Summer Plant Culling Criteria of Interior Spruce: Keeping the Bad and Throwing the Good?[1]

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Abstract — Morphological criteria by which spruce nursery stock, or any conifer crop is culled generally raises discussion at the nursery gate. The discussion does not focus on the bulk of the crop but on those seedlings just over or under height and diameter limits. In British Columbia, some workers believe that 'good' small seedlings are being culled in favour of tall 'poor' stock. To address some of these concerns, standard and substandard (culls) blackout treated spruce stock derived from three seed origins (registered natural stand, registered seed orchard and full-sib controlled cross) was summer planted at Red Rock Research Station (RRRS), near Prince George, BC in early July 1993. RRRS is an uncompetitive environment. Very liberal grading criteria were used (the plug must hold together and the seedling should be taller than 9 cm) when this crop (16 of the 26 seedlots were of seed orchard origin) was lifted at RRRS. 1752 seedlings were planted and they were monitored during 1993 and into the 1994 season. Height and root collar diameter (RCD) of all seedlings was measured at planting and in September 1993. Seedlings were then classed as 'culls' or 'standards' based on morphology at planting according to B.C. Forest Service (BCFS) seedling specifications for interior spruce (*Picea glauca, P. engelmannii* and their naturally occurring hybrids) summer plant stock. Of the 781 seedlings classified as culls, 8.9 % were underheight, 7.9 % were overheight, 60.3 % had inadequate RCD, 20.5 % were underheight with poor RCD, and 2.3 % were overheight with poor RCD. Survival until June 1994 was excellent: greater than 98 percent regardless of class. Stem volume increment in 1993 was similar between cull and acceptable class seedlings but cull seedlings had significantly greater relative stem volume growth rates. These results raise concerns about present grading criteria for summer planting, particularly for seed orchard stock which tended to have smaller RCD. Further monitoring of the summer planted stock will be necessary to determine whether present grading criteria are in fact too conservative and should include some of the seedlings presently being culled.

Growth patterns after planting were also examined in relation to seed origin and nursery treatment. Preliminary conclusions suggest that 1) seed orchard seedlots do not display unusual variability compared to natural stand seedlots, 2) blackout can effectively produce morphologically uniform seedlings suitable for summer planting programs and 3) blackout may promote abnormal terminal bud flushes. The cause and control of the latter issue remains to be ascertained. Otherwise, blackout is an efficient method to deliver quality seed orchard stock to the field for summer planting.

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INTRODUCTION

Recently, foresters and nursery workers have expressed uncertainties regarding the quality of spruce *(Picea* sp*.)* seedlings derived from seed orchard (Class A) seed, as opposed to seedlings from natural stand (wild) seed collections. Their concerns surround the morphology and physiology of interior spruce seed orchard stock as well as the operational feasibility of using this stock in summer planting programs (Hawkins 1993b). During the 1970's, seedlings from the coastal Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) seed orchard program were regarded with similar scepticism as stock from the interior spruce seed orchard program is presently. However, inquiries into coastal Douglas-fir seed orchards concluded, that no data existed to indicate Class A seedlots were inferior to Class B (natural stand) in terms of nursery performance (Mueller et al. 1981).

Morphologically, spruce seed orchard seedlings are perceived to be tall and spindly with small root collar diameters (RCD) and inadequate root system development (Hawkins 1993b). Additionally, these seedlots are believed to have more height variability than natural stand seedlots (Hawkins 1993b). Physiologically and phenologically, seed orchard seedlings have exhibited developmental variation in timing of budset, development of frost hardiness, and dormancy onset when grown under non-blackout nursery conditions (Hawkins 1993a; Krasowski et al. 1993). Whether this physiological variation is greater than that observed for natural stand collections is unknown (Hawkins 1993a). Logistically, seed orchard stock often fails to meet summer plant deadlines (Hawkins 1993b) due to the difficulty in 'setting' it up for planting. In nursery operations and during field outplanting, it is operationally and economically desirable to have morphologically and physiologically uniform stock (Lang 1989). Consequently, it is pertinent to address these concerns so that B.C.'s interior spruce seed orchard program may fulfil its potential and become a successful and integral component of the intensive provincial regeneration program.

Modified nursery culture may help prevent the undesirable characteristics displayed by some seed orchard stock (Hawkins 1993b). Rather than employing drought and nutrient stressing, common nursery practice to regulate seedling height (D'Aoust and Cameron 1981; Matthews 1981; Johnson 1985), blackout (photoperiod manipulation, short-day treatment or darkout) has proven to be an effective method for height control (Arnott and Mitchell 1981; D'Aoust and Cameron 1981; Hawkins and Draper 1991; Bigras and D'Aoust 1993). Through simulating a later time in the growing season, blackout enhances morphological uniformity, apical budset, frost hardening and dormancy onset (Colombo et al. 1981; Silim et al. 1989; Bigras and D'Aoust 1993). In turn, these benefits may increase field survival (Silim et al. 1989). Extremely long blackout treatments, such as 8 h or shorter daylength nursery regimes, can have negative impacts on post planting phenology and frost resistance (Hawkins and Hooge 1988; Odlum and Colombo 1988; Bigras and D'Aoust 1993). However, moderate blackout treatment (11h to 14h) may prove successful in reducing the morphological and physiological variability of seed orchard seedlots as well as in natural stand and full-sib controlled cross seedlots (Hawkins 1993c; Hawkins and Krasowski 1993).

A trial involving Silviculture Branch, Research Branch and Forest Region staff was established at Red Rock Research Station (RRRS) in February 1993 (Hawkins 1993b). The primary objectives of the trial were to 1) compare the morphological and physiological variability among seed sources (registered natural stand, operational seed orchard and full-sib controlled crosses from the research program) at the nursery and after summer planting and 2) if necessary, make nursery culture recommendations that address concerns surrounding seed orchard seed (Hawkins 1993b). This paper will discuss these objectives in light of summer planted seedlings' morphology and growth patterns through the summer of 1993 after planting, survival rates, and bud flush phenologies into the spring of 1994. Additionally, seedlings will be described in terms of the traditional culling criteria outlined by the B.C. Forest Service (BCFS) for summer planted spruce.

MATERIALS AND METHODS

Nursery

Seed of 50 spruce *(Picea glauca* (Moench) Voss, *P. engelmannii* Parry and their naturally occurring hybrids) seedlots from three seed sources (registered natural stand collections, registered seed orchards, and full-sib controlled crosses) was sown on February 17, 1993, into 415B polystyroblocks (Beaver Plastics, Edmonton, AB; 112, 105 mL cavities per container) and cultured at RRRS near Prince George, B.C. (Lat. 53°45'N, Long. 122°41'W) as described by Hawkins (1993d) and Hawkins and Krasowski (1993).

Seeds were germinated and grown under modified nursery regimes outlined by Draper and Hawkins (1989) and Hawkins and Draper (1991). Blackout was applied to 26 of the 50 seedlots, starting in late May when mean seedlot height was approximately 10 cm (Hawkins 1993b). Ten of the seedlots were from natural stand collections, six were from seed orchards, and ten were full-sib families. Seedlots originating north of 53°N latitude received a 14h day whereas those originating south of this latitude received an 11h day (Hawkins 1993b). Blackout treatments lasted for 17 days (Hawkins 1993c). Untreated seedlings from the 26 blackout treated seedlots, as well as those from the remaining 24 seedlots, served as controls and received water and nutrient manipulation for height regulation as would be applied in nurseries where blackout was not available.

Summer Plant

Two grading criteria were used at summer lift: the root plug must hold together (cohesive) and seedlings must be at least 9 cm tall (Hawkins 1993c). These liberal culling standards, compared to BCFS's regular summer lift 415B stocktype specifications of minimum RCD of 2.6 mm, height between 140 mm and 280 mm with a target of 220 mm, cohesive root plugs, and visible terminal bud, were used because of the low number of cavities sown for each seedlot treatment (blackout and control) (Hawkins 1993c).

On July 5, 8, and 15, 1993 (approximately 17 days after removal from short-day treatments), all 26 blackout treated seedlots and their untreated control counterparts were planted into an experimental field at RRRS (Hawkins 1993c). A completely randomized design was established where six randomly selected seedlings from each seedlot treatment unit (STU: a styroblock receiving a specific cultural treatment) were planted in rows, with 30 cm spacing within and among rows (Hawkins 1993c). Each STU was replicated five or six times depending on the number of blocks sown (Hawkins and Krasowski 1993). In total, 1752 seedlings were planted into the RRRS experimental field.

Height to the nearest mm and RCD to the nearest 0.1 mm were measured at the time of planting and again after the remaining 1993 summer season of growth (September 7). Root and shoot dry weights (to the nearest mg) for summer planted stock were estimated at the time of planting by destructively sampling three randomly selected seedlings per STU (Hawkins 1993d). Post-planting survival was assessed in September, October, November, 1993 as well as in May and June 1994. Additionally, bud-flush characteristics were assessed for terminal buds in early June 1994. Terminal leader buds were subjectively classified as 1) normal, completely flushed and extended; 2) none, not flushed at all; or 3) abnormal, partially/ irregularly flushed. Abnormally flushed buds indicated that bud-break had occurred but there was very little extension of the preformed shoot beyond the open bud scales. These seedlings often had a rosette of multiple leaders. Summer planted seedlings will continue to be monitored for the next two to four seasons (Hawkins 1993c).

Mean values were calculated for height, RCD, stem volume, stem volume increment (stem volume in September-stem volume at planting) and relative volume growth were calculated using six seedlings per STU planted into the experimental field at RRRS. Dry shoot and root weight means were calculated using three seedlings per STU. Morphological characteristics were computed by the main factors of interest: seed origin (wild, seed orchard and full-sib controlled cross), seedlot and nursery treatment (control and blackout). Morphologies of all seedlings at planting were subjected to a theoretical cull procedure according to the BCFS specifications already described. This enabled the morphologies and 1993 summer growth of all (substandard or culls included) seedlings and just 'acceptable' (standard) seedlings (after the theoretical cull) to be compared. Culled seedlings were separated into five exclusive cull classes: 1) underheight (< 140 mm) with acceptable RCD; 2) overheight (> 280 mm) with acceptable RCD; 3) acceptable height with inadequate RCD (< 2.6 mm); 4) underheight with inadequate RCD (< 140 mm and RCD < 2.6 mm); and 5) overheight with poor RCD (> 280 mm and RCD < 2.6 mm). Estimated dry shoot and root weights for culled and acceptable seedlings were obtained by merging mean STU weights from destructively sampled seedlings with mean STU height and RCD values from the planted seedlings. The theoretical cull in this instance was performed on styroblock mean heights and RCDs rather than on an individual seedling basis. Potentially this resulted in some acceptable seedlings being included with the cull seedling weights and *vice versa*. Post-planting survival as of June 1994 (percentage of living seedlings) was computed for the above cull and acceptable categories.

Statistical Analyses

General Linear Models procedure (GLM) in SAS (SAS 1988) was used to analyze the significance of seed origin, seedlot and nursery treatment on seedling morphological characteristics, recovery and post-planting survival (ANOVA model presented in Table 1). Analysis of variance was performed on parameters of interest including and excluding theoretically culled seedlings to test if sources changed in significance with all seedlings compared to just the acceptable ones. SYSTAT's (Wilkinson 1990) Kruskal-Wallis non parametric one-way analysis of variance was used to analyze the frequencies of seedlings in the three apical bud-flushing categories

Table 1. ANOVA model used to compare morphological and growth characteristics of 415B seedlings summer planted at RRRS in July 1993. Root and shoot weights were done on STU means: the experimental unit was STyroblock (SO SL PP) with 240 df.

Source	df	Error Term
Seed Origin	2	SL(SO)
SeedLot (SO)	23	SD(SO SL PP)
PhotoPeriod [a]	1	SL(SO) * PP
SO * PP	2	SL(SO) * PP
SL(SO) * PP	23	SD(SO SL PP)
SeeDling (SO SL PP) [b]	1696	
Total	1747	

a. PhotoPeriod was the nursery treatment of interest.
b. Seedling was the experimental unit.

according to seedling class (five cull classes and acceptables), nursery treatment (blackout and control) and seed origin. Results were considered statistically significant at alpha = 0.05.

Equations

(1) Stem volume (mL) = 1/12 x x (RCD)2 x height where RCD and height are in cm.

(2) Relative Stem volume growth (mL/mL/season) =log 10 (Stem volume in SEP) - log 10 (Stem volume at planting).

RESULTS

Seed Origin

Seed origin had very little influence on seedling morphology as measured at planting or after a partial summer of field growth (Tables 2, 3 & 4). Only seedling height at planting was significantly impacted by seed origin (Table 2). Full sib mate-rial was taller than seed orchard stock which was taller than the wild seedlots. There were significant interactions between seed origin and nursery treatment for height and stem volume at planting as well as for height in September.

Full-sib seedlings had the greatest mean values for height (Table 4), dry root and shoot weights (Table 3). RCD values were similar among seed origins. By September, with the exception of height, seed orchard seedlings exhibited the most desirable characteristics, having the greatest mean values for RCD, stem volume increment and relative stem volume growth (Table 4). In general, relative stem volume growth was greater for seed orchard and full-sib seedlings compared to natural stand seedlings (Figure 1). Hence, at planting and in September seedlings derived from tree improvement seed (full-sib and seed orchard) were larger than seedlings from natural stand collection seed. Post-planting survival was excellent, being greater than 99 percent regardless of seed origin (Table 4).

Seedlot

Seedlot was a significant source of variation for all morphological parameters in July as well as for height, RCD and stem volume in September (Tables 2, 3 & 4). There were significant interactions between seedlot and nursery treatment for height in July and for height, RCD and relative stem volume growth in September. Interactions among seedlot and nursery treatment were expected due to the great variability displayed among seedlots in response to blackout application (not presented).

Seedling morphology and survival parameters varied among seedlots of the same seed source as well as among seedlots from different seed sources. As assessed in June 1994, post-planting survival values were high for all seedlots.

Photoperiod

At planting, nursery treatment (photoperiod = blackout) significantly reduced seedling height, stem volume and shoot weight (Tables 2, 3 & 4). Height and stem volume were still significantly affected by nursery treatment in September (Table 2). Interactions between nursery treatment and seed origin or seedlot are noted in the previous sections. Relative stem volume growth however, was greater for blackout seedlings than for controls (Table 4). Post-planting survival until early June 1994 was excellent for all seedlings regardless of whether they were blackout treated or controls, culls or acceptables (Table 4).

Blackout treatment however, impacted bud-break characteristics of seedlings in their second year of growth (June 1994) (Table 5). Where controls lowest value for successful flushing was 58 percent in the underheight, poor RCD cull class, the highest successful flushing value for blackout seedlings was 57 percent in the acceptable class (Table 5). In general, more blackout seedlings, all classes included, failed to flush or had funny (unusual form) flushes during their second season than did control seedlings.

Table 2. Mean square (MS) and probability of F [P(F)] for assessed morphological parameters at planting in July 1993 and at the end of the growing season, September 1993, for all seedlings planted (ALL), acceptable seedlings only (STD), and cull seedlings only (CULL). Sources were considered significantly different at alpha = 0.05. Abbreviations: HT, height; RCD root collar diameter; VOL, stem volume; VINC, stem volume increment; and VGRO, relative stem volume growth rate.

			July 1993			September 1993				
Source	df		RCD	HT	VOL	RCD	HT	VOL	VINC	VGRO
ALL										
Seed Origin	2	MS	0.050	95894	0.441	3.555	67367	1.851	0.516	0.070
		P(F)	.9718	.0090	.1963	.2441	.0513	.1544	.3880	.6216
SeedLot(SO)	23	MS	1.756	16454	0.252	2.370	19876	0.912	0.523	0.144
		P(F)	.0001	.9991	.0001	.0001	.0001	.0001	.0001	.0001
PhotoPeriod	1	MS	2.811	1621102	10.44	0.090	1618145	21.23	1.942	0.261
		P(F)	.1260	.0001	.0001	.8371	.0001	.0001	.0204	.2908
SO*PP	2	MS	0.611	40320	0.450	2.621	51805	0.341	0.009	0.221
		P(F)	.5852	.0080	.0418	.3016	.0050	.2810	.9733	.3871
SL(SO)*PP	23	MS	1.115	6721	0.123	2.075	7862	0.254	0.313	0.223
		P(F)	0.0001	.0001	.0001	.0001	.0001	.0024	.0001	.0001
SeeDling(SO SL PP)	1696	MS	0.294	1148	0.040	0.575	1357	0.124	0.106	0.038
STD										
Seed Origin	2	MS	0.568	13986	0.081	0.989	8327	0.307	0.079	0.006
		P(F)	.4521	.0558	.4724	.5283	.2434	.5231	.7999	.9179
SeedLot(SO)	23	MS	0.691	4264	0.105	1.507	5538	0.460	0.350	0.067
		P(F)	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
PhotoPeriod	1	MS	0.048	596252	4.426	1.740	616508	6.779	0.258	0.085
		P(F)	.6582	.0001	.0001	.1988	.0001	.0001	.2794	.2374
SO*PP	2	MS	0.181	12248	0.219	0.137	14727	0.382	0.026	0.005
		P(F)	.4771	.0128	.0177	.8718	.0171	.1615	.8850	.9229
SL(SO)*PP	23	MS	0.237	2310	0.045	0.994	3016	0.194	0.210	0.058
		P(F)	.0353	.0001	.0251	.0025	.0001	.0220	.0070	.0002
SeeDling(SO SL PP)	1696	MS	0.147	632	0.027	0.483	899	0.114	0.112	0.024
CULL										
Seed Origin	2	MS	0.228	71429	0.351	5.316	61303	1.959	0.651	0.092
		P(F)	.4977	.0092	.0223	.0376	.0282	.0405	.1555	.4047
SeedLot(SO)	23	MS	0.317	12340	0.078	1.400	14653	0.530	0.322	0.098
		P(F)	.0193	.0001	.0001	.0003	.0001	.0001	.0001	.0002
PhotoPeriod	1	MS	0.822	702117	3.292	1.258	686242	11.10	2.304	< .001
		P(F)	.1382	.0001	.0001	.4446	.0001	.0001	.0025	.9667
SO*PP	2	MS	0.501	24558	0.230	2.688	37790	0.131	0.015	0.223
		P(F)	.2585	.0159	.0397	.2937	.0033	.5718	.9267	.3065
SL(SO)*PP	23	MS	0.349	4923	0.062	2.079	5090	0.229	0.201	0.179
		P(F)	.0071	.0001	.0006	.0001	.0001	.0029	.0008	.0001
SeeDling(SO SL PP)	1696	MS	0.184	1448	0.027	0.585	1623	0.112	0.090	0.041

Theoretical Cull

At planting, the only change in significance levels after theoretically culling seedlings to BCFS was for seed origin which became insignificant as a source of variation for height (Table 2). As mentioned previously, SL and SL * NT significantly influenced recovery of seedlings. In September, seedlot became a significant source variation for relative stem volume growth after seedlings were culled (Table 2). Additionally, culling created a significant seed origin by nursery treatment interaction for stem volume as well as

Table 3. Mean square (MS), probability of F [P(F)] and mean shoot and root masses (main effects only) at planting in July 1993.

			All seedlings		Standard seedlings	
Source	df		Shoot	Root	Shoot	Root
Seed Origin	2	MS	752587	23209	752999	22946
		P(F)	.0920	.3150	.0799	.3218
SeedLot(SO)	23	MS	283785	19098	266408	19255
		P(F)	.0001	.0001	.0001	.0004
PhotoPeriod	1	MS	4732550	115	4314247	195
		P(F)	.0001	.8869	.0001	.8540
SO*PP	2	MS	130163	31208	108623	31310
		P(F)	.1001	.0104	.1463	.0069
SL(SO)*PP	23	MS	51087	5566	51919	5037
		P(F)	.7372	.7766	.2015	.8892
STyroblock(SO SL PP)	238	MS	64308	7306	67314	7748

		All		Standard	
		Shoot (mg)	Root (mg)	Shoot (mg)	Root (mg)
Seed Origin	Full sib	1436	376	1450	382
	Seed orchard	1335	351	1379	363
	Wild	1270	349	1295	357
Seedlot [1]					
Photoperiod	Control	1477	360	1480	367
	Blackout	1207	357	1254	366

[1] Not presented because there are 26 seedlots.

eliminating a significant interaction between nursery treatment and seedlot for RCD and stem volume growth.

In July, mean values for seed origin height, RCD, root weight and shoot weight were increased after culling (Tables 3 & 4). In September, mean heights and RCDs after theoretically culling (acceptables only) were larger compared to when all seedlings were included. However, pooled stem volume increment and relative stem volume growth values were lower for just the acceptables compared to all seedlings combined (culls + acceptables) (Table 6). In fact, culled seedlings as a class alone had greater relative stem volume growth for each seed origin compared to just acceptables (Figure 1).

Of the 781 seedlings that were classified as culls, 381 were controls and 400 were blackout treated (Table 6). When the 781 culled seedlings were divided into five cull classes, 8.96 % (70) were underheight, 7.94 % (62) were overheight, 60.31 % (471) had inadequate RCD, 20.49 % (160) were underheight with poor RCD and 2.30 % (18) were overheight with poor RCD (Table 6). Although more blackout seedlings failed to meet minimum height specifications, mean height of this cull class was the same for blackout and control seedlings. The majority of seedlings were culled because of inadequate RCD yet by the end of the summer all five cull classes had RCD above minimum specifications for planting (Table 6). Stem volume increment for the culls was similar to that for acceptable seedlings. Culled and acceptable seedlings had similar root weight values although acceptables had a greater shoot weight value than the cull classes (not presented).

Table 4. Mean values at planting (July) and after one summer (September) for RCD, height (HT), stem volume (VOL), volume increment (VINC), relative volume growth rate (VGRO) and survival (SURV) by seed origin (SO), photoperiod (PP), classification (CLASS) and major interaction combinations. SO levels, full sib (FSIB), seed orchard (SORC) and natural stand (WILD); PP levels, control (CON) and blackout (BOUT); and CLASS levels, standard (STD) and CULL.

			July 1993			September 1993					
Source	Level	n	RCD (mm)	HT (mm)	VOL (mm^3)	RCD (mm)	HT (mm)	VOL (mm^3)	VINC (mm^3)	VGRO ($mm^3 \cdot mm^3$)	SURV (%)
All		1748	2.79	190	0.416	3.79	188	0.754	0.339	0.261	99.5
SO	FSIB	598	2.80	202	0.437	3.83	198	0.788	0.351	0.265	99.5
	SORC	432	2.79	194	0.431	3.86	194	0.799	0.368	0.275	99.8
	WILD	718	2.78	178	0.389	3.72	178	0.699	0.310	0.249	99.2
PP	CON	875	2.82	220	0.490	3.79	218	0.863	0.373	0.253	99.7
	BOUT	873	2.75	160	0.341	3.79	159	0.645	0.304	0.269	99.3
CLASS	STD	967	3.13	199	0.522	3.94	197	0.832	0.310	0.186	99.8
	CULL	781	2.36	179	0.284	3.61	178	0.657	0.374	0.354	99.1
FSIB*CON		300	2.83	237	0.520	3.79	232	0.905	0.385	0.244	99.7
FSIB*BOUT		298	2.76	167	0.353	3.88	163	0.670	0.317	0.286	99.3
SORC*CON		216	2.87	231	0.535	3.81	232	0.933	0.398	0.247	99.5
SORC*BOUT		216	2.71	158	0.326	3.91	156	0.664	0.338	0.304	100.0
WILD*CON		359	2.79	200	0.438	3.78	199	0.785	0.348	0.264	99.7
WILD*BOUT		359	2.77	156	0.340	3.65	158	0.612	0.273	0.234	98.9
STD*FSIB*CON		174	3.09	232	0.593	3.84	230	0.910	0.317	0.174	100.0
STD*FSIB*BOUT		184	3.08	176	0.446	3.95	171	0.725	0.279	0.194	99.5
STD*SORC*CON		124	3.19	233	0.639	3.95	231	0.985	0.346	0.171	100.0
STD*SORC*BOUT		105	3.11	175	0.449	4.08	172	0.786	0.338	0.217	100.0
STD*WILD*CON		196	3.15	207	0.549	3.90	207	0.849	0.300	0.179	99.5
STD*WILD*BOUT		184	3.17	174	0.467	3.99	174	0.773	0.306	0.188	98.9
CULL*FSIB*CON		126	2.46	243	0.419	3.72	235	0.898	0.479	0.341	99.4
CULL*FSIB*BOUT		114	2.24	151	0.205	3.76	148	0.583	0.378	0.434	99.1
CULL*SORC*CON		92	2.44	228	0.396	3.63	233	0.864	0.468	0.350	99.0
CULL*SORC*BOUT		111	2.34	142	0.209	3.74	140	0.548	0.339	0.386	100.0
CULL*WILD*CON		163	2.35	191	0.305	3.64	189	0.709	0.405	0.366	100.0
CULL*WILD*BOUT		175	2.35	138	0.206	3.29	140	0.444	0.238	0.282	98.9

Survival values did not appear to be influenced by cull classification but cull seedlings had fewer individuals with a normal flush (Table 5). Survival was greater than 98.5 % regardless of whether seedlings were culls or acceptables.

There were 967 seedlings classified as acceptable (standard) because they met BCFS summer planting specifications. Of these seedlings, 494 were controls and 473 were blackout treated (Table 6). Although blackout seedlings had smaller mean heights at planting and in September than control seedlings, RCD values were similar between treatments (Table 6). Blackout treated seedlings had a smaller stem volume increment than controls over the summer growth period.

DISCUSSION

Interior spruce seedlings derived from seed orchard seed have proven to be vigorous growers (Hawkins and

Table 5. Bud break characteristics of seedlings planted in July 1993 and assessed in June 1994 at RRRS by cull classification and photoperiod. Terminal leader bud break characterized as normal, failed to flush (None) or abnormal rosette - many short leaders (Funny). Abbreviations as in Table 4.

			Percentage of Seedlings		
Classification	PP	n	Normal	None	Funny
HT < 140 mm	CON	11	64	27	9
	BOUT	59	30	24	46
HT > 280 mm	CON	62	79	18	3
	BOUT	0	-	-	-
RCD < 2.6 mm	CON	265	81	14	5
	BOUT	206	49	35	16
HT < 140 mm & RCD < 2.6 mm	CON	26	58	23	19
	BOUT	134	22	39	39
HT > 280 mm & RCD < 2.6 mm	CON	17	76	24	0
	BOUT	1	0	100	0
CULL summary	CON	381	78	16	6
	BOUT	400	37	35	28
STD summary	CON	494	87	11	2
	BOUT	473	57	27	16
TOTAL	CON	875	83	13	4
	BOUT	873	48	31	21

Krasowski 1993). This fact and seed orchard stock's reputation of displaying greater morphological (spindly seedlings) and physiological variation, when compared to natural stand stock, has caused B.C. silviculturists and nursery managers to express concerns regarding the quality and utility of seed orchard seed derivatives. During this study, however, seed origin only influenced seedling height at planting but otherwise had no impact (P > 0.95) on morphological parameters calculated at planting and after the remaining summer of field growth. Further-

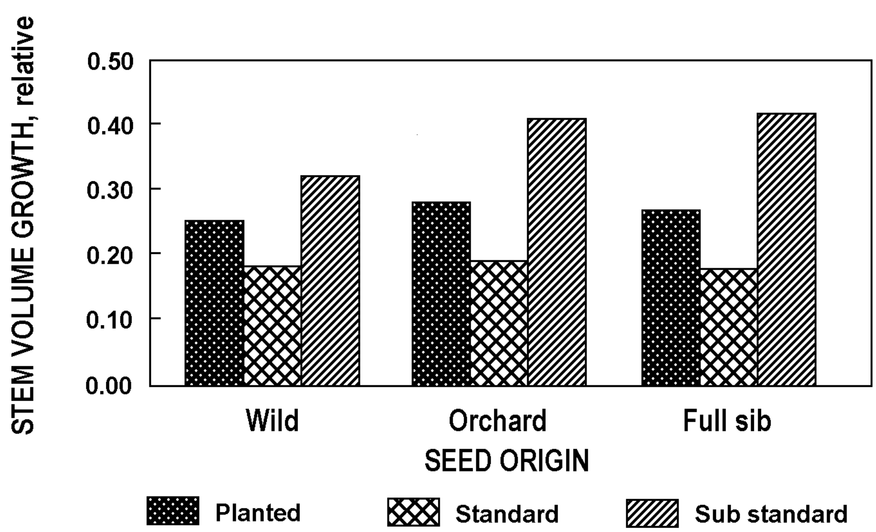

Figure 1. Relative stem volume growth (mL· mL· season) by seed origin for all seedlings planted in July1993, standard seedlings after culling, and for culled sub standard seedlings.

Table 6. Mean morphological characteristics of summer planted (July) seedlings by cull class and summer growth (September) with respect to classification. Abbreviations as in Table 5.

			July 1993		September 1993			
Classification	PP	n	RCD (mm)	HT (mm)	RCD (mm)	HT (mm)	VINC (mm^3)	VGRO ($mm^3 \cdot mm^3$)
HT < 140 mm	CON	11	3.00	125	2.96	145	0.123	0.119
	BOUT	59	2.97	125	3.51	131	0.193	0.181
HT > 280 mm	CON	62	3.21	302	4.01	296	0.501	0.202
	BOUT	0	-	-	-	-	-	-
RCD < 2.60 mm	CON	265	2.26	205	3.68	204	0.474	0.405
	BOUT	206	2.27	163	3.76	158	0.394	0.415
HT < 140 mm & RCD < 2.60 mm	CON	26	1.82	118	2.96	115	0.174	0.418
	BOUT	134	2.09	118	3.25	121	0.236	0.387
HT > 280 mm & RCD < 2.60 mm	CON	17	2.33	303	3.67	284	0.626	0.364
	BOUT	1	2.21	365	3.61	360	0.762	0.420
CULL summary	CON	381	2.41	217	3.66	215	0.454	0.363
	BOUT	400	2.31	143	3.55	142	0.312	0.371
STD summary	CON	494	3.14	223	3.89	221	0.341	0.191
	BOUT	473	3.12	175	3.99	173	0.318	0.213
TOTAL	CON	875	2.82	220	3.79	218	0.390	0.266
	BOUT	873	2.75	160	3.79	158	0.315	0.285

more, when stock was graded to BCFS specifications the significance of seed origin was completely lost. Nursery treatment and seedlot proved to be the main sources of variation for seedling morphology whether the analysis was performed on the entire, standard, or culled populations. In studies performed by Hawkins (1993a), seed orchard seedlots were found to be within the observable range of height variation for natural stand seedlots and displayed no unusual nursery growth patterns. In fact, Hawkins (1993b) noted that within the nursery there did not appear to be any poor performing seed orchard seedlots (all were vigorous) as there were with natural stand seedlots. Likewise, the morphological parameters observed during this study, showed seed orchard seedlots to possibly have more desirable characteristics (greater heights, RCD, shoot and root weights, stem volume increment and relative volume growth) at planting and after a partial field season, than did natural stand collection seedlots. Although natural stand seedlots were better balanced than seed orchard seedlots at planting, these differences were minimal by September.

Blackout is not totally accepted as an appropriate nursery regime. Concerns exist regarding seedling RCD, root mass, susceptibility to reflush after summer planting and altered post planting bud phenology (c.f. Krasowski et al. 1993) as a result of blackout treatment. Overall, blackout stock was shorter than control seedlings. However, blackout seedlings' RCDs were equal to or greater than control seedlings in both the culled and acceptable classes. The dry root weights of blackout treated stock (all seed origins) closely paralleled those of untreated stock, indicating that blackout did not reduce seedling root mass. Experiments by Hawkins and Draper (1991) and by Hawkins and Krasowski (1993) have shown some seedlots to actually increase their root mass after removal from blackout in response to blackout treatment. Although this root growth phenomenon was not observed in this experiment, the shorter heights and consequently, smaller shoot weights for blackout treated seedlings, combined with similar RCD and root weights to controls resulted in seedlings with smaller height to RCD and shoot weight to root weight ratios. These smaller ratios are characteristic of the preferred 'sturdy' morphotype for seedlings (Burdett et al. 1984). The severe blackout treatments used in previous experiments may have resulted in lower quality seedlings and hence, blackout's poor reputation. The moderate regimes used presently, produced morphologically suitable seedlings for summer planting. Nursery treatment did not influence the number of seedlings culled or accepted according to BCFS specifications.

The absence of reflush (data not presented) after planting in July 1993 suggests the blackout treatments administered were sufficient to control nursery seedling height growth while also maintaining bud development (Hawkins 1993b). In June 1994 when apical buds were assessed for flushing characteristics (Table 5) one-third had failed to flush or had broken their apical buds but had not or had only partially extended (1 to 3 cm) their preformed leaf primordia. More blackout treated seedlings failed to flush or had unusual terminal bud flushing characteristics compared to control seedlings. Similar results have occurred in studies by Krasowski et al. (1993) for spring planted, blackout treated spruce seedlings. Krasowski et al. (1993) suggested that buds reactivating growth earlier in the spring are more affected by frost injury. Perhaps this occurred in our experiment. Alternatively, Hawkins and Hooge (1988) have reported greater early-winter terminal bud mortality in blackout treated Sitka-white hybrid spruce seedlings. As suggested by Hawkins and Draper (1991), these differences between control and blackout treated seedlings could possibly be minimized if nursery crop lifting was based on seedlings achieving common physiological requirements rather than aiming for certain developmental goals or meeting time requirements. The timing of bud injury is important to address. If it occurred during the remaining summer after planting it would suggest that summer planting of blackout treated nursery stock should perhaps be reconsidered. However, if the damage occurred during the winter or following spring, it would indicate that some degree of risk involving apical bud injury to seedlings is associated with any planting program, whether it is spring or summer planting.

Culling seedlings at the time of planting to BCFS specifications is a standard nursery practice. However, growth of summer planted seedlings during the partial summer after planting was tested in this experiment in relation to these grading criteria. The majority of seedlings were culled because they had inadequate RCD and/or were underheight. Of the seedlings culled because of poor RCD, many had RCD between 2.5 and 2.6 mm, just under minimum RCD specifications. It is believed that these seedlings would have reached BCFS RCD specifications if lifting had been delayed a few days or if blackout application occurred when seedlot mean height values were approximately 10 mm larger than they were in this experiment (Hawkins 1993c). Culls that were underheight (< 140 mm), primarily a result of blackout application, were generally sturdier seedlings with smaller height to RCD ratios than the taller acceptable seedlings. During studies related to planting check, Burdett et al. (1984) concluded that height measurements can be an inadequate estimate of biomass accumulation in newly planted trees. Burdett et al. (1984)

found that container seedlings with low height to RCD ratios obtain rapid early height growth compared to taller seedlings with greater height to RCD ratios which expend more energy towards diameter growth rather than height growth. In other words, stem diameter is added at the expense of height in less sturdy seedlings. Consequently, the sturdier culls may experience more height growth than the less sturdy acceptable seedlings during next season's growth period. Typically, taller trees are less successful than shorter trees on high snowfall sites, droughty sites, and sites prone to vegetation press because often this increase in height is not paralleled with a similar increase in RCD (Hawkins 1993a), i.e. sturdiness.

Further evidence suggesting present summer plant culling standards may be an inappropriate measurement of seedling quality, comes from observations of relative volume growth over the summer. When relative volume growth was examined for all seedlings (before culling), non-culls (standards) and culls (not acceptable), the culls exhibited the greatest values. Relative volume growth measured in mL/mL/season, is expected to be greater for the culls which had smaller stem volumes at planting than the non-culls. That is, it is easier for the smaller culls to double their stem volume than it is for the larger acceptable seedlings. However, stem volume increment, the actual amount of volume added over the first growing season, was similar between culled and acceptable seedlings. Thus, the culls greater volume growth was not just because these seedlings started out with smaller volumes than did the non-culls. It was because they expressed more relative volume growth. The effects of culling summer planted trees according to BCFS specifications appear to have decreased rather than increased the growth potential of stock. Consequently, seedlings that were considered 'poor' according to the BCFS standards may prove to be the best performers, assuming they maintain a similar rate of volume growth over the following growing seasons.

While it is presently practical to cull seedlings strictly based on height and RCD measurements, it may be biologically prudent to include height to diameter ratios in the culling criteria. It is recognized that this approach is impractical in our present nursery grading scheme. However, once machine grading is introduced, culling based on heights, root collar diameters and acceptable ratios between the two will be possible. This approach should be implemented at that time.

Thus far, characteristics of concern, suggesting the inferior quality of seed orchard stock compared to natural stand stock, have not been apparent. In fact seed orchard seedlots have displayed favourable morphologies and growth patterns. Blackout treatment, appears to have controlled the morphological variability in all seed sources producing uniform seedlings. Blackout's influence on 1994 apical bud flushing characteristics appears to be negative, however no conclusions on the long term effects of these results can be made until next season's shoot growth is observed.

Between 1985 and 1989, 59% of all coastal Douglas-fir seed was supplied from seed orchards (El-Kassaby et al. 1992). In New Brunswick, all seed used to produce black spruce *(Picea mariana* (Mill.) B.S.P.) seedlings for reforestation is obtained from seed orchards (Morgenstern and Park 1991). The interior spruce program in B.C. should be able to meet 60% of the seed needs by the end of the decade. Hopefully this experiment, further studies and the above information will encourage B.C. foresters and nurseries to become more confident with spruce seed orchard seed and chose to use it in their regeneration programs.

PRELIMINARY CONCLUSIONS

Seedlings produced from interior spruce seed orchard seed are being met with reluctance by the operational forestry community. These trees are vigorous growers with the reputation of displaying unusual amounts of morphological and physiological variation within and among seedlots. Recent studies have shown nursery treatments, specifically blackout, to be an effective tool for controlling vigorous seedlots. Preliminary conclusions from the summer plant show that seed orchard seedlots are not outliers (unusual) in terms of morphological parameters. In fact, these seedlots possessed more favourable morphological characteristics than did natural stand seedlots. Blackout treatment produced shorter seedlings. They were morphologically uniform and ready for summer planting. Although blackout was observed to have negatively impacted apical bud flushing, the impact this may have on the future performance of seedlings cannot be concluded until further shoot growth data has been collected. According to the present culling criteria, many of the smaller seedlings are unacceptable for planting. However, these seedlings were sturdier and displayed better relative volume growth than did the acceptable seedlings. Consequently, the present method of grading seedlings for summer planting may be too conservative. BCFS specifications may need to be modified to include these more desirable sturdy morphotypes. However, this may not be practical until machine grading is introduced into nurseries. Regardless, seedlings that were culls performed well and the rationale behind morphological specifications should be revisited.

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