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Annosus Root Disease of Western Conifers

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Annosus root disease, caused by *Heterobasidion annosum* (Fr.) Bref. (=*Fomes annosus* (Fr.) Karst.), occurs in temperate zones throughout the Northern Hemisphere, and is common on conifers in the western United States. Infected trees suffer root and butt decay, and root mortality, resulting in reduced vigor, windthrow, predisposition to bark beetles and outright mortality.

While annosus root disease is a normal part of most forest ecosystems in the West contributing to structural and compositional diversity, incidence and impacts have increased in recent decades due to management practices that favor the disease and changes in stand compositions that have increased numbers of susceptible hosts. In many situations, the disease has attained epidemic proportions. Various

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resource values are compromised by these high levels of annosus root disease, prompting use of management strategies to restore a more natural level of disease activity.

Distribution and Hosts

Annosus root disease is found on all western conifer species but is of most concern on true firs, hemlocks, and pines. Incense cedar, coast redwood and sequoia are sometimes infected in California. Western juniper is infected throughout its range. Annosus is common and causes extensive decay in old-growth western and mountain hemlock stands. Many mixed conifer stands throughout the inland west and California have high levels of infection, resulting in extensive mortality, especially of true firs.

Pine communities also have high levels of disease and exhibit varying levels of impact. Douglas-fir-dominated stands in northern and central Idaho and to a lesser extent, northeastern Washington have substantial amounts of annosus-caused mortality, especially on dry sites where Douglas-fir grows with ponderosa pine, but Douglas-fir in California, Oregon and most of Washington are not seriously affected. Hardwoods are generally resistant or immune, although madrone and a few shrub species are occasional hosts.

Incidence and severity of annosus root disease varies by locality, stand type, and management history. Generally, stands having a history of logging-related disturbance are most severely affected. Stands that were partially-cut, especially those with multiple removals, will have the highest level of annosus root disease.

Partially cut grand fir- and white fir-dominated mixed conifer stands in southern and central Oregon and northern California have especially high incidences of annosus root disease. Incidence is also particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in dry Eastside pine types. In Oregon, annosus root disease has mostly been associated with occurrence of large stumps — usually 18" and larger in diameter. Subalpine fir stands show evidence of root disease associated with stumps much smaller — as small as 6 to 8" diameter.

In the western United States there are two different intersterility groups, or biological species of *H. annosum*. These two biological species have distinct host preferences. The P-group infects pines, incense-cedar, western juniper, pinyon, and manzanita; the S-group infects true firs, giant sequoia, Douglas-fir and hemlocks. The fungus very rarely spreads between host species of these two groups, either between trees or stumps and trees. However, saprophytic stump colonization can involve either strain. Thus, P-group *H. annosum* may colonize grand fir stumps but root disease will not develop in pines or firs surrounding these stumps.

Evidence of Annosus Root Disease

In The Stand

The typical pattern of annosus root disease in stands involves scattered small groups of dead trees centered around large old stumps. There are often old dead snags and downed trees with rotten roots near the center of pockets, adjacent to the old stumps. At the perimeter of centers, more recent mortality may be found, along with symptomatic trees. Mortality usually does not start to occur around stumps until 15 or more years after they are created.

In stands of susceptible species, annosus root disease usually occurs in discrete centers. The presence of *H. annosum* in these centers may be verified by observing several common characteristics. In stands of resinous species such as pine, dead and or dying trees or understocked areas are identified readily and may be suspect.

Upon encountering such centers, look for evidence of gradual, periodic tree death at the perimeter of the center. Symptomatic trees may have thin, chlorotic foliage and reduced height and lateral branch growth. This indicates that infected roots are dying, which will eventually lead to death of the tree. Frequently, infected trees will be attacked and killed quickly by bark beetles that infest weakened trees. In centers, old infected stumps, stubs, or scarred trees may be found.

In hemlock stands, annosus root disease often does not produce readily identifiable evidence of infestation. Mortality is infrequent to rare in standing trees, but trees with extensive root and butt rot may be broken or windthrown. Usually, the presence of *H. annosum* is discovered when the stand is thinned or harvested and decay and stain at stump height is observed. In some true fir stands, similar conditions may be observed, although mortality is more frequent, often resulting from bark beetle attacks.

Signs and Symptoms

Heterobasidion annosum readily produces fruiting bodies, or conks, on infected host tissues. Determining occurrence of *H. annosum* conks is a highly reliable method of diagnosing annosus root disease. Dead and dying trees will frequently have fruiting bodies on their roots and/or root collars. On pines, small leathery buff-colored conks, one-eighth to one-fourth inch (0.3 to 0.6 cm) in diameter, and sometimes larger, are produced on the outer bark at the root collar, under the bark of dead trees, and in the duff layer (fig. 1). Similar conks are found, but less frequently, on true firs. On most species of conifers, early stages of fruiting bodies appear as small buff-colored pustules scattered on the surface of dead infected roots (fig. 2). More mature conks, two to three inches (5.0 to 7.6 cm) across, may be found in crevices of the root collars of infected hemlocks, or in or just under the soil duff layer on the root collars of pines.

Large conks often grow in the interiors of hollow or extensively decayed hemlock, true fir, and ponderosa pine stumps and roots (fig. 3) or under the bark of decaying pine stumps. Fully mature fruiting bodies may be 10 inches (25 cm) across or larger. *H. annosum* conks have a buff to dark brown-colored upper surface with concentric furrows and a smooth, cream-colored under surface that has tiny pores and a narrow sterile (non-pored) margin. Conks are perennial and may have more than one tube layer.

Fig. 1. Small button conks of *Heterobasidion annosum* on the root collar of a ponderosa pine. Note: these were formed below the duff layer, which was removed for this photograph.

Fig. 2. Characteristic buff-colored pustules that form on the exterior of *H. annosum*-infected roots.

Fig. 3. Mature *H. annosum* conk in the interior of a ponderosa pine stump

Fig. 4. Ectotrophic mycelia on the exterior of an infected root.

Fig. 5. Characteristic red stain in the interior of a live *H. annosum*-infected grand fir root.

Fig. 6. Typical laminated advanced decay caused by H. annosum.

A light, tawny-brown colored fungal growth may be found on the exteriors of infected roots of pines, true firs, and Douglas-fir (fig. 4). This serves as the primary mechanism for root to root spread, growing along the surface of roots and moving onto the roots of adjacent trees across contacts and grafts. Some other root disease fungi form similar mycelia, and its occurrence alone cannot be used to diagnose the disease.

Wood decay and stain caused by *H. annosum* are variable. In true firs and hemlocks, wood of infected roots and lower boles usually develops a red-brown to purple stain in the heartwood with an irregular margin (fig. 5). Stain is less common in pines. Decay in pines and true firs is initially laminated, meaning the deteriorating wood comes apart at the annual rings (fig. 6). Small, elongated pits, roughly one-twenty-fourth by one-sixteenth of an inch (1 mm by 2 mm) may be found, but only on one side of delaminated sheets. Commonly in hemlock, true firs, and Douglas-fir and less commonly in pine, advanced decay will be wet, spongy, and stringy with large white streaks and scattered small black flecks (fig. 7). This decay is often found in the interior of roots.

Crown symptoms are seen in some live infected trees, most often pines, Douglas-fir, and juniper, and less frequently in other hosts. Infected trees with a substantial proportion of the root system infected may have fading thinning crowns, chlorotic foliage, and reduced height and

Fig. 7. White streaks and black flecks throughout wet spongy advanced decay most often found on *H. annosum*-infected grand fir, Douglas-fir or hemlock.

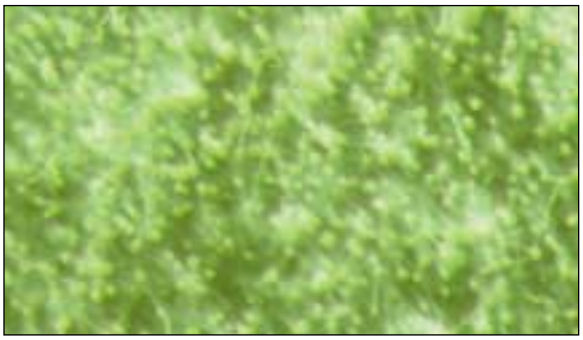

Fig. 8. *Spiniger meineckellus* conidiophores characteristic of the asexual form of *H. annosum*. These are produced on incubated infected material and provide positive diagnosis and identification of infection. 50X magnification.

lateral branch growth. In recent root excavations of annosus-infected live ponderosa pine in the southern Blue Mountains, at least 90 percent of the root systems were killed by the pathogen before crown symptoms were noticeable. Crown symptoms are also produced by other root diseases, such as black stain root disease, caused by *Leptographium wageneri* var. *ponderosum* (Harrington & Cobb).

Because conks are not always found, decay is highly variable, and crown symptoms may be caused by other agents, positive identification of *H. annosum* infection by finding definite signs and symptoms is not always assured. Frequently, other more readily identifiable fungal pathogens are found and mistakenly identified as being the sole or primary cause of tree decline or mortality. Because of this, masking of annosus symptoms by those of other pathogens is common. Additional techniques for positive diagnosis of *H. annosum* are frequently needed. When *H. annosum* infected wood is incubated at high humidity in a plastic bag, wrapped in wet paper, or cultured on nutrient media, the fungus produces characteristic asexual fruiting structures (conidia and conidiophore) of its Imperfect state, *Spiniger meineckellus* (Olson) Stalpers (=*Oedocephalum lineatum* Bakshi) (fig. 8). These are diagnostic and confirm the identity of the fungus.

Life Cycle

Heterobasidion annosum is a wood decay fungus. The microscopic fungal threads (hyphae) that comprise the vegetative state of the pathogen grow through woody tissues by secreting enzymes that break down the cellulose and lignin of the wood cells to simple carbohydrates that the fungus uses for food. While decay is often in "dead" heartwood, in some species (notably pines), living cells of the cambium and phloem are attacked and killed. In true firs, the inner sapwood is commonly attacked and the fungus may gradually invade and kill the outer sapwood. Trees so attacked can be girdled and killed or rendered susceptible to bark beetles or to toppling because of extensive root decay.

Two kinds of spread are important in the life cycle of *H. annosum*: local, underground tree-to-tree spread within a center and long distance, aerial spread that establishes new centers. Most local spread involves hyphal growth within and along the surface of roots. When there is contact between an infected root and a healthy root, *H. annosum* hyphae can grow across the contact to the healthy root and begin growing on the surface and through the phloem and xylem. By this means, the fungus spreads from tree to

tree, creating an enlarging disease center in the stand.

Rates of center enlargement depend on stand and site conditions and generally are estimated to be between 1.6 and 5 feet (0.5-1.5 m) per year. Some centers eventually cease enlarging, but others continue to spread for years. All the factors affecting rate of spread are not fully understood. Numerous field observations indicate that the disease in seedling and sapling size pine trees around large stumps will spread to the limit of the rooting zone for the stump and then stop. In similar stands of poles or larger size trees, the root disease will continue to spread, moving beyond the rooting zone of the original stump that served as the source of the infection.

Long distance spread occurs when airborne sporidia produced from *H. annosum* conks disperse and infect freshly-exposed stump surfaces or woody tissues at wounds. Wounds can be colonized and result in decay anywhere on the roots, butt, or upper bole. While infections resulting from wound colonization usually result in decay of the scarred tree, they rarely cause root disease since the decay is usually compartmentalized within the bole and the infection does not extend to the exterior of roots where it can spread between trees.

Sporidia on tree wounds or freshly cut stump surfaces germinate, produce hyphae that colonize exposed wood, and initiate new infections. Spores also can percolate down through soil and infect wounded roots. The fungus has been isolated from insects that feed on lower stems and roots, but insect transmission of the pathogen has not been verified. Another spore type, the asexual conidia, is also produced, but its role in the life cycle is uncertain.

Sporulation, spore germination, and colonization of wounds or stumps are affected by temperature and humidity. Spores are produced throughout the year, except in extreme cold, very high heat, or during prolonged drought. Stump colonization is unlikely when stump temperatures are high and relative humidity is low. Stumps are susceptible to infection for 2 to 4 weeks following cutting. Colonized stumps less then 6 inches in diameter may heat sufficiently during hot summer days to kill *H. annosum* mycelium in the wood.

Once established in roots, the fungus may persist for several decades in resinous tree species. In non-resinous species such as firs and hemlocks, persistence may not be as long, but good data are wanting. As long as viable hyphae remain in old roots they can infect roots of susceptible trees that become established in old centers, thus regenerated trees may be damaged or die prematurely.

Damage

True firs

True firs infected by *H. annosum* suffer direct mortality, butt rot (and associated reduction in merchantable volume), predisposition to bark beetles, and windthrow. Impacts are observed in both enlarging centers (fig. 9) and as isolated single diseased trees (fig. 10). Losses are greatest in stands of pure fir or where fir basal area exceeds 26 square ft./acre (20 square m/ hectare), where total stand basal area exceeds 100 square ft./acre (75 square m/hectare), where stand age exceeds 120 years, and in stands that have been partially cut. Surveys in the Rockies, the Northwest, and the Southwest indicate that *H. annosum* is widespread and prevalent in true firs. Except during droughts, activity of fir engraver beetles (Scolytus ventralis LeConte) is closely associated with occurrence of root disease in firs.

Pines

Annosus root disease has been serious on pines in some localities and under certain site and stand conditions. Generally,

stands on poor, dry sites suffer the greatest impacts (fig. 11). There is some indication from root excavations and stump investigations that infection rates are actually rather high throughout the pine type but mortality is manifested mainly on the poorer sites. There are indications that *H. annosum* readily infects pines on better sites but causes mainly growth loss rather than mortality in such situations. In some cases, planted pine have had high rates of infection. High levels of damage have occurred where off-site planting stock had been used. Loss of site productivity, loss of vegetation cover, and the risk of tree failure in campgrounds and other recreation facilities are effects of annosus root disease in pine.

Fig. 9. A small annosus root disease center with several toppled grand fir.

Fig. 10. A recently toppled *H. annosum* infected grand fir with extensively rotted roots showing the characteristic laminated decay.

Fig. 11. An annosus root disease center in young ponderosa pine.

Western and Mountain Hemlock

Infected hemlocks are seldom killed outright by annosus root disease unless they are broken or windthrown. Most damage to hemlocks occurs as decay in roots and the lower butt, though rot also may be substantial in the stems of older trees. Decay is usually associated with wounds. Decay is almost always confined to the cylinder of woody tissue present when the tree was wounded, a condition known as compartmentalization.

Incidence of decay is higher in older trees and stands more than 120 years old. Younger hemlocks seldom have appreciable decay even if there is a high incidence of wounds associated with a history of partial cutting. While some infection occurs from stump colonization, minor amounts of decay result when rotations are short. Direction to maintain stands over longer rotations and to use more frequent entries will increase the incidence of annosus root disease and associated decay in hemlock stands.

Disturbances associated with high use areas such as campgrounds and other recreation areas in hemlock types will predispose trees to large amounts of *H. annosum* infection. Hazard tree potential will likely be a major concern, especially in older trees.

Prevention/Control-Silvicultural

True fir

True firs seem to be especially susceptible to annosus root disease as well as several other common root diseases and stem decays. In mixed-conifer stands with a substantial true fir component, partial cutting should be avoided or minimized. When intermediate entries are done and fir will continue to be managed on the site, care needs to be taken to minimize both wounding of residuals and site disturbance.

Reducing rotation length to less than 120 years will usually limit losses where other root diseases and stem decays are not a concern. Restricting cutting to summer months may reduce potential of stump and wound colonization by *H. annosum* in some warm, dry localities. It has been suggested that thinning overstocked true fir stands having annosus root disease will reduce disease impacts by increasing vigor of residuals. The success of this strategy has not been well supported by research.

Mixed Conifer

In many mixed-conifer stands that have been partially cut, annosus root disease may have already developed to levels considered excessive. Because of past cutting practices and the absence of fire, many stands previously dominated by pine have become dominated by less fire resistant species, especially true firs. Where such a trend has occurred and root disease affects are impacting management goals, it is recommended to reverse the pine-to-fir trend. Regeneration-type cultural systems and use of prescribed fire can both be effective in discriminating against the shade-tolerant true firs and restoring the stand to a state more similar to its historic condition.

Western hemlock

Western hemlock stands will not develop significant levels of decay unless managed to ages beyond 120 years. Impacts can be further minimized by requiring logging techniques that minimize damage to residuals during intermediate entries. Injured trees should be removed during entries since they are most susceptible to decay. Thinning of overstocked stands should not be avoided since increases in growth and yield of residuals resulting from stocking control are usually many times greater than the increased amount of decay. Managers should strive for a mixture of other species such as Douglas-fir and western redcedar in stands where hemlocks are affected by annosus root disease.

Prevention/Control-Chemical

Stump infection by *H. annosum* can be largely prevented by treating freshly cut stump surfaces with a light coating of granular Sodium Tetraborate Decahydrate or Disodium Octaborate Tetrahydrate. Currently, the only borate products registered for annosus control are Sporax® and Tim-Bor®. Properly treated stumps are protected at an efficacy level of at least 90 percent from colonization by airborne spores of *H. annosum*. Currently, the Pacific Northwest and Southwest Regions of the USDA Forest Service have provisions that can be specified in timber sale contracts requiring purchasers to treat stumps.

Stump treatment with borate is currently recommended only for those timber production sites with known annosus root disease potential where cultural control is not viable. Such situations include treatment on dry pine sites, mixed conifer sites where true firs will be managed in the future, and all true fir sites. The recommended minimum stump treatment size is 12 inches diameter for pine and true fir felled using chainsaws. Where mechanical shearers are used, the minimum diameter should be reduced to 8 inches. High elevation true fir stumps should be treated down to 8 inches regardless of type of felling.

Stump size recommendations have varied in the past, especially between different USDA Forest Service Regions and states. However, differences in stump sizes for effective treatments are not believed to be substantial between similar stand types in different areas.

Borate stump treatment is not effective on stumps of trees that are already infected. In stands with numerous already-infected stumps, silvicultural treatments should be employed to deal with the disease. Where possible, stands should be managed by conversion to full stocking of site-adapted, less susceptible species.

Stump treatment should be standard procedure when cutting conifers in recreation and other high-use areas. In California, treatment of all conifer stumps in recreation areas is required. It is strongly recommended that stumps of highly susceptible species be treated in Oregon and Washington. Treatment is also recommended for pine and true fir seed orchards, progeny test plantations, and other stands of high value trees.

Assistance

If you need assistance in recognizing and controlling annosus root disease, contact your local State Forester or your local USDA Forest Service Forest Health Protection office.

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Pesticides used improperly can be injurious to humans, animals, and plants. Follow directions and read all precautions on the labels. Consult your local forest pathologist, county agricultural agent, or State extension agent about restrictions and registered uses of particular pesticides.

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