Extension Note

Assessment of a 14-year-old Mixed Western Redcedar:Red Alder Plantation in Southwestern British Columbia

Introduction

Mixedwood stands of broadleaf–conifer trees can have many advantages over single-species monocultures (Green and Klinka 1994). Benefits may include:
- enhanced stand yield due to more complete utilization of growing space and/or improved soil nutrition (Rothe and Binkley 2001; Binkley 2003),
- improved stand resilience due to reduced risk of catastrophic disease and insect damage and enhanced windfirmness (Deal et al. 2017),
- improved wood quality by encouraging natural branch pruning, and
- enhanced biodiversity and wildlife habitat for a greater variety of animals (Felton et al. 2010).

The combination of western redcedar (Thuja plicata Donn ex D. Don in Lamb.) (referred to here as cedar) and red alder (Alnus rubra Bong.) (referred to here as alder) are good candidates for mixes from a competition reduction standpoint. The theory, as described in Kelty (1992, 2006), is that component species should have good ecological combining ability depending on whether they have complementary resource use—light, for example. Alder has rapid juvenile height growth and is shade intolerant. Cedar, on the other hand, is slower growing and shade tolerant. The result of growing these tree species in mixture, either together at plantation establishment (this study) or by delaying alder establishment, is likely a two-tiered canopy. Intimate mixes of shade-intolerant alder and shade-tolerant understorey cedar enables more effective utilization of the light resource. The understorey cedar is able to survive and grow under reduced light (used by overhead alder) because of its greater light-use efficiency. The addition of an understorey layer of shade-tolerant trees such as cedar or hemlock may offer increased timber production over the long term.

Alder fixes nitrogen and can improve the growth of species in mixture. This has been reported in the Pacific Northwest for Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) (Murray and Miller 1986) and Sitka spruce (Picea sitchensis Bong.) (Courtin and Brown 2001). Western redcedar may also improve the form and quality of alder by promoting branch pruning.

The objective of this Extension Note is to document 14-year results from an alder and cedar replacement series experiment (Figure 1). This trial was
designed for long-term growth and yield monitoring of alder and cedar mixedwoods. To date, we are aware of only one other report that has documented results from a similar replacement series trial (Hardwood Silviculture Cooperative [HSC] 2017).

Study Area

The trial is located near Coombs, on Vancouver Island, B.C. It is within the Coastal Western Hemlock (CWH) zone and in the CWHxmi biogeoclimatic variant at an elevation of 125 m above sea level and a northeast aspect of gentle to flat slope. The site is representative of the HwFd – Kindbergia and Cw – Sword fern site series (01/05) (Green and Klinka 1994). The soils range from loamy glaciomarine sediments with few coarse fragments (> 2 mm) to more loamy sand glaciofluvial deposits containing about 40% coarse fragments. The nutrient regime ranges from medium to rich, and the moisture regime is fresh. Humus forms range from Hemimor to thin Humimor forest floors (Green et al. 1993).

Prior to harvesting in 2000, the trial area contained a mixed deciduous–conifer stand that was heavily dominated by red alder. Harvesting activities resulted in compaction along extraction routes and debris burn piles.

Methods

Four mixtures (treatments) were planted in March 2002 in a replacement series using cedar:alder in the following proportions: 100:0, 75:25, 50:50, and 0:100 (Figures 2 and 3). Cedar and alder were planted at the same time within three 35 × 35 m plots per treatment (replications), and treatments were allocated randomly for most plots except for pure alder, which were established in areas as part of a commercial alder plantation. Each plot contained a total of 225 trees (15 × 15 grid) at a density of 1600 stems per hectare (sph). An inner measurement plot of 81 tagged trees (9 × 9 grid) was remeasured over time. The remaining area external to the measurement plot was considered a buffer. The trees were last measured in 2015 (14 years plantation age) for height, diameter at 1.3 m (dbh), and condition.

The experiment was analyzed as a completely randomized design with three replications (plots) per treatment. Analysis of variance (ANOVA) was used to test growth differences of cedar and alder, using treatment as the dependent factor. Treatment means were considered significantly different at \( p \leq 0.05 \). The Bonferroni adjustment was used for post hoc tests on significant means. All data analyses were performed using SYSTAT (1997) software.

Tree volume was calculated using volume equations from Kozak (1995) for cedar and alder where:

\[
\text{Volume (m}^3\text{)} = 10b_0 + b_1 \log_{10}d_{bh} (\text{cm}) + b_2 \log_{10}\text{height (m)} \quad (1)
\]

Kozak (1995) provided individual tree species coefficients for the CWH

![Figure 1](image1.png)

**Figure 1.** A western redcedar:red alder replacement series research trial was established in 2002 to explore mixed-species stand dynamics.

![Figure 2](image2.png)

**Figure 2.** Inter-planting arrangement of western redcedar (C) and red alder (A) within treatment plots (only a portion of trees/treatment is shown).

![Figure 3](image3.png)

**Figure 3.** Treatment plot layout, tree tag numbers, and cutblock boundary for the western redcedar:red alder replacement series mixed-species trial (Experimental Project 1331).
biogeoclimatic zone. The various model coefficients used for cedar and alder were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Cedar</th>
<th>Alder</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_0$</td>
<td>$-4.11247$</td>
<td>$-4.41410$</td>
</tr>
<tr>
<td>$b_1$</td>
<td>$1.67310$</td>
<td>$1.86871$</td>
</tr>
<tr>
<td>$b_2$</td>
<td>$1.075530$</td>
<td>$1.097540$</td>
</tr>
</tbody>
</table>

Relative yield (RY) was calculated as the proportion of each species yield in mixture relative to its yield in monoculture (Kelty 1992). In other words, the relative yield for cedar or alder from the 75:25 or 50:50 treatments was calculated as a proportion of the 100:0 or 0:100 treatments yield (Figure 4). Yield for each species was calculated as mean individual treatment volume ($m^3/ha$). For example, volume per hectare of cedar in the 50:50 treatment was equal to the mean individual volume of cedar ($\text{MIVC}$) in that treatment $\times$ number of trees per hectare $\times$ proportion of cedar in that treatment:

$$\text{Volume (}m^3/\text{ha}) \text{ cedar (50:50)} = \text{MIVC} \times 1600 \times 0.50$$  \hspace{1cm} (2)

As a result, RY removes any confounding due to mortality but overestimates actual experiment volumes. Relative yield of cedar and alder in the 50:50 treatment was calculated as:

$$\text{RY cedar (50:50)} = \frac{\text{volume/ha cedar (50:50)}}{\text{volume/ha cedar (100:0)},}$$

$$\text{RY alder (50:50)} = \frac{\text{volume/ha alder (50:50)}}{\text{volume/ha alder (0:100).}}$$

Relative yield total (RYT) for a mixture is the addition of the RY for each component; that is, $\text{RYT (50:50)} = \text{RY cedar (50:50)} + \text{RY alder (50:50)}.$

### Results and Discussion

#### Survival

The overall survival for cedar and alder was 96 and 87%, respectively. The survival across treatments is shown in Figure 5. The low (63%) survival of alder in the 50:50 treatment was due largely to one plot that had 44% survival (plot 5). This was likely due to microtopography—a flat area with cold air ponding. Alder seedlings are very sensitive to frost, and repeated replanting and mortality did occur in this area. Otherwise, the alder survival for the other two 50:50 treatment plots was 71 and 76%, respectively. Cedar survival was not significantly different across treatments. The 0:100 alder survival was greater compared to the mixtures (Figure 5).

#### Height

At age 14 years, the dominant height of alder from all treatments was 12.1 m, which was significantly greater than that of cedar (8.5 m). Cedar height was not significantly different between the 100:0 and 75:25 treatments, but in the 50:50 treatment, it was significantly greater than that in the other two treatments (Table 1; Figures 6 and 7). This pattern was the same for cedar diameter, basal area, and volume (Figures 8–10). For height, this result was in contrast to the HSC (2017) study, where the 100:0 treatment had the greatest height, and cedar height decreased with increasing alder proportion (26-year results).

In contrast to cedar, alder height growth was always smallest in the 50:50 treatment. Alder height was 39% taller in the 0:100 treatment compared to the average of the mixture treatments (Table 1; Figure 6). In this study, alder grown in mixture often developed a fuller crown compared to the pure stands. The reduced alder density in the mixtures (with concurrent increase in cedar density to maintain consistent total stand density) provided additional canopy space for alder branch development, delaying alder crown lift and branch pruning. As a result, alder in...
**Table 1**  Fourteen-year mean (and standard deviation [SD]) for height, diameter (dbh), tree basal area, and individual tree volume for western redcedar and red alder by treatment. Different lowercase letters signify mean differences at \( p \leq 0.05 \).

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>100:0</th>
<th>75:25</th>
<th>50:50</th>
<th>0:100</th>
<th>MSEa</th>
<th>F ratio</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cedar</strong></td>
<td>Height (m)</td>
<td>6.22a (1.84)</td>
<td>6.55a (1.96)</td>
<td>7.14b (1.34)</td>
<td>—</td>
<td>30.60</td>
<td>9.50</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>dbh (cm)</td>
<td>8.80a (3.59)</td>
<td>9.02a (3.42)</td>
<td>10.9b (3.26)</td>
<td>—</td>
<td>177.6</td>
<td>14.83</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>Basal area (m²) × 10³</td>
<td>7.10a (5.22)</td>
<td>7.31a (4.79)</td>
<td>10.2b (5.74)</td>
<td>—</td>
<td>391.8</td>
<td>14.58</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>Volume (m³)</td>
<td>0.027a (0.023)</td>
<td>0.029a (0.022)</td>
<td>0.040b (0.024)</td>
<td>—</td>
<td>0.006</td>
<td>11.08</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td><strong>Alder</strong></td>
<td>Height (m)</td>
<td>—</td>
<td>10.4a (3.02)</td>
<td>9.15b (2.99)</td>
<td>13.6c (2.20)</td>
<td>624.8</td>
<td>97.5</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>dbh (cm)</td>
<td>—</td>
<td>11.8a (4.77)</td>
<td>9.00b (4.38)</td>
<td>11.9a (3.30)</td>
<td>241.5</td>
<td>16.68</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>Basal area (m²) × 10³</td>
<td>—</td>
<td>12.7a (8.82)</td>
<td>7.85b (6.60)</td>
<td>12.0a (6.15)</td>
<td>536.0</td>
<td>12.03</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td></td>
<td>Volume (m³)</td>
<td>—</td>
<td>0.068a (0.055)</td>
<td>0.040b (0.041)</td>
<td>0.079a (0.046)</td>
<td>0.041</td>
<td>19.03</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

a MSE = mean square error.

**Figure 6** Fourteen-year height of western redcedar and red alder by treatment.

**Figure 7** Transition from 75:25 western redcedar: red alder mixed plot to 100% red alder plot (photo Jan. 2018).

Diameter (dbh), basal area, and volume

Cedar diameter (dbh), basal area, and volume in the 50:50 treatment were significantly greater than in the other treatments. This contrasts with results from the 13-year growth of cedar in the HSC (2017) study, where the cedar had the greatest diameter in the 75:25 treatment and the greatest volume in the 100:0 treatment.

Alder diameter (dbh), basal area, and volume all had similar responses. They were significantly less in the 50:50 treatment than in either the 75:25 or the 0:100 treatments, which did not significantly differ (Table 1; Figures 8–10).

Relative yield

The RYT for the 75:25 or 50:50 treatment was close to 1.0 for cedar and alder (1.02 and 0.98, respectively) (Table 2), which indicates that there is no advantage or disadvantage to the combined mixtures relative to the monoculture (Vandermeer 1989). From the standpoint of increased production, this is a neutral outcome. If the management goal is not total production (e.g., see list in Introduction), then the mixture might be warranted.

Otherwise, the results so far indicate that growing a pure stand of cedar would be preferable, considering
that alder may reach an optimum harvesting diameter at half the rotation age of cedar. If the $RY_T$ value is less than 1, this indicates antagonism between species and a better production outcome for the monoculture.

Figure 11 shows that growing alder (0:100) results in yields that are nearly three times the volume of cedar (100:0) at 14 years (Figure 12). If maximizing biomass is the management objective, then a pure alder monoculture is preferable. The site index of alder, based on mean alder top height from the 0:100 treatment, was 30.9 m, calculated using Site Tools software (BC MFLNRO 2015) with Nigh and Courtin (1998) site index curves.

The results also indicate that alder was not negatively affecting cedar yield, and cedar yields have increased relative to expected yields by 7 and 46% for 75:25 and 50:50 treatments, respectively (Table 2). This may suggest that some level of benefit may be occurring, since mean individual cedar volumes appear to increase with increasing alder proportion (50:50 > 75:25 treatment) (Table 1). However, this result may be simply a function of declining cedar density as alder proportion increased in these mixtures.

The $RY$ analysis used here did not consider mortality; therefore, the $RY$ results do not reflect real changes in spatial distribution and actual stand volumes. Relative stand volumes are based on an adjustment of mean tree volumes relative to experimental design expectations of density and proportion (Kelty 2006). As such, the lower percent survival of alder (Figure 5) noted in the mixtures, in particular the 50:50 treatment, influenced the actual yield outcomes (Table 2). The general interpretations, however, are unchanged, with cedar growth apparently benefiting from alder mixture, with a concurrent decline in alder productivity. As Jolliffe (2000) stated, facilitation or other sorts of mixed-species interference can be difficult to determine using
replacement series designs.

Future analysis needs to consider not only survival and tree health but also total above- and below-ground biomass measures such branch size, leaf and needle litter, root growth, foliage, and soil nutrition.

**Conclusions**

This study has indicated that mixing western redcedar with red alder may increase individual cedar growth (Figure 13). Cedar height, diameter, basal area, and individual tree volume were greater in a 50:50 mixture relative to either the pure stand or a mixture of 75:25 cedar:alder. For alder, the 50:50 mixtures had the lowest levels of these parameters.

The conclusion that cedar benefits from alder mixture relative to pure stands should be considered premature given the early age of this trial and the need for more comparable research results elsewhere. For example, the HSC trial in Washington State (HSC 2017) produced different growth trends for the same cedar:alder mixtures. However, from a total stand productivity perspective, a comparison of volume per hectare growth did not indicate any clear advantages of the mixtures, since optimum stand volume for cedar or alder was achieved with the pure-species treatments.

In this study, more emphasis was placed on the effect of alder on cedar than cedar on alder. One reason for this is alder’s nitrogen-fixing ability. Another is that, in many lowland coastal conifer plantations, alder will establish naturally and influence conifer growth so that brushing treatments are often undertaken. A useful guideline would be to consider the density at which alder negatively influences conifer growth. Comeau et al. (2000) reported that up to 400 sph of alder had little influence on Douglas-fir or cedar growth at 10–12 years. This report suggests that up to 800 sph of alder may be acceptable when growing with cedar alone. The continuation of these and other studies until rotation age will help confirm these trends. At that time, forest managers may have more options for treating alder in conifer plantations.


Kozak, A. 1995. Development of Schumacher’s volume equation by BEC zones and species. Report to B.C. Min. For., Resources Inventory Br., Victoria B.C.


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