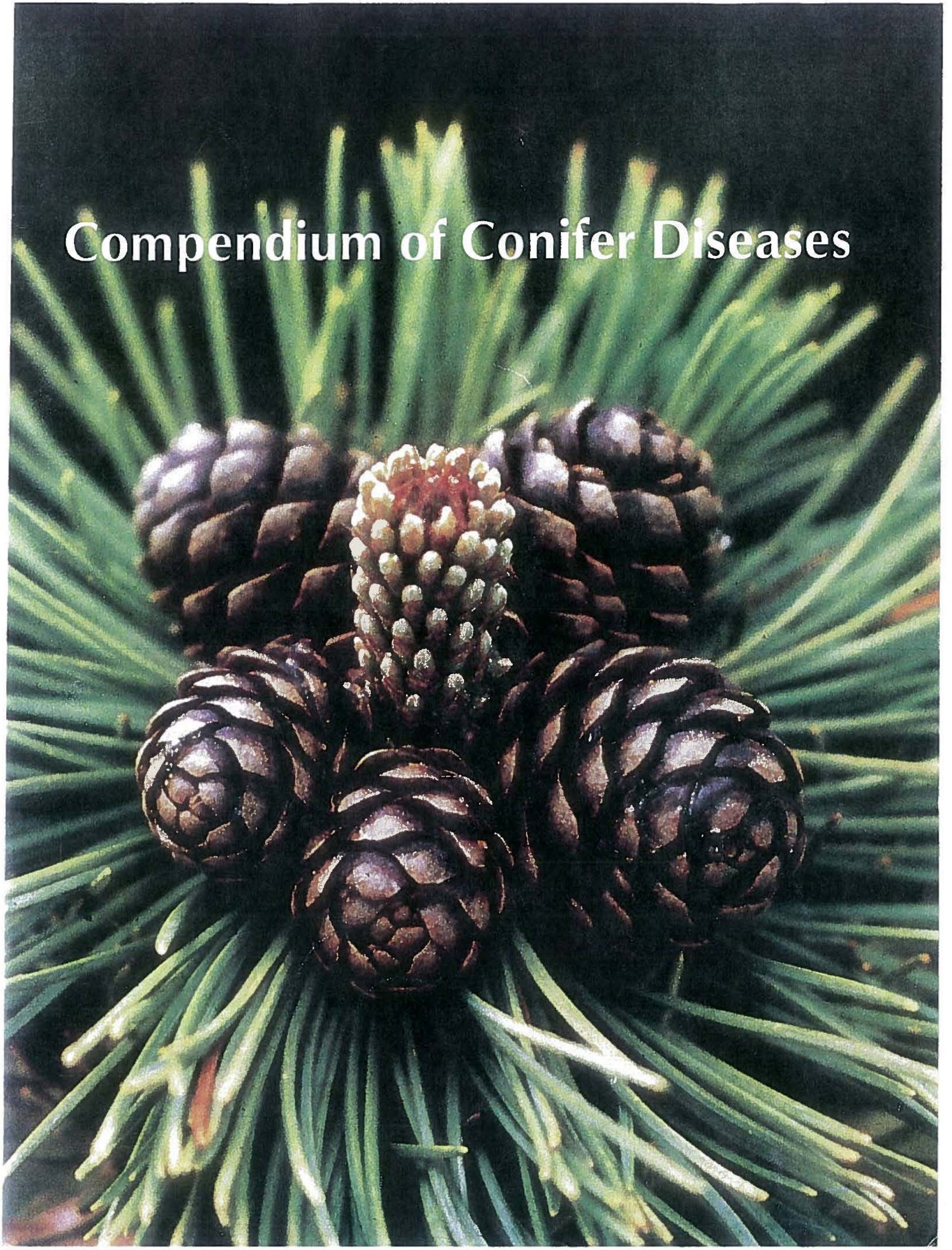
Compendium of Conifer Diseases



Compendium of Conifer Diseases

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Older trees are more susceptible to damage by this fungus, although even very young trees are susceptible to infection. Infections occur most frequently in dense stands where self-pruning creates infection courts for the fungus.

Disease Management

The fungus is not thought to utilize wounds for infection courts. Therefore, avoidance of wounding during silvicultural and harvesting operations does not affect *P. pini*. The most effective management for this heartrot is to use a "pathological rotation age" 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 reduce the rate of infection and decay development.

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(Prepared by K. Lewis)

Rust-Red Stringy White Rot

Other names: the Indian paint fungus

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

Hosts: All native species of *Abies* and *Tsuga* in western North America are major hosts; *Picea engelmannii*, *Picea glauca*, and *Pseudotsuga menziesii* are minor hosts.

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

Symptoms and Diagnosis

The early symptom of the decay caused by *Echinodontium tinctorium* is 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 (Plate 51). 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 (Plate 52) may occasionally protrude from the bark in rusty punk knots, which 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, perennial, woody basidiocarps (conks) are the most visible and diagnostic signs of this disease (Plate 53). *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 bole. 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 at maturity. The lower surface is light gray to tan and 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 western aboriginals as a source of pigment for making dyes and paints (Plate 54).

Disease Cycle

Sporulation occurs predominately during cool, wet, fall and spring months, although light sporulation can occur throughout the year when mean daily temperatures are 4–16°C. Basidiospores 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 adapted to cold, high-elevation, interior mountainous habitats. Most infections probably occur during the spring. The primary infection courts of this fungus are currently believed to be small (1–2 mm in diameter), recently shade-killed twigs and exposed stubs of living secondary branchlets on branches near the bole. Basidiospores germinate to form monokaryotic hyphae that penetrate and colonize the dead wood and pith tissue of the branch. Studies indicate that monokaryons are immediately capable of causing substantial decay on their own prior to development of the dikaryon. The fungus is heterothallic, and its mating behavior is controlled by a bifactorial sexual-incompatibility system. Consequently, infections by at least two compatible mating types in relatively close proximity are required for anastomosis and formation of the dikaryon. Once it reaches the bole, the dikaryotic thallus causes rapid decay of heartwood and produces an extensive decay column before a fruiting body can form. Mycelia appear to grow along branch traces from the heartwood to reach the bark and amass growth under branch stubs to initiate basidiocarp formation. The basidiocarp may continue to develop on standing and downed trees for many years and release basidiospores annually until the nutrient and energy reserves in the heartwood are exhausted.

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 *Phellinus pini* in this region. The fungus causes the greatest damage in mature and overmature 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 break, accelerating their demise by decomposing organisms. 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 trees later become nurse logs, releasing nutrients and mulch essential for the survival of conifer seedlings during regeneration.

Predisposing Factors

Trees growing at sites that reduce vigor and in dense stands in which shade-suppressed trees have the small, dead twigs and exposed branch stubs that serve as infection courts are predisposed to attack. Infections of trees in the vicinity of infected trees bearing basidiocarps also are more numerous on densely shaded sites. This is particularly true in cold, humid habitats that favor sporulation and basidiospore germination. Large wounds on boles or branches do not appear to be utilized by the fungus to enter its hosts, but they may serve as sites for basidiocarp formation. Stands in which the trees are of various ages tend to have more decay than those in which trees are of similar age. Older trees are at greater risk of attack and are more susceptible to windthrow because of their larger volume of heartwood.

Disease Management

Planting should be avoided on sites that do not promote vigorous growth of fir and hemlock species. Sites on cold, shaded slopes that favor sporulation and basidiospore germination are most likely to harbor diseased trees. Nonhost species should be planted on high-hazard sites with high incidence of the fungus. Forest stands containing fir or hemlock as dominant species should be thinned to prevent shade suppression and reduce relative humidity under the canopy, thus avoiding conditions that promote sporulation and formation of infection courts. Trees bearing basidiocarps should be removed as a sanitation measure during precommercial thinning cuts and after logging, since decay incidence and volume loss increase in stands containing actively sporulating basidiocarps. Wounding of merchantable timber during thinning should be avoided, since wounds may provide exit points for basidiocarp formation and entry points for other decay fungi. Management strategies should favor stands with trees of similar age to avoid the higher incidence of the fungus and the greater damage it causes in stands with trees of different ages. Commercial harvests should be completed before the dominant, merchantable species have reached their predetermined pathological rotation ages specific for each site.

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(Prepared by A. D. Wilson)

Stem Rusts

All the stem rusts of pines are in the closely related genera *Cronartium*, *Peridermium*, or *Endocronartium*, except pine twist rust, caused by *Melampsora pinitorqua*. The alternate hosts of these rusts are a diverse array of angiosperms. Indeed, the host association is often the best aid for identification, since morphological distinctions are subtle or lacking in many species.

Cronartium telia produce teliospores packed together in columns that resemble hairs. They are usually formed on the undersides of leaves. Aecia are peridermioid, and yellow, echinulate aeciospores form beneath the peridium, which ruptures at maturity.

Most *Cronartium* rust fungi are heteroecious (host-alternating) and macrocyclic, forming three infectious spore stages during their life cycles. Aeciospores are disseminated by the wind during the spring and are capable of long-distance dispersal to alternate hosts. Uredia and urediospores are formed first on the alternate host and function as conidia, causing new infections on the same plant species and allowing an increase in inoculum during the growing season. Telia typically form in the uredial pustules, often during periods of cool weather. When leaves are wet, teliospores germinate to form basidia, and basidiospores are released.

Basidiospores are also dispersed by wind, but they are more delicate than aeciospores or urediospores. Effective dispersal is generally limited to distances of 500 m or less. Basidiospores germinate on needles or young shoots, and germ tubes either enter through stomata or penetrate the epidermis directly. Pycnia (spermagonia) appear the following spring or later, and pycniospores are carried by insects from one pycnium to another, effecting fertilization. Aecia are formed on fertilized infections a year later. *Cronartium* rust fungi form a perennial mycelium in the stems of their pine hosts, producing pycnia along the margins of expanding cankers and aecia in tissues that bore pycnia the previous year. In most cases, the rusts are ephemeral on the angiosperm host.

Autoecious, pine-to-pine rusts have a simpler life cycle. Pycnia, uredia, telia, and basidiospores are not formed. Spores morphologically identical to aeciospores are formed on pine, are dispersed by the wind, and initiate new infections on pines. These "imperfect" rusts are placed in the form genus *Peridermium* on the basis of aecial morphology. Alternatively, they may be grouped in *Endocronartium* on the basis of cytological evidence that meiosis occurs in the germinating "aeciospores." *Peridermium* (*Endocronartium*) species are closely allied with individual *Cronartium* species on the basis of hosts, morphology, and most recently, molecular evidence.

Rusts of Soft Pines

White Pine Blister Rust

Other names: rouille vèsiculeuse des pin a cinq feuilles (French); Blasenroste (German); moho ampoua del pino blanco (Spanish)

Causal organism: *Cronartium ribicola* J. C. Fisch.

Hosts: Telial hosts include *Pedicularis* spp. (Asia only) and all *Ribes* spp.; aecial hosts include all *Pinus* spp. within the foxtail, stone, and white pine groups of the *Haploxylon* subgenus.

Distribution: throughout the range of the hosts in Asia, Europe, and North America

Symptoms and Diagnosis

On pines, conspicuous, orange aeciospores are produced during the spring on slightly swollen fusiform cankers that encircle branches and near the margins of diamond-shaped cankers on stems (Plate 55). Cankers on smooth stems and branches have orange margins, which are readily seen when moistened. Old cankers often have roughened bark where aeciospores have ruptured the periderm. They also may have resinous constrictions and evidence of secondary organisms, which cause necrotic patches, dead branches, and dead cankers. Since most stem cankers originate from branch cankers, they frequently have a branch or branch stub at the center.

Disease Cycle

Germ tubes from basidiospores enter pines through stomata of needles during late summer (Plate 56). The first symptom is a yellow or red needle spot that appears the following spring. By fall, the first signs of orange hyphae are clearly visible in the bark at the bases of infected needles. Within 2 years, dark lesions containing pycnia develop in the infected area. Flies attracted to the sweet pycniospore droplets facilitate dikaryon formation between compatible mating types. Genetically diverse, dikaryotic aeciospores are produced during the following spring. The fungal tissue in the canker margin remains haploid, and pycniospores are produced annually from spring to fall along the periphery. Germ tubes from aeciospores enter alternate hosts (usually *Ribes* spp.) via stomata. Urediospores are produced throughout the summer and infect additional *Ribes*