Black Stain Root Disease of Conifers

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The black stain fungus—*Leptographium wageneri* (Kendrick) Wingfield*—infects and kills several species of western conifers. The fungus colonizes water-conducting tissues of the host's roots, root collars, and lower stems, ultimately blocking the movement of water to foliage. Severely infected trees exhibit wilting symptoms characteristic of vascular wilt diseases. Black stain kills young trees within a year or two of infection. Older infected trees decline more slowly (over 2 to 8 years) and are often predisposed to bark beetle infestation.

Distribution

Black stain root disease is thought to be native to western coniferous forests. Although the disease was first discovered in 1938, further spread went virtually undetected until the 1970s. Tree mortality associated with the disease was often mistakenly attributed to other, more easily identified root diseases or to bark beetles, which are commonly associated with the rapid decline and death of black stain-infected trees.

Black stain occurs in many locations throughout the western United States. At present, the greatest development of the disease occurs in southeastern and northwestern California, southwestern and east-central Oregon, the central Sierra Nevada, and southern Colorado. In recent years, reports of black stain in young, intensively managed stands have increased dramatically, especially in Oregon and California. The disease affects trees in high-use recreation areas and areas important for wildlife management as well as those on lands dedicated to timber production.

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*Other names have been given to the fungus that causes black stain root disease: *Ophiostonia wagneri* (Goheen and Cobb) Harrington is the name of the sexual stage; *Ceratocystis wageneri*, and *Verticicladiella wageneri* are no longer considered taxonomically correct.

Hosts

The principal hosts of *L. wageneri* are Douglas-fir, ponderosa pine, Jeffrey pine, pinyon, and singleleaf pinyon. Seldom-damaged hosts in the United States include lodgepole pine, western hemlock, mountain hemlock, sugar pine, western white pine, and knob-cone pine. Tree species highly resistant or immune to infection are "cedars" (Alaska yellow-cedar, Port-Orford-cedar, western redcedar, and incense-cedar), spruce, larch, junipers, and true firs.

Recent research indicates that there are three distinct variants of *L. wageneri*, each with specific host preferences. One (var. *wageneri)* attacks pinyon, another (var. *pseudotsugae)* attacks Douglas-fir, and the third (var. *ponderosum)* attacks hard pines and occasionally hemlocks. Although limited cross-over has been shown experimentally with the Douglas-fir and hard pine variants, natural occurrences have not been detected. For purposes of resource management, each of the variants can be considered host specific.

Black stain root disease occurs over a wide range of environmental conditions, from the hot and semi-arid Southwest to cool Pacific coastal areas. Soil type does not appear to be a major factor in the distribution of the disease. Soil moisture and temperature, however, may influence disease distribution significantly. Cool, moist soil conditions in spring and early summer are ideal for infection,

Figure 1 — *Crown symptoms of black stain root on young Douglas-fir.*

Figure 2 — *Faded, sparse crown of ponderosa pine with black stain root disease.*

growth, and tree-to-tree spread of the pathogen.

Symptoms and Damage

Trees infected by the black stain fungus usually exhibit symptoms of gradual decline before they die (figures 1 and 2). In early stages of decline, terminal growth is reduced and older needles become chlorotic. As the disease progresses, older needles are shed prematurely, new needles are somewhat stunted and yellow, and reduced internodal growth is evident on lateral branches. In advanced stages, new growth is compact and chlorotic, with a tufted appearance, and tree crowns exhibit very sparse foliage. They also bear "distress" cone crops. Very small trees, or those affected by other significant stress factors, may succumb quickly without exhibit-

Figure 3 — *Typical dark sapwood stain associated with black stain root disease.*

Figure 4 — *Cross section through affected root showing arc-shaped pattern of black stain.*

Figure 5 — *Black stain root disease center in a second-growth ponderosa pine plantation.*

hibiting gradual decline symptoms; foliage may change rapidly from green to yellow or reddish brown.

Crown symptoms of trees affected by black stain root disease are very similar usually a lighter color and typically are wedge-shaped in cross-section or they discolor the entire sapwood radius.

Black stain root disease affects groups of trees in distinct infection centers (figures 5-7). Typical infection centers have trees in various stages of decline near the perimeter and dead trees in the interior nearer the origin of initial infection. Infection centers usually occur in well-stocked stands where a preferred host predominates or occurs in unmixed clumps. In stands where species composition is well mixed,

Figure 6 — *Typical black stain root disease center in a Douglas-fir plantation.*

Figure 7 — *Black stain root disease center in singleleaf pinyon.*

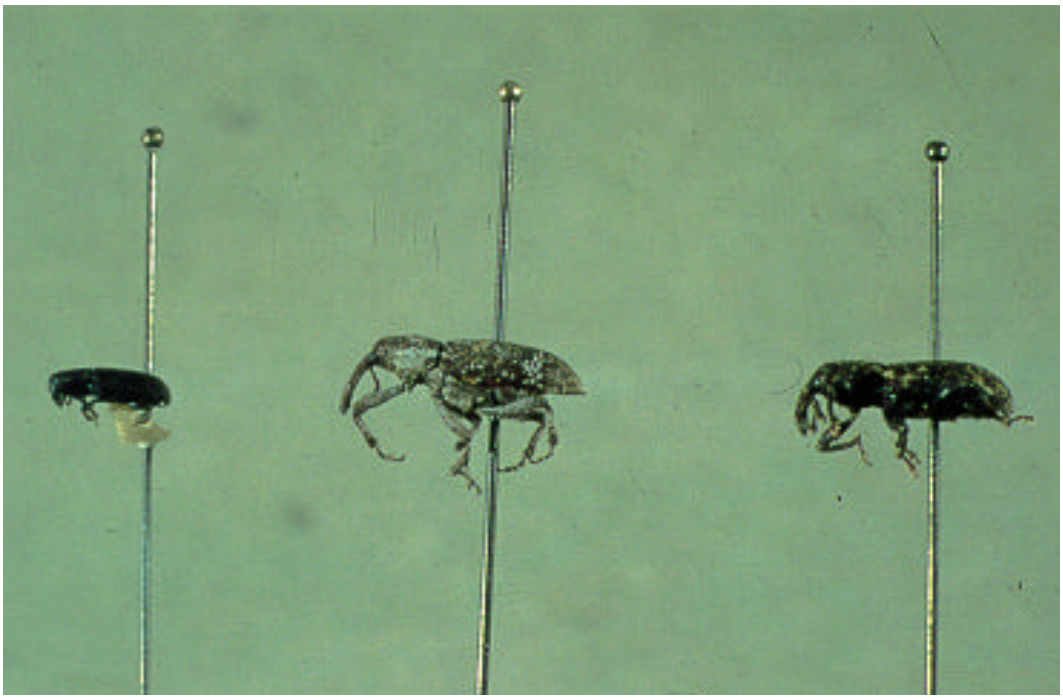

Figure 8 — *Insect vectors of the black stain root disease fungus on Douglas-fir:* Hylastes nigrinus, Steremnius carinatus, *and* Pissodes fasciatus.

infection and mortality are less common, but isolated trees or tree clusters can be infected.

Disease Cycle

Long-distance spread of the black stain fungus involves insect vectors (figure 8). The root-feeding barkbeetles *Hylastes macer* LeConte and *H. nigrinus* (Mannerheim) are believed to be the primary vectors of the fungus on ponderosa pine and Douglas-fir, respectively. Two weevils—*Steremnius carinatus* (Boheman) and *Pissodes fasciatus* LeConte—have also been implicated as vectors in Douglas-fir, but their involvement in local and long-distance spread of the pathogen is still poorly understood.

Vector insects commonly breed in roots of recently dead or dying host trees including those infected by *L. wageneri.* Several vector species—*H. nigrinus, P. fasciatus,* and *S. carinatus*—also breed in Douglas-fir stumps, which are susceptible to infection by *L. wageneri* for up to 7 months after stems have been severed.

Leptographium wageneri sporulates readily inside insect galleries in infected roots and root collars. Stalked, microscopic fruiting bodies **(conidiophores)** form on gallery walls, each bearing a sticky spore droplet that protrudes into the gallery. These sticky spore droplets are well suited to insect dispersal (figure 9). During emergence, some young adult beetles are contaminated with spores as they brush against spore droplets in galleries or pupal chambers. Contami-

Figure 9 — *Enlargement (25x) of fruiting bodies of the black stain root disease fungus in an insect gallery, showing sticky spore masses.*

-nated beetles fly (or walk) from brood trees, burrow through the duff and soil, visit roots of healthy, recently dead, or dying trees, and deposit spores on root sapwood exposed during feeding. Wounds that expose sapwood xylem are required for infection, because *L. wageneri* hyphae are unable to penetrate live bark and cambial tissues.

Once established, the black stain fungus colonizes root and stem sapwood xylem, reducing water uptake and the vertical ascent of xylem sap by clogging water conducting vessels with hyphae and host reaction compounds. In live trees, the fungus is confined to tracheids; parenchymatous tissues are not invaded. Infected trees die (usually in summer, when soil moisture is depleted) because of inability to take up water.

Black stain infection centers are most prevalent in areas where substantial tree damage or site disturbance has occurred, especially along roads and skid trails, in areas having a history of tractor logging and resultant soil compaction, and in areas that have been precommercially thinned. The appearance of infection centers in areas of disturbance reflects vector insect preference for stressed trees.

Once a new infection center is established, spread of the infection from tree to tree occurs through root grafts between healthy and diseased trees and through intimately associated roots via limited growth (< 15 cm, or about 6 in) of the pathogen through soil. Small rootlets (< 5 mm., or .2 in diameter) serve as infection courts where roots are not grafted. Infection centers in ponderosa pines and pinyons enlarge on the margin at an average annual rate of 1.0 m/yr (3.2 ft/yr). Infection centers in Douglas-fir enlarge at a rate of 0.8 to 1.5 m/yr (31.5 to 59.1 in/yr), but enlargement of infection centers with this host often decreases markedly when stands reach 30 to 35 years of age. The rate of enlargement of black stain infection centers is 3 to 5 times faster than that of other common root diseases.

Leptographium wageneri is relatively nonpersistent in infected root systems, remaining active usually no more than 1 year after its host dies.

Management and Cultural Controls

In recent years, black stain root disease has been detected in many new areas, often causing locally severe damage. Incidence appears to be steadily increasing. At the present time, there is no effective cure for already diseased trees, and genetically resistant host genotypes have not been identified. Current management strategies for control of black stain root disease are either preventive or corrective.

Preventive Management

Black stain root disease is favored by several traditional management and road maintenance activities that are used throughout the range of its hosts. By modifying or eliminating some of these influences and by minimizing site disturbances, tree injuries, and the opportunity for successful insect vectoring, further spread of the pathogen can be reduced.

Minimizing site disturbance:
Management treatments for disease-prone areas should be those that cause the least site disturbance, particularly avoiding soil compaction and disruption of the soil profile. Where timber is being harvested, high-lead and skyline yarding are preferable to tractor logging and should be selected when an option exists. When tractor-logging, the area covered by skid trails should be minimized, and yarding should be restricted to the dry season (mid to late summer), when the risk of serious soil compaction is reduced. Skid trails should be designated on the ground before beginning falling activities, and tree falling should be done to the yarding lead. Soils particularly prone to compaction by heavy equipment should not be tractor-logged.

New road construction through established young Douglas-fir plantations (<30 years old) or second-growth stands of ponderosa pine should be avoided, especially within 1.6 km (1 mile) of known black stain disease centers. If new roads must be established or old roads re-opened, injured trees and those with root collars partially covered by fill or side cast from the right-of-way after construction should be removed. Damaged and partially buried trees are often weakened and have been shown to be attractive to insect vectors of black stain. Many new infection centers begin in rights-of-way cut for roads. Special care should be exercised in road and site construction when developing new recreation sites.

Minimizing tree injury: During road building and maintenance, recreation site development, and timber harvest activities, creating flooded or poorly drained areas in or around Douglas-fir plantations or second-growth stands of ponderosa pine should be avoided. Vectors of black stain root disease often visit trees with roots in flooded or poorly drained soils. Using rotary-blade brush-cutting machinery to clear roadsides adjacent to Douglas-fir plantations is another practice to avoid, for newly created tree stumps and trees that are damaged but not severed by the blades are attractive to vectors. Special care should also be taken to avoid damaging young plantation trees when harvesting sawtimber in adjacent stands.

Modifying silvicultural practices:
Precommercial thinning in Douglas-fir plantations should be done after the vectors of black stain have emerged and established themselves for breeding in other dead, dying, or down materials. Vectors usually emerge in the spring or early summer. In areas where black stain is a potential probem, precommercial thinning should be sched-

uled between the last of June and the first of September to ensure that thinning slash will be red and dry by fall. This will limit opportunities for insect vector population build-up. In areas where summer months are often dry and droughty, the period of precommercial thinning may be extended into late September.

Corrective Management

Where black stain root disease is already established, a few silvicultural remedies are available. Cultural controls should be incorporated into silvicultural prescriptions and should not disrupt the normal management schedule unless incidence in stands is moderate or worse (more than 5% of trees affected).

When establishing new plantations near areas where black stain is a known management concern, a mix of species should be planted to provide future options for species manipulation. Where black stain is already causing significant mortality in young Douglas-fir stands, resistant or immune tree species should be favored over Douglas-fir in precommercial thinning or cleaning operations, especially in active infection centers and in buffer zones immediately adjacent to them. The width of buffer zones should be based on the number of years before the next scheduled entry and a potential pathogen spread rate of 1.5 m/yr (4.9 ft/yr). Buffer zones are typically two to five normal tree spacings wide, depending on the tree species, size class, and stocking control guidelines for that species.

When resistant species selections are lacking and precommercial thinning is necessary, avoid thinning in active infection centers and in buffer zones adjacent to them. Thinning in active infection centers should be avoided, because odors from freshly cut stump surfaces of infected trees are more attractive to vectors than odors from cut surfaces of healthy trees. This leads to increasing disease in crop trees adjacent to active infection centers.

In the central Sierra Nevada of California, mixed conifer stands of ponderosa pine, incense-cedar, and firs often progress to a more advanced seral stage when black stain root disease is active in the pine, because death of the pines favors the other resistant species. When ponderosa pine is the dominant species in such stands, a mixture of resistant tree species should be favored in and around black stain centers during precommercial and commercial thinnings. Patch cutting and creation of 15.2-m (50-ft) buffers around disease centers is often recommended during intermediate or selective harvest entries in ponderosa pine stands to prevent the continued spread of the pathogen. Patch cutting in infected pinyon in recreation areas has also been recommended but does not appear to be effective unless buffers much wider than 15.2 m (50 ft) are used.

Assistance

Technical assistance in recognizing black stain root disease and developing vegetation management prescriptions to reduce or eliminate losses is available from USDA Forest Service, Forest Pest Management (FPM), or other extension, municipal, or State forestry offices.

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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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