Five Year Field Performance of Short Day Nursery Treated Engelmann Spruce Seedlings in the Nelson Forest Region of British Columbia [1]

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Abstract–Engelmann spruce (Picea engelmannii Parry) seedlings of seedlot 5261 were subjected to a series of twelve short day treatment combinations (4 photoperiods by 3 durations) at Red Rock Research Station (RRRS) and grown under standard operational conditions at Surrey Nursery in 1988. Nursery treatment at RRRS significantly affected seedling morphology. Surrey stock was taller than RRRS stock. The 12 RRRS treatments plus the operational seedlot from Surrey Nursery were planted at Split Creek in the Kettle River Valley on June 13, 1989. At year five, excellent survival rates were still displayed by all treatments. As observed after nursery culture, height and root collar diameter were still significantly affected by nursery treatment after five field seasons. Photoperiod was a more significant factor than application duration. Ranges of height, root collar diameter, and stem volume for all 12 treatments were greater at planting than at year five; treatment differences were diminishing. Small stock at planting was growing at a greater rate than the larger planting stock. No significant growth difference existed between RRRS short day treated seedlings and Surrey operational stock after five seasons. Small, phenological effects from short day treatments were observed in the first year but were not significant. Overall, results suggest, when stock is spring planted from storage, short day nursery treatment is an effective tool to achieve both nursery and field objectives without compromising either.

INTRODUCTION

Short day treatment also known as photoperiod regulation or blackout is a procedure currently used by northern nurseries to help control height of vigorous conifer seedlings (Hawkins and Draper 1988,1991; Draper 1989). The cultural strategies simulate a later stage in the growing season. Seedlings are subjected to a shorter day length than the critical day length (Hawkins and Draper 1988; Bigras and D'Aoust 1993). In addition to achieving height control, seedlings have improved shoot to root ratio, root growth capacity, enhanced frost hardiness, and earlier dormancy through the use of short day treatments (Draper 1989, Hawkins and Draper 1991). However, short day treatment has potential field liabili-

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ties (Hawkins and Hooge 1988, Odlum and Colombo 1988, Salim et al. 1989, Bigras and D'Aoust 1993). Short day treated stock may flush earlier and grow later into the season, thereby increasing the potential for frost damage in the plantation. If severely frost damaged, a plantation may have increased mortality, or reduced early growth, potentially making the plantation unacceptable.

In 1988, no commercial nursery in the central interior of British Columbia had blackout facilities. There were many questions, both from the nursery and the field, surrounding the impact of blackout on conifer seedlings. The apparent benefits of blackout culture coupled with the concerns lead to a major nursery research trial at Red Rock Research Station (RRRS), near Prince George, BC (lat. 53° 45' N, long. 122° 42' W, elev. 620 m) commencing in 1988 (Hawkins and Draper 1988, 1991). Daylengths of 13, 15, 17, and 19 (ambient) h were applied for 2, 4 and 6 weeks duration to six interior spruce *(Picea glauca* (Moench) Voss, *P. engelmannii* Parry and their naturally occurring hybrids) seedlots ranging in latitude from 49° - 55° N (Hawkins and Draper 1988,1991). After short day treatment, seedlings were raised under ambient day length for the rest of the growing season until lift and freeze storage in early November 1988. The results of the nursery trial are reported elsewhere in detail (Hawkins and Draper 1991). Summarizing the nursery phase, photoperiod had a greater impact on seedling morphology than did application duration and seedlots generally responded in a like manner - height was proportional to photoperiod.

Five of the six seedlots grown at RRRS in 1988, after over-winter freeze storage, were planted in the spring of 1989, back in the area where the seed was collected, for observation of phenological abnormalities and long term growth (Draper 1989). All six of the seedlots were also planted in a common garden at RRRS in the spring of 1989 for detailed phenological observations (Hawkins and Draper 1991). Krasowski et al. (1993) reported on establishment of the five seedlots at the widely distributed field sites after the first field season. Generally in the field, treated seedlings were shorter at planting than untreated seedlings but had greater first field season leader increments than did untreated stock. Although significant, the differences between root collar diameters were small. Seedlings exposed to the shortest day for the longest duration tended to have more terminal buds that did not flush. However, significant phenological effects were observed for only one seedlot on two sites with major spring frost events in 1989 (Krasowski et al. 1993). Hawkins and Draper (1991) reported minimal phenological perturbations for the interior spruce seedlots in the common garden at RRRS.

Fifth season (1993) plantation performance of seedlot 5261 established in the Nelson Forest Region of British Columbia in 1989 is described. The emphasis is nursery treatment influences on sapling morphology, condition, and phenology.

MATERIALS AND METHODS

Plant Material and Nursery Culture

Engelmann spruce registered seedlot 5261 (Copper Kettle, lat. 49° 44' N, long. 118° 54' W, elev. 1650 m) was sown on March 14, 1988 at RRRS in PSB 313B styroblocks (Beaver Plastics, Edmonton, AB) and grown under common culture except for the time of blackout (Hawkins and Draper 1991). Starting July 6, 1988, seedlings received a dynamic system of short day treatments (Hawkins and Draper 1988, 1991) consisting of four photoperiods (13, 15, 17, and 19 (ambient photoperiod) h), each applied for 3 durations (2, 4, and 6 weeks). From November 2 to 4, 1988, seedlings were lifted and placed in frozen cold storage at -2°C ± 1°C until spring planting in 1989 (Hawkins and Draper, 1991).

Seedlot 5261 was also grown under operational conditions of water and nutrient regulated culture at the British Columbia Forest Service, Surrey Nursery (lat. 49° 4' N, long. 122° 46' W, elev. 20 m) in 1988. Stock was placed in frozen cold storage in the late fall of 1988. This is referred to as the operational stock.

Planting Sites

Stock of seedlot (SL) 5261 was shipped from storage at RRRS and Surrey Nursery in early June and planted on June 13, 1989, at Split Creek (lat. 49° 51' N, long. 118° 45' W) in the Kettle River Valley of the Nelson Forest Region. The predominantly lodgepole pine stand was formerly salvage logged because of mountain pine beetle infestation in 1987 and 1988 and was burned in the fall of 1988 (Thompson, 1989). Burning removed the LFH horizon. However, greater than 60 cm of rooting depth was still observed. This site has a 0-5 percent south western slope and is in the ICHmw2 BEC subzone (Ecosystems of B.C., 1991) at an elevation of 1375 meters.

The site consisted of five blocks with 13 randomized treatment rows in each (Thompson, 1989). Each row was spaced two m apart with 25 seedlings in a row planted one m apart. Good planting quality was maintained by two planters and no planter effects are suspected (Thompson, 1989). Of the 13 rows, 12 consisted of RRRS blackout treated stock and one of operational stock from Surrey Nursery. The operational stock was also planted in the area surrounding the research plantation.

On May 8, 1989 all stock grown at RRRS in 1988 (72 treatments), including seedlot 5261, was planted in a common garden at RRRS (Hawkins and Draper, 1991). The design was a randomized complete block. Phenology assessments were done at weekly or more frequent intervals during the active growing season and year end morphologies were measured (Hawkins and Draper, 1991).

Statistical Analysis

A completely randomized block design incorporating the RRRS nursery culture was chosen for a three-way factorial analysis (Table 1). The design was simplified when the operational seedlot was included in the analysis (Table 2). Analysis of data at the end of nursery culture simplified the initial model further (Table 3).

The Systat Statistical software package (Wilkinson, 1990) was used to compare treatment means. First and fifth year treatment effects on morphological parameters were compared using Systat's hypothesis contrasting procedure (orthogonal contrasts). This procedure was also used to compare photoperiod and duration effects on treated versus operational stock. Percentage data for survival was normalized using an arcsin transformation (Neter and Wasserman, 1974, pp. 508-509). Additionally, Kruskal-Wallis one way analysis was used to determine if class derived sapling forms were significant after five years (NPAR: Systat). Main treatment effects and interactions were considered significant at alpha < 0.05.

Measurements

Post-planting assessments of RRRS treated SL 5261, as well as the Surrey stock, began June 14, 1989 (Thompson, 1989). Total height (±5 mm) and ground level stem diameter (GSD) (±0.1 mm) were measured on all seedlings in the spring (pre-flush) and fall (post-flush) in 1989. Year five measurements and assessments were done in September 1993. Mean values for height and GSD were calculated and analyzed in relation to one of two models (Tables 1 & 2). Stem volume was calculated as one-third stem basal area at ground level x height. Seedling condition (vigour) was assessed at the time of each measurement as recommended by Herring and Pollack (1985).

Detailed phenology assessments were done during the first field season starting on June 27, 1989, two weeks after planting. They continued on a fortnightly frequency until terminal bud formation was complete, indicating shoot growth had finished (Thompson, 1989). Consult Krasowski et al. (1993) for more details on first year field data collection, analysis and interpretation. Condition codes were used to record foliage damage, leader and/or stem damage, bud phenology, and presence of insects as outlined by Draper (1989). Seedling condition by treatment was recalculated after each fall measurement series. Only first and fifth year results from Split Creek are presented and discussed.

RESULTS AND DISCUSSIONS

Nursery Morphology

The nursery segment for this series of short day treated seedlings was reported by Hawkins and Draper (1991). In brief, the shorter photoperiod treatments significantly reduced crop height (Figure 1, Table 4) for all seedlots including Engelmann spruce, seedlot 5261. Duration main effects on height were not significant. This suggests for the duration and photoperiod combinations tested, application durations greater than two weeks do not increase the height control attained in the crop. Photoperiod and duration effects on mean root collar diameter (RCD) values were significant. Ambient (19 h) and 17 h photoperiods did not affect RCD with any of the applied duration periods. However when shorter photoperiods (13 and 15 h) were combined with longer durations (4 and 6 week), a significant reduction in RCD was observed (Figure 2, Table 4). This indicates the negative impact of excessive photoperiodic reduction. There was no greater control of seedling height but RCD growth was slowed or stopped. The phenomenon is presumedly related to the lost photosynthetic productivity of extreme treatments. It is possible that for SL 5261 a different photoperiod - duration combination would have been more successful in producing the ‘ideal’ morphotype; possibly a 13 h photoperiod for one week. For spruce, the ‘ideal’ morphotype would have a shoot to root ratio of about two (Thompson 1985) and a height to RCD ratio approaching 40 (Burdett et al. 1984).

Table 1. ANOVA model incorporating RRRS nursery design into the field layout.

Source	df	Error term
Block [1]	4	Tree (B P D)
Photoperiod	3	B * P
Duration	2	B * D
B * P	12	Tree (B P D)
B * D	8	Tree (B P D)
P * D	6	B * P * D
B * P * D	24	Tree (B P D)
Tree (B P D)	1440	

[1] Block is random and Photoperiod and Duration are fixed factors.

Table 2. ANOVA model for the introduction of the operational seedlot with the 12 RRRS treatments of seedlot 5261.

Source	df	Error term
Block [1]	4	Tree (B T)
Treatment	12	B * T
B * T	48	Tree (B T)
Tree (B T)	1543	

[1] Block is a random factor and Treatment is fixed.

Table 3. ANOVA model for seedlot 5261 at the end of RRRS nursery culture.

Source	df	Error term
Photoperiod [1]	3	Seedling (P * D)
Duration	2	Seedling (P * D)
P * D	6	Seedling (P * D)
Seedling (P D)	348	

[1] Photoperiod and Duration are fixed factors.

First year common garden data for seedlings planted at RRRS revealed that short day treatments had little effect on Engelmann spruce, seedlot 5261. The mean height range between photoperiod and duration levels was only 12 and 5 mm, respectively (Hawkins and Draper, 1991). Analysis of GSD increment displayed different trends among the other seedlots of interior spruce (Hawkins and Draper, 1991). The general trend was for short photoperiod treatments to have greater GSD increments. However SL 5261 showed greater diameter increments with increasing photo-period. It should be noted that RRRS is considered offsite for this seedlot.

Morphology at Split Creek

After planting at Split Creek, treatment mean heights were shorter and GSD was greater than sampled in the nursery (Table 4). This reflects i) seedlings were planted deeper than the root collar, and ii) culling at the nursery tended to increase the average diameter of the crop with little effect on height. The mean height after planting of all 13 and 15 h durations was below the lower limit of 120 mm for this stocktype as defined by BC Forest Service seedling growing contract specifications. The operational treatment was significantly taller than all RRRS produced stock, being on average 88 percent (88.1 mm) taller than stock from the P 15 h D 4 week treatment. GSD of the operational stock was about the same as that of the tallest RRRS stock.

After the first growing season, height was significantly affected by block, photoperiod and duration (Table 5). Block and duration were also significant for GSD and there were significant P*D interactions for both variables (Table 5). The P*D interaction for height resulted at a photoperiod of 19 h where height increased with duration rather than decreasing. The interaction for GSD was caused by the 6 week duration of 15 and 17 h photoperiods increasing from the 4 week measurement while it decreased in the other two photoperiods. The extreme range between blocks was 0.88 cm for height and 0.27 mm for GSD, certainly of no biological interest. Height increased significantly with each photoperiod and increments were similar among photoperiods (Table 5). This suggests short day treatment does not carryover to the field in terms of leader elongation. Krasowski et al. (1993) reported better leader increments for the short day treated stock on other sites in this experimental series. Stock from the short photoperiod treatments were still the shortest after the first season. Photo- period had no affect on GSD (Table 5) but seedlings treated with the shortest photoperiods had the greatest increments. This suggests a positive field response during the first field season by those seedlings receiving blackout treatment. The operational stock was still significantly taller than any other treatment after one year (Tables 5 & 6). The greater mean height range by photoperiod and duration at Split Creek, 46 and 21 mm, compared to those at RRRS, is within that experienced operationally. This further reinforces the observation the common garden stock was offsite at RRRS. Survival was excellent, greater than 97 percent in all cases except one where it was 93 percent (Table 6).

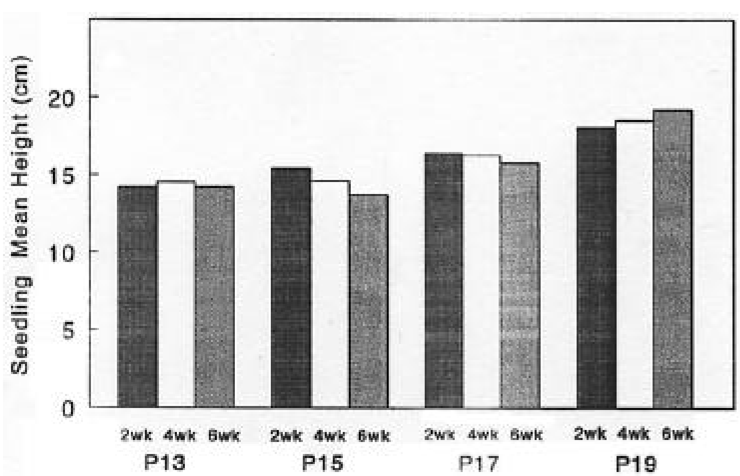

Figure 1. Mean seedling height at the end of nursery culture in 1988 at RRRS by photoperiod and duration. Modified from Hawkins and Draper (1991).

Height, GSD and stem volume are morphological factors that provide a good estimate of seedling performance after outplanting (Mexal and Landis, 1990). These were used to compare treatment effects after the fifth growing season (Tables 5 & 6). Photoperiod and duration continue to have significant effects on height (mean range of P = 49 mm, D = 30 mm), GSD (P = 1.1 mm, D = 1.2 mm), and stem volume (P = 18 mL, D = 15 mL). In general, longer photoperiods combined with shorter durations resulted in taller seedlings with larger GSD and greater stem volume.

The percent extreme range (largest mean - smallest mean) / smallest mean) * 100) for height by photoperiod, duration and 13 treatments was 6, 3, and 13 percent respectively at year five. At planting, these differences were 36, 2 and 88 percent. Clearly the shorter stock was growing at a greater rate. A similar trend was observed for GSD. At planting percent extreme ranges by photo-period, duration and treatment were 18, 9, and 33 percent but had decreased to 5, 5, and 18 percent at year five. These data suggest the effect of nursery treatment is decreasing. Consequently, short day treatments may influence growth patterns of seedlings after nursery culture and in the initial years in the field. However, long term differences among nursery treatments, while statistically significant, are not thought to be biologically significant by the end of five growing seasons.

At year five, survival was significantly influenced by photoperiod but not by duration (Table 5). Stock raised under the 15 h photoperiod had significantly lower survival, 95.7 percent, than did stock raised under the other three photoperiods. *Rhizina undulata* did account for 2.4 percent of the mortality in the P 15 h - D 2 week treatment. This may have been sufficient to cause photoperiod differences. There was a trend for survival to increase as photoperiod increased towards ambient

Table 4. Comparison of stock morphology from RRRS and the Surrey Nursery operational seedlot (OPSL) at the end of nursery culture at RRRS (sample) and on measurement after planting at Split Creek (Split). Height (HT), RCD and GSD in mm.

Photoperiod (hours)	Morphological Variable & Site	Spring 1989 Application Duration (weeks) 2	4	6
19	HT RRRS	181.0	185.0	192.0
	HT Split	150.0	150.6	157.3
	RCD RRRS	3.11	3.02	3.04
	GSD Split	3.18	3.21	3.26
17	HT RRRS	164.0	163.0	158.0
	HT Split	143.6	146.2	146.2
	RCD RRRS	3.22	2.83	2.50
	GSD Split	3.36	3.23	3.16
15	HT RRRS	154.0	145.0	142.0
	HT Split	117.0	100.4	116.7
	RCD RRRS	3.15	2.82	2.50
	GSD Split	3.26	3.01	2.85
13	HT RRRS	142.0	145.0	142.0
	HT Split	113.0	112.1	111.0
	RCD RRRS	2.93	2.39	2.16
	GSD Split	3.08	2.66	2.53
OPSL	HT Split	188.5		
	GSD Split	3.16		

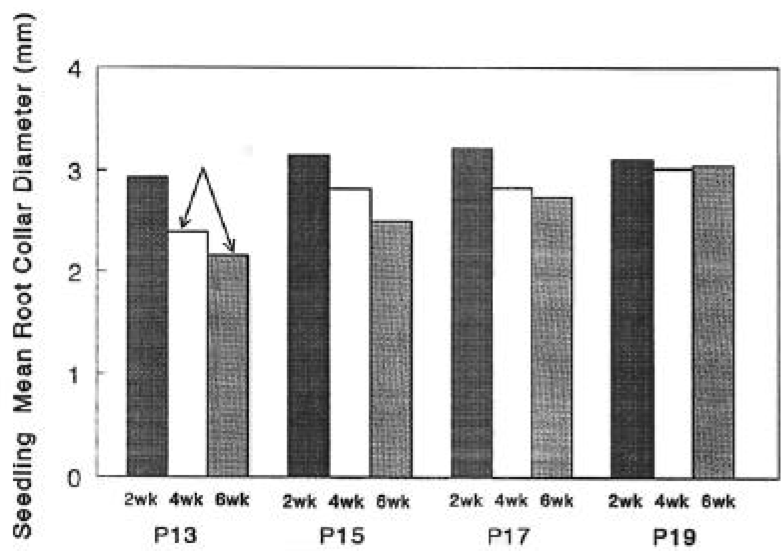

Figure 2. Mean seedling root collar diameter at the end of nursery culture in 1988 at RRRS by photoperiod and duration. Arrows indicate the impact of duration at shorter photoperiods on diameter. Modified from Hawkins and Draper (1991).

Table 5. Mean height (HT), GSD, stem volume (SVol) and survival (SURV) for each block, photoperiod (h), application duration (weeks) and the operational seedlot (OPSL) after the first (89) and fifth (93) growing seasons. Mean squares (MS) and probabilities (Pr) of significance for variables using the model in Table 1. Means followed by the same letter are not significantly different; LSD at alpha = 0.05.

Source	HT89 mm	GSD89 mm	HT93 mm	GSD93 mm	SVol93 mL	SURV93 %
Block						
1	214.6b	4.71c	896.0ab	23.57a	139.5a	97.8a
2	207.0a	4.66c	888.1ab	23.21a	136.3a	96.0a
3	213.6b	4.73c	905.1b	24.52c	156.8b	98.5a
4	205.8a	4.56b	907.0b	24.05b	148.8b	97.2a
5	206.1a	4.46a	865.6a	23.60a	137.3a	97.8a
Photoperiod						
13	186.6a	4.59a	865.8a	23.67ab	138.4a	97.3b
15	194.9b	4.56a	878.0a	23.19a	134.7a	95.7a
17	223.6c	4.67a	911.0b	23.99b	149.3b	98.1b
19	232.6d	4.65a	914.7b	24.30b	152.6b	98.9b
Duration						
2	219.2b	4.71c	913.1b	24.44b	151.5b	98.6a
4	198.1a	4.50a	882.9a	23.19a	136.8a	96.4a
6	210.9b	4.65b	881.1a	23.74a	142.9a	97.6a
OPSL	260.3	4.62	902.4	23.55	141.0	96.7

ANOVA		Fall 1989				Fall 1993							
Source	df	HT		GSD		HT		GSD		SVol		SURV	
		MS	Pr	MS	Pr	MS	Pr	MS	Pr	Ms	Pr	MS	Pr
B	4	5441	.005	3.818	.000	824	.030	74	.020	$228*10^{6}$	.001	0.039	.614
P	3	181217	.000	0.625	.193	2145	.001	81	.022	$268*10^{6}$	.001	0.173	.033
D	2	55531	.000	5.970	.000	1585	.006	191	.001	$267*10^{6}$	.006	0.150	.080
B*P	12	1359	.508	0.543	.173	498	.077	29	.317	$65*10^{6}$	.229	0.038	.800
B*D	8	1584	.366	0.276	.694	369	.290	56	.023	$98*10^{6}$	.054	0.065	.356
P*D	6	17106	.000	2.254	.000	1585	.001	160	.001	$295*10^{6}$	.001	0.110	.083
B*P*D	24	3466	.000	0.606	.048	511	.021	51	.002	$111*10^{6}$	.001	0.056	.533
Error	1440	1450		0.396		305		25		$51*10^{6}$		0.059	

daylengths. This observation is the opposite of Salim et al. (1989) who postulated that nursery blackout treatment promoted field survival. However, such high percentages, 96 versus 99 percent, may indicate that short day treatments had no effect on seedling survival at this site. Survival of the operational stock was also very good at 96.7 percent (Table 5). Overall on this site, survival is not an issue. Seedling condition in the fall of 1989 monitored by Krasowski et al. (1993) suggested that a possible *Rhizina* infection may have caused the observed mortality rather than exposure to short day nursery treatment.

No differences existed at year five between the Surrey Nursery operational stock and the RRRS stock when orthogonal contrasts were used to compare photoperiod, duration, and all PxD treatments. This suggests the quality of the stock produced at RRRS was similar to that of stock produced at Surrey Nursery. Performance similarities in stock from the two nurseries also reinforces conclusions at the other trial sites (Krasowski et al. 1993) and in a common garden (Hawkins and Draper 1991). Furthermore, any concerns about research stock produced at RRRS being different from operational stock production should be alleviated by these data.

Phenology and Condition

In the common garden at RRRS, stock of seedlot 5261 flushed and set lateral buds more

Table 6. Mean height (HT, mm), GSD (mm), stem volume (SVol, mL) and survival (SURV, %) for all treatment combinations and the operational seedlot (OPSL) after the first (89) and fifth (93) growing seasons.

Photoperiod (h)	1989 Duration (weeks)			1993 Duration (weeks)		
	2	4	6	2	4	6
19 HT	234.2	227.7	235.9	933	905	905
GSD	4.66	4.65	4.63	24.60	24.30	24.01
SVol	-	-	-	156.8	151.3	149.6
SURV	98.4	98.4	100	98.4	98.4	99.2
17 HT	220.6	214.7	235.4	886	916	932
GSD	4.69	4.59	4.86	23.17	23.8	25.01
SVol	-	-	-	137.5	146.8	163.7
SURV	99.2	96.0	99.2	99.2	96.0	99.2
15 HT	220.8	174.4	189.5	953	834	852
GSD	4.83	4.36	4.57	24.70	21.49	22.79
SVol	-	-	-	160.7	113.2	127.5
SURV	99.2	96.0	93.6	98.4	96.0	92.8
13 HT	201.4	175.7	182.6	886	876	835
GSD	4.69	4.55	4.54	24.69	23.17	23.16
SVol	-	-	-	148.4	135.0	130.8
SURV	98.4	97.6	99.2	98.4	95.2	98.4
OPSL HT	260.3			902.4		
GSD	4.62			23.55		
SVol	-			141.0		
SURV	96.7			96.7		

rapidly when cultured under a 13 h photoperiod and 6 week application duration (Hawkins and Draper 1991). Krasowski et al. (1993) reported similar results early in the growing season at Split Creek. The 13 h photoperiod treated stock also displayed the greatest number of unflushed terminal buds at Split Creek. Phenology class assessments continued during the summer until fall measurements but revealed no further significant treatment differences (Krasowski et al. 1993). There was no earlier flush or later bud set for the short day treated stock but it had more terminal buds that failed to flush in the first field season.

Previous studies have observed that short day treated coniferous stock may flush earlier in the spring and grow later into the fall compared to untreated stock (Hawkins and Hooge 1988; Odlum and Columbo 1988; Salim et al. 1989). Higher survival has also been reported for seedlings planted in interior British Columbia when treated with short days in the nursery (Salim et al. 1989). After the first growing season at Split Creek, 5.6 percent of the seedlings had either a forked (multiple) leader, a dead or unflushed terminal bud, a dominant lateral branch, or a combination of these. However, 84 percent of the seedlings that displayed first year form problems were unaffected at year five. A damaged apical bud caused by early or late frost when the bud was active and susceptible to freezing could result in forking or lateral dominance (Carey 1978). At year five, 10.4 percent of all seedlings showed possible form defects although statistical analysis using Kruskal-Wallis by nursery photoperiod or duration and field block determined that defect could not be attributed to any of the independent variables. This level of forking is probably a function of interactions of genotype and environment, and can be regarded as an endemic level of forking. Experience with other plantations suggest that it will probably have little subsequent effect on plantation quality.

SUMMARY AND CONCLUSIONS

While shorter seedlings, such as those produced by the photoperiod treatments in this trial, may have early advantages over taller seedlings, these were not demonstrated by seedlot 5261 at Split Creek. The seedlings in this trial overcame any possible size disadvantages, demonstrating that blackout produced seedlings are physiologically equal to and possibly superior to those from operational nursery regimes. It remains to be seen whether this more rapid early growth is continued past five years. This trial demonstrates that if blackout treatments are used to achieve operational morphological criteria, the stock thus produced are not physiologically disadvantaged. For seedlot 5261, the nursery treatment with the greatest height and second largest root collar diameter at year five was the intermediate photoperiod (P 15 h) and the shortest duration (D 2 week). This was the nursery treatment suggested as being the best to attain nursery objectives and to have minimal impacts in the field (Hawkins and Draper 1991). It is also closest to current operational treatments. In fact, at year five, this treatment combination resulted in the second largest stem volume (Table 6). There were no significant differences between the operational stock from the Surrey nursery and the RRRS nursery treated stock. This has two major implications:

i) similar five year performance was achieved even though RRRS short day stock was significantly smaller at planting than Surrey nursery operational stock suggesting that
   a) blackout culture may be less stressful than nutrient and water culture or
   b) given time in a similar environment the genotype of various nursery treat-ments will be expressed in a like manner; and

ii) stock produced at RRRS is comparable to operational stock and field results using RRRS stock are therefore applicable.

Concerns over altered bud phenology in response to shortened photoperiods were not realized on this site. However seedlings receiving the extreme nursery treatments had more terminal buds that failed to flush. Similar effects were also observed in stock subjected to extreme treatment during the first field season in the common garden at RRRS. When moderate treatments were used; longest possible day applied for the shortest duration to attain nursery objectives, 15-h for 2 weeks in this case; field performance was not negatively influenced and was possibly influenced positively.

Results may vary year to year as climate, site conditions, and stock type are not constants. The genetic component is constant but environment and presumably its interaction with genotype is dynamic. Similarly, conclusions obtained may be different if short day treatments were applied in different years, at different times, or if the plantation was established in different seasons. However, preliminary analysis of different interior spruce seedlots established on different sites after winter freeze storage suggests the success of short day treatments is probably quite broad (EP 1042 unpublished data). The results suggest the culture is appropriate for vigorous seedlots when applied judiciously. Furthermore, low phenological alterations, high survival, and good growth were observed for these treatments 5 years after spring planting from freeze storage.

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