Extension Note

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British Columbia's Southern Interior Forests

Armillaria Root Disease Stand Establishment Decision Aid

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Abstract

In the Southern Interior of British Columbia, Armillaria (*Armillaria ostoyae*) root disease (DRA) causes considerable losses in immature stands by killing natural and planted coniferous trees. Tree mortality usually begins about 5–7 years after stand establishment, peaks around age 12, and then declines, although mortality can continue throughout a rotation. On the roots of older trees, repeated non-lethal infections will result in growth loss. The disease also increases the susceptibility of trees to attack by other pathogens and insects. DRA poses a long-term threat to forest productivity and sustainable forest management because current silviculture practices increase the amount and potential of Armillaria inoculum and put regenerated or residual trees at risk of becoming infected. This threat can be moderated by planting trees that are more resistant to Armillaria or by modifying silviculture practices to minimize exposure of trees to Armillaria inoculum in managed, second-growth stands. This extension note provides a revised table of host susceptibility ratings for species as well as a decision key to help natural resource managers choose from among several different treatments.

KEYWORDS: *Armillaria root disease,* Armillaria ostoyae*, decision key, forest health, forest management, root disease management, inoculum, stump removal.*

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Introduction

In the Southern Interior of British Columbia, Armillaria (*Armillaria ostoyae*) root disease (DRA) causes considerable losses in immature stands by killing natural and planted coniferous trees. Tree mortality usually begins about 5–7 years after stand establishment, peaks around age 12, and then declines, although mortality can continue throughout a rotation. On the roots of older trees, repeated non-lethal infections will result in growth loss. The disease also increases the susceptibility of trees to attack by other pathogens and insects. DRA poses a long-term threat to forest productivity and sustainable forest management because current silviculture practices increase the amount and potential of Armillaria inoculum and put regenerated or residual trees at risk of becoming infected. This threat can be moderated by planting trees that are more resistant to Armillaria or by modifying silviculture practices to minimize exposure of trees to Armillaria inoculum in managed, second-growth stands.

The likelihood that trees will be infected and damaged or killed by DRA varies among species and also between biogeoclimatic (BEC)[1] zones. Two major factors involved are: (1) the frequency of exposure to inoculum and the quality of that inoculum (inoculum potential); and (2) host reactions to contact and invasion by DRA inoculum (host resistance). The former varies by BEC zone, subzone, and site series, with the highest exposure probably occurring in the Interior Cedar–Hemlock moist warm subzone (ICHmw). The latter varies by species, host genetics, age, and vigour (adaptation to local site).

The probability of significant damage in infected stands is a combined function of inoculum potential and host reactions. Differences between Southern Interior BEC zones in DRA-caused damage are largely attributable to differences in the distribution of inoculum. In all but the driest and wettest site series in the ICH, DRA is universally present. In the other zones, Armillaria is distinctly patchwise distributed, typically within large (at least 1 ha and sometimes >10 ha) patches. Subzones can differ significantly and, in theory, a much more precise ranking could be provided at a subzone level. For instance, the Interior Douglas-fir moist warm (IDFmw) subzone may be similar to the ICH with respect to DRA distribution and damage. However, in general, we lack the necessary information to distinguish between subzones.

Resistance (being the ability to ward off or limit infection after exposure to inoculum) depends in part on tree vigour, which is generally greater in the ICH than in the IDF, Montane Spruce (MS), Ponderosa Pine (PP), Sub-Boreal Spruce (SBS), and Engelmann Spruce–Subalpine Fir zones. A revised table of host susceptibility ratings for species is provided in this extension note (Table 1). This table is intended to supersede those host susceptibility tables presented in the *Root Disease Management Guidebook* (British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) and in Morrison *et al.* 1991. Only those species that are well adapted to a particular zone are considered. For instance, subalpine fir is only ranked in the MS, ICH, SBS, and ESSF zones.

The purpose of Table 1 is to present information about the susceptibility of various species to killing by DRA. The table does not describe the frequency or extent of damage on host species within their corresponding BEC zone, nor is it intended to replace B.C. Ministry of Forests and Range stand establishment guidelines for preferred and acceptable species.

Forest managers need tools to help make informed decisions about DRA and best management practices. This Stand Establishment Decision Aid (SEDA) provides such a tool in the form of a decision key (Figure 1), which describes several different treatments. The main outcomes (treatments) are: (1) remove inoculum, (2) plant or encourage natural regeneration of DRA-resistant species or uniform mixtures containing resistant species, and (3) ignore DRA and accept a loss of volume at rotation. Use of the first two treatments may be limited by site factors or management constraints not related to DRA (e.g., erodible or calcareous soils, ecological sensitivity, etc.). The necessity of dealing with DRA, when it is present and threatening, is seldom the only consideration in regeneration decisions.

The decision key is actually a "decision flowchart," which first differentiates between the distribution of DRA and the extent of damage within BEC zones and subzones and then provides appropriate measures to minimize losses to DRA in regenerating stands.

[1] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Armillaria Root Disease – Southern Interior Forest Region

Duncan Morrison

Mycelial fan of Armillaria ostoyae *under the bark of a Douglas-fir root.*

Characteristics of Susceptible Stands

- Newly established and managed stands of highly susceptible conifers (see Table 1), especially in the ICH biogeoclimatic zone,[1] but also in the IDF, PP, MS, SBS, and ESSF zones.
- Moist climatic regions such as the ICH have a higher incidence of infection than wet (e.g., ESSF) or dry (e.g., IDF) climatic regions. Furthermore, the wettest and driest site series generally have a lower incidence of Armillaria than mesic site series.

Hosts

- All coniferous trees, deciduous trees, shrubs, and some herbaceous plants are susceptible to infection by the fungus. Relative susceptibility of host trees to killing by Armillaria is given in the host susceptibility table.

General Information

- *A. ostoyae* is the most widespread and damaging root disease pathogen of conifers in the Southern Interior of British Columbia. It causes mortality and, in trees that sustain non-lethal infections, limits growth potential.
- *A. ostoyae* is a facultative parasite. During its parasitic phase, it invades and kills host tissue (mainly roots and fresh stumps). In undisturbed mature stands in the ICH, especially on moist site series, up to 90% of trees will have Armillaria lesions on their roots. After harvesting stems on diseased sites, root systems remain alive for a couple years during which time the fungus can escape from small contained infections and invade the whole stump and root system. Spread within the host is limited to the parasitic phase. During the saprophytic phase, it uses invaded tissues as a food source and will produce rhizomorphs (shoe-string-like bundles of fungal mycelium). In this state, it can survive for many years on larger dead roots and stumps.
- Disease spread occurs below-ground by mycelial growth across root contacts between infected tissue and healthy, adjacent trees or via rhizomorphs growing through the soil. Infection by spores is very rare.
- Above-ground symptoms of disease include basal resinosus in most conifers, chlorosis of needles, reduced terminal growth, and stress-induced cone crops. However, above-ground symptoms on individual trees vary in both kind and extent and may only become evident immediately preceding death of the tree. This is particularly true for individual trees in young stands.
- To confirm occurrence of *A. ostoyae* on suspect infected trees, close examination under the bark of roots and root collar area is recommended. White mycelial fans can be seen under the bark or along the cambial zone on colonized roots. Another species of Armillaria, *A. sinapina*, co-exists with *A. ostoyae* throughout much of its range. *A. sinapina* is usually considered a weak pathogen that at times assumes the role of a secondary parasite, attacking stressed trees including those under attack by *A. ostoyae.* It is difficult to distinguish between *A. ostoyae* and *A. sinapina* in the field as both species form white mycelial fans. If there is tree mortality, assume you are dealing with *A. ostoyae*.
- Rhizomorphs may be found on infected roots or in the soil. Advanced decay appears as yellow stringy white rot. Clusters of honey mushrooms form in the late summer/early fall at the base of infected trees, stumps, or overlying infected roots.
- Armillaria may be associated with other root diseases such as *Phellinus sulphuracens* (*P. weirii*).
- Distribution of the disease can be uniform or patchy depending on the climatic region and (or) BEC zone.
- In young plantations and natural stands, the disease is manifest as small groups of two or three symptomatic or killed trees and there may be many such groups per hectare.

Harvesting and Silviculture Considerations

- Many forestry practices affect the incidence and severity of Armillaria root disease. Any practice that creates stumps, especially large ones, increases the amount of inoculum on infested sites. Rapid regeneration of infested sites after harvest with highly susceptible conifers will result in considerable mortality as young trees are exposed to inoculum when it is at, or near, its peak potential. Treatment strategies for managing DRA consist of either reducing the amount of inoculum (stump removal), or selecting species for regeneration that have a low susceptibility to killing. Treatments will vary by BEC zone (refer to Figure 1) and, in some cases, no treatment strategies are suitable/available. In these circumstances, a significant yield reduction should be expected.

[1] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

Host Susceptibility Table

TABLE 1. Host susceptibility[a,b] to killing by DRA in 20- to 80-year-old trees by BEC zone; species susceptibility is rated as "low," "medium," and "high."

Species[c]	PP	IDF	MS	ICH	SBS	ESSF
Fd	M	H	H	H	H	–
Bl	–	–	H	H	H	H
Bg	–	H	–	H	–	–
Hw	–	–	–	H	–	H
S	–	M–H	M–H	M–H	M-H	M–H
Py	M	M	–	M	–	–
Pw	–	–	–	M	–	–
Pl	–	M	M	M	M	M
Lw[d]	–	L	L	L	–	–
Cw[b]	–	L	–	L	–	L
Ep[e]	–	L	L	L	L	–
At[e]	–	L	L	L	L	L
Ac	–	L	L	L	–	L

[a] Susceptibility is not a good single index of damage. For example, in undisturbed stands in the IDF, Fd is as susceptible or more so than in the ICH, but is not exposed to inoculum as often as in the ICH. Hence, DRA impact on Fd is much lower in the IDF than in the ICH. Ratings are only provided for species common in, and suitable for, the respective BEC zones

[b] All conifer species are quite susceptible to killing when young (with the possible exception of Cw). The ratings here reflect the degree to which they become resistant with age, usually starting about age 15–20. Mortality rates for young cedar are significantly lower than other conifers in juvenile stands. Smaller trees exhibit high frequency of compartmentalization and callusing at the root collar and the rate of callusing increases with tree size. Hence, resistance in Cw appears to occur much earlier than other conifers.

[c] For explanation of tree species abbreviations, go to *http://www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-species.html* and click on "Download BC Tree Code List."

[d] Lw becomes increasingly resistant to *A. ostoyae* only after the age of 20–25 years. On good sites, rapid growth characteristics of Lw at early ages enable trees to contact inoculum sooner than other regenerating conifers, resulting in high mortality rates for Lw in younger stands, comparable to that of Fd.

[e] Ep and At have low susceptibility to killing until about age 40 or until they are overtopped, then susceptibility increases.

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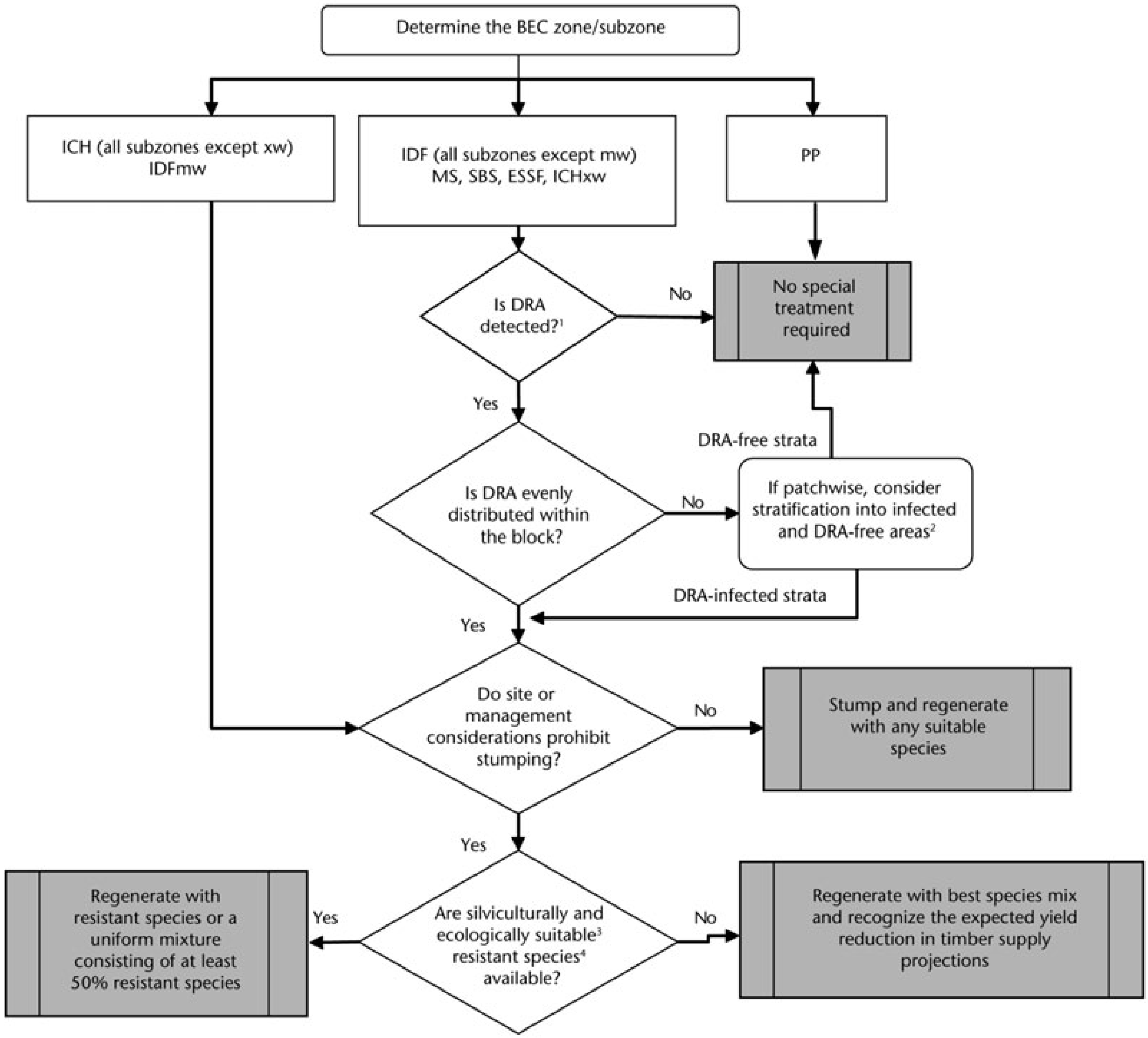
FIGURE 1. Decision key for different treatment strategies for Armillaria-infested sites by BEC zone/ subzone for the Southern Interior Region.



1 Look for presence of DRA in pre-harvest stand. Evidence most commonly found on younger (all-aged stands) or intermediate and suppressed trees. Also consider local experience in similar cutblocks.

2 Techniques for delineating strata are described in the *Root Disease Management Guidebook*.
Note: Strata known or assumed to be infected need not be surveyed. Surveys detecting even minimal levels of DRA in stratified blocks should advance to the next level in the decision key bearing in mind that in undisturbed mature stands, only a small proportion of infected trees exhibit above-ground symptoms. If Phellinus root disease is present, refer to the corresponding decision aid.

3 Suitable with respect to performance on site and that it meets timber supply objectives of the management unit.

4 Resistant species are classified as "L" in the host susceptibility table (see Table 1).

Armillaria Root Disease – Southern Interior Forest Region

Harvesting and Silviculture Considerations (continued)

- Following partial cutting, the build-up of inoculum in stumps allows the pathogen to invade and kill trees in the residual stand. Mortality usually starts about 5 years after the partial cut and often continues for many years because each newly killed tree adds fresh inoculum.
- Surveys are not practical for predicting disease levels, especially during the free-to-grow window because mortality in conifers in the regenerating stand usually begins 5–7 years after stand establishment and does not peak until trees reach about the age of 12 years old.
- In the ICH, surveys of disease incidence in undisturbed (pre-harvest) stands are unreliable. However, if the disease is detectable, it is clearly present and probably serious. The pathogen can be completely quiescent in such stands, (i.e., it is present only as contained root lesions), but following cutting there can be widespread invasion of stumps and root systems, and high inoculum potential.

Regeneration/Establishment

Site Preparation

- The impact of Armillaria root disease in new plantations can be reduced by mechanical removal of stumps and major roots during harvest (push-over harvest) or after harvest. Stumping is not a practicable treatment on all sites, especially those with constraints such as steep slopes, and erodible and calcareous soils.
- The testing of biological agents such as *Hypholoma fasciculare* to treat forest root disease is a relatively recent development in British Columbia. Currently, no proven biological agents are commercially available for use against root pathogens.

Planting

- When inoculum removal is not an option, regenerating stands with resistant species is preferred.
- Plant conifers that have a low susceptibility to killing by the fungus (Table 1). Use of species from the "high-" and "medium-" susceptible categories in very high proportions is not recommended. Early survival of more susceptible host species (e.g., Douglas-fir) could be enhanced if planted in uniform mixtures containing at least 50% of a resistant host such as western redcedar. Uniform species mixtures comprising up to 50% of resistant conifers (e.g., Cw, Lw) and no more than 50% of hosts with high susceptibility to killing is recommended. If moderately susceptible hosts are available, the proportion of resistant hosts in mixtures may be reduced to 30% provided the proportion of susceptible hosts is less than 40% of the species composition. Ecological suitability may limit the choice of species.
- To increase stocking and species diversity, natural regeneration of resistant hosts (e.g., Cw) may be encouraged. Reliance on the ingress of natural regeneration to meet the minimum proportion of resistant hosts on an infested site is not recommended because it is unlikely to result in the uniform mixture required to reduce mortality and disease spread between trees.
- Faster-growing species may die more quickly than slow-growing ones because they tend to contact inoculum sooner and when the inoculum potential of the fungus is high. Lw is one fast-growing species that suffers high mortality rates when less than 15 years old.
- Similar to western redcedar, hardwoods may help mitigate damage caused by DRA in new plantations. However, hardwoods may become more susceptible to killing after age 40, especially in stands where they are mixed with conifers and overtopped. Hardwood stumps can become inoculum sources after they die or are cut down.
- To improve stocking levels, resistant conifers may be fill-planted in openings caused by the disease.

Plantation Maintenance

- Cleaning or brushing of hardwoods can increase DRA inoculum. If brushing is unavoidable, it is best done as early as possible so that the stumps created are small. Cutting of herbaceous material or woody shrubs apparently has little effect on increasing DRA inoculum.
- Because precommercial and commercial thinning increases the amount of inoculum on site, these activities also increase DRA incidence and severity. This increase in inoculum can be prevented by using techniques like pop-up spacing, which removes infected roots and stumps from the soil.
- Multiple stand entries maintain high fungal inoculum potential because the stumps that feed the fungus become available at regular intervals.
- On infested sites, retain or favour healthy planted or naturally regenerated tree species with high resistance to DRA (e.g., Cw and Ac); this practice will increase the number of barriers acting to deter spread by the fungus between susceptible host species.

Potential Productivity Implications

- Forest management practices that create stumps and allow rapid regeneration of sites with susceptible hosts may exacerbate disease levels over and above that which would normally occur in nature by exposing trees to fungal inoculum while its inoculum potential is still high.
- Armillaria is universally present in all subzones throughout the southern ICH except perhaps on the driest and wettest sites. The proportion of diseased trees that show above-ground symptoms is lower in the ICH than in any other zone.
- In the MS, IDF, SBS, and ESSF zones, the distribution of Armillaria can be somewhat patchy, occurring as distinct centres typically within larger (1–10+ hectares) patches. Infected patches are usually characterized by scattered single or small clumps of dead and symptomatic trees; however, the actual incidence of infection is always noticeably higher than what can be detected above-ground.
- Increased inoculum on sites will lead to mortality or growth loss in trees that sustain non-lethal infections, hence reducing ecosystem productivity. Indirect effects of the disease include increased susceptibility to windthrow and insect damage.
- Cumulative mortality in Douglas-fir stands in the ICH can be as much as 20% by age 20 years, resulting in unacceptable stocking in juvenile stands.
- The probability of infection by *A. ostoyae* increases with increasing diameter at breast height. Roots will continue to contact inoculum in the soil throughout the course of a rotation.
- An operational adjustment factor (OAF) developed for Armillaria root disease and applied to Douglas-fir managed stands in the ICH showed that for medium-severity Armillaria infections, the long-term productivity was reduced by 7.2%.

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Test Your Knowledge . . .

British Columbia's Southern Interior Forests: Armillaria Root Disease Stand Establishment Decision Aid

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. What are the main treatments (options) to deal with Armillaria root disease in the decision key?
   - A) Remove stumps (inoculum) after harvest
   - B) Plant species mixtures including more resistant species
   - C) Ignore and accept a loss of volume at rotation
   - D) All of the above

2. In which biogeoclimatic zone is Armillaria inoculum almost universally present?
   - A) ICH
   - B) SBS
   - C) PP
   - D) ESSF

3. What is the resulting damage caused by Armillaria root disease?
   - A) Reduced tree growth and site productivity
   - B) Tree mortality
   - C) Conversion to other tree species
   - D) All of the above

4. Which of the following signs and symptoms are not diagnostic of Armillaria root disease?
   - A) Creamy white mycelial fans under the bark and in the cambial zone
   - B) Red or black rhizomorphs in the soil
   - C) Honey mushrooms at the base of the tree or overlying infected roots
   - D) Red-brown stain in the wood

ANSWERS

1. D 2. A 3. D 4. D