ARMILLARIA ROOT DISEASE

State Forester Forum

Introduction

Root diseases are the most damaging native forest diseases in northern Idaho. They are also, unfortunately, the most difficult to recognize and manage. Infected trees suffer reduced growth, mortality, and increased attractiveness and susceptibility to bark beetle attack. At the stand level root diseases reduce timber volume and stocking, alter the rate and direction of forest succession, and interfere with short- and long-term forest management objectives.

Root diseases are caused by fungi that colonize and gradually decay tree roots, causing a loss of root system function and structure. Loss of root function gradually weakens and kills trees. Loss of root structure can result in windthrow of live trees and accelerated collapse of dead ones.

The most important root diseases in Idaho are Armillaria root disease, laminated root rot, and annosus root disease. Any combination of the fungi that cause these diseases, referred to as "root disease complexes", may be found in the same stand, and sometimes on the same tree.

Recognition and consideration of Armillaria root disease is critical for forest management planning in northern Idaho. In southern Idaho it is found in higher-elevation lodgepole pine but infrequently in lower-elevation, dry sites.

Susceptibility to Armillaria Root Disease

- Highly susceptible: Douglas-fir, subalpine fir, and grand fir.
- Moderately susceptible: Engelmann spruce, western redcedar, and western white pine.
- Least susceptible: Western larch, lodgepole pine, and ponderosa pine (generally).

Key Point: *Variation in host resistance to Armillaria root disease is not expressed before approximately age 15 to 20. Prior to this age conifer species are considered equally susceptible.*

Biology

Armillaria root disease is caused by the fungus *Armillaria ostoyae*. Other *Armillaria* species infect conifers in Idaho but these are typically found on trees dead or dying from other causes. The mushrooms, or fruiting bodies, of *A. ostoyae* are golden-colored and grow in clumps from the base of infected stumps or trees, often after fall rains (Figure 1).

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Figure 1. *Cluster of Armillaria fruiting bodies at base of infected sapling. (Photo by Gregory M. Filip, USDA Forest Service)*

Spores from these fruiting bodies establish new clones, or genets, of the fungus. Rates of spore-spread appear higher in relatively moist versus dry forests in the Inland West. Variable numbers of *A. ostoyae* genets can exist within a stand, occupying separate areas or abutting as they expand. Spore infection by *A. ostoyae* is considered relatively rare in the short-term and is not considered in disease management.

Around an established genet, the mycelium, or vegetative tissue of the fungus, spreads approximately one to several feet per year along roots and tree-to-tree at root contacts. The mycelium grows between the bark and inner wood, subsequently decaying root wood from the outside. *Armillaria ostoyae* also grows short distances through the soil and along root surfaces by means of fine, root-like structures called rhizomorphs.

Armillaria ostoyae can stay alive in infected root systems of dead trees for several decades, causing new infections as roots of non-infected trees contact inoculum, or fungus-infected woody tissue, of the previous stand. Because of the ability to persist on a site, cause mortality in successive forest generations, and expand when susceptible hosts are present, root disease is referred to as a "disease of the site."

Disease severity in a forest occupied by one or more genets of *A. ostoyae* can be highly variable and expressed as any combination of large centers of concentrated mortality; small, widely-distributed centers of concentrated mortality; or diffuse mortality (see discussion regarding "types" of disease expression within Armillaria root disease). Genets can expand over just fractions of an acre to tens or even hundreds of acres, but it is unlikely the fungus occupies all areas equally; this will affect the amount of disease that develops. Many other factors such as stand structure and composition, habitat type, fire history, management history, and most likely genetic variation in the fungus, affect genet dynamics and disease expression. Long-lived genets may also become discontinuous, or "patchy", over many forest generations. All of these variables interact in complex ways, many of which we do not yet understand, to influence disease severity.

Tree species vary in this susceptibility to Armillaria root disease beyond age 15 to 20, but prior to that are considered equally susceptible, so species such as western larch and pines can be readily killed in young stands. Depending in part on host resistance, infections of *A. ostoyae* can be either progressive or callused. Progressive infections grow unimpeded and kill the host upon girdling the taproot or root collar. Callused, resin-soaked

lesions can localize an infection until the tree dies from other causes, at which point the fungus is well-positioned to colonize the cambial region of the root system. Such increases in *Armillaria* inoculum, or fungal-colonized woody material, may be responsible for mortality of adjacent, disease-susceptible trees in following years.

Fire can reduce the impact of Armillaria root disease by killing disease-susceptible, fire-intolerant hosts such as Douglas-fir and grand fir while promoting the more disease-tolerant seral species such as western larch and pines, but there is no evidence that fire has a "cleansing" effect on underground root disease inoculum. In theory inoculum could actually increase after fire due to colonization of fire-killed trees' root systems that had pre-existing infections.

Figure 2. *Concentrated mortality of Armillaria root disease showing various snag ages and stages of tree decline. (Photo by Gregory M. Filip, USDA Forest Service)*

Recognizing Root Disease in a Stand

Stand-level "signatures" can aid in identifying the presence of root disease. Root disease centers, or areas of concentrated mortality, are the most obvious (Figure 2).

Variously-aged snags and trees with symptomatic crowns will be dispersed in and around such centers, or diffusely throughout a stand. Death of susceptible species cause gaps in the overstory canopy that promote conifer regeneration - most often of mid- or late-successional, disease-susceptible species - or ingrowth of brush. Small groves of hardwoods such as aspen, birch, or maple can be a clue that root disease has had a long-term impact on the site, allowing space and resources for hardwoods to grow. Hardwoods such as birch and aspen are, however, also susceptible to Armillaria root disease.

Bark beetles and root disease are closely associated when populations of the former are low. Reduction in tree vigor and changes in host physiology caused by root disease make trees more attractive to bark beetles, and so they are often found in root-diseased stands. Bark beetles also work alone, however, so to distinguish bark beetle and root disease mortality examine the patterns of damage. Bark beetles kill groups of trees in a relatively short period of time (acute mortality), usually 1-4 years; whereas, root disease, on the other hand, results in chronic decline (long term) and mortality. If you diagnose bark beetle mortality in a stand be aware root disease may be present as well. However, since bark beetles kill living trees, evidence of root disease infection may be subtle or undetectable at that point.

Identifying Armillaria Root Disease

Descriptions and images of root disease-symptomatic trees can be found in "A Field Guide to

Diseases & Insect Pests of Northern and Central Rocky Mountain Conifers". Foresters and landowners should always have this guide on hand when attempting to diagnose forest insect and disease problems.

Root diseases cause gradual loss of root function and structure, an effect reflected in the type of symptoms that develop in infected trees (Figure 3).

Figure 3. *Typical root disease crown symptoms. (Photo by Susan K. Hagle, USDA Forest Service, www.forestryimages.org)*

These include:

- Reduced terminal and lateral growth over a span of several to many years;
- thinning of the crown, often proceeding from the bottom up and inside out;
- off-color or chlorotic (yellowing) foliage;
- slight to heavy resinosus (pitch-streaming) around the base of the tree;
- flushes of small cones, referred to as "stress cones", which can persist after the tree dies; and/or wood decay with unique features characteristic of each root disease.

A very common symptom of *Armillaria* infection is resinosus at the base of the tree in reaction to its roots being attacked by the fungus (Figure 4).

Figure 4. *Basal resinosus caused by Armillaria infection*

It can occur around the entire base of the tree or above just one lateral root. Resinosus often occurs several years in a row so there can be older, dried pitch and fresh pitch at the base of the same tree. Lesser amounts of basal resinosus can occur with other root diseases so this is not strictly diagnostic for Armillaria.

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Armillaria root disease can best be diagnosed by the presence of "mycelial fans" under the bark on the lateral roots or at the root collar (Figure 5).

Figure 5. *Mycelial fans of Armillaria (Photo by Gregory M. Filip, USDA Forest Service)*

Mycelial fans are fungus tissue that appears similar to white latex paint. The fungus grows up to the root collar along infected roots, killing the roots and then girdling the tree. The best place to check for mycelial fans is directly beneath areas of fresh resinosus. The fans often exist just at or below the groundline, so scrape away soil from the base of the tree and lateral roots and remove the bark. Fungus mycelium grows into the inner-bark of Douglas-fir so look for it and pockets of fresh resin within the bark at the root collar.

> **Key point:** *When attempting to diagnose root disease, chopping into a tree even a few inches above groundline often reveals little useful evidence, particularly on large, declining or recently-dead trees. Don't be afraid to do some digging!*

The size of an infected tree will affect expression of disease symptoms. Larger trees, with more expansive root systems, will develop symptoms more gradually than a sapling or seedling, which may succumb relatively quickly and develop few if any crown symptoms. Large trees may not show symptoms for years after infection until much of their root system is compromised. Therefore any disease-susceptible tree within 30-feet of an infected tree should be considered infected.

> **Key point:** *A general rule-of-thumb is only about half of all root disease-infected trees can be detected by above-ground symptoms at any one time.*

Management

Root disease management should be site-specific and based on stand management objectives, the root disease or disease complex present, estimates of root disease severity, stand structure and composition, and stand history. Management of root disease is not a "one-size-fits-all" proposition so the following should be viewed as guidelines.

Determine objectives: Formulate management objectives for the stand in question. A timber production objective requires very careful consideration of root disease; other objectives may not.

Estimate "root disease severity": An estimate of root disease severity (Table 1) provides a "snapshot" of current root disease impact and mortality, as well as the best estimate of future mortality and the trajectory of stand structure and composition. Root disease severity, and thus appropriate management, can vary throughout a stand.

Regeneration harvest: If root disease is severe and few disease-resistant species are available to select as leave-trees, and your objective is timber production, then the best option from a disease management standpoint is to clearcut the stand and start over.

> **Key Point:** *Salvaging trees dead and dying due to root disease will capture the volume before it becomes unmerchantable, but due to the biology of the fungi that cause root disease, salvage does not reduce continued mortality or halt spread of root disease.*

Stand establishment: Trees planted on sites with Armillaria root disease need to be disease-tolerant. Western larch or pine species would be good choices, depending on the site; Douglas-fir, subalpine fir, and grand fir will be severely damaged. ***Ensure quality-control during planting since "J-rooted" seedlings of any species are more readily damaged by root disease.*** Soil compaction appears to increase root disease damage so plan skid trails carefully and minimize the area occupied by landings.

> **Key Point:** *Managing for disease-tolerant species is usually the most effective and cost-efficient means of managing root diseases.*

Precommercial stands: Many stands composed of disease-susceptible species have been established, either by planting or natural regeneration, in the presence of moderate to severe root disease. Such stands often show few symptoms of disease until age 10-15, after roots of the growing trees have contacted inoculum from the previous stand, and numerous pockets of Armillaria root disease begin to appear. In such instances, whether precommerical thinning has been done or not, the best option may be to destroy the current stand and start over with disease-tolerant species; this will be a painful decision but a better long-term yield will almost certainly result.

If a young stand has extensive root disease mortality but includes well-distributed, disease-tolerant species then delay thinning at least several years to allow the root disease time to "select" which trees will survive before you invest in thinning. If thinning is eventually done leave a higher-than-normal stocking of disease-tolerant trees in anticipation that more will die as the stand matures. In many instances, however, root disease will reduce stocking to where only "clumps" may need thinning.

Young stands with a "light" root disease severity rating can be thinned without delay, but always emphasize selection of disease-tolerant species over maintenance of uniform spacing.

Achieving root disease management objectives during precommercial thinning requires close administration of thinning crews, but without it a poor job of thinning can result, reducing a forester's options, in the form of species composition, for literally decades to come.

> **Key point:** *Carefully planned and administered precommercial thinning, that favors and promotes root disease-tolerant species, will aid long-term disease management and protect your investment in site preparation, stand regeneration, and thinning.*

Commercial stands: Thinning is not recommended in stands impacted by Armillaria root disease if Douglas-fir or grand fir will compose more than 30% of leave-trees. Many susceptible trees in such a stand will already be infected, even if not displaying symptoms, and die within a few years of thinning.

A landowner may be sorely tempted to thin a root-diseased stand, leaving the best-looking Douglas-fir and grand fir, with the expectation these trees will experience "increased vigor" and thus somehow better resist root disease. The evidence is not clear at this time whether thinning accelerates damage due to root disease in a stand, ***but it is clear that mortality rates of susceptible species do not decrease after thinning***.

> **Key point:** *Armillaria root disease can infect and kill susceptible species of any age and size, regardless of perceived or actual vigor.*

Management of stands impacted by Armillaria root disease should emphasize promotion and maintenance of seral species. Silvicultural approaches that achieve this objective are recommended even for stands with a light root disease severity rating. Managing for disease-susceptible species, and harvesting the disease tolerant species, will result in ever-increasing amounts of disease inoculum and only serve to worsen root disease severity and reduce management options for the next rotation.

> **Key point:** *Long-term root disease management should take a "**do no harm**" approach by maintaining and promoting mature seral species and their natural regeneration, planting carefully with disease-tolerant species suited to the site, and avoiding actions that will increase inoculum levels.*

Inoculum removal: Using machinery to remove stumps and large roots from the ground in root-diseased stands can reduce short-term damage in the subsequent stand due to reduction in inoculum, but long-term results are mixed. Inoculum removal requires ***very careful*** consideration based on slope, soil moisture and type, and site productivity. While it is not considered economically practical in commercial forests of Idaho, private landowners with small parcels of land impacted by root disease might consider this option under the right circumstances.

Fertilization: At this time there is no evidence that fertilizing reduces either spread or severity of Armillaria root disease.

Table 1. Root Disease Severity

Root Disease Severity	Range of Conditions
Light	Includes stands with no evidence of root disease, stands with no mortality but numerous trees displaying symptoms, and stands with ***up to 20% canopy reduction due to root disease mortality***.
Moderate	Includes stands with ***20-75% canopy reduction due to root disease mortality***. At the lower end of this range there will be many trees with root disease symptoms, while at the upper end much of the remaining overstory canopy consists of disease-tolerant species. Moderate severity stands are changing quickly; mortality rates are high.
Severe	Includes stands with ***at least 75% canopy reduction due to root disease mortality***. These stands are usually composed (originally) of only the most susceptible species. At the lower end of this range only a few susceptible overstory trees remain although there may be densely stocked, susceptible regeneration; at the upper end no susceptible species remain in the overstory. Mortality rates in this category will begin to slow because most susceptible species are already dead.

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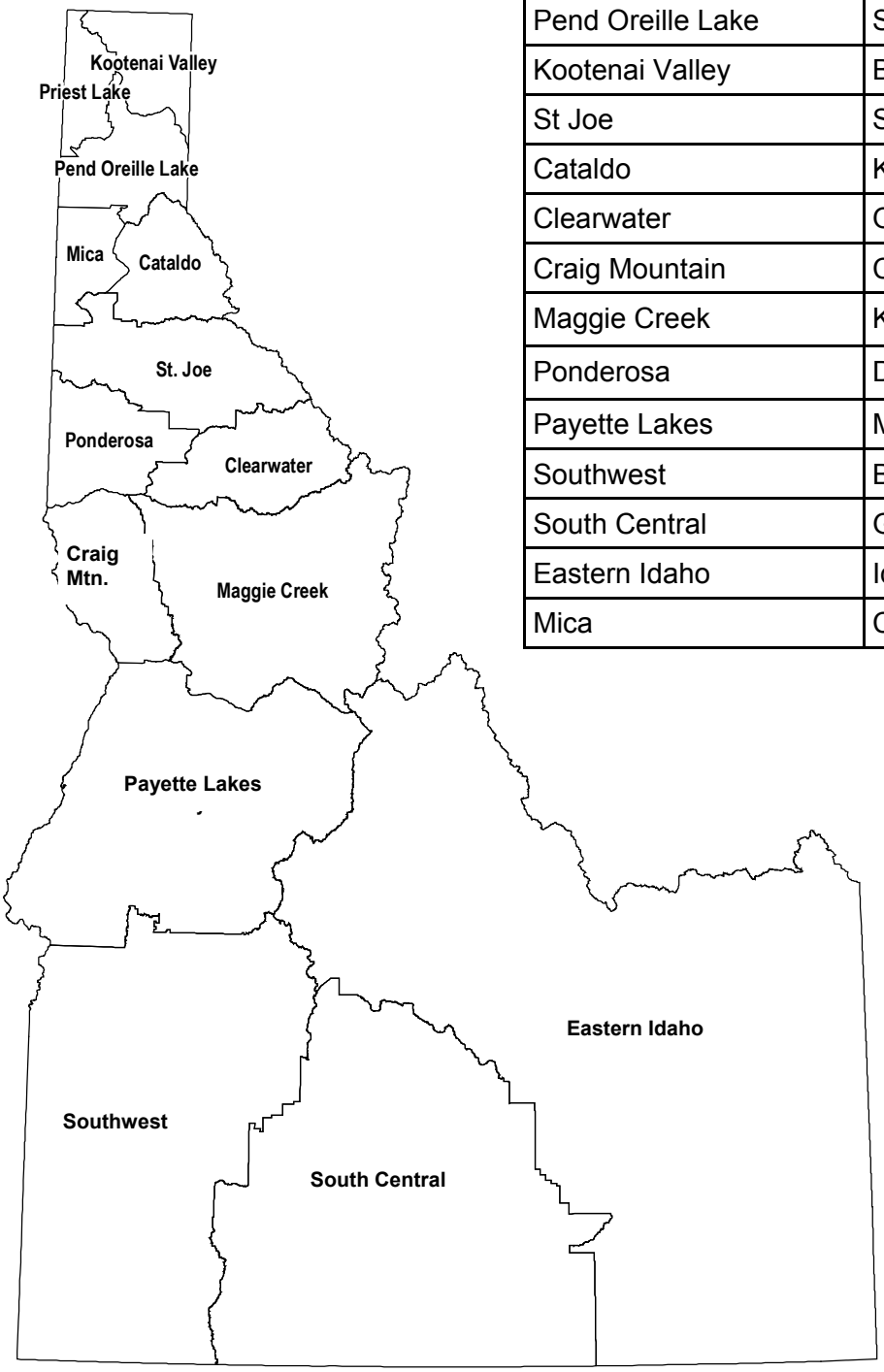
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