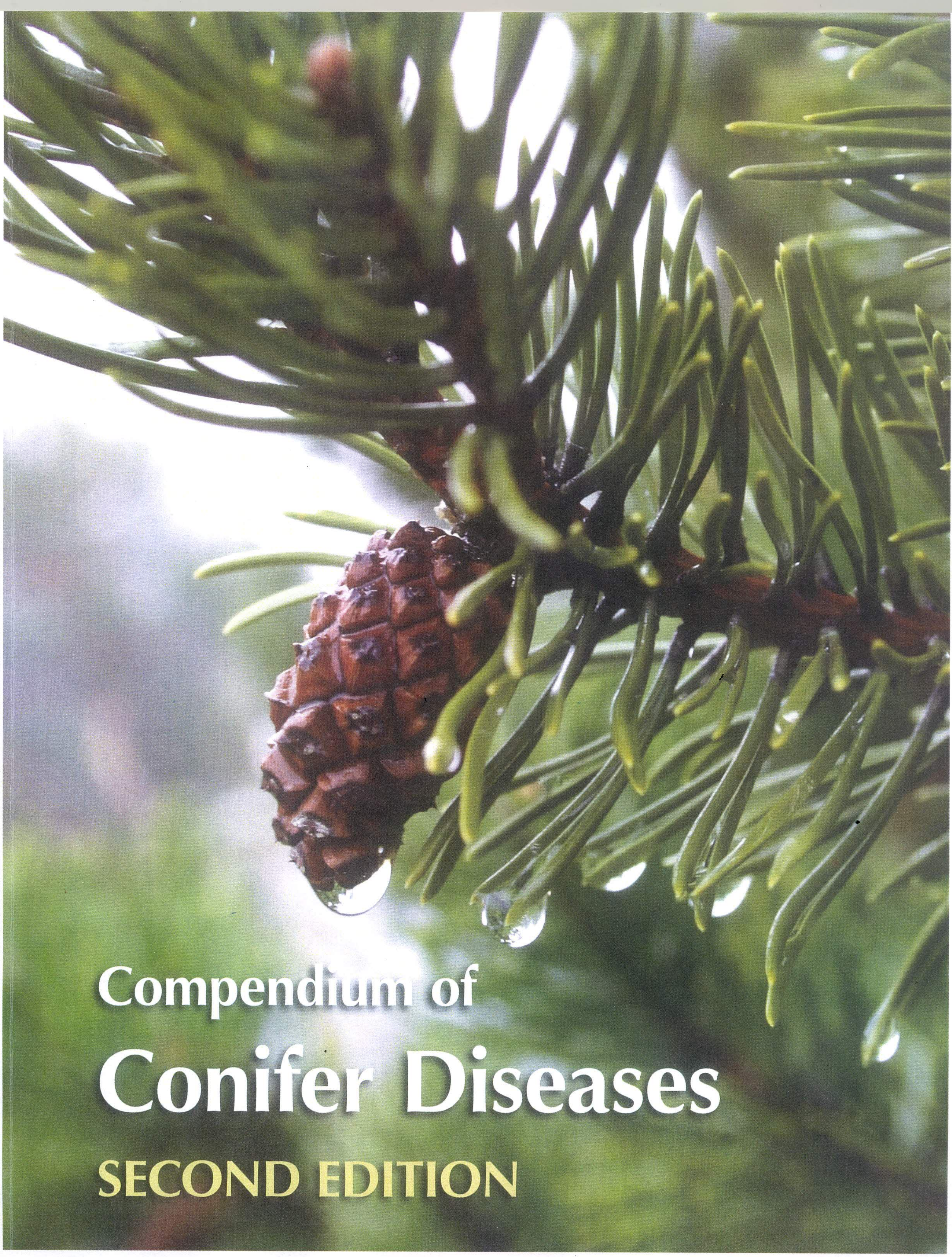

Compendium of Conifer Diseases

SECOND EDITION

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APS PRESS
The American Phytopathological Society
St. Paul, Minnesota, U.S.A.

large (two to three per linear millimeter), angular pores. The context is cinnamon brown and punky in texture.

Disease Cycle

Basidiospores are wind dispersed, and the infection courts are thought to be at small branch stubs or other natural openings where the heartwood is exposed. The frequency of infection is greatest in dense stands where self-pruning creates infection courts. In *Pinus strobus,* infection is associated with old injuries from the white pine weevil. Basidiospores germinate, and the monokaryons initiate decay. Dikaryons are formed after anastomosis with other compatible monokaryons. Once the dikaryon reaches the stem heartwood, the fungus begins to decay the heartwood in both directions. *P. pini* can infect only living trees, although in trees that have been killed or broken, the decay can continue until the resource is exhausted. The mycelium in living trees is thought to follow branch traces from the heartwood to the bark, where a sporocarp is produced. On dead and downed trees, sporocarps tend to be resupinate and frequently develop from cracks in the stem.

Effects on Tree and Forest, Ecological Role

Losses caused by *P. pini* are greater than those of any other heartrot fungus in the northern temperate forests, in part because of the relatively broad host range of this group of fungi and their common occurrence. The greatest damage occurs in older stands where the fungus has had time to cause more infections and develop in the heartwood. In British Columbia, it is estimated that volume losses to this heartrot are 5–10% of harvested volume. Softening of the heartwood by *P. pini* enhances excavation by woodpeckers and other cavity excavators and contributes significant habitat for cavity-nesting species. It also predisposes trees to breakage and windthrow and therefore contributes to habitat for organisms that utilize downed logs and to nutrient cycling.

Disease Management

The fungus enters trees through natural openings such as branch stubs. Therefore, avoidance of wounding during silviculture and harvest operations does not reduce the incidence of disease caused by *P. pini.* The most effective management for this heartrot fungus is to use a "pathological rotation age" (the age at which volume losses to decay equal gains resulting from growth) to determine when stands should be harvested. Selective harvesting may be effective in promoting multiple ages and a more open canopy structure, both of which may reduce the rate of infection and decay development.

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(Prepared by K. Lewis)

Rust-Red Stringy Rot

Other name: Indian paint fungus

Causal agent: *Echinodontium tinctorium* (Ellis & Everh.) Ellis & Everh.

Hosts: Major hosts, all native species of *Abies* and *Tsuga* in western North America; minor hosts, *Picea engelmannii, P. glauca, Pseudotsuga menziesii, Larix occidentalis*

Distribution: Coniferous forests in western North America from Mexico to Alaska

Symptoms and Diagnosis

Echinodontium tinctorium causes a brown to reddish orange rot of heartwood that may significantly weaken the wood even during incipient stages. In advanced stages of decay, the wood becomes stringy and eventually takes on a whitish cast as lignin is removed (Fig. 83). Occasionally, wood separations (laminations) may occur between annual growth rings as the wood dries. The decay is classified as a white rot since both lignin and cellulosic components are removed. The bright orange coloration often associated with decay (Fig. 84) may occasionally protrude from the bark as rusty punk knots that are reliable indicators of the fungus. Decay may extend up to 7 m above and below a basidiocarp and into large branches. Two conks separated vertically by at least 1.5 m on the bole indicate extensive rot, and several conks indicate that the tree is unmarketable. The large (up to 40 cm wide × 20 cm thick), hoof-shaped,

Fig. 83. White rot caused by *Echinodontium tinctorium* in grand fir. (Courtesy A. D. Wilson)

Fig. 84. Advanced rust-red stringy rot, caused by *Echinodontium tinctorium,* in mountain hemlock. (Courtesy A. D. Wilson)

perennial, woody basidiocarps (conks) are the most visible and diagnostic signs of this disease (Fig. 85). *E. tinctorium* is the only hydnaceous hymenomycete in western North America that produces a perennial basidiocarp. Basidiocarps usually develop under dead branch stubs, but they occasionally form on the undersides of dead branches close to the trunk. Living conks produce a very distinctive aroma that is diagnostic of this fungus. The upper surface is dark gray brown to black and appears hairy with light margins when immature; it becomes harder and deeply cracked with concentric grooves and ridges when mature. The lower surface is light gray to tan, irregularly poroid at the margin, and bears long, thin and brittle to thick and rigid pendant teeth (spines) that turn white with buff felty tips during active sporulation. The teeth are flattened to cylindric and may fuse in older basidiocarps. The dark orange to brick red internal contextual tissues were commonly used by indigenous people of western North America as a source of pigment for making dyes and paints (Fig. 86).

Disease Cycle

Fruiting bodies (conks) form after extensive advanced decay develops and produce basidiospores for decades on living trees and for several years on standing dead trees. Spores may be produced for at least 10 years from conks on trees that have been felled, but conk survival is poorer on trees bucked into logs than on felled, intact trees. Sporulation on conks occurs predominately during cool, wet fall and spring months, although light sporulation may occur throughout the year when mean daily temperatures are 4–16°C. Spores are dispersed primarily by wind and must be exposed to subfreezing temperatures for a period of one to several months before significant germination can occur. This may explain why the fungus has become adapted to cold, high-elevation, interior mountainous habitats. Most infections probably occur in the spring. The primary infection courts of this fungus appear to be small (1–2 mm in diameter), recently shade-killed twigs and exposed stubs of living secondary branchlets on branches near the trunk rather than trunk wounds. Thick-walled basidiospores germinate to form monokaryotic hyphae that penetrate and colonize dead wood and pith tissue of the branch. The fungus is heterothallic, and its mating behavior is controlled by a bifactorial (tetrapolar) sexual incompatibility system. Consequently, infections by at least two compatible mating types (in relatively close proximity) are required for anastomosis and formation of the dikaryons, although monokaryons are capable of causing decay in heartwood prior to development of the dikaryons. Despite previous reports, a prolonged dormant–infection phase requiring activation by mechanical wounds, top breaks, or frost cracks to allow air access to the trunk interior is not required before decay can be initiated. Vegetative hyphae enter the heartwood of the main branch through secondary branch traces by active mycelial growth or as small branches become encased by radial tree growth. Once the fungus enters the stem, dikaryotic mycelia cause rapid decay of the heartwood and produce an extensive decay column before fruiting bodies form. Decay is not confined to any particular part of the stem. In older trees, decay often occupies the entire heartwood and extends into roots and larger branches. Mycelia appear to grow outward along large branch traces from the heartwood to reach the bark and amass growth under branch stubs to initiate basidiocarp formation. Basidiocarps may grow very large on old-growth trees and continue to release basidiospores until the nutrient and energy reserves in the heartwood are exhausted. During the final stages of decay, the heartwood may completely disintegrate, leaving a hollow in the tree.

Effects on Tree and Forest, Ecological Role

The Indian paint fungus is the predominant cause of heartrot and volume losses in native species of living true firs and hemlocks in coniferous forests of western North America. Heartwood volume losses attributed to this fungus in conifer stems are second only to those caused by *Porodaedalea* (*Phellinus*) *pini* in this region. It is responsible for 80% of the decay in old-growth grand and white fir stands in eastern Oregon and Washington in the United States and 30% of the decay in advanced fir regeneration. The fungus causes the greatest damage in mature trees that have exceeded the 100- to 150-year pathological rotation age, although significant volume losses can occur in much younger trees. *E. tinctorium* contributes significantly to the predisposition of living trees to windthrow and bole breakage, particularly in *Abies* spp., accelerating their demise by de-

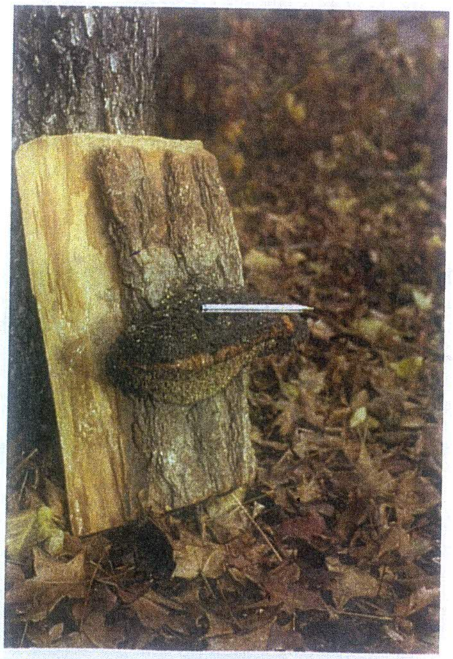

Fig. 85. Conk of the Indian paint fungus, *Echinodontium tinctorium*, on grand fir. (Courtesy E. Hansen–© APS)

Fig. 86. Sectioned conk of *Echinodontium tinctorium* on a young grand fir in the U.S. state of Oregon. (Courtesy E. Hansen–© APS)

composer organisms. The fungus can severely weaken trunks of host trees, resulting in potential hazard to people and buildings in developed recreation sites or along roads and trails. It also serves as an early decomposer itself by initiating decomposition processes that contribute to nutrient and carbon recycling from the heartwood of mature standing trees. These later become nurse logs, releasing nutrients and mulch essential for the survival of conifer seedlings during regeneration.

Predisposing Factors

Hosts are predisposed to attack on poor sites that reduce vigor and in dense, shaded stands that cause shade-suppressed trees to have small, dead twigs and exposed branch stubs that serve as infection courts. Infections in trees in the vicinity of trees bearing basidiocarps also are more numerous on dense, shaded sites. This is particularly true in cold, humid habitats that favor sporulation and basidiospore germination. Thus, north-facing, high-elevation stands tend to have greater disease incidence. Large wounds on boles or branches do not appear to be infection courts, but they may serve as sites for basidiocarp formation. Trees in uneven-aged stands tend to have more decay than those in even-aged stands. Old trees are at greater risk of attack and have greater susceptibility to windthrow because of the larger volume of heartwood in these trees.

Disease Management

Stand management options for the disease depend on objectives for the stand, for example, timber production or wildlife habitat and recreation. For timber or recreational objectives, stands may be managed for up to 150 years if a reasonable growth increment is maintained, unless substantial tree injury exists, reducing time until rotation. Stands with a high incidence of wounding and poor live-crown ratios usually have high decay levels and can be managed for cavity habitat to an approximate age of 80 years. Large-diameter, hollow grand fir trees and logs created by *E. tinctorium* decay account for 41% of all bear dens in northeastern Oregon. The artificial inoculation of trees with *E. tinctorium* has promoted bird-nesting sites in Oregon and increasing numbers of cavity- and bark-nesting birds in dead trees with broken tops in advanced stages of decay. For timber production, nonhost conifer species should be planted on high-hazard sites, for example, sites that do not promote vigorous growth of fir and hemlock species and sites with a high incidence of the fungus. Sites on cold, shaded slopes that favor sporulation and basidiospore germination are most likely to harbor diseased trees. The removal of pine species for timber products, leaving predominantly true firs, has increased the incidence of *E. tinctorium* in forests of interior western North America. The greater risk of *E. tinctorium* infection in firs has led to stand prescription changes to favor retention of western hemlock in Oregon. Forest stands containing fir or hemlock as dominant species should be thinned early to prevent shade suppression and reduce relative humidity under the canopy, avoiding conditions that promote sporulation and formation of infection courts. Removing trees bearing conks during precommercial thinning and logging may help reduce the future incidence of decay in residual and regeneration stands. Wounding of marketable timber during thinning or harvesting operations should be avoided, since wounds may provide exit points for conk formation and entry points for other decay fungi. Stands with low incidences of wounding but poor live-crown ratios should be thinned to improve live-crown ratios and leader growth. Management strategies should favor even-aged stands to avoid the higher incidence of the fungus and greater damage found in uneven-aged stands. Commercial harvests should be completed before the dominant, marketable species have reached their predetermined pathological rotation ages specific for each site. Highly hazardous trees with a combination of excessive failure potential (having several large conks) and damage potential (proximity to frequent human and structural targets) may need to be removed, depending on the frequency and duration of road traffic or human activity.

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(Prepared by A. D. Wilson)

Hazard Trees

A "hazard tree" or "danger tree" is defined as any tree or its parts that may fail because of damage, defect, or disease and cause injury to people or their property. Hazard-tree identification and management require unique skills that combine science and intuition. They involve observation, experience with tree defects and diseases, thorough investigation, and adequate documentation. Forest trees, especially large ones, greatly enhance the beauty and enjoyment of recreation sites, lake and stream shores, buildings, and roadways. Pathogens, insects, wildfire, and weather events, however, can cause major damage to forest trees, resulting in their failure and possible injury to people or damage to their property.

There are six steps for properly evaluating hazard trees: (i) determine the tree species, defects, and failure potential; (ii) determine the type of human activity in the area; (iii) determine the tree's potential-failure zone; (iv) determine whether the tree is a danger to people or their property; (v) document the hazard-tree assessment; and (vi) determine what action to take if the tree is a danger. The effects of defects and diseases vary by tree species, so it is important to correctly identify tree species and their defects in order to properly assess tree-failure potential. The type of human activity in the area, whether it is traffic on roads, camping in a recreation site, or walking on a trail, determines the type of assessment and the amount of hazard. There are three questions to consider when determining the tree's potential-failure zone: (i) Is it the entire tree or only its parts that are defective? (ii) Is the ground sloped so that the tree can roll or slide if it fails? (iii) Is the tree leaning away from potential targets? At least two factors determine whether the defective tree or its parts pose a danger to people or their property: (i) Will the tree or its parts actually strike the target if it is stationary? (ii) What is the probability that the target will be struck if it is moving? Documenting hazard-tree assessments is important because, often from a legal standpoint, if the survey is not documented, then it has not been done. Finally, what action is to be taken following the hazard-tree assessment? Should the hazardous tree or its parts be removed? Are wildlife