

Performance of Ponderosa Pine and Western Larch Planted North of Natural Ranges

RP #05-03 Summary Following the First and Second Growing Seasons

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Introduction

The fourth assessment of the recently published Intergovernmental Panel on Climate Change agrees that it is highly likely that global climate warming over that past half century is a function of human activity and that global temperature rises of between 2 degrees and 4.5 degrees Celsius will occur over the next century (Working Group 1, Intergovernmental Panel on Climate Change, 2007). It is likewise predicted that the climatic conditions of the Cariboo region of British Columbia will become significantly hotter and drier (Aitken 2005). Extensions in growing seasons, especially in springtime, have already been observed in many areas around the world, and it is expected that there will be increased species distribution shifts towards the poles and to higher elevations (Walther *et al.* 2002).

The pace of change will likely outstrip the ability of vegetation to move by natural distribution (Walther *et al.* 2002; Iverson 2004). Modeling of migration rates of select eastern North American trees suggests an advance of 10 km in 100 years would occur naturally into new suitable habitat resulting from climate change (Iverson 2004). An abundance of parent trees would be required for this to occur, suggesting that tree species that are rare at the edge of their distribution, a condition that is often the case for any species at a range edge, will migrate even more slowly. Fragmentation, agricultural areas and urbanization can also be barriers to dispersal for trees (Noss 2001). Also, as climate is changing at an unprecedented pace, trees, with their long life-spans, may not adapt quickly enough to maintain current levels of forest cover. Opportunities to acclimatize, evolve genetically, or move to more suitable sites increases the resistance and resilience of forests to change (Noss 2001) and such adaptation requires time. It is thus likely that people will have to plant tree species outside of their current ranges to ensure sufficient stocking for future forestry operations.

Forest managers will need to carefully consider how they move genetic material within the province of British Columbia. The Ministry of Forests and Range has focused efforts on the rules around seed transfer in British Columbia (southern provenances of currently endemic species), but there has been little study about moving species northwards out of their range. This study incorporates the methodical movement of tree species and genotypes from the south towards the north. Western larch (*Larix occidentalis* Nutt.) and ponderosa pine (*Pinus ponderosa* P. Laws. exC. Laws.) are two species native to British Columbia with limited ranges. Western larch is not native to the Cariboo, occurring naturally in south-eastern British Columbia and further south. Ponderosa pine is found in the southern interior of the province and extends only into the extreme southern fringe of the Cariboo region. Our objective is to compare the growth of these two species outside of their current range among various biogeoclimatic units in the Cariboo region.

Materials and Methods

Study Area

UBC Alex Fraser Research Forest, Gavin Lake Block, 75 km NE of Williams Lake, BC

Cutblock 135 (UTM 10N 585107, 5813214) is in the Sub-Boreal Spruce dry warm biogeoclimatic subzone in the Horsefly variant (SBSdw1) (Steen and Coupé, 1997; Klinka *et al.*, 2004a). Plots are located in an area identified as being site series 01, with modifiers ‘drier’, ‘zonal’ and ‘wetter’ that indicate a variety of conditions within the site unit (Klinka *et al.* 2004b). The site was harvested as a small clearcut in winter 2002-2003, with removal of lodgepole pine (Pl) and retention of Douglas-fir (Fd) regeneration. It was artificially regenerated with Pl and Fd in 2003. The ponderosa pine (Py) and western larch (Lw) plots (3 of each) were established in May 2005. Removal of non-target species will be required within five years of planting to prevent interference of sample tree growth. The planting stratum is located on a slight slope with SW aspect with a high content of coarse fragments. Cold air pooling in depressions is a hazard in the general stratum but the hazard is low within the plots themselves.

Cutblock 137 (UTM 10N 590390, 5811773) is in the transition zone from the Interior Cedar-Hemlock moist cool biogeoclimatic subzone (Horsefly variant) to the SBSdw1 (ICHmk3-SBSdw1) (Klinka *et al.*, 2004a). Site series in the ecosystem mapping polygon containing the study site are ICHmk3 08 (70%), modifiers ‘flat-depression’ and ‘drier’, 04 (20%) and 05 (10%) both with ‘flat-depression’ modifier (Klinka *et al.* 2004b). ‘Flat-depression’ indicates the terrain is fairly level but has shallowly concave and water-receiving areas that may be prone to frost hazard. The 08 site series was established specifically to describe generally warm, rich, productive slopes in this transitional area (Klinka *et al.*, 2004a). The stand was harvested in the winter of 2004-2005 in a clearcut silvicultural system having been even-aged and of uniform structure. The cutblock was planted with Pl, Fd, hybrid white-Engelmann spruce and western redcedar in the spring of 2005, after the Py and Lw plots were planted (3 of each). Research plots are thus planted purely with either Py or Lw and span the growing conditions present at the site.

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CP 426-04 (UTM 10N 609623, 5715108) occurs in the Interior Douglas-fir dry cool biogeoclimatic subzone, Fraser variant (IDFdk3) (Steen and Coupé, 1997). Site series at the study area is 01, and aspect is primarily east. Slopes average 10% (0-20%). Six plots (2 Lw and 4 Py) were established off the 802 road. The area was clearcut in June/July 2003 and is being managed as a mix of natural and artificial regeneration due to a poor- to moderate cone crop, and excessive rockiness. The entire block was rear-raked to enhance natural regeneration, but was also low-density planted at 800 lodgepole pine per ha.

CP 224-04 (UTM 10N 653982, 5687360) is in Sub-boreal Pine Spruce moist cool biogeoclimatic subzone (SBPSmk) (Steen and Coupé, 1997). Site series in the study areas are 01 and 05, and aspect is primarily east. Slopes average 35% (10-60%). The area was clearcut with reserves in September/October 2002 and artificially regenerated. Natural regeneration occurs among

uneven-aged residuals. Three plots (all Lw) were established with the intent that non-target trees would be removed before they affect growth of the target trees.

Experimental Design and Treatments

Using a completely randomized design, treatment unit (plot) locations and species allocations were randomly assigned within pre-chosen strata with suitable site conditions for each species in three biogeoclimatic subzones (treatments): SBSdw1, ICHmk3-SBSdw1 and IDFdk3 for each population of Lw and Py. An additional three replicates of Lw were planted in an additional treatment in the SBPSmk. Each study area contained three replicate treatment units each of Lw and Py (except for CP 426-04 where there were two Lw plots and four Py plots) to accommodate variability in site conditions. Plots were 15.1 m in radius (0.072 ha). Perimeters are marked in yellow/black flagging on stakes and vegetation. Plot centres are marked with an iron railway spike in the ground as well as an orange PVC electric conduit pipe painted glo-orange on top and marked with a paint stick with RP # 05-03 and plot number. UTM coordinates of all plot centres have been collected (NAD 83, UTM Zone 10 North) and filed digitally in the two licensees' geographic information systems. Each treatment unit was planted at nominal 1200 stems/ha (3.1 m intertree triangular spacing, minimum 2.0 m intertree distance). Between 80 and 95 trees were planted in each plot. The planting method was the same at all sites. Loose organics were screefed and seedlings planted in mineral soil. Stumps and fixed logs were taken advantage of for cattle protection. At AFRF, planting site selection was conducted by one staff person and the planting conducted by additional trained AFRF staff from May 10-12, 2005. Trees were stored overnight in cool places on site over the time it took to plant the plots. The same hired planter planted all of the 100 Mile House treatments and replicates, with CP 426-04 planted on April 30, 2005, and CP 224-04 was planted on May 8, 2005.

The same seed lots and stock types were used in all treatment plots. These two populations are:

Py Seed Lot #45260 Py 1-0 PSB 410A seedlings, elevation 900 m (source SW of Kamloops, BC);

Lw Seed Lot #60748 Lw 1-0 PSB 313B seedlings, elevation 950 m (source Kalamalka Research Station orchard, Vernon, BC).

Assessment plots with 11.28 m radii (0.04 ha) containing an average of 43 trees each were nested within the treatment plots. The remaining treatment plot area was to serve as a buffer to the sample trees so as to simulate pure stand conditions. Following the Ministry of Sustainable Resource Management, Terrestrial Information Branch, Resources Information Committee standards and procedures for growth and yield (2003), plots were divided into pie-shaped, 0.01 ha site sectors. Each site sector was subdivided into 0.005 ha tagging sectors. Starting in the first sector (clockwise from north), trees were marked with plastic numbered tags and a short piece of flagging, attached to six-inch wire pigtailed, near the plot centre first, then outward by moving side-to-side across the pie-shaped sector. As the circumference of sector 1 was reached, the last sideways pass was made in the direction of sector 2 so that the last tree tagged in sector 1 was as near as possible to the first tree to be tagged in sector 2. Trees near the circumference were numbered first, then inward by moving side-to-side across the sector so that the last tree marked is the one closest to the plot centre. These procedures were repeated for the remaining sectors. Assessment plot perimeters are marked in yellow/black flagging on stakes and

vegetation, as are sectors along cardinal directions, while the remaining sector boundaries are ribboned with orange.

Measurement of Variables

Sample trees were to be measured and assessed for condition immediately after planting (Year 0) and then again at Year 2, 5, 10 and 15. Due to a shortfall of funding in 2005, the Year 0 measurements were not conducted, nor were sample trees marked with number tags (aside from the IDFdk3 site where trees were marked with bamboo stakes). It was hoped that Year 1 measurements and conditions could be assessed in the spring of 2006 before bud-break, however, measurements were not possible until after new growth had already started. As such, root collar diameters were not collected for Year 1. All measurements were possible in the fall of 2006 after bud-set (Year 2).

Tree height (vertical point above germination at base of terminal bud), length (along stem if leaning 45% or greater), and root collar diameter at ground-level were measured using a tape measure and vernier calipers. Tree condition was assessed as good, fair, poor, moribund or dead and supported by provincial standard damage code data and comments. A database in MS Access (Microsoft Corp. 2003) was created for data management.

Statistical Analysis

One-way analysis of variance and interpretations of results are based on these assumptions:

- 1) Trees planted are independent of each other. This assumption can be made at early stages of growth when trees are not yet affecting each other.
- 2) Tree heights, height increments, and diameters are normally distributed.
- 3) Treatment units as well as population variances are homogeneous. As such, any treatment effects observed are due to the ecological conditions of the subzone and variant, and not to differences that may exist between plots.

Data were verified by entering them twice into the database and checking for discrepancies. All statistical tests were carried out at $\alpha = 0.05$ (MINITAB Release 14). Sample trees that were dead, missing, or mechanically damaged by cattle trampling or markedly cut back by snowshoe hares were culled from the data for assessing growth, but were included in the summaries of seedling condition. Frost-damaged trees were included in growth analyses as growing-season frost is a function of the site conditions.

Results

Seedling Survival and Condition

Figure 1 compares conditions of Lw and Py for Years 1 and 2 across the biogeoclimatic treatments. Pine survival and condition in general following both growing season was better than that of larch. Eighty-nine to ninety-eight percent of the pine ranked as good or fair in Y1, while 74-90% of the larch fell into those categories. Following Y2, percentages dropped to 78-89% for the pine and 45-67% for the larch in these categories. Correspondingly, pine had fewer dead and missing (2-7 % Y1 and 2-14 % Y2), while larch had 10-20 % Y1 and 14-34 % Y2.

Mortality occurred most often in the ICHmk3-SBSdw1 transition in Y1 (20% Lw, 7% Py) and in Y2 (34% Lw, 14% Py).

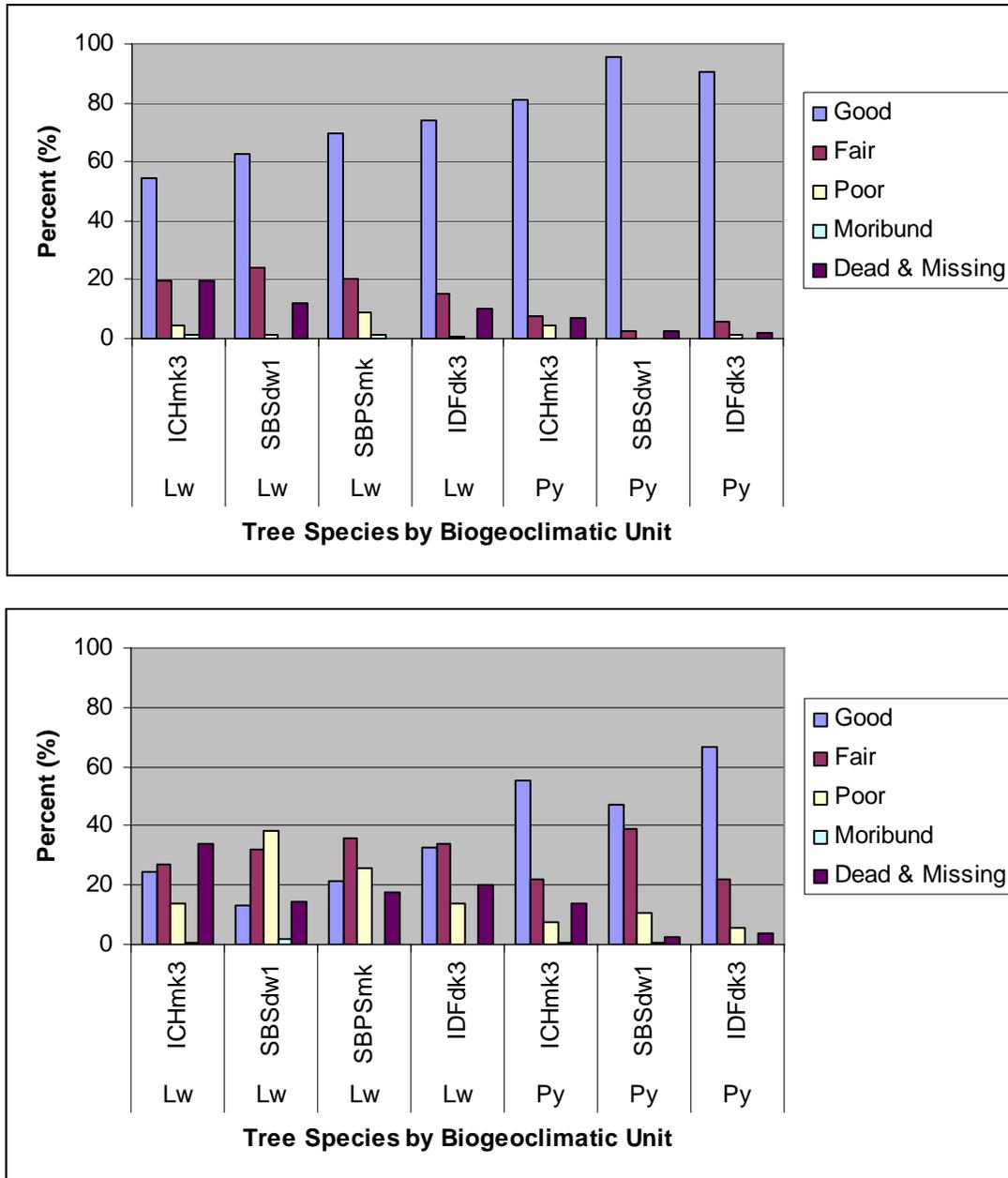


Figure 1: Condition of western larch and ponderosa pine in various biogeoclimatic units following Year 1 (top) and Year 2 (bottom)

Table 1 summarizes the predominant damage agents observed across treatments. Growing season frost damage occurred on the larch in all biogeoclimatic units but especially in the IDFdk3. The larch also received greater animal damage. Snowshoe hares and voles nipped leaders and chewed bark on many, especially in the ICHmk3-SBSdw1 and SBSdw1, and less so in the SBPSmk. Scarring was also observed mostly at these sites, largely attributable to chewing of bark. Cattle also range in these sites and some trampling was evident. Pine had far less animal damage than the larch. Obvious snow press and vegetation competition affected both species but only to a small degree. The vigour of the pine in the IDFdk3 was generally very good after Y2, however, the terminal bud and adjacent needles on several were killed, possibly by the pine needle sheathminer (*Zelleria haimbachi* Bsk.). All plots also contain individuals that were assessed as “poor” but had no apparent causal agent.

Table 1: Cumulative summary of occurrences of damage agents observed after two growing seasons for western larch (Lw) and ponderosa pine (Py) planted in different biogeoclimatic subzones/variants

Damage Agent	<i>ICHmk3-SBSdw1</i>		<i>SBSdw1</i>		<i>SBPSmk</i>		<i>IDFdk3</i>	
	<i>Lw</i> (n=138)	<i>Py</i> (n=144)	<i>Lw</i> (n=134)	<i>Py</i> (n=141)	<i>Lw</i> (n=89)	<i>Py</i> -	<i>Lw</i> (n=91)	<i>Py</i> (n=176)
Frost*	16	0	13	0	17	-	36	0
Animal Damage (includes hares, voles, cattle)	39	12	27	3	18	-	2	0
Scarred (source unknown but animal suspected)	20	12	18	2	21	-	2	1
Snow Press	2	8	3	7	2	-	1	0
Vegetation Competition	0	0	0	3	0	-	0	1
Unknown Leader Damage	0	0	0	0	0	-	0	34**

* Frost in Lw usually killed leader and has lead to crooks in stems or sometimes death.

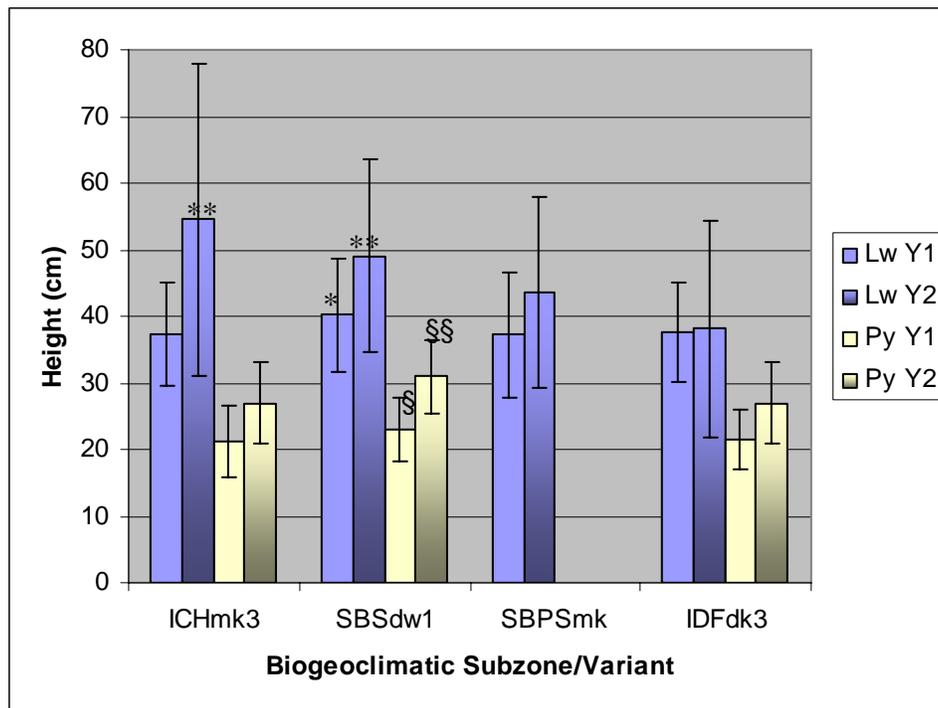
** 27 occurrences of terminal bud & adjacent needles dead + 1mm hole at base of dead tissue (cause: Pine Needle Sheathminer?).

Seedling Height and Diameter Growth

Mean tree heights after two growing seasons are listed in Table 2 and graphed in Figure 2. Mean Y2 diameters at ground-level are listed in Table 2 and depicted graphically in Figure 3.

Table 2: Mean Y1 and Y2 tree height and Y2 diameter (cm) for western larch (Lw) and ponderosa pine (Py) planted in different biogeoclimatic subzones/variants

<i>Biogeoclimatic Unit</i>	<i>Y1</i>		<i>Y2</i>			
	<i>Lw Ht.</i>	<i>Py Ht.</i>	<i>Lw Ht.</i>	<i>Lw Diam.</i>	<i>Py Ht.</i>	<i>Py Diam.</i>
ICHmk3-SBSdw1	37.4 (n=106)	21.3 (n=132)	54.5 (n=89)	1.00 (n=89)	27.0 (n=122)	0.83 (n=122)
SBSdw1	40.2 (n=118)	23.1 (n=137)	49.1 (n=105)	0.69 (n=105)	30.9 (n=132)	0.72 (n=132)
SBPSmk	37.3 (n=90)	-	43.7 (n=89)	0.64 (n=89)	-	-
IDFdk3	37.6 (n=75)	21.5 (n=172)	38.1 (n=62)	0.71 (n=62)	30.0 (n=172)	0.78 (n=172)



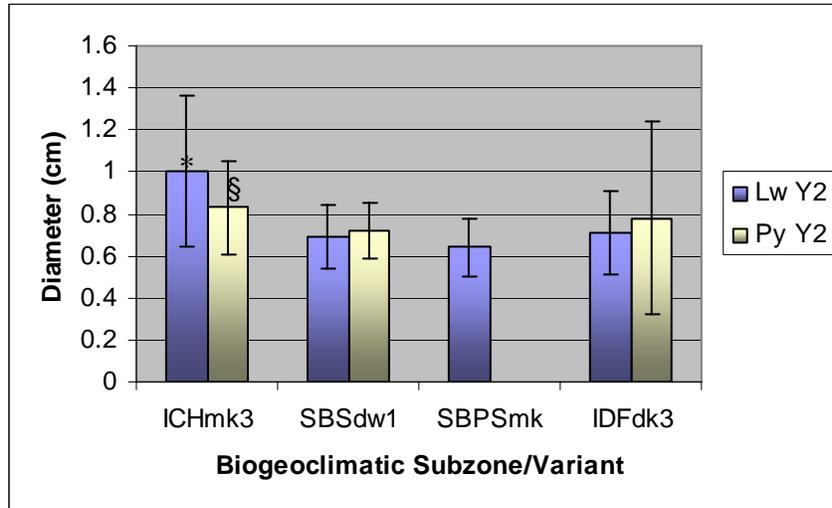
* Y1 Lw: SBS significantly different than ICH, SBPS and IDF ($\alpha=0.05$, $p=0.025$)

** Y2 Lw: ICH significantly different than SBS, SBPS and IDF; plus SBS significantly different than SBPS and IDF ($\alpha=0.05$, $p<0.001$)

§ Y1 Py: SBS is significantly different than ICH and IDF ($\alpha=0.05$, $p=0.002$)

§§ Y2 Py: SBS is significantly different than ICH and IDF ($\alpha=0.05$, $p<0.001$)

Figure 2: Mean heights and standard error (Y1, Y2) for western larch (Lw) and ponderosa pine (Py) planted in different biogeoclimatic subzones/variants



* Y2 Lw: ICH significantly different than SBS, SBPS and IDF ($\alpha=0.05$, $p<0.001$)

§ Y2 Py: ICH significantly different than SBS ($\alpha=0.05$, $p=0.024$)

Figure 3: Mean Y2 ground-level diameters and standard error for western larch (Lw) and ponderosa pine (Py) planted in different biogeoclimatic subzones/variants

Larch: After Y1, tree heights in the SBSdw1 were significantly greater than in the other treatments ($\alpha=0.05$, $p=0.025$). After Y2, however, those growing in the ICHmk3-SBSdw1 transition were significantly taller than those in the other sites, including the SBSdw1, while those in the SBSdw1 continued to be statistically different than those in the SBPSmk and IDFdk3 sites ($\alpha=0.05$, $p<0.001$).

At the end of the second growing season, larch in the ICHmk3-SBSdw1 had a significantly greater mean diameter at ground-level than those in the SBSdw1, SBPSmk and IDFdk3 ($\alpha=0.05$, $p<0.001$). No statistical differences were detected between the other treatment combinations.

Pine: The tallest trees were found in the SBSdw1 site in Y1 and Y2 respectively ($\alpha=0.05$, $p=0.002$; $\alpha=0.05$, $p<0.001$). These trees, however, had the smallest mean diameter following Y2 (0.72 cm) as compared to those in the ICHmk3-SBSdw1 treatment where diameter was significantly greater (0.83 cm). No other statistical differences were detected.

Discussion

Aside from the IDFdk3 plots, seedlings were not numbered and flagged upon planting in 2005 so it is not guaranteed that all were relocated a year later when enumeration occurred. Survival was not complete at the beginning of the second growing season as several were found dead, often having very little plant structure remaining. The planting configuration with regular spacing helped with relocation but, based on this spacing, it is likely that there were some dead seedlings that were not relocated despite intensive searching, especially in the SBPSmk. In the plots in this

treatment, 30 “planting spaces” were identified within heavy grass but without evidence of seedlings. Mortality following the first growing season might thus be underestimated.

Growing-season frost damage was observed in larch in all treatments. The predominance of its occurrence in the IDFdk3 is evident in the small mean height increment measured there from Y1 to Y2 (0.5 cm). The climate in this variant during the growing season is predominantly dry, more so than the other biogeoclimatic units (Klinka *et al.* 2004), so it is expected that this area would have a higher frequency of clear night skies and low relative humidities that promote this phenomenon (Steen *et al.* 1990). All plots at this site saw frost damage though none were located in microsites where cold-air pooling would necessarily be expected. They all had very low occurrence of broad-leaved vegetation of sufficient height to help retain radiative heat loss from the ground at night, however (Steen *et al.* 1990). Animal damage was minimal at this site for both species.

Most damage by voles, snowshoe hares and cattle was observed in the ICHmk3-SBSdw1 and SBSdw1 sites where about a third of sample trees were affected, and less so in those in the SBPSmk. Hares prefer the dense, shrubby habitat supported by these more moist sites (Eder and Pattie 2001). The greater snow accumulations in these areas (Klinka *et al.* 2004) are not a deterrent to these snow-adapted animals in winter. In this season, they eat willow and alder, which grow among planted seedlings. Voles, too, are active in winter, insulated by deep snow packs where they forage on grasses and young tree bark (Eder and Pattie 2001). The observation that fewer pines were nibbled than larch suggests these animals prefer the latter. Obstacle-planting was used wherever possible in the plots to reduce cattle trampling, yet there was still minor cattle damage. Some damage is to be expected whenever cattle graze in young plantations. Not all damage and mortality to larch in these sites is attributable to known agents. Western larch is known to have low tolerance for moist conditions and low light (Klinka *et al.* 2000), so these factors may have affected some individuals in the sample as well.

The highest mean heights for both larch and pine following Y1 were seen in the SBSdw1. This trend continued for the pine after Y2. By that time for larch, however, those in the ICHmk3-SBSdw1 were tallest, although larches in the SBSdw1 remained taller than those in the SBPSmk and IDFdk3. After the second growing season for both species, the samples with the greatest mean diameter were in the ICHmk3-SBSdw1. Interestingly, though pine growing in the SBSdw1 had the highest mean height among the treatments, it had the lowest mean diameter. The mean diameter of larch there was also quite small. These tall but thin trees might be a function of the more brushy conditions at this site. Photographs taken during the second growing season (see APPENDIX) show patchy but regular distribution of alder and some willow at this site. The shrubs and herbaceous plants there have had since 2003 to recover and reestablish after harvesting, whereas those in the ICHmk3-SBSdw1 have only had since 2005. This more advanced growth might be affecting light competition for both pine and larch and causing them to put on more height than diameter increment. Likewise, the comparatively reduced level of light competition in the ICHmk3-SBSdw1 may be contributing to the good demonstration of volume growth there. It will be interesting to monitor these height:diameter ratios over the next few years to see if this pattern persists in the SBSdw1 site or is eventually expressed in the ICHmk3-SBSdw1 in two year's time.

Conclusions

For the populations of western larch and ponderosa pine represented by the two seed lots planted in these particular sites, it appears that the greatest volume increment is occurring in the ICHmk3-SBSdw1 transition zone and SBSdw1. Trees at these sites had the most animal damage though, especially the larch. Both larch and pine growing in the SBSdw1 may be exhibiting significant height growth as a response to light competition with brush. Growing-season frost damage occurred on larch in all treatments, particularly at the IDFd3 site where more than a third of the sample trees were set back. Larch growing in the SBPSmk maintained the best condition after Y2 (67% good or fair), while pine fared well in the SBSdw1 and IDFd3 (89% and 86 % good or fair respectively). Pine survival and condition in general following both growing season was better than that of larch. Further monitoring should be pursued according to the project work plan timeline.

Acknowledgements

This project was conceived by Ken Day, MF, RPF, of the UBC Alex Fraser Research Forest and Wayne Nuyens, RPF and Silviculturist, West Fraser Mills Ltd. and designed with input from Dr. Sally Aitken, UBC Faculty of Forestry and Teresa Newsome, Research Silviculturist, Ministry of Forests and Range. West Fraser Mills Ltd., 100 Mile Lumber provided all of the seed stock and each licensee contributed planter and supervisory time for the initial out-planting in 2005. West Fraser Mills Ltd., 100 Mile Lumber and Williams Lake Divisions have provided funding support through the Forest Investment Account Land Base Investment Program. Plot establishment and data collection was completed with the assistance of Johann Baart, Kristen Rasmussen, Max Kroeschel, Claire Durand-Viel and Claire Choquet under the supervision of Cathy Koot from the UBC Alex Fraser Research Forest.

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APPENDIX

Photos from Plot Centres Looking South in each Treatment During Y2 (2006)

SBSdw1



Plot 1 - Lw



Plot 2 - Py



Plot 3 - Py



Plot 4 - Lw



Plot 4 - Py



Plot 6 - Lw

ICHmk3-SBSdw1 Transition



Plot 7 - Lw



Plot 8 - Py



Plot 9 - Lw



Plot 10 - Lw



Plot 11 - Py



Plot 12 - Py

IDFdk3



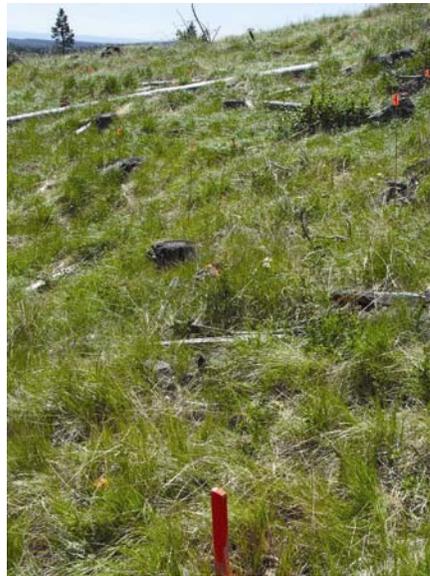
Plot 13 - Lw



Plot 14 - Lw



Plot 15 - Py



Plot 16 - Py



Plot 17 - Py



Plot 18 - Py

SBPSmk



Plot 19 - Lw



Plot 20 - Lw



Plot 21 - Lw