Red Alder Plantation Management

A Manager’s Guide to Reducing Mortality Within Red Alder Plantations

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Prepared for Peter Marshall, Suzanne Simard, and Stephen Mitchell
Executive Summary

Observations of plantation failures in British Columbia have left some forest managers questioning whether it is viable to transition from managing conventional species to managing *Alnus rubra* (red alder). These mortalities and plantation failures often deter forest managers from managing red alder as anything more than a nuisance. This paper will recommend practices in order to reduce mortalities and plantation failures when managing red alder.

One of the key strategies that provides the greatest reduction in mortality is appropriate site selection, with this the areas prone to frost or drought can be avoided, as they are significant contributors to plantation failures. In addition, mechanical site preparation prior to planting is beneficial by improving rooting mediums for red alder and herbicide treatments will reduce competition with brush species. Despite being well-known for its capacity to dominate disturbed sites, for red alder natural regeneration is unreliable. Artificial regeneration should be used instead to ensure plantation success. Inspection the planting stock during planting is very important to check for any seedling mortalities. Finding these mortalities early on will allow more time to arrange an order for fill-planting, to avoid ingress of brush and plantation failure.

Plantation failures caused by nursery stock failure is rare, but there can be ~10% of the inventory suffer mortality from desiccation in cold storage, especially for smaller stock types. Choosing an appropriate stock type can improve survival of red alder in the plantation. Red alder can be successfully planted in both spring and summer, yet spring is a more suitable choice so that seedlings have an opportunity to establish an adequate rooting system prior to frost and drought events. Plantations should be surveyed in May to assess significance of brush competition and also in October to determine if planted stock has hardened prior to fall frosts. With the information from surveying in these times of the year appropriate measures can be planned in order to improve the overall success of the plantation.

These kinds of measures will provide the plantation with the necessary advantages in order to prevent damaging agents from having severe impacts on plantations or causing a plantation failure. Ensuring plantation success will require additional silvicultural treatments, but if done during the initial stages of establishing the plantation the investments should pay off.
Keywords

RED ALDER MANAGEMENT

ESTABLISHING RED ALDER PLANTATIONS

IMPROVING PLANTATION SUCCESS

APPROPRIATE SITE SELECTION

ADDRESSING MORTALITY

REduCing Plantation FailureS

preventing seedling mortality

damaging agents

preventing seedling predation

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Background

Between the years of 2011 and 2015, my experiences with Western Forest Products (WFP) as an Assistant-planner and Assistant-forester have taken me to several locations along the southern coastal regions of British Columbia where red alder has being managed as a commercial species. Two locations where my employment with WFP had taken me had significant differences in the success of red alder plantations. In the Stillwater Division, Powell River, red alder management appears rather successful and outside of WFP’s tenure there are many instances where red alder is being managed successfully. Most of the red alder management in the Powell River area is being done by a company called Northwest Hardwoods (NWH) and plantations have generally been successful. Though some plantations had significant challenges and silvicultural practices were needed to ensure plantation success. However, where red alder management is occurring in WFP’s Port MacNeill Division, there have been plantation failures. These failures and successes between the two regions suggested that there is more action needed based on site conditions to ensure plantation success.

By researching this issue, the goal is to provide a synthesized information source for practitioners to successfully plan and prescribe actions to establish a successful red alder plantation in coastal British Columbia.
Methods

In order to research this topic, the focus was on obtaining information through personal communications, acquiring materials from forest licensees, and reading research theses and articles on the management of red alder. However, that is not to say that online materials have not been considered, but those materials were not focused upon for this essay. The reason for this is to have an accumulation of information from experienced individuals practicing management of red alder rather than a synthesis of online materials.

Questionnaires and interviews with NWH provided much of the information found throughout the paper, as NWH is a company of experienced individuals when it comes to managing red alder. Arbutus Grove Nurseries and WFP nurseries were also contacted in a similar manner in order to get a better understanding of their experiences with the production of red alder planting stock.

NOTE:

Because time constraints, the paper has been written in the perspective of considering only pure red alder plantations, not mixed stands, and as such this paper will not cover advantages or challenges from mixed wood management.
Silvics of red alder

*Alnus rubra* (red alder) is a deciduous, broad-leaved species that is short lived compared to most commercial conifer species. This species occurs in the Coastal Douglas-fir (CDF) and Coastal Western Hemlock (CWH) biogeoclimatic zones, within cool temperate and cool mesothermal climates, and within submontane and montane ecosystems (Figure 1; Forest Practices Branch, Ministry of Forests [FPB], 2008).

Red alder has a high seed production capacity, where cone-like catkins are capable of producing between 50-100 seeds each, and seed production can begin as early as 6-8 years from germination (Sheldon, 1978; FPB, 2002). A strong competitor for natural regeneration in openings, red alder is often first seen on moist-rich benches and gentle slopes after logging and fire events have exposed mineral soil, a preferred seedbed for red alder (Worthington, Norman P., Ruth, R.H., Matson, E.E. [Worthington et al], 1962).

Red alder performs well on sites with deep, well-drained soils, moist sands and gravels, but does not seem to perform well on sites with prolonged overflows (Figure 2; Worthington et al, 1962). Typically red alder will be found in pure stands as a pioneer species on floodplains or heavily disturbed areas, but it can also be found on hillsides during secondary succession (FPB, 2008). Red alder is known to perform well in nitrogen-
deficient sites because of its symbiotic relationship with a nitrogen-fixing organism *Frankia alni* that develops soon after red alder has germinated (FPB 2008).

**Damaging Agents**

*Microtus townsendii* (voles)

A field guide by Sullivan (1997) describes how voles feed upon seedlings, girdling the root collar, bole, or lower branches of seedlings. Sullivan (1997) also describes how instances of both seed predation and seedling damage increase on a 3-4 year cycle which follows the vole population cycle. Hughes (personal communication, December 21, 2014) emphasized that the damage voles cause could lead to plantation failures and the frequency and severity does not differ between coniferous and red alder plantations. This frequency may catch managers off guard should the plantation occur next to suitable vole habitat. Voles are known to utilize sites with tall grasses, dense brush, and heavy slash as security cover. Strategies for managing vole damage in plantations include site avoidance or mechanical site prep on sites voles may use for habitat (Tables 3 and 4).

*Odocoileus* species (deer)

Deer is a relatively common species throughout B.C. and is likely to be found in the same regions that red alder would be found. The damage caused by deer is often in the form of browsing of terminal and lateral shoots which, if repeated, leads to stunted and bushy growth. Occasional browsing is not an issue in red alder plantations because the damage caused is often of a low severity, potentially causing growth impediment on seedlings in the plantation, rather than widespread mortality or plantation failures (Harrington, 1984). Sullivan (1997) depicts other forms of damage caused by deer, such as shredding bark, damage from antler rubbing, and browsing foliage up to 1.5 metres in height. Reasons that plantations are more likely to be attacked are: small cut-block size, small planting stock, ease of access to the plantation; and plantations being located adjacent to winter ranges, security cover, or shelter (Sullivan, 1997).
Though most feeding occurs in the summer and fall, damage can occur in winter and early spring when other food sources are not as accessible (Sullivan, 1997). Though overall deer have a lower significance in plantations, should damage caused by deer become more prevalent then measures reduce damage from occurring, measures such as predation deterrence or population control may be an option (Table 3 and 4).

**Cervus species (elk)**

Much like deer, elk are a common species found throughout B.C and are likely to be found within the same regions as red alder. Elk too are known for browsing the terminal and lateral shoots of seedlings, as well as damaging seedlings from antler rubbing. However, elk are known to trample and uproot seedlings as herds migrate and forage. Aside from the mortality that occurs from uprooting and trampling, elk damage is similar to damage that deer can cause to plantations, causing stunted and bushy growth. Damage from elk is more likely to occur in the fall season because of the high protein content of foliage in the autumn months (Scott, 2008). Although elk damage is an issue for red alder in September and October, it can also occur in drier summer months, and when other food sources are not accessible (Hughes, pers comm). Plantations are more likely to be damaged where there is an ease of access to the plantation and when plantations are located adjacent to winter ranges, security cover, or shelter (Hygnstrom, Timm, and Larson, 1994). In order to reduce damage to plantations, similar methods like predation deterrence and population control can be used that apply to deer (Table 3 and 4).

**Competing vegetation**

As red alder is a shade intolerant species, it will not perform well when competing against other tree or brush species. Seed germination is generally poor if seeds are buried, or in conditions of low light, as light is a critical element necessary for successful germination (FPB, 2002). As such, if natural regeneration is chosen for the site then adequate site selection should be done to optimize seedling establishment (Table 1). Though plantation failures are not typically an issue when adjacent to riparian areas, issues may arise when regeneration is in or
adjacent to sites with a dense coverage of shrubs, herbs, or residual timber (Worthington et al, 1962). This poses a problem since *Rubus* species and red alder generally occur in similar sites with rich and moist soil and both are commonly found within or adjacent to riparian areas. This makes *Rubus* species significant competitors on sites suitable for red alder plantations.

Though *Rubus* species may have a low dispersal rate, but seeds will last in soil beds for long periods of time, and remain dormant until conditions are favourable (FPB, 2002). Should *Rubus* species establish and overtop red alder within three years the plantation will likely suffer significant mortality (FPB; 2002; Hughes, pers comm). In order to reduce mortality and avoid plantation failure adequate measures such as herbicide treatments will need to be taken during those first three years to ensure plantation success (Table 5).

Some sites suitable for planting of red alder may also overlap with sites that have a high coverage of *Gaultheria shallon* (salal), a species that can be highly competitive. As an evergreen species, if salal were first to dominate on a site it would likely outcompete red alder. Salal should not be overlooked when performing a Site Plan, regardless of the rapid growth characteristics of red alder (Table 1).

Though red alder seedlings are capable of surviving in conditions of partial shade for several years, without exposure to full sunlight the seedlings will eventually die, and only trees maintaining dominant crown-positions in the plantation will survive mortality (Harrington, 1990). On sites where red alder is growing in a mix with coniferous species, like coastal Douglas-fir, it generally out-competes the conifers for the first 20 years, competes on par for the following 20 years, and slowly dies out over the next 20 years as it approaches the end of its natural life-cycle (Worthington et al, 1962).

*Pathology and Entomology*

At young ages red alder is not significantly vulnerable to losses from diseases. Although there are numerous foliage diseases, canker causing diseases, and other types of diseases they tend to be secondary invaders having little impact on plantations (Harrington, 1990). Red alder tends to
be vigorous enough to survive most diseases unless the tree was significantly damaged by another agent.

One disease that appears to be of greater concern is the disease *Phytophthora alni* (*P.alni*) which appears to be having negative impacts on *Alnus* plantations throughout the globe. *P.alni* causes lower stem bark lesions, root and collar necrosis, and crown-dieback (United States Department of Agriculture [USDA], 2010). Damage like this could look similar to damage caused by voles. In Bavaria, Jung and Blaschke (2004) found that infected stands were capable of spreading the disease to other stands along rivers and streams, and that nurseries often carried infected stock, as their water sources were carrying the disease.

Though seemingly an isolated case in a faraway land, such series of events could happen in any country, nursery, or plantation. If outbreaks occur, the source should be traced so that adequate measures may be taken to mitigate the effects upon stands. A study in Alaska by Adams et al. (2008) found the *P.alni* is currently in a state of isolated incidents, with no situations like that of Bavaria, and that there were alternate causes of mortality in the regions studied. However, Adams et al. (2008) did recognize the importance that this disease species could have for the hardwood market for the north-western regions of North America. Although appears that further studies are needed to adequately assess whether there are other instances that would raise concern within B.C.

Insects are not usually a primary concern in red alder management. Species such as the *Malacosoma* species (Tent caterpillars), *Eriocampa* and *Hemichroa* species (Sawflies), and *Altica* species (Alder beetles) may cause growth reduction, possibly substantial damage, but plantation failures are rare (Harrington, 1990). Though Tent caterpillars and Alder beetles can cause mortality for individual hosts in a plantation, insects do not often cause widespread mortality in plantations unless the trees are weakened by other agents (Scott, 2008; Worthington et al, 1962).

Overall, through various sources it seems that diseases and insects act as secondary agents that may cause mortality and no particular practices are necessary in planning plantations.
Low temperature extremes

Red alder appears to be susceptible to sudden changes in temperature, often resulting in crown damage and potentially mortality (Deal and Harrington, 2006). Frost in the midst of the growing season, such as radiation frost, is often a factor involved in widespread mortality in red alder plantations, and occurs in the spring months of April and May (Hughes, pers comm; Niemiec, Ahrens, and Hibbs, 1995). Frost in the fall months of October and November, will often cause crown dieback and when successive frost damage occurs mortality can result (Hughes, pers comm; Worthington et al, 1962). Aside from frost caused mortality, snow can also damage alder plantations, producing flattened seedlings or snapped stems. Although there is the potential for young red alder seedlings to have vegetative sprouting from the lower stem or roots when subject to substantial damage, this process is not guaranteed, and should not be relied upon (Hughes, pers comm). Harrington (2006) describes how planting stock from nurseries may suffer significant damage and mortality if the stock had been exposed to an unseasonable frost during active growth. From the various sources, it appears that frost is the most frequent and significant cause of mortality, and careful consideration should be given to planning the planting and surveys to check up on a plantation (Table 1, 6, and 8).

High temperature extremes

Sunscald can occur on the South and West sides of stems, something that should be checked for while surveying the plantation (Deal and Harrington 2006; Table 8). Though rarely causing mortality, sunscald can weaken red alder seedlings enough that they could become subject to other damaging agents mentioned in this paper. Aside from sunscald, drought can be a problematic issue for red alder plantations, even though red alder has evolved to survive in regions with lower summer rainfall (Hughes, pers comm; Deal and Harrington, 2006). When red alder establishes on sites that are drought-prone they are likely to become stressed in high temperature extremes. Even outside those drought-prone sites, red alder is likely to become stressed when subject to repetitive dry-spells. The damage that comes from this stress can cause chlorosis, premature leaf fall, dieback of foliage, and possibly mortality (Russell, 1991). Though
drought conditions are considerable for plantations, generally this species can react to such conditions through closing off of the stomata until conditions are favourable, or dropping the leaves entirely, and with that in mind the drought conditions may not be as concerning as red alder’s lack of cold hardiness (Farnden, Montigny, and Larson, 2012). However, on southern aspects, or on steep slopes of continental regions, the risk of widespread mortality in red alder plantations will be higher than other sites (Niemiec et al, 1995). Careful planning should be given when planning the location of red alder plantation (Table 1).

**Red Alder Management**

*Identifying Key Indicators*

Adequate site selection will increase the chances for successfully establishing a plantation. Suitable ecosystems in coastal British Columbia for growing red alder are the CWH dry-maritime [dm], very wet-maritime [vm], dry-submaritime [ds], and very dry-maritime [xm] ecosystems (Hughes, pers comm; Table 1). Site series that are suitable for the establishment of red alder tend to be the 07 and 05 site series of the ecosystems above, where soil moisture regimes and soil nutrients regime represent richer sites with higher moisture content (Hughes, pers comm; Figure 2; Table 1).

Indicator species that can be used to assist in judging the suitability of the site are of the *Juncus* variety, as the indicate sites with characteristics suitable for red alder. Whereas sites with significant coverage of *Blechnum spicant* (deer fern) or salal are generally unfavourable sites for red alder (Hughes, pers comm; Table 1). Other sites that should be avoided are sites in cold-air drainages and sites with frost pockets, which are frequently found to be significant contributors to plantation failures. Consideration should be given to appropriate ecosystems and site selection, avoiding sites prone to drought or frost, or poor soil characteristics (Table 1).
Table 1 Considerations for site selection (Hughes, pers comm)

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Goal</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suitable ecosystems</strong></td>
<td>Enhance plantation success</td>
<td>• CWH dm (optimal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CWH vm and ds (better performance)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CWH xm (suitable on 07 site-series)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CDF mm (site specific)</td>
</tr>
<tr>
<td><strong>Site selection</strong></td>
<td>Identifying suitable sites</td>
<td>• 5→6 SMR and D→E SNR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 05 and 07 site series (CWH vm1 01 site-series)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Well-drained soils with fine sand and silt content</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Seasonal flooding is acceptable (not prolonged overflows)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sites with significant coverage of <em>Juncus</em> species</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Southerly aspects (some difficulty on steep slopes).</td>
</tr>
<tr>
<td></td>
<td>Identifying high risk sites</td>
<td>• Cold-air drainages, frost-pockets, or sites prone to droughts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Significant coverage of <em>Blechnum spicant</em> (wet &amp; poor)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sites with significant brush competition (<em>Rubus</em> &amp; salal)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tall-grassy sites (vole habitat)</td>
</tr>
</tbody>
</table>
**Planning the planting program**

Appropriate planting season selection improves the performance and chance of survival or red alder, thus improving the overall success of the plantation. In terms of seasons that are most suitable for planting red alder, spring (mid-March) is suggested as the best option. Though this can leave seedlings vulnerable to spring drought and frost, at least the seedlings will have time to developing a suitable rooting system to survive the harsh conditions (Hughes, pers comm). However, that isn’t to say that summer planting is not an option, but should only be done on sites that do not have moisture deficits, as that would leave seedlings stressed and vulnerable to frosts (Hughes, pers comm). If necessary, summer planting could coincide with mechanical site preparation in order to churn soil, removing organic matter, and providing a better rooting medium for red alder to establish (Table 5). Hughes (pers comm) advises against fall planting, as that time of year is when red alder growth is most rapid and planting in fall would cause seedlings to wither.

The planting density of the plantation can be a useful tool in order to mitigate the impact from previously mentioned damaging agents, though there can be trade-offs when implementing one method over another (Table 2). Such as how allowing the natural ingress of trees can mitigate the overall effect of foraging species upon a plantation, but an excessive number of stems can increase the chance of snow-snap, and managing density to avoid snow-snap can an inverse effect for foragers.
**Table 2** Considerations for planning red alder plantations (Hughes, pers comm).

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Goal</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Harvest Planning</strong></td>
<td>Enhance plantation success</td>
<td>Finishing harvest in spring, doing site preparations in the summer, and planting thereafter allows red alder to dominate the site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spring planting, mid-March, allows seedlings to develop adequate root systems prior to spring droughts and frosts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Summer planting is suitable for sites with a low risk for moisture deficits (coincides well with mechanical site preparation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pre-emptively order ~10% additional planting stock in order to address early mortalities in the plantation</td>
</tr>
<tr>
<td><strong>Planting Program</strong></td>
<td>Enhance plantation success</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Planting between 1100-1600sph is typical, densities vary depending on the plantation manager</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Planting under 2000sph avoids damage from snow snap, but may require thinning if heavy natural ingress occurs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Allowance of heavy natural ingress can mitigate severity of damage to plantation from foragers</td>
</tr>
<tr>
<td><strong>Density Management</strong></td>
<td>Enhance plantation success</td>
<td></td>
</tr>
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</tbody>
</table>
Post harvest treatments

Post harvest treatments can greatly improve the success of a red alder plantation when conditions are not as favourable for seedlings to develop at their maximum potential. It should be noted that logging will not necessarily kill the brush, but instead damage and disperse brush through the site. This dispersion is a problem as some brush species are capable of vegetative reproduction and *Rubus* species are capable of sprouting and flushing the following year from both roots & dispersed stems (Worthington et al, 1962). Vegetative reproduction of brush species at that rate would produce significant competition within red alder plantations, which would likely require herbicide treatments to ensure plantation success (Table 3).

The first three years after planting red alder are considered to be the most crucial for ensuring red alder dominance on the site, so the treatments are best done sooner than later, taking on the proactive stance rather than reactive (Hughes, pers comm). Prescriptions that involve managing the slash and brush in the site can allow red alder to establish itself as the pioneer species, as it is ecologically accustomed to being (Table 3). By brushing the site after harvesting, the plantation has more time to establish dominance before the brush species sprout and establish its dominance. Treatments like scarification and burning are also beneficial, as they remove the organic materials and increasing access to better rooting mediums (Table 3).

Should a mix of red alder and coniferous species occur in the plantation it may be desired, or required, that the plantation be thinned in a manner to free red alder from competing conifers. Alternatively, instances where a pure stand of red alder has reached a density that growth is not maximised, then thinning would provide a competitive release and improve the growth rate of the plantation. As previously mentioned, thinning would also reduce the chances of snow-snap in winter months, should the site be at a higher risk of significant snow accumulations (Table 3).
Table 3 Considerations for improving plantation success in the post-harvest stage (Hughes, pers comm).

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Goal</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slash</td>
<td>Predation deterrence</td>
<td>Leaving accumulations of slash can reduce ungulate access to seedlings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and mitigate damage to seedlings</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Enhance plantation success</td>
<td></td>
</tr>
<tr>
<td>site-prep</td>
<td></td>
<td>• Raking brush increases seedling dominance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Scarification improves access to favourable rooting medium</td>
</tr>
<tr>
<td>Burning</td>
<td>Remove brush and organics</td>
<td>Removal of brush, slash, and organic materials improves the establishment of red alder on the site (FPB, 2002)</td>
</tr>
<tr>
<td>Brushing</td>
<td>Enhance plantation success</td>
<td>• Herbicide treatment (manual brushing is very costly)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Delayed brush dominance allows red alder to outperform brush</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Critical to control brush performance in first three years, so as to allow red alder to dominate</td>
</tr>
<tr>
<td>Spacing</td>
<td>Enhance plantation success</td>
<td>May be necessary if plantation density and/or density of alternate species inhibit plantation performance</td>
</tr>
</tbody>
</table>


**Tree nurseries**

Natural regeneration of red alder is unreliable, as it requires significant seed sources during years where seed production is high. However if natural regeneration does establish on a site the density can be beyond the site capacity and lead to periods of impeded growth and self-thinning. Although red alder has a high capacity to sprout between the ages of 5-10, this capacity decreases with age, and the process appears to be ineffective for reproduction purposes (FPB, 2002; Sihota, 1979). The use of cuttings and coppicing do not appear to be viable, as the cuttings do not root easily, and coppicing does not provide merchantable timber (Sihota, 1979; Worthington et al, 1962). Because red alder cuttings do not readily root and coppicing is neither predictable, nor a method capable of producing merchantable logs, the primary methods for establishing a plantation is either natural or artificial regeneration (Sihota, 1979). Since natural regeneration is not reliable, it is more effective to use artificial regeneration to establish red alder plantations.

However utilizing tree nurseries to provide seedlings can have drawbacks, as there are instances where red alder plantations suffer significant mortalities due to nursery stock failures (Hughes, pers comm). Though there has been no research relating the mortalities to the nursery found, there does tend to be an issue with cold storage, where smaller seedling sizes die of desiccation (Hughes, pers comm). This notion is supported by Bavis (personal communication, February 18, 2015), who has noticed issues with mortality in stock that had been in cold storage, suggesting there may be frost damage prior to ‘lifting’, but the damage is not noticed until several weeks into cold storage, and mortality caused can be 10% of the inventory.

Selection of the appropriate stock type can improve the likelihood of seedling survival depending on the damaging agents the site is likely to have (Table 4). By getting to know the nursery the supplies your planting program you can have a good idea of the quality you can expect. In general it is good practice to check on the planting stock at the nursery and during planting, looking for a fibrous rooting system and numerous buds on the seedlings (Scott, 2008). This is a way to address sites known for having seedlings damaged by sunscald, as planting stock with numerous buds on the lower sections of the stem will be adequately shaded, and less likely
to incur damage from sunscald (Scott, 2008). Another general measure during this phase is to arrange for fill-planting of an additional 10% planting stock to account for early mortalities (Table 2 & 4; Hughes, pers comm).

When planning a plantation, the preferential collar size is between 4-5mm, with a height between 30cm-50cm, so the seedlings will have good root to shoot ratio (Hughes, pers comm). Being cost effective, the stock types for coastal B.C. that could match these characteristics would be the 415D and 512 stock sizes (Table 4). Although the 615 stock is also suitable stock type, the performance difference does appear worth the difference in cost (Hughes, pers comm). However, the best suggested stock type for overall performance of red alder is the 310 ½&½ stock, where the nursery stock spends half of the year in plug form, then transferred into a natural-bed to develop bare root structures prior to shipment (Hughes, pers comm). This method can improve the seedling’s caliper size and stockiness, also making the seedling less susceptible to pathogens, and improve the stock’s survival in cold storage (Hughes, pers comm).

Unfortunately, 310 ½&½ stock is not always available from nurseries since there is not enough demand, which is likely due to the lack of red alder management in B.C., and also because not all tree nurseries have bare root fields (Stoffelsma, personal communication February 18, 2015). Storage of red alder stock does have its challenges, as bud-break occurs soon after being thawed, as such the stock often needs to be transported frozen, and thawed prior to planting (Stoffelsma, pers comm). As such a practice that should be avoided is ‘hot-lifting’, where planted stock is stored in without refrigeration and is not dormant prior to planting(Hughes, pers comm; Thomas D et al, 2010). This method can have a disastrous effect on a red alder plantation and should (Hughes, pers comm). Though it is considered rare to come across mass mortality in red alder plantations either in a nursery, or in operational forestry, there are instances of it occurring, and surveying at time of planting or shortly thereafter is a good measure to watch for such mortalities (Table 8).
Table 4 Methods for mitigating plantation mortalities when working with nurseries (Hughes, pers comm).

<table>
<thead>
<tr>
<th>Method</th>
<th>Goal</th>
<th>Comment</th>
</tr>
</thead>
</table>
| **Order larger stock** | Enhance plantation success       | ● Often perform better under stress  
● Have greater survival chance in cold storage  
● May provide more food than ungulates require  
● May grow beyond ungulate’s reach faster |
| **Stock Sizing**    | Enhance plantation success        | ● Acquire stock with 4-5mm caliper and 30-50cm heights  
● 310 ½ &½ found to perform best  
● 415D or 512 stock type are cost effective choice |
| **Nursery Cooperation** | Improve nursery stock survival    | Bare-root stock can be protected from frost by watering stems during frost seasons. Stems bent over with ice from watering will recover (Deal and Harrington, 2006). |
|                    | Quality assurance                 | ● Inspect nursery stock for fibrous root systems (Scott, 2008)  
● Assess stock for numerous buds on lower sections of stem (shade to avoid sunscald) (Scott, 2008) |
|                    | Improve business relations with tree nurseries | ● Know the quality to be expected  
● Use seed stock from southern and low elevation sites to grow drought tolerant planting stock (Carnell et al, 2006)  
● Use seed stock from northern and high elevation sites to grow frost tolerant planting stock (Carnell et al, 2006) |
Planting

From experience and various sources it appears that red alder is a rather sensitive species. Essentially, this species is as sensitive, if not more sensitive, than *Psuedotsuga menziesii* (coastal Douglas-fir), and planters should focus planting red alder in the same microsites that coastal Dougals-fir would be planted in (Hughes, pers comm). Microsites that should be avoided when planting are: rocky, dry, or wet microsites; microsites at the tops of mounds or bottoms of depressions; and especially microsites with red-rot (Hughes, pers comm). Red-rot is essentially a collection of decaying wood close near the surface and can have devastating effects on planted seedlings by drawing out moisture in drier months of the year. Seedlings planted in red-rot are likely to suffer mortality by July and it is best if planters avoid planting in such microsites (Table 5; Hughes, pers comm).

Fertilizing at time of planting (FATP), is a good method to get the best benefit from fertilizer, as fertilizer is not as effective for red alder seedlings aged 3-5 years old (Table 5; Hughes, pers comm). Though fertilizer can improve the performance of planted stock, it is not a necessary measure to ensure the success of the plantation. However, should the plantation be at risk of damaging agents then fertilizer could be used as a tool to improve the plantation’s endurance when subject to the damaging agents. Fertilizer packs that are generally used are Alder pak and Triple Super Phosphate. Though costly, these fertilizer packs contain far more fertilizer than typical fertilizer packets use on coniferous species, and the difference between fertilized and non-fertilized red alder seedlings has been described as a *night and day* difference (Table 5; Hughes, pers comm). During the planting phase it must be certain that the fertilizer packet gets under the duff layer in order to be most effective. (Hughes, pers comm). Utilizing fertilizer can be an effective method for sites where herbicide treatment is restricted (Hughes, pers comm).

Though fertilizer is not a guaranteed method for seedling survival and plantation success, fertilizer can provide a performance boost necessary for seedlings to overcome brush competition.
Table 5 Methods to improve the survival within red alder plantations (Hughes, pers comm)

<table>
<thead>
<tr>
<th>Method</th>
<th>Goal.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microsite Selection</strong></td>
<td>Enhance seedling survival</td>
<td>• Screefing removes organic matter and improves access to mineral soils</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Avoiding microsites that are dry, wet, or rocky</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Avoiding microsites with red-rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Plant red alder as you would plant coastal Douglas-fir</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td>Enhance seedling performance</td>
<td>• Ensure fertilizer packets are below duff layers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• FATP improves establishment and performance over brush</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Alternative for sites where herbicide treatment is restricted</td>
</tr>
<tr>
<td><strong>Planting Quality Control</strong></td>
<td>Quality assurance</td>
<td>Ensure planters know appropriate planting sites for red alder and use of fertilizers</td>
</tr>
</tbody>
</table>
Wildlife management

Depending on site characteristics and history of the surrounding area, prescriptions like mechanical protection or providing alternate food sources may be needed in order to deter wildlife from predating on seed and seedlings (Table 6). The predation upon seedlings of any variety can be devastating to individual seedlings, though with the exception of voles this predation is not known to frequently cause plantation failures. As previously mentioned in this paper, voles can have a significant impact upon the success of plantation, though generally it is often when their population cycle is at its peak. Ungulates generally have mild impacts to a plantation, yet can still impact plantations when alternative food sources are unavailable. Methods to provide alternative seed sources for voles to feed on have been attempted, but its operational implementation appears to be under development (Sullivan, 1997).

Alternatively to predation deterrence, a choice may be population control for species that are inhibiting the plantation’s success, though the method’s effectiveness varies, they may be viable options given the circumstances of the plantation (Table 7). However, some practices tend to be frowned upon by the general public, and careful consideration should be given to this prior to implementation.
Table 6 Methods for deterring predation upon red Alder seed and seedlings (Sullivan, 1997).

<table>
<thead>
<tr>
<th>Method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed repellant</td>
<td>Despite effectiveness against voles, the method has a tendency to reduce germination capacity of red alder seed</td>
</tr>
<tr>
<td>Alternate food sources</td>
<td>• Aerial or mechanical application of alternate seed supply for voles to feed on (method still under development)</td>
</tr>
<tr>
<td></td>
<td>• Allowing growth of <em>Rubus ursinus</em>, <em>Epilobium angustifolium</em>, and <em>Vaccinium</em> species for ungulates to browse (may impeding seedling growth)</td>
</tr>
<tr>
<td></td>
<td>• Introducing salt licks (Hygnstrom et al, 1994).</td>
</tr>
<tr>
<td></td>
<td>• Method can enhance habitat of other seedling foragers</td>
</tr>
<tr>
<td>Deer repellant</td>
<td>Generally unsuccessful, yet “Deer Away” is recommended.</td>
</tr>
<tr>
<td>Mechanical protection</td>
<td>• Leaving slash throughout cut-block (limit ungulate access)</td>
</tr>
<tr>
<td></td>
<td>• Use of mesh or plastic cones (order to reduce damage from deer browsing)</td>
</tr>
<tr>
<td></td>
<td>• Method less effective with elk and uncertain with voles</td>
</tr>
<tr>
<td></td>
<td>• Use of fencing is effective with ungulates (high costs)</td>
</tr>
<tr>
<td>Herbicide treatments</td>
<td>Crowns can be treated to heights of up 1.5m (High costs)</td>
</tr>
</tbody>
</table>

Table 7 Methods to control population of species predating on seed and seedling (Sullivan, 1997).

<table>
<thead>
<tr>
<th>Method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat management</td>
<td>Use of herbicide and/or scarification of security cover (increase access of predators)</td>
</tr>
<tr>
<td>Poisoning</td>
<td>• Generally fails due to population growth cycle of voles</td>
</tr>
<tr>
<td></td>
<td>• Not widely acceptable for use upon ungulate species</td>
</tr>
<tr>
<td>Predation</td>
<td>• Use of martens, weasels, or raptors to predate upon vole population</td>
</tr>
<tr>
<td></td>
<td>• Make use of trap lines and hunters (ensure they are following government regulations)</td>
</tr>
</tbody>
</table>
Surveying

In order to adequately plan for the losses that may occur from previously described phases and damaging agents, surveys should be done at several points while establishing the plantation. To plan ahead, surveys during or shortly after planting occurs can show the causes of mortalities within the plantation (Table 8). Mortality from poor planting quality takes more time to occur than just a few weeks (Hughes, pers comm). So finding seedling mortalities during planting or shortly thereafter is likely due to nursery stock failure. Performing a survey in May allows the manager to determine if there is a significant coverage of brush species that requires a prescribed treatment (Table 3). Surveying in mid-October will reveal whether or not the seedlings’ stems are brown and hardened, for if they are still green they are likely to be susceptible to frost damage (Hughes, pers comm). From these surveys adequate measures can be taken, whether it is to request more seedlings for fill-planting, or a prescription for a brush treatment to mitigate competition on the site.

Table 8 Considerations for times to survey to adequately plan for plantation success (Hughes, pers comm).

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Goal</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>During planting</strong></td>
<td>Planning ahead</td>
<td>- Mortality within weeks of planting likely from nursery stock failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ensure planters adequately use proper planting microsites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ensure planters get fertilizer below duff layer</td>
</tr>
<tr>
<td><strong>May survey</strong></td>
<td>Planning ahead</td>
<td>If there is significant brush in the site, adequate measures can be</td>
</tr>
<tr>
<td></td>
<td></td>
<td>taken to reduce competition with planted stock</td>
</tr>
<tr>
<td><strong>Fall survey</strong></td>
<td>Planning ahead</td>
<td>- Should survey mid-late October, prior to leaf-fall, should see stems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>browning, if still green they will be vulnerable to frost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Fill-planting may be required to account for losses from frost</td>
</tr>
<tr>
<td><strong>Damage</strong></td>
<td>Indicators</td>
<td>- After frost-events look for frost cracks along South and West side of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stems (Deal and Harrington, 2006).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- After prolonged dry season, look for sunscald on South and West side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of stems (Deal and Harrington, 2006).</td>
</tr>
</tbody>
</table>
Recommendations for practitioners

PLANNING PLANTATIONS

- Select appropriate ecosystems & site series (Table 1)
- Avoid cold air drainages, frost pockets, sites prone to drought, and flooded areas
- Ensure site has adequate light exposure and rooting medium

POST HARVEST TREATMENTS

- Be proactive, addressing issues within first three years of planting
- Use mechanical site prep to remove organic matter and pile slash or brush as needed.
- Burn slash piles and brush piles if possible
- Alter potential vole habitat (remove tall-grassy sites)

REFORESTATION

- Use artificial regeneration and aim for a density below 2000sph
- Plant in mid-March and plan for at least 10% fill-planting
- Order 310 ½&½ stock type if possible, if not 415D or 512 is adequate
- Fertilize at time of planting

QUALITY ASSURANCE AND SURVEYING

- Survey at time of planting to find extent of nursery stock failures
- Survey in May to assess brush competition
- Survey in October to see if stems have hardened for winter
- Check for sunscald or frost crack damage on stems of seedlings

SILVICULTURE PRESCRIPTIONS

- Space or thin plantation to maintain density below 2000sph
- Provide mechanical protection if browse damage is extensive
- Use herbicide treatments when possible or fertilizer if herbicide use is restricted
Conclusion

Red alder has the potential for being a commercially viable species for management at an operational scale in B.C. Through the various recommended practices mentioned throughout this paper, many of the major factors that could lead to the failure of a red alder plantation can be addressed. Some practices come at a higher cost than others, but in the end the costs are to ensure protection of the investments already made. However expected market prices of red alder can be a deciding factor as to whether or not management of red alder is deemed viable. Should market prices or market opportunities show potential for profits, then consideration should be given to the management of this species.

An important method to improve the plantation success is to manage red alder proactively, rather than reactively. Adequate site selection is the first and crucial step, otherwise natural regeneration is unlikely to succeed and artificial regeneration will struggle to survive. The removal of brush through burning or chemical applications is required for optimal performance in the early stages of growth. Planning ahead for fill-planting will provide the opportunity to address mortalities that may be found during planting. If the plantation is only surveyed once a year, at the very least have it surveyed prior to leaf-fall to check if stems have hardened prior to winter (Hughes, pers comm). These are the necessities in terms of practices to be done for a red alder plantation.

Information needed for further assessment of this topic would be case studies for plantations that failed. Looking into which stage led to the plantations failure and then assess what alternative practices could have been done to improve the plantation’s success. More information on the potential impact of Phytophthora alni on coastal B.C. management of red alder would be necessary to determine if the pathogen is as threatening as it appears on a global scale. Studies on the desiccation during cold storage on nursery stock would also provide insight for nurseries and operational managers. Lastly, looking into operational application of alternate seed to deter predation of red alder seed could provide an opportunity to improve natural regeneration reliability in areas adjacent to vole habitats. Filling knowledge gaps with information like this, the management of red alder could be a more viable option than currently perceived.
Literature Cited

**NOTE:** Tables captions in the paper with a citation at the end indicate that information in the table is primarily from that source, except for citations provided within the table itself.


