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A Retrospective Investigation of Advanced Western Redcedar Regeneration in the ICHwk1, ICHmw2, and ICHmw1 of the Nelson Forest Region – Experimental Project 1174

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A Retrospective Investigation of Advanced Western Redcedar Regeneration in the ICHwk1, ICHmw2, and ICHmw1 of the Nelson Forest Region – Experimental Project 1174

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ABSTRACT

Several existing unmanaged stands in the Interior Cedar Hemlock (ICH) zone of the Nelson Forest Region are two- or multi-storied, with the lower storey consisting of advance western redcedar (*Thuja plicata* Donn). A common managerial question is whether to harvest the overstorey and retain the understorey to develop into the next crop, or part of the next crop, or to clearcut, prepare, and plant the site. There is growing interest in using understorey western redcedar and other species of advance regeneration for crop trees, as several advantages can be realized. Site preparation and planting costs can be reduced or eliminated, post-harvest brush problems can be reduced by keeping the site occupied, trees are naturally adapted to the site, and advance regeneration can also give a head start on the next rotation. Opinions of foresters working in the ICH zone vary as to whether advance cedar, and advance regeneration in general, is a viable option for future crop trees. It is uncertain whether it will release and become a crop tree with good form. The results of this retrospective investigation indicate that advance cedar has good potential for release in the ICHwk1, ICHmw2, and ICHmw1 subzones.

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1 INTRODUCTION

Interest is growing in using understorey western redcedar (*Thuja plicata* Donn) and other species of advanced regeneration for crop trees. Several advantages can be realized: site preparation and planting costs are reduced or eliminated, post-harvest brush problems can be reduced by keeping the site occupied, trees are naturally adapted to the site, and advanced regeneration can give a head start on the next rotation (Smith 1986). Depending on the average height of the reserved cedar, the "green up" criteria for cutblocks can be met earlier. When compared to clearcut, burn, and plant scenarios, using advanced regeneration can increase aesthetic quality, and also some aspects of wildlife habitat quality (McCaughey and Ferguson 1988).

Opinions of foresters working in the Interior Cedar Hemlock (ICH) zone (Braumandl and Curran 1992) vary as to whether advanced cedar regeneration, and advanced regeneration in general, is a viable option for future crop trees (Corrin and Peterson 1987). It is uncertain as to whether it will release and become a crop tree with good form. Stem and root rots are thought to be common in older and suppressed stems. The need for more information on the potential of advanced regeneration in British Columbia has been pointed out in several recent reports (Minore 1983; Corrin and Peterson 1987; Still et al. 1988; Butt and Bancroft 1990; Schulting and Schulting 1990; DeLong 1994).

A study completed in the northern Rocky Mountains of the United States identified the tree, site, and stand characteristics that were associated with cedar's diameter increment response to release (Graham 1982). Several studies have shown that factors associated with post-harvest release are also generally related to pre-harvest vigour regardless of species. These may include larger trees, more vigorous trees (more live crown and good colour), and younger trees in combination with larger sizes (Hatcher 1964; Herring 1977; Siedel 1983; McCaughey and Schmidt 1982; Ferguson and Adams 1980; Helms and Standiford 1985; Oliver 1986). Aspect can also have an important effect on a shade-tolerant tree's ability to release. Graham (1982) found that diameter growth of released western redcedar appeared to be best on north-facing slopes. He felt that the characteristics of cooler, more northerly slopes ameliorated the changes in micro-climate caused by release cutting. On cooler aspects, light-sensitive stomata of shade leaves would be open less often than on warmer aspects (Graham 1982).

1.1 Objectives

The main objective of this study was to determine whether understorey western redcedar releases after harvest in the ICH zone of the Nelson Forest Region, and if so, to evaluate the relationships between site, stand, and tree characteristics. Specific objectives were to:

1. compare the growth of released cedar trees with the growth of trees on adjacent sites that were not released. *Null hypothesis*: there is no difference in growth rate of advanced cedar trees after release cutting, as compared to trees in uncut areas.
2. determine if growth after release differs among subzones (ICHwk1, ICHmw1, ICHmw2). *Null hypothesis*: growth rate of released advanced cedar is the same in the ICHwk1, ICHmw1, and ICHmw2 subzones.

3. determine if decay is related to the presence of harvesting damage or origin (seedling or vegling) of the tree. *Null hypothesis*: decay is not related to harvesting damage or origin of the tree.
4. determine whether site, stand, or morphological characteristics of western redcedar may be useful in predicting post-harvest response.

2 METHODS

2.1 Sampling

A retrospective approach was used for this study. Sixteen randomly chosen sites that met the following criteria were sampled in the summer of 1993.

- Sites were located in the ICH zone, specifically the ICHmw1, ICHmw2, and ICHwk1.
- Cedar was the leading species on the inventory label.
- Advanced cedar regeneration was left on site and was at least five years old at the time of harvest.
- Sites were harvested 10 or more years ago. This would have allowed enough time for trees to release.
- Sites had received no further silvicultural treatments (spacing, brushing and weeding, etc.) since harvest. This was to eliminate the release from these treatments and because advanced cedar was usually discriminated against in stand-tending prescriptions.
- Sites were at least five hectares in size. The minimum opening size was used to ensure enough sample trees could be found at least one tree length away from the timber edge.

Where available, adjacent unharvested areas with similar characteristics were used as unreleased “controls.” Cedar on the control sites were sampled in the same manner as in the harvested openings.

A transect line with a random start was established at each site within the pre-determined strata. Fifteen points were systematically located at a minimum of 25 m intervals along the transect. For larger strata, intervals were lengthened to the cover strata. The nearest cedar to the point on the transect was the plot centre for a 3.99 m radius (1/200 ha) and a 7.97 m radius (1/50 ha) plot. This cedar tree was also the sample tree for stem analysis (Table 1). Although a completely random selection of sample points is desirable, systematic sampling can be more efficient (Freese 1962). Freese (1962) also pointed out that if there is no definite pattern in the population, using random sampling formulae on systematic data can give a reasonable estimate of the sampling error. There did not appear to be a pattern of distribution of advanced western redcedar in the sampling units.

Total length of each sample tree was measured from the point of germination to the top, and then divided into five equal segments. Discs 5–10 cm thick were cut from the bottom of each segment for stem analysis. An additional disc was cut at breast height if this stem segment was not already sampled. Sample trees were cut into five equal segments to get the best estimate of height and diameter growth over the life of the tree. A binocular microscope was used for age counts from pith to bark. The point at which tree-ring width had obviously increased was marked

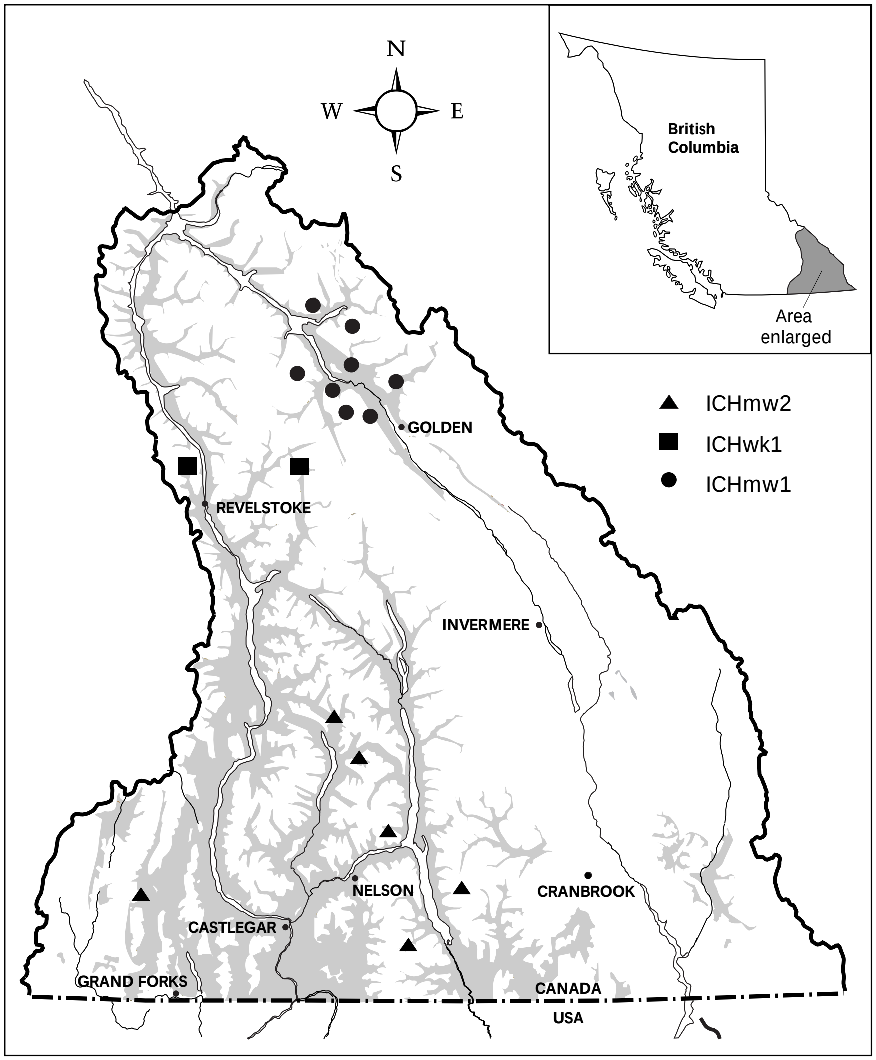

FIGURE 1 *Distribution of western redcedar and sample site locations*

as the calendar year of release. It was also cross-referenced with year of harvest. Both the outside diameter of the disc (including bark) and the diameter at the time of release were measured and recorded. Scarring, sunscald, rot, and compression wood distribution were documented on photocopy images. If a disc had visually identifiable decay, it was broadly identified as white stringy, brown cubical, *Armillaria* spp., or decay resulting from logging scars.

2.2 Data Analysis

Data were analyzed to test the hypotheses outlined in section 1.1.

1. Growth of trees in harvested openings compared to growth of trees in unharvested (control) areas: this was tested in four steps. Step one compared tree growth (height and diameter increment) in harvested openings to growth in the control areas before harvest. This tested the assumption that trees were growing at similar rates before harvest and

TABLE 1 *Measurements made at each site and plot*

Site	3.99 m plot for layers 2, 3, 4[a]	7.97 m plot for layer 1[b]	Sample tree
Subzone	No. of stems	No. of stems	Origin; seedling, vegling
Site series	Species	Species	Lean; horizontal, vertical distance (cm)
Elevation (m)	Average height and diameter (cm)	Height (m)	Pathology
Soil texture	Origin; planted, natural, advanced	dbh (cm)	Vigour
Percent slope	Modal height of vegetation (cm)	No. of stumps	Height (cm)
Aspect			
Year of harvest	Percent cover of vegetation	Stump species	Live crown length (cm)
Season of harvest		Average diameter of stumps (cm)	Diameter of each of 5 discs (mm)
Method of harvest		Percent crown closure	Identify decay in each disc

[a] Layer 2 = 7.5 to 12.4 cm dbh; layer 3 = >1.3 m height to 7.4 cm dbh; layer 4 = ≤ 1.3 m height.
[b] Layer 1 ≥ 12.5 cm dbh.

justifies completing step two. Step two compared tree growth in harvested openings and control areas after harvest. Step three compared tree growth before and after harvest in the controls, to justify step four. Step four used the pre-harvest growth of trees in harvested openings as controls if there were no unlogged sites. Analysis of variance (ANOVA) was used for each of these steps.

2. Growth after harvest by subzone: this was tested by comparing means of height and diameter growth of each subzone.
3. Decay relative to harvesting damage and origin of tree: this was not tested statistically. Observations were made.
4. Highly correlated independent variables: these were indicated by producing a correlation matrix. Stepwise linear regression was used with these variables to determine if site, stand, and tree variables could be useful in predicting post-harvest growth of cedar.

3 RESULTS

Sixteen openings were sampled; however, only three (Wilson, Chatter, and Hope) had adjacent uncut areas that were similar enough to use as controls (Table 2). The average age of the cedar was higher in the controls because larger mature trees were sometimes picked up in the random

TABLE 2 *Sample site descriptions*

Subzone variant	Site series	Aspect	Location	Sample size (n)	Average age at harvest	Average age when sampled	Average height at harvest (cm)	Average height when sampled (cm)	Year of harvest	Live crown (%)
ICHwk1	6	W	Albert Canyon	15	23	33	112	324	1983	92
	1	E	Columbia River	15	47	64	154	719	1976	94
ICHmw2	1	NW	Alkokli	15	47	63	184	662	1977	91
	1	W	Bremner	15	82	98	192	686	1977	93
	1	N	Coffee	15	32	56	128	825	1969	94
	4	NE	Grand Forks	15	38	54	85	404	1977	91
	1	S	Placer	15	54	69	342	476	1978	93
	1	SE	Wilson	15	39	53	187	537	1979	94
	1[a]	***SE***	***Wilson control***	***15***	***92***	***105***	***469***	***507***	***NA***	***42***
ICHmw1	1	E	Beavermouth	15	31	43	125	686	1981	87
	1	SE	Beaver river	15	41	54	142	290	1980	81
	3	W	Blackwater ridge 1	15	49	62	197	282	1980	71
	1	NW	Blackwater ridge 2	15	46	58	175	284	1981	82
	1	E	Chatter	15	30	47	67	324	1976	84
	1	***E***	***Chatter control***	***15***	***75***	***96***	***293***	***350***	***NA***	***50***
	1	E	Colpitti	15	41	57	155	556	1977	95
	1	W	Hope goodfellow	15	42	54	86	252	1981	87
	1	***W***	***Hope goodfellow control***	***15***	***90***	***105***	***135***	***159***	***NA***	***57***
	5	NE	Olafson	15	21	43	88	443	1971	87

[a] Bold italic type indicates control

sample. These trees were kept in the analysis to avoid bias against those that may have released and grown well in the controls. The majority of sampled cedar in the released openings were under 2 m in height at the time of harvest. These blocks were commonly prescribed as clearcuts, and therefore smaller advanced regeneration was more likely to survive harvesting than larger stems.

In the ICHwk1 subzone (Revelstoke Forest District), 10 openings were initially sampled, but sufficient advanced cedar regeneration was only found on two of the sites. On the eight rejected openings, sampled trees were generally the same age as the opening (i.e., if the opening was harvested 15 years ago, the cedar tended to be 15 years old). To qualify as advanced regeneration, the stems had to be five years old at the time of harvesting.

3.1 Release

There was no significant difference ($Pr>F$ = 0.23) between diameter or height increment before harvest on the controls and the harvested openings, indicating that trees were growing at similar rates before harvest (Figures 2 and 3). When compared to control openings, height and diameter increments after harvest on the harvested openings were not significantly different at the 0.05 level ($Pr>F$ = 0.07). To better match the size and age of trees in the harvested openings, the analysis was also completed without the larger, older trees (>100 years) in the controls. However, difference in growth was still not significant ($Pr>F$ = 0.06).

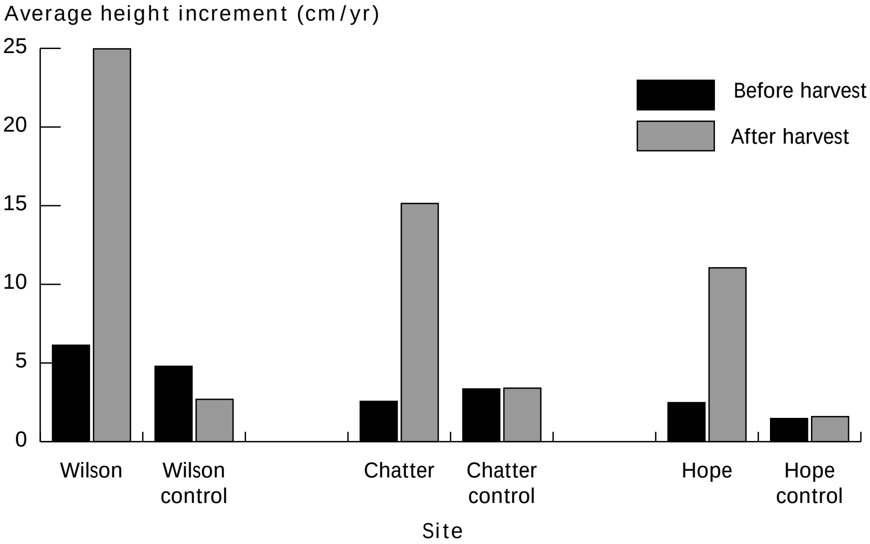

FIGURE 2 *Average height increment before and after harvest on sites paired with controls*

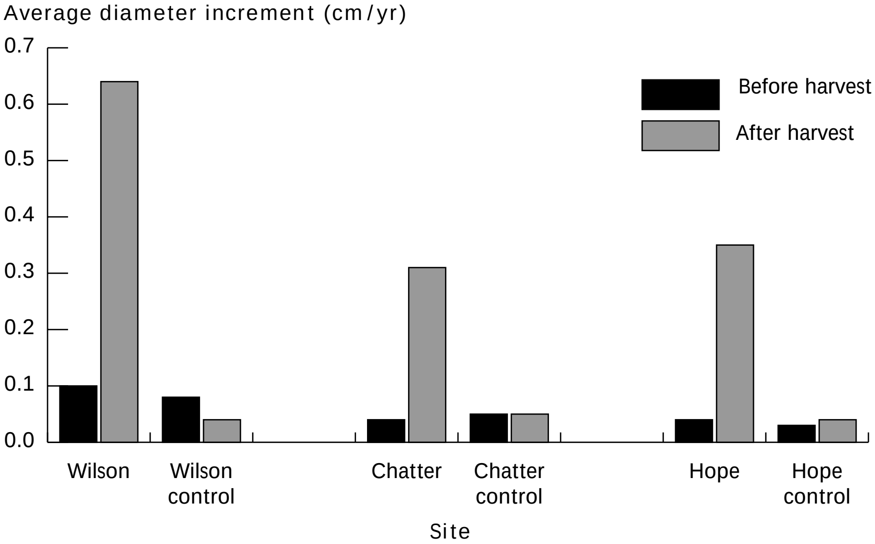

FIGURE 3 *Average diameter increment before and after harvest on sites paired with controls*

Although the difference in growth rate was not significant to the 0.05 level, it was very close (0.06). The lack of statistical significance is probably due to the low number (three) of paired sites.

Tree growth before and after harvest in the controls was not significantly different (Figures 2 and 3). This justifies using the pre-harvest growth as a control for the sites that could not be paired with an unlogged site. When height and diameter increment before and after harvest were compared on the harvested openings, there was a highly significant difference (*Pr>F* = 0.0001) (Figures 4 and 5). On average, trees released in both diameter and height one to two years after harvest.

Generally, growth-rate differences between subzones were not significant. However, diameter growth was significantly higher in the ICHwk1 than

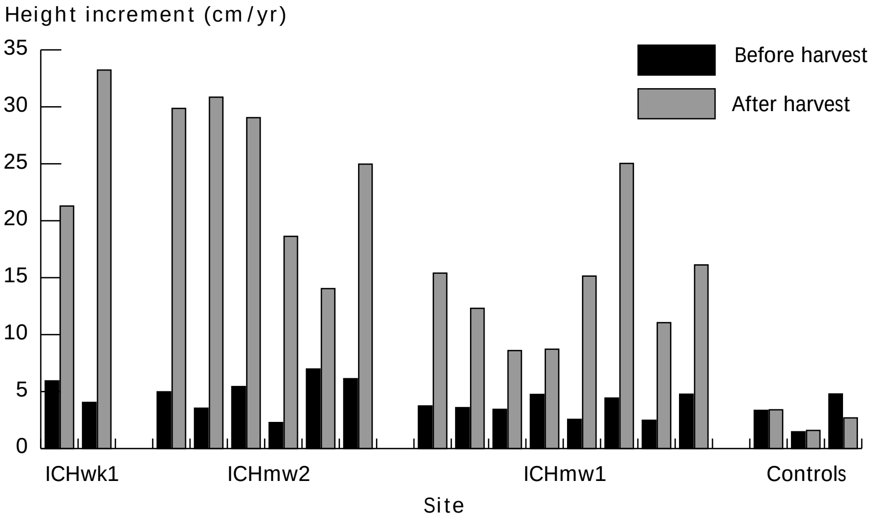

FIGURE 4 *Average height increment before and after harvest (all sites)*

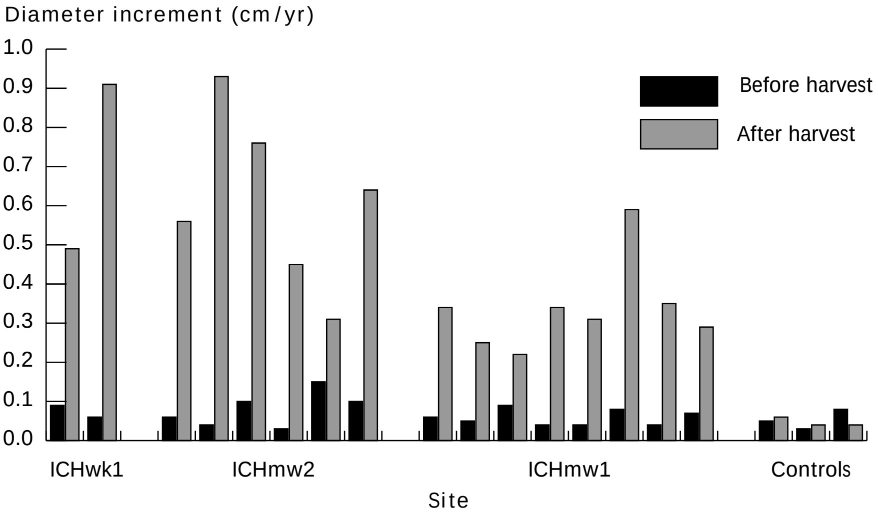

FIGURE 5 *Average diameter increment before and after harvest (all sites)*

in the ICHmw1 subzone (Figure 6). The average diameter growth was 0.7 cm/year in the ICHwk1, 0.55 cm/year in the ICHmw2, and 0.3 cm/year in the ICHmw1. The average post-harvest height growth was 27 cm/year in the ICHwk1, 23 cm/year in the ICHmw2, and 14 cm/year in the ICHmw1 (Figure 7).

3.2 Decay

The proportion of stems with decay was lower in the harvested openings (23%) than in the controls (44%). The stems with decay tended to be smaller and older in the controls than in the harvested openings. Close to one-half of the stems with decay in the harvested openings were scarred by logging (Figure 8).

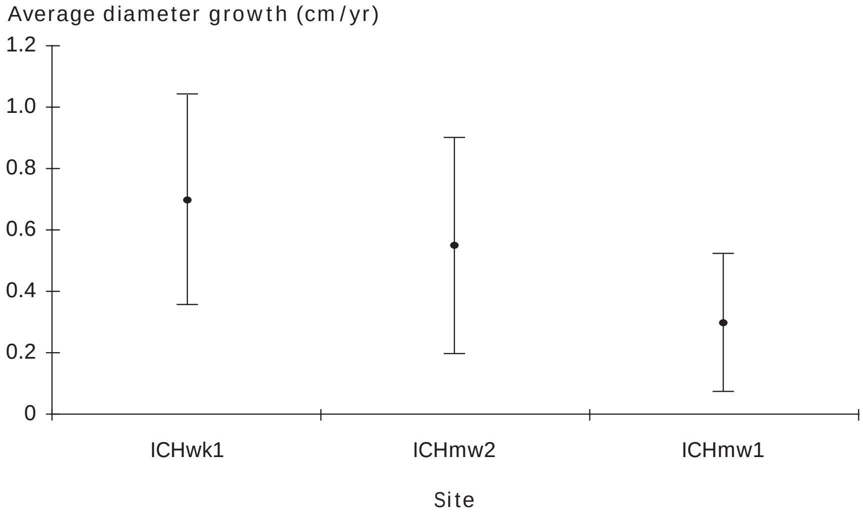

FIGURE 6 *Average post-harvest diameter growth of released trees by subzone*

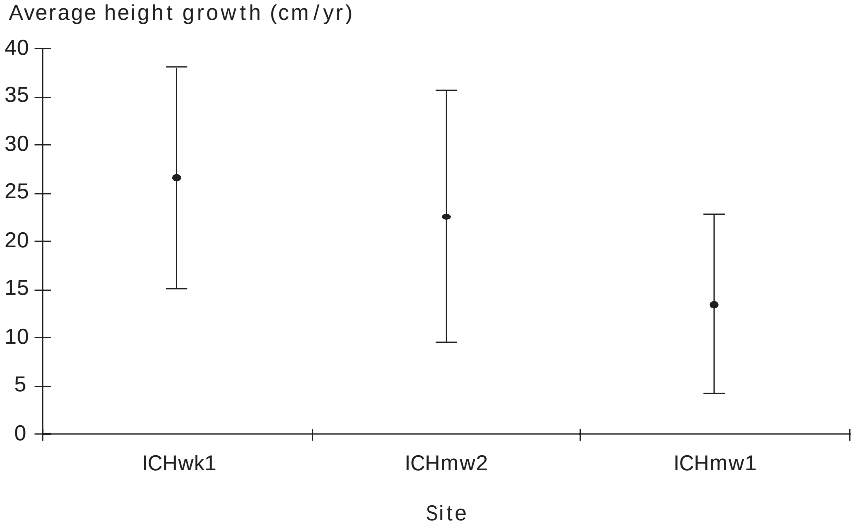

FIGURE 7 *Average post-harvest height growth of released trees by subzone*

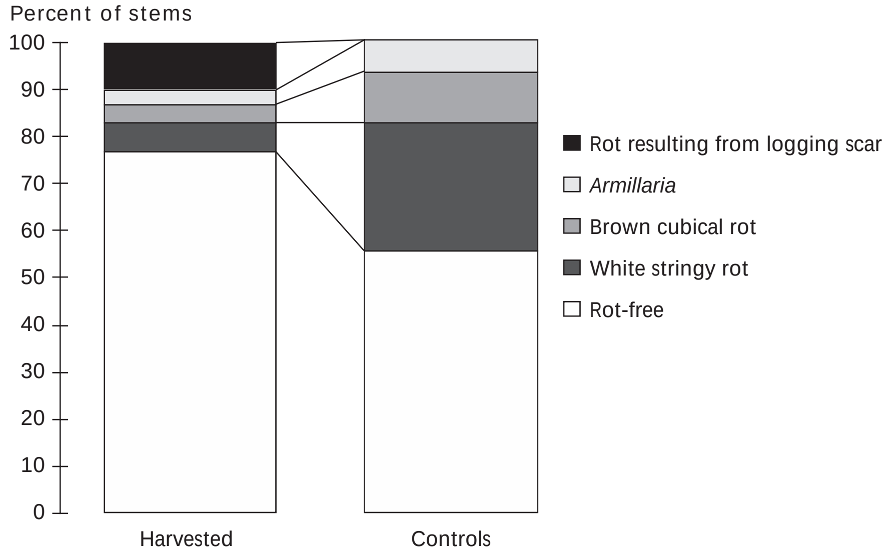

FIGURE 8 *Percent of stems with decay in harvested and control blocks*

3.3 Origin of Stems

The majority of stems in both the harvested openings and the controls were of vegling[1] origin (Figure 9). As Parker and Johnson (1994) pointed out, positive determination of veglings is clearly limited to trees that are still attached to the parent tree, or to trees that can be uprooted. Origin of larger cedars can only be surmised. For this study, the origin of each stem was determined by pulling up root systems and by excavating the roots of larger stems (Figure 10). The larger, older stems in the controls (which

FIGURE 9 *Origin of cedar stems in controls and released blocks*

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[1] The term "vegling" was first used to describe cedar regeneration that developed from vegetative processes by Parker (1979).

FIGURE 10 *Typical vegling root morphology*

were absent in the harvested openings) were thought to be of seed origin. These stems appeared to have root structures that were typical of seedlings, and were roughly the same age as the mature stems of the other species in the stand. These larger, older trees probably originated by seed after wildfire along with the other species in the stand. It is likely that fewer trees of seed origin were present in the harvested openings (2% compared to 16%) because the larger stems had been harvested. The origin for a number of stems could not be determined.

3.4 Regression Analysis

The first step of the stepwise regression analysis was to create a correlation matrix to select the most highly correlated independent variables (Table 3). Stepwise linear regression with combinations of these variables yielded low non-significant r^2 values. Therefore, unexplained variability in post-harvest growth was very high.

Residual basal area[2] was the only independent variable that was significantly correlated to post-harvest release in diameter and height growth (Figure 11). Factors that were hypothesized to be significant in a tree's ability to release (age, and size of tree before harvest) were not correlated with post-harvest growth (Appendix 1).

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[2] Residual basal area is a measure of the quantity of layer 1 and 2 stems (in m^2) left on the opening after harvesting.

4 DISCUSSION

4.1 Release

The results indicate that advanced western redcedar regeneration can release and grow well on circum-mesic sites in the ICHwk1, ICHmw2, and ICHmw1 subzones. As expected, the average growth of trees after harvest was highest in the ICHwk1, followed by the ICHmw2 and ICHmw1 subzones, respectively. The average post-harvest height growth was 27 cm/year in the ICHwk1, 23 cm/year in the ICHmw2, and 14 cm/year in the ICHmw1. The average diameter growth was 0.7 cm/year in the ICHwk1, 0.55 cm/year in the ICHmw2, and 0.3 cm/year in the ICHmw1. However, with one

TABLE 3 *Correlation matrix (r values)*

Independent variables	Average height increment post-harvest	Average diameter increment post-harvest
Residual basal area	**–0.59**	**–0.56**[a]
Age	0.23	0.34
Pre-harvest diameter growth	0.45	0.41
Pre-harvest height growth	0.04	0.006
Regeneration density when sampled	–0.38	–0.45
Percent vegetation when sampled	0.15	0.15
Pre-harvest basal area	–0.27	–0.21

[a] Bold denotes significance to $\alpha = 0.05$.

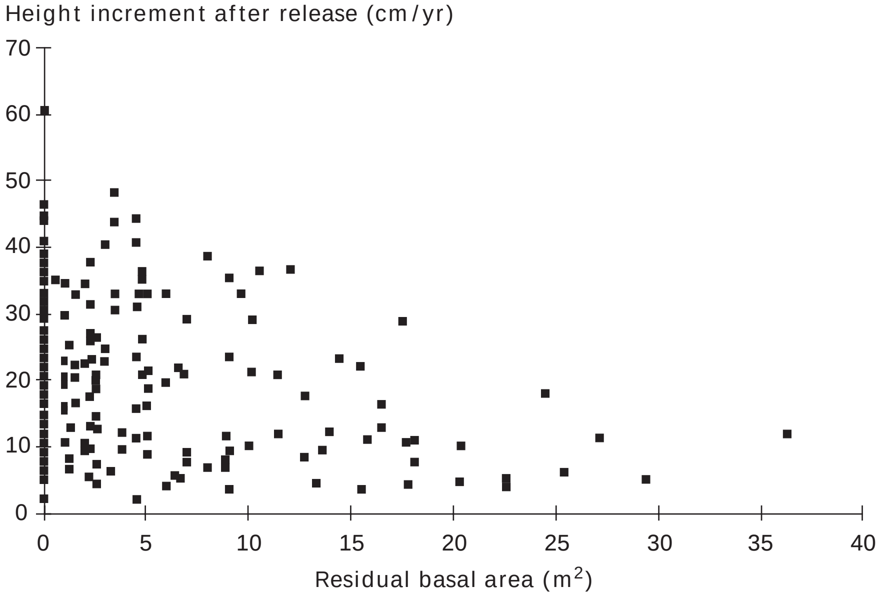

FIGURE 11 *Residual basal area versus post-harvest average height growth*

exception, these differences were not significant. Diameter growth in the ICHwk1 was significantly larger than in the ICHmw1 after harvest. Pre-harvest size or age did not seem to affect post-harvest growth. The release in height and diameter occurred within one to two years after harvest on the majority of sites. With release this immediate, it is doubtful that many stems were significantly damaged by sunscald.

Advanced regeneration in general was the least abundant in the ICHwk1. There was an average of 300, 1000, and 2700 stems per hectare of advanced regeneration in the ICHwk1, ICHmw2, and ICHmw1 subzones, respectively. The low numbers of advanced regeneration in the ICHwk1 may be partially explained by the fact that old-growth stands are much more common than in the ICHmw1 and ICHmw2 (Braumandl and Curran 1992). Advanced regeneration tends to be less common in old-growth stands. Openings in the ICHmw1 and ICHmw2 tended to be younger seral-stage stands at the time of harvest. Younger stands (< 140 years) appear to offer more opportunity for using advanced cedar regeneration than old-growth stands.

4.2 Decay

There was a surprisingly low proportion of cedar trees with decay in the harvested openings. About 25% of the stems sampled in these openings had decay. Almost half of this decay appeared to be introduced by logging damage, which could potentially be avoided or reduced. However, decay introduced by logging scars may not be serious on smaller stems. The type of decay that is introduced by logging scars can be restricted to the core of wood put down before the time of the injury (D. Morrison, Canadian Forest Service, pers. comm., 1994). Therefore, the core of decay may be confined to a relatively small part of the tree by the time it is mature. Brown cubical rots, *Armillaria ostoyae*, and other white stringy rots were not very common (about 5%) on the released trees. However, *Armillaria ostoyae* may have been more common, given that it can be difficult to detect on cedar. In a study in Idaho, a stand of released and thinned advanced cedar exhibited a decline in growth rates 5–10 years after treatment (Koenigs 1969). Fifteen years after treatment the released trees were chlorotic. This decline in growth was attributed to *Armillaria ostoyae* infection. While no such decline was noted in this study, more research is required on *Armillaria ostoyae*-infected advanced cedar.

Decay was more common in trees in the control plots. About 45% of the stems in the controls had decay, over half of which was white stringy rot. It may be that severely decayed trees on recently harvested blocks cannot compete with other, more vigorous stems and die in the first few years after harvest. With only three control sites, it is difficult to say whether this trend would hold on other sites. The sites in this study were harvested 10–25 years ago, and it is possible that decay incidence in the released trees could increase as the sapwood changes to heartwood over longer periods of time (B. van der Kamp, University of British Columbia, pers comm., 1995). Cedar that has been released for more than 25 years needs to be investigated. When growth in diameter and height were compared on decayed stems and stems without decay, there were no significant differences. There was also no difference between subzones in decay incidence. In a study investigating western hemlock in the ICH zone, decay incidence was not significantly related to aspect, site quality, or subzone.

4.3 Origin of Stems

Local foresters express concern that cedar regeneration of vegetative origin can have more rot, be of poorer form, and may not have the same release potential as regeneration originating from seed. One of the most interesting results in this study was that over 90% of the sampled trees in released openings were of vegetative origin. Parker and Johnson (1987) also found that veglings far outnumbered trees established from seed on undisturbed sites beneath mature stands in Idaho. It appears that veglings tend to be more successful than seedlings at establishing and growing in an undisturbed understorey environment. Seedlings appear to require mineral soil disturbance for successful establishment (Parker 1979; Mahoney 1981). There were not enough trees of seed origin in the harvested openings to compare the growth of veglings and seedlings. In a study in northern Idaho, Parker (1979) found that veglings exhibited comparable growth to seedlings after release. Given the good post-harvest growth rates of the veglings in this study, growth rates are likely to be comparable as well.

4.4 Regression Analysis

The regression analysis did not produce any reliable equations to predict the release potential of advanced western redcedar on the sites sampled. The best equation explained only 30% of the variation in growth. Other researchers studying the release of advanced regeneration have also not found reasonable predictive equations (Seidel 1983; Oliver 1986). Despite the lack of predictive equations, observations of site, stand, and morphological characteristics and their relation to release potential are useful.

Aspect Other research has indicated that trees may be able to release better on cooler, more northerly aspects or on sites where the overstorey is removed gradually to ameliorate change in the micro-environment (Koenigs 1969; Graham 1982). Aspect did not appear to have an effect on release in this study; however, the majority of sites sampled were on more neutral aspects as opposed to due south or north. Cedar on steeper, due-south aspects may not release as well as cedar on the sites we sampled. Enough moisture may be available on circum-mesic sites in the ICHwk1, ICHmw2, and ICHmw1 subzones, so that when trees are released and exposed to increased sunlight, the shade leaves are capable of adapting and continuing to photosynthesize regardless of aspect. Advanced cedar in the ICHdw (driest subzone in the ICH), which was not sampled in this study, may not behave in the same way, if released. There may not be enough moisture on these sites to mitigate the change in micro-environment. This needs to be verified with further study.

Residual basal area With increasing residual basal area, post-harvest growth in diameter and height decreased. More within-site variability in post-harvest growth occurred with greater amounts of residual overstorey. Post-harvest growth tended to be less and trees took longer to release on these sites. Therefore, any level of overstorey left on site may compete for light and moisture with understorey trees. Trees seem to release best where all of the overstorey is removed. Similar results were produced by research conducted in Oregon. Seidel (1985) observed that post-harvest growth in diameter and height of true fir and mountain hemlock was highest in clearcuts, intermediate in shelterwood cuttings, and lowest in uncut stands. Herring (1977), Graham (1982), and Bassman and Zwier (1992) also concluded that one of the major factors affecting the growth of advanced regeneration is tree competition.

Recent research in Idaho showed that moisture was a more significant factor in the growth of cedar seedlings than competition for light (Adams and Mahoney 1991), but this research was conducted on a drier site than the subzones we sampled in the Nelson Forest Region. Moisture and light could not be separated in our retrospective study. However, sites in the ICH zone may have enough moisture available, therefore competition for light may be a more significant factor.

4.5 Tree Characteristics

Percent live crown Percent live crown is a measure of the vertical proportion of a stem with live crown on it, not actual leaf area. Understorey cedar typically has a small percent vertical live crown, but the crowns can be very wide (as wide or wider than the tree height in some cases). Therefore, understorey cedar can have a fairly high leaf area available for photosynthesis. We tried to consider crown width when estimating a percent live crown, but this became a very subjective measure. Using this technique in the controls, the average live crown ranged from 40–50%. Because this study was retrospective, percent live crown of the released trees at the time of harvest could not be determined, although it is reasonable to assume that it was similar to the controls. The majority of released cedar had over 80% live crown. Therefore, it appears that advanced cedar with live crowns of 40% or more will respond to release and percent crown will increase over time. To verify this, a better method of measuring the amount of live crown on a stem needs to be developed for western redcedar. In a study in California where advanced red fir regeneration was released, percent live crown was recommended as a useful guide to predict post-harvest growth. Trees with live crowns of 40% or more tended to grow more rapidly (Oliver 1986). The method of measuring percent live crown was not described in detail in this study.

Stem form On average, 70% of the sampled trees in both released and control openings had a "hockey stick"-shaped stem or "sweep." Most of these stems in the released openings appeared to be outgrowing the deformity so that it would not affect future stem quality. This needs to be monitored in the longer term. The horizontal distance of sweep on stems in the controls tended to be greater than that of stems in the released openings. A greater horizontal distance is likely a function of the low light levels in the uncut controls, where a tree would grow outwards more in search of light.

5 CONCLUSIONS

Western redcedar is a valuable species for management. In the form of advanced regeneration, it is abundant in the majority of stands in the ICH zone of the Nelson Forest Region. The results of this study help to strengthen the case for using advanced western redcedar as part of future crops to reduce planting costs and avoid expensive site rehabilitation. It has good potential for release in the ICHwk1, ICHmw2, and the ICHmw1 subzones, and has been under-utilized to date.

- Age and size do not appear to affect its ability to release. Young trees at the time of harvest do not necessarily release better than smaller, older trees. The range of age and size of advanced cedar in this study was limited to what was left after harvest. The average age of released cedar at the time of harvest was approximately 40 years (range = 21–82 years) and average height was approximately 150 cm (range = 67–342 cm). The release potential of larger cedar needs to be investigated.
- Decay incidence was lower than expected in the harvested openings. However, it is possible that the incidence of decay could increase as the sapwood changes to heartwood. More research is required to look at decay in advanced cedar that has been released longer, as well as the relationship that advanced cedar has with *Armillaria ostoyae*.
- The majority of advanced cedar regeneration in the ICH zone is of vegetative origin, but this does not appear to affect the ability of advanced cedar to release. Most of these stems had some degree of sweep, but seemed to be outgrowing it. This will be monitored in ongoing investigations.
- Residual overstorey on harvested sites appears to negatively affect the ability of advanced cedar to release. Therefore, overstorey should be completely removed to achieve the best post-harvest growth. This may not hold for steep, due-south aspects or on sites in the driest subzone (ICHdw). Some overstorey protection may be required on these sites.
- Advanced cedar stems with live crowns of less than 40% may not release as well as stems with greater live crowns. However, a better, more consistent method of measuring the amount of live crown needs to be developed.

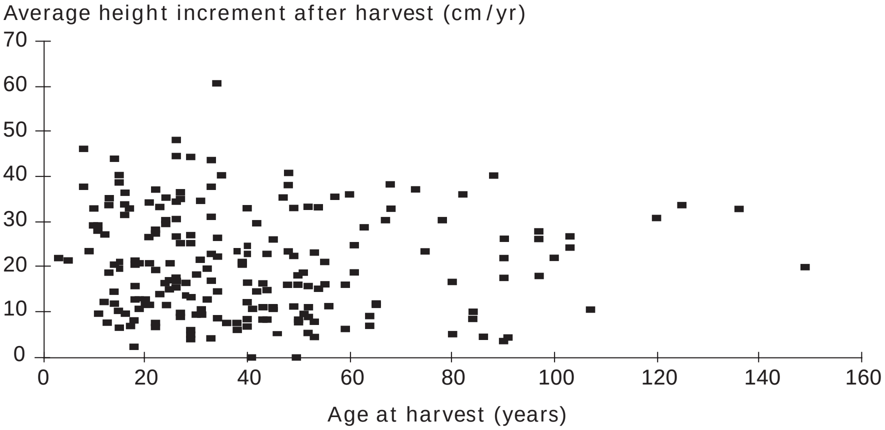

FIGURE 1 *Age of trees at harvest versus average post-harvest height growth*

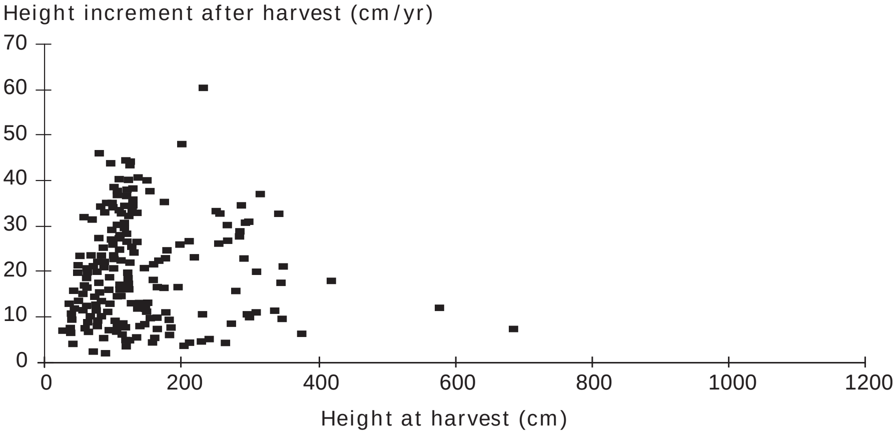

FIGURE 2 *Height of trees at harvest versus average post-harvest height growth*

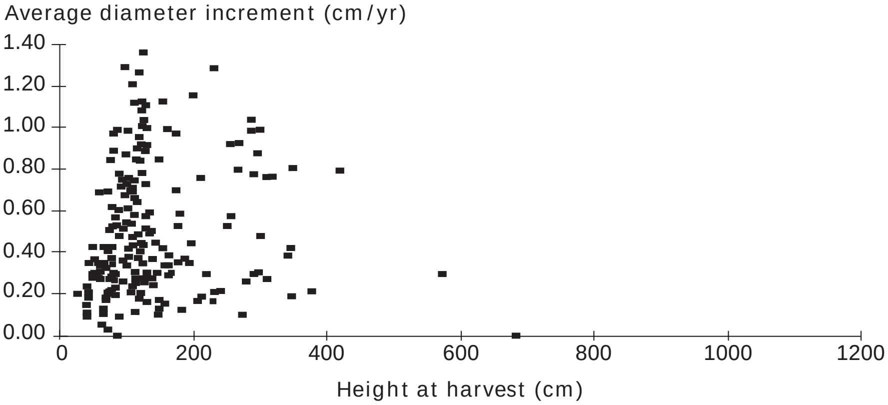

FIGURE 3 *Height of trees at harvest versus average post-harvest diameter growth*

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