differences in shoot mass will remain.

The blackout treatments which are most appealing in this study are the longest ones. However, these nominal 15 h and 13 h day treatments induce responses that are to be expected from much shorter conventional static 8 h or 10 h days (Hawkins and Hooge[14], table 1). It appears that the dynamic approach used in this study enhanced seedling response to shortened days. Perhaps, seedlings not only respond to the absolute day length but to the rate at which the day length is changing, i.e. the 'dynamic day'.

The best dynamic blackout treatments have resulted in stock which is in balance (shoot:root ratios), has good root mass, has achieved early frost hardiness, and has adequate time for dormancy induction processes. These results run counter to traditional local nursery belief which suggests that blackout treatments result in seedlings with inadequate root mass and insufficient caliper.

Regardless of what the stock looks like at the nursery gate, the potential liabilities presented at these meetings [14.16] of stock grown under blackout must be kept in mind. That is, the accelerated spring flush and the delayed fall budset. Therefore, the nursery treatment cannot be fully evaluated until after early field assessments are in.

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