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Root Diseases in Eastern Oregon and Washington

Abstract

Root diseases are important natural disturbance agents affecting all tree species and all forest ecosystems of the Pacific Northwest. They influence stand structure, density, composition, function, and yield. The root diseases of greatest concern in eastern Washington and Oregon are annosus root disease, Armillaria root disease, laminated root rot, and black stain root disease. For these diseases some information is available on root disease ecology, population dynamics, biology of the pathogens, and the natural processes that regulate them. Less is known about disease effects at the watershed or landscape level or how diseases interact with other disturbances and how they respond to management strategies. Decision support, such as the Western Root Disease Model, is being developed.

In response to a shift in forest species and structure following a century of fire suppression and partial cutting, root diseases are believed to have spread causing more inoculum on more sites than existed in historical times. Stand management to restore historical vegetation conditions may intensify disease; however, in cases where diseased stands are converted to seral species, incidence and severity of root diseases will likely decline. Treatments that retain high stocking of host species, or allow host regeneration, will likely result in increased levels of root diseases because inoculum remains on the site. Spore infections may increase with partial cutting where stumps are not chemically treated. Disturbance increases activity of some insects, which may act as vectors of root disease pathogens.

Root diseases are important natural disturbance agents in forest ecosystems of the Pacific Northwest. All tree species are affected by one or more root pathogens, but some are more affected than others, and no forested area in Washington or Oregon is without some level of root disease. Root diseases affect all forest resources, either directly or indirectly. They affect forest resources on millions of acres throughout eastern Oregon and Washington and annually kill and reduce the growth of timber by hundreds of millions of cubic feet. They exert a profound influence on forest structure, density, composition, function, and yield. Root diseases are important gap formers; they create openings of various sizes in the forest, depending upon the pathogen(s) and hosts present. These gaps are then colonized by a variety of forb, shrub, tree, vertebrate, and invertebrate species. Root diseases contribute to plant and animal diversity by creating a wide variety of tree ages and stand structures and, under natural conditions and levels, are in overall balance with other ecosystem components. However, changes in forest communities, largely because of past management practices, have often upset the natural balance, resulting in increased incidence and severity of root diseases. Once established, most root diseases become diseases of the sites, with fungal pathogens being sustained as saprophytes in dead stumps and root systems in the soil for decades. Subsequent generations of susceptible hosts that become established are infected.

Forest conditions in eastern Washington and Oregon have been steadily changing to increased dominance of shade-tolerant, root disease-susceptible species as a result of more than 100 years of fire suppression and of extensive selective harvesting of the most valuable conifers. The greatest changes in vegetation and pathogen responses have occurred in low- and middle-elevation grand fir, Douglas-fir, lodgepole pine, and ponderosa pine climax forests. Stands that were once maintained in pine and western larch by ground fires are now stocked with a higher proportion of shade-tolerant species, mostly Douglas-fir and true firs. Pine stands that are not being converted to other species, in many cases have become overstocked. In turn, root pathogens have responded to the greatly increased abundance of susceptible hosts.

Root diseases increase fuel and thus elevate fire risks for normally fire-resistant seral species. Furthermore, root diseases can convert susceptible forests to persistent root-diseased areas consisting of brush and small trees on large areas. In addition to changing the composition of a stand, harvesting itself can increase root disease pathogen-infected inoculum, intensifying the infection potential on the site. Stump infection can occur via airborne spores colonizing freshly-cut stump surfaces or via the causal pathogen in the soil moving through the root system.

There are some generalizations that apply to most root disease pathogens: (1) The common root diseases are caused by fungi that are able to invade and colonize living root tissue. (2) Root disease fungi live below ground most of their lives but they are root, not soil, inhabitors. The pathogenic nature of these fungi enables them to avoid competition for food with saprophytic soil organisms. (3) Root disease fungi cause dysfunction in root systems by killing cambial tissue, disrupting the transport system, or by consuming cellulose, thus causing loss of structural integrity. (4) Most pathogenic fungi can survive as saprophytes within root systems, in some cases for decades after the hosts are dead.

Four root diseases are of greatest concern in managed forests of eastern Oregon and Washington (Filip and Hoffman 1990, Campbell and Liegel 1996, USDA Forest Service 1999): (1) armillaria root disease caused by *Armillaria ostoyae*, (2) laminated root rot caused by *Phellinus weirii*, (3) annosus root disease caused by *Heterobasidion annosum*, and (4) black stain root disease caused by *Leptographium wageneri*. Two less-common root diseases are important: schweinitzii root and butt rot caused by *Phaeolus schweinitzii*, primarily of Douglas-fir and western larch, but other conifers as well, and tomentosus root rot caused by *Inonotus tomentosus*, of most concern in Engelmann spruce, but to a much lesser extent in other conifers also. These two diseases occur in mature stands, but are not fast spreading and do not result in more than low to moderate mortality, and more often lead to butt decay that may result in stem breakage or defect. Management options are limited and seldom attempted with these two diseases; thus they will not be dealt with further here. As techniques improve our ability to discern genetic differences between organisms, our understanding of natural groupings change and new names are published. The scientific name of each of the above listed pathogens has been revised at least once in the past two decades.

Annosus root disease (Otrosina and Scharpf 1989, Schmitt et al. 2000)—Two forms of *H. annosum* are recognized in Oregon and Washington: "P-group," which affects chiefly pine and less frequently larch and Douglas-fir, and "S-group," which affects chiefly true firs, and less frequently causes mortality to spruce, western hemlock, and mountain hemlock. Some hosts are less frequently killed outright by annosus root disease than by other root diseases. Other hosts may be infected for years before succumbing. Infection results in reduced strength and wood value due to decay, stain, and breakage. Douglas-fir is a common host in the intermountain region, but in eastern Oregon and Washington the disease is most damaging to true firs and ponderosa pine in stands where harvesting has occurred. The most severe damage to ponderosa pine stands is to those on marginal-quality dry sites or where there has been severe mechanical damage to the soil.

The fungus infects its hosts in two ways: by mycelial growth across root-to-root contacts and by windblown spores. Spore infection of freshly cut stumps is the primary way that new infection centers start. After growing vegetatively down through the stump and root system, the fungus can move to adjacent trees across root contacts, but it does not grow through the soil. The fungus can remain viable in large stumps for at least 50 years. The fungus can also infect wood exposed when living trees are wounded, although stem decay is usually the result, rather than root disease.

The incidence of annosus root disease can increase under certain management regimes. Of special importance are partial removals of susceptible species and soil compaction. With more entries, more stumps are created that become infected and initiate disease centers. Further, wounds created during road building, harvesting, and yarding provide additional entrance points for the pathogen. Usually this increases the incidence of butt rot in residual trees as the fungus is encased in woody tissue, rather than growing on the outside of the root system where spread via root contact is possible. Annosus root disease is the only disease discussed in this paper for which the use of a chemical treatment can be appropriate. Treating recently cut stump surfaces with a registered boron-containing fungicide can minimize stump infection and subsequent disease in adjacent trees and regeneration. Stump treatment is especially important where partial cut entries leave residual host trees, or regeneration harvests that allow establishment of disease-susceptible trees that will be retained and managed. Boron-containing fungicides chemically alter the surfaces of stumps, making that surface inhospitable for spore germination and infection. This treatment is recommended for stands when true firs will be retained, and for low-productivity pine communities with a history of annosus root disease. While there is a clear association between annosus root disease and sites with compacted soils, the mechanism for increased levels of infection is not well understood. It likely includes host stress induced by the physical changes in soil structure as well as the abundance of infected stumps usually associated with these sites. Additional useful references for annosus root disease include Russell et al. (1973), Thies (1979), Woodward et al. (1998), and Filip et al. (1992, 2000).

Armillaria root disease (Shaw and Kile 1991)—The causal pathogen is widespread and quite variable in virulence, sometimes being very aggressive killing susceptible and sometimes many less-susceptible hosts in large centers. In most cases, the pathogen is less aggressive; scattered trees, primarily susceptible host species, are infected and killed. Armillaria root disease is often associated with trees under stress. It is frequently found on sites with compacted soils, along skid roads, where trees have been poorly planted, or where there has been a poor match of stock to site. Generally, on diseased sites, even properly planted trees will have a higher incidence of armillaria owing to stress induced by poor or unnatural lateral root expansion. Naturally regenerated trees, especially of those species less susceptible to infection, are most likely to survive to maturity.

The pathogen can spread by spores, but spread by that means appears to be uncommon. Spread between trees in a new stand is mostly by mycelium growing across root grafts or contacts or by root-like rhizomorphs. Rhizomorphs play a role in spread, they can grow from colonized host material several feet through the soil, sometimes contacting and infecting healthy roots. The fungus can survive for at least 35 years in old-growth stumps and roots. The primary effect of armillaria root disease is that it kills the infected trees; in some cases it may initially cause butt rot and reduced growth. Infected trees can be wind thrown, but they more often die standing. Armillaria root disease centers that occur in older stands appear to retain standing dead trees for relatively long periods; they often do not quickly result in large quantities of down woody material.

Strategies designed to maintain vigorous tree growth are likely to reduce the effects of armillaria root disease. Additional strategies include using resistant species where possible for regeneration, minimizing the number of stand entries, avoiding soil disturbance by careful selection of equipment and season of operation, and using the most resistant on-site species as seed sources with natural regeneration. Additional references for Armillaria root disease include Morrison (1981), McDonald et al. (1987), Filip et al. (1989, 1999), and Roth et al. (2000).

Laminated root rot (Thies and Sturrock 1995)—This is probably the most widespread and difficult to manage of the root diseases that forest managers commonly must deal with in eastern Oregon and Washington. It affects nearly all species of conifers. Douglas-fir, hemlocks, and true firs are highly susceptible; larch and spruce are moderately susceptible; and species of pine and cedar are tolerant to resistant. Hardwoods are immune. Infection in a young stand begins when roots of young trees contact residual infested stumps and roots from the preceding stand. Crown symptoms may appear 5 to 15 years after initial infection but are usually not seen until at least half of the root system is affected. As roots decay, a tree may die standing but then topple within a few years. Owing to a loss of structural root support, live infected trees with green crowns also frequently fail. Windthrow is more common with this disease than with those caused by other root pathogens. Root disease centers frequently regenerate to some proportion of highly susceptible conifers. Infection and decline of these trees often does not occur until they are 15 or more years old.

The causal pathogen spreads very infrequently by windblown spores, and it can grow only a short distance into the soil. Virtually all spread is by mycelia on or within roots. The fungus persists on the site in the large roots and stumps of dead or cut trees. When a site infested with *Phellinus weirii* is regenerated with susceptible tree species, the disease nearly always causes extensive mortality in the new stand.

Mitigating strategies that are being tested and used operationally include regenerating diseased sites with less susceptible species and removing, or rarely, inactivating inoculum. Infested roots left in the soil may harbor the pathogen for 50 years or longer. Ignoring this disease in stands, regenerating with highly susceptible species, or allowing such species to proliferate, will result in continued spread and increased inoculum loads. Distribution of the pathogen in an infested stand has generally been perceived as being clustered around discrete disease centers. However, recent mapping of infested stands has provided evidence that the distribution of infected trees is sometimes much more diffuse than previously thought. A diffuse pattern of distribution may mean significantly more infected trees and higher long-term losses than expected due to reduced growth in diseased stands. Additional references for laminated root rot include Filip and Schmitt (1979) and Hadfield (1985).

Black stain root disease (Harrington and Cobb 1988, Hessburg et al. 1995)—This disease is unique among the root diseases affecting conifers in the Northwest because the pathogen can be spread by root-feeding insects (as well as root-to-root spread of the mycelium and short-distance growth through soil) and because it is a vascular wilt disease that readily kills trees but does not cause root decay. Black stain root disease is caused by three recognized varieties of the pathogen; two are of concern in Washington and Oregon: one of these is found primarily on Douglas-fir, the other primarily on ponderosa and lodgepole pines and western and mountain hemlocks. The disease, caused by what is believed to be a native pathogen, was first reported in western Oregon on Douglas-fir in 1976 (Johnson 1976), in central Oregon on pines in 1982 (Filip and Goheen 1982), and is now recognized in most parts of eastern Oregon and Washington. The disease appears to be increasing in intensity. For example, it was first reported at a few locations on the Burns Ranger District in the southern Blue Mountains in 1989. While black stain has obviously been active in this area for some time, until 1989 pine mortality in the area had been mistakenly attributed only to bark beetles. By 1995 District records and an informal survey found the disease to be widespread, affecting a substantial number of ponderosa pine stands in the southeastern part of the District (Thies et al. 1997).

Black stain root disease causes many of the same symptoms as other root diseases, but it often kills host trees more quickly. Reduced terminal or branch growth and increased needle density gives foliage at the end of the branches a "tufted" or "lion's tail" appearance (Cobb 1988). These crown symptoms found in ponderosa pine (but not Douglas-fir) can be used to predict the presence of the disease and to some degree its severity. Differences in needle retention do not contribute to the lion's tail appearance. Ponderosa pine with the lion's tail symptom retains foliage for about the same time (4-5 years) as healthy trees (Kelsey et al. 1998). Disease centers appear as small (usually 0.1 acre or less) groups of dead and symptomatic trees. This disease does not decay the supporting roots, as do the other three major root diseases; thus dead trees remain standing for years unless other root diseases are also present.

Insect vectoring introduces and contributes to black stain spread in Douglas-fir in western Oregon (Witcosky and Hansen 1985, Hansen et al. 1988) and in ponderosa pine in northern California (Goheen and Cobb 1978). In eastern Washington and Oregon, ponderosa pines with black stain root disease occur as scattered individuals or scattered small clumps, suggesting insect transmission; however, specific insect vectors have not been identified. Infection is believed to occur when adult root-feeding bark beetles and weevils inadvertently carry spores into the trees during their feeding and egg laying activities. Fruiting bodies of the fungus form in the egg-laying galleries of the insects; as mature insects emerge, sticky spores adhere to the insects and are dispersed by them. The spore-carrying bark beetles and weevils feed and breed in roots of low-vigor trees, so the occurrence of black stain root disease in disturbed areas probably reflects the insect's preference for stressed or injured trees. Once introduced into a tree, the fungus can move to adjacent trees across root contacts or by growing up to 6 inches through the soil. Tree-to-tree spread does not depend on the low vigor of host trees. However, the fungus is relatively non-persistent; survival appears to be limited to a year after the tree dies.

If the insect vectors for pines were similar to those in Douglas-fir we would expect that site disturbance such as thinning, fire, soil compaction, or new road construction would attract the insect vectors and increase spread and intensification of the disease. While there have been relatively few studies conducted in ponderosa pine stands, there appears to be an association between disturbance in stands and increased activity of probable insect vectors (C. Niwa, entomologist, Pacific Northwest Research Station, Corvallis, OR, personal communication) and site disturbance and increased incidence of black stain root disease (C. Schmitt, pathologist, Blue Mountain Pest Management Service Center, LaGrande, OR, personal communication). Additional references for black stain root disease include Goheen (1976) and Hessburg (1984).

Several general references provide management information and additional pictures that are useful for identification and survey of the root diseases discussed in this paper: Filip 1986, Hadfield et al. 1986, and Scharpf 1993, Allen et al. 1996, Hansen and Lewis 1997, Filip 1999.

There are at least six sources of documentation of large-scale evaluations or syntheses of information concerning root diseases in eastern Washington and Oregon. These documents can be used to find relevant literature and to gain insights into the extent, intensity, and ecological function of root diseases, and future development of diseased forest ecosystems: (1) A literature review and synthesis by Hagle and Goheen (1986) discusses root diseases in relation to species composition, site characteristics, cutting history, and fire effects. (2) Hessburg et al. (1994) divides the forests of eastern Oregon and Washington into the five major climax plant series named after the dominant climax conifers and discusses the changing roles of pathogens (and insects) from historical to current conditions. (3) A literature review by Filip et al. (1996) covers roles of insects and diseases, including root diseases, in the Blue Mountains, relations with management, research, and selected segments of the ecosystem. (4) Campbell and Liegel (1996) provide an overview of the relation of forest health to disturbance in Oregon and Washington and list as the four root diseases of most concern the same diseases discussed here. (5) Hessburg et al. (1999a) compared historical and current vegetation maps constructed from interpretations of 1932-66 and 1981-93 aerial photos respectively. Change analysis compared historical and current landscape patterns, vegetation structure and composition, and landscape vulnerability to insect and pathogen disturbances. (6) Hagle et al. (2000a, 2000b) and Byler and Hagle (2000) assessed the role of pathogens and insects in forest succession over a 40-year period for major vegetation classes in two ecoregions of the middle and northern Rocky Mountains by using 1935- and 1975-era aerial photos, pest evaluation reports, and field verification of a sample of the polygons. On the basis of these trends and functions, future trends in succession classes were projected for the succeeding 40-year period ending in 2015.

Current strategies for managing root diseases in eastern Washington and Oregon focus on maintaining good stand vigor, manipulating the species mix to a higher proportion of less-susceptible species, minimizing site disturbances, especially to soil, and, in the case of annosus root disease, treating the tops of larger fresh host stumps with a boron-containing fungicide. In general, this means thinning with fire or saw to improve general growth of the trees, or selecting trees in a way to allow for a species conversion. Additional references on root disease management include Schmitt et al. (1984), Hadfield et al. (1986), Filip and Hoffman (1990), Filip and Schmitt (1990), Schmitt et al. (1991), Filip et al. (1995), Byler (1997), and Thies (1999).

Critical gaps exist in the knowledge necessary to most effectively manage root diseases and affected stands: (1) interactions and relations of pathogens with other disturbance processes or agents, (2) pathogen population dynamics (including so called "clones"), (3) natural processes of pathogen population regulation, and (4) various ecological functions. While a good deal is known about the primary diseases of concern and the biology of the pathogens, there is little empirical data to support disease behavior modeling at any scale.

Decision support for root disease is available in the form of the Western Root Disease Model (Frankel 1998). This model simulates the effects of armillaria root disease, laminated root rot, annosus root disease, and bark beetles on stand dynamics and operates in conjunction with the Forest Vegetation Simulator to evaluate the effects of many silvicultural practices. Hessburg et al. (1999b) suggest a way to model landscape vulnerability to disturbance from root diseases.

Conclusions

In summary, managers will have to plan with caution and knowledge of field conditions to successfully solve one root disease problem without encouraging another. Managers need to be aware of available management tools and of the limits of current technology. Assistance from a specialist may be required to assess existing root disease conditions, future risks, and assure that the best management options are identified.

The root diseases of greatest concern to managers in eastern Washington and Oregon are annosus root disease, armillaria root disease, laminated root rot, and black stain root disease. A great deal is known about the biology of the pathogens and how they affect individual trees and the effect diseases have on stands. Less is known about disease effects at the watershed or landscape level, how diseases interact with other disturbances, such as fire, and how they will respond to new management strategies. There has been a significant shift in forest species and structure as a result of the past century of fire suppression and partial cutting, and the diseases have responded, in some cases, with dramatic increases in the area and number of trees affected. As managers reintroduce fire and shift species composition and stand structure toward historical norms, they will continue to face significant challenges from root diseases. Root diseases now likely occupy more sites with more inoculum than existed in historical times. Stand management activity to restore historical conditions may exacerbate disease activity in some cases. As trees are cut to effect stand conversions, stumps and roots from trees with laminated root rot, armillaria root disease, or annosus root disease will remain and add inoculum to the site, and spore infections of otherwise healthy stumps will likely increase annosus root disease wherever partial cutting is conducted. In time, a shift to more thrifty stands with a lesser component of fir and a larger component of pine and larch has the potential to reduce the effect of the dominant root diseases. In some cases there may be increases in root diseases of ponderosa pine, including annosus and perhaps black stain root diseases. While insects are the suspected vectors for black stain root disease in eastern Oregon and Washington, the species are not known, and therefore the effects of management on the vectors are not known. Managers are dealing with different ecosystems in eastern Washington and Oregon now than existed a century ago. Changes in the ecosystems have taken place below ground as well as above ground and go well beyond the dominant tree species to include pathogens and other flora and fauna.

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Note

This special issue of *Northwest Science* is a set of papers reviewing the state of knowledge about disturbance processes in eastern Oregon and Washington, related management practices, and effects on key management issues.