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Forest Insect and Disease Management Guide for the Northern and Central Rocky Mountains

Produced by:

USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Missoula, MT, and Boise, ID

Idaho Department of Lands, Forestry Division, Insects and Disease; Coeur d'Alene, ID

Montana DNRC, Forestry Division, Forest Pest Management; Missoula, MT

Formatted into a comprehensive manual by Brennan Ferguson;
Montana DNRC, Forestry Division, Forest Pest Management

Note: The acronym FIDL = "*Forest Insect & Disease Leaflet*"

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Bark Beetles

Wood Borers

Stem (Insects)

Branch and Terminal (Insects)

Seed and Cone (Insects)

Foliage and Shoot (Insects)

Defoliators

- Alder flea beetle
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- Douglas-fir tussock moth
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Decays and Heart Rots

Dwarf Mistletoes

Branch and Terminal (Diseases)

Animal & Abiotic Damage

Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Animal Damage

By Marcus Jackson
US Forest Service

Topics

Animal damage

There are many species of wildlife in the forest, but the number of animals causing important tree injuries is relatively small	Hosts: All species

Damage

Principal animals causing damage to tree crops include deer, elk, beaver, porcupines, rabbits, mice, squirrels, gophers, and birds. The damage consists of browsing of foliage, buds, and young shoots; destruction of seed; gnawing of bark, often to such an extent that trees are girdled; or physical injuries to trees. Although the injuries resulting from these animals are less important in the aggregate than those caused by fire, insects, diseases, or domestic animals, relatively large losses on limited areas may ensue from their feeding and other activities.

The greatest damage to the forest from wildlife occurs when interference with normal biological processes (stand management activities, for example) cause an animal species to multiply prolifically or to be restricted in its normal food supply. When either of these two things happen, the forest is likely to suffer unusual amounts of injury, so great that steps may need to be taken to eliminate or reduce similar injury in the future.

Web Source: http://icwdm.org/

Cite as: Jackson, M. 2004. Management guide for animal damage. 1 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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March 2004

Abiotic Diseases: Overview

By
Marcus Jackson
US Forest Service

Topics

Abiotic damages

Abiotic tree diseases are caused by non-living agents that do not multiply and spread from tree to tree.	**Hosts:** **All species**

Related Guides:

-Drought

-Chemical

-Floods

-Spring freeze

-Winter injury

Damage

Whereas most insects and biotic diseases affect a particular tree species, or group of tree species, abiotic diseases will often affect various tree, shrub, and herbaceous species sharing the same or adjacent space.

However, different species and trees of different ages and vigor often vary in their susceptibility to damage.

Identification

Identification of abiotic diseases often requires learning the history of the site, comparing injury between trees and other plants of the same and different species, looking for patterns across a site, and ruling out damage from other agents such as insects and diseases. Factors causing these diseases may operate for only a brief period (frost), for most of the growing season (prolonged summer drought), or accumulate over a series of years (pollution).

Cite as: Jackson, M. 2004. Abiotic diseases: Overview. 1 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

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March 2004

By Marcus Jackson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Chemical Injury

Injury is usually found along roads, rights-of-way, fuelbreaks, dwellings, or other areas where road salts and herbicides are	Host: All species

Topics

Root Uptake

- Symptoms can be confused with other soil problems or drought.
- Some species will develop a spiral pattern of branch dieback.
- Develop one sided or top dieback.
- Upper crowns tend to develop greater damage than lower crowns.

Identification

Chemical injury often follows a pattern consistent with application of the chemical. Injury from road salt is usually near a road and herbicide injury can sometimes be seen ad a swath about the size of a spray boom and in disturbed areas where noxious weeds are sprayed. Chemical injury is often more extensive in low area where certain chemicals accumulate after runoff. In many situations, plant tissue samples can be submitted to a laboratory to determine the amount of a chemical in the plant tissue. However, the analysis can be expensive. If a chemical is suspected of causing tree injury, chemical application history should be obtained to determine if patterns of injury and tree injury symptoms are consistent with any chemicals applied at or near the site. Symptoms vary with the type and amount of chemical used. Injury symptoms can be in the form of foliar discoloration, premature defoliation, deformed growth, shoot dieback, branch dieback, reduced winter hardiness, and mortality.

Injury Caused by Salts

Salts can damage trees either by entering the roots as the salts leach into the root zone or through the foliage or leaf scars on twigs after salt spray settles on trees near high-speed roadways. Injury symptoms can differ for the different entry methods

Root uptake - salt damage is often evident soon after spring thaw in conifers and soon after budbreak in hardwoods.

When damage is severe:

- buds may not break at all and branches or whole trees may die.
- buds will break with reduced foliage that soon turns brown and dies.
- buds further down a branch may break and the trees that survive look ratty.

In less severe cases:

- marginal browning will occur on hardwood leaves and needle tip browning on conifers.
- symptoms can intensify through the season culminating with premature leaf drop.

- Trees that survive injury from salts will often show reduced growth and vigor.

Injury symptoms will usually be worse on trees that are exposed to higher levels of salt, such as those closer to where the salts were applied or trees that are downhill or in depressions where salts may accumulate after runoff.

Foliar and twig uptake

On hardwoods:

- bud break may be delayed for several weeks or buds may be killed resulting in twig dieback.
- When terminal buds are killed, lateral buds will often break resulting in witches' broom-like growths.
- Unlike damage caused by root uptake, marginal browning rarely occurs when salts are received as salt spray in hardwoods.

On conifers:

- Tip browning from salt spray is common. This browning can progress towards the base of a needle throughout the growing season.
- When severe, 2- and 3-year-old needles may fall prematurely.

Patterns of Injury from Salt Spray

More Damage

- Lower in the crown.
- On the sides of trees facing a high-speed road.

Less Damage

- Trees sheltered from spray.
- Branches higher in crowns.

Salt Injury Management

There are several tools that may be used in an attempt to reduce salt-caused injury to trees.

- Large amounts of water can be used to flush salts out of the soil since they are prone to leaching. However, watering should be carried out as early as possible in the spring for maximum benefit. There is potential to exacerbate tree injury on soils that are prone to water logging and excessive water can have a negative affect on nutrient availability to trees.
- There has been a trend to use de-icing agents other than sodium chloride, since they are often deemed less damaging to vehicles, roads, and vegetation. Although, some of these agents have potential, some of the salts, such as calcium chloride and magnesium chloride appear to damage vegetation.
- Road salts are over-applied in many situations. If machines were better calibrated to apply the optimum level of salt for reducing surface ice, while not applying excessive levels of salt, there would be less damage to trees.
- In areas where trees will be planted and road salt is expected, plant more salt-tolerant trees if feasible.

Injury Caused by Herbicides

Preemergence: Photosynthetic inhibitors (simazine) -high rates cause leaf yellowing. May be confused with nutrient deficiency, drought, or viral infections.

Postemergence:

- Growth regulators (glyphosate) - abnormal leaf development, tip yellowing, and dieback; (2,4-D; picloram) – similar to glyphosate in addition to twisted petioles and shoots.
- Contact (paraquat) -injury results from drift causing small dead spots on foliage. May be confused with leaf spot diseases or insect feeding injury.

Herbicide Injury Management

- Read the herbicide label carefully and follow the application directions explicitly.
- Make sure equipment is properly calibrated and use products that pose the least risk to trees.
- Contact of non-target trees must be avoided; however, damage of trees inadvertently contacted by some herbicides could be reduced by immediately washing herbicide off affected areas. Similarly, removing branches contacted by herbicides could reduce damage to the rest of a tree by systemic herbicides if only a few branches are contacted.
- Activated charcoal may deactivate soil-active herbicides on a limited basis.
- Plant tolerant species.

Other Reading

Derr, J. F., and B. L. Appleton. 1988. Herbicide Injury to Trees and Shrubs. Blue Crab Press. Virginia Beach, VA. 72pp.

Dobson, M. C. 1991. De-icing Salt Damage to Trees and Shrubs. Forestry Commission Bulletin 101. London. 64pp.

Miller, P. R. 1993. Abiotic Diseases. *In* Diseases of Pacific Coast Conifers. USDA For. Serv. Ag. Handbook 521. Pacific Southwest Research Station. Albany, CA. pp.1-32.

Boutz, G. A. and R. W. Stack. 1986. Herbicides (Air Pollution). *In* Diseases of Trees in the Great Plains. USDA For. Serv. GTR RM-129. Fort Collins, CO. pp 33-35.

Cite as: Jackson, M. 2004. Management guide for chemical injury. 4 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

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March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Drought Injury

By Marcus Jackson
US Forest Service

Drought injury is caused by periods of subnormal rainfall.	**Host:** **All species**

Topics

Damage

Severity of damage may vary from slight foliar injury to complete tree death. Young trees are more seriously affected than older ones. Trees in shallow soil are more readily affected than the same species in deep soil. Drought can predispose trees to increased damage and mortality from bark beetles, root diseases, and canker-causing fungi.

Key Points

- Drought injury occurs on extremely dry sites, usually after 2 or more years of moisture deficiency.
- The cumulative effect of consecutive dry periods reduces soil moisture below tree requirements.
- Injury may result from a season of extremely low precipitation.
- Drought can predispose trees to increased damage and mortality from bark beetles, root diseases, and canker-causing fungi.

Identification

Trees die from the top down and from the outside in. Injury is most severe on south and southwest slopes. The most striking symptom is discoloration of the foliage, which may be preceded by wilting. In conifers, the needles turn reddish-brown in late summer, autumn, or early winter, generally beginning from the tips of the youngest needles. In hardwoods, the leaves turn yellowish to reddish, beginning usually at the tip or margins, but occasionally midway between the main veins, progressing to brown. Leaves may turn completely brown in some situations. Premature leaf drop commonly results, and the growing season is effectively shortened.

Management

- Well managed stands are more resident to drought than dense, overstock stands.
- Appropriate seed sources should be used for reforestation.
- Thinning and other management activities may be postponed during severe drought to avoid additional stress to retained trees.
- High value trees will better withstand the effects of drought when competing weeds are controlled and trees are properly irrigated, mulched and fertilized.

Other Reading

Miller, P. R. 1993. Abiotic Diseases. *In Diseases of Pacific Coast Conifers.* USDA For. Serv. Ag. Handbook 521. Pacific Southwest Research Station. Albany, CA. pp.1-32.

Cite as: Jackson, M. 2004. Management guide for drought injury. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Damage-agent is not in field guide.

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Management Guide for

Flooding Damage

Most trees can withstand a few days of flooding during the growing season, but riparian species tend to be more tolerant than upland species

Topics

Key Points

- Damage occurs in young ponderosa pine, generally less than ten feet tall.
- Trees are not killed but may be stunted or deformed.
- Experimental control uses insecticide to kill moths as they emerge from pupae in soil under damaged trees.

Damage

Flooding can cause anaerobic conditions, a lack of oxygen, resulting in poor root growth or root death. Eventual death of a tree can occur after extended flooding. Since the effects of flooding on trees involves complex interactions between flood characteristics, soils, and individual tree tolerances, predictions of tree survival from flood conditions are difficult to make. Flooding can damage trees indirectly by modifying soil characteristics. Current can wash away soil, exposing roots or deposit soil around a tree, smothering the roots.

Flood Characteristics

There are different kinds of floods and certain flood characteristics affect tree survival. Floods during the growing season are generally more damaging to trees than floods that occur before trees leaf out in the spring. Trees are damaged more by floods that last for longer periods of time and damage is generally greater on trees with standing water around them than trees in saturated soil. Damage is usually greater on trees where the foliage is submerged and tends to increase as more foliage is covered with water. Cold water is usually less damaging than warm water and moving water less damaging than stagnant water because of higher oxygen content. Runoff containing herbicides and other chemicals from lawns, agricultural fields, and other areas can contaminate water and further damage trees. Impacts from chemicals depend on the concentration and type of chemical. Young trees are especially susceptible to physical injury from fast water currents and floating debris.

Management

Select flood tolerant species for planting on flood-prone sites.

Identification

Consider the flood history of the site and affects on tree species present. Moderate damage may cause a yellowing and some browning of the foliage. Patterns of foliar injury can be variable. Sometimes the injury symptoms will start in the bottom of a tree and move up and move from the inside to the outside, but symptoms may be similar to drought injury, working from top to bottom and outside to inside under different conditions. Severe damage can cause dieback and tree mortality.

Tree health, size, age, and species can all affect the ability of an individual tree to survive flooding. Vigorous trees tend to be damaged less by temporary flooding than stressed trees. Since large trees tend to have more of their crowns out of the water, they tend to survive better than small, submerged trees. Young trees and very old trees tend to suffer more damage from flooding than other trees. Riparian species, such as cottonwoods, willows, and cedar are more tolerant of flooding than other species, such as many of the pines.

Other Reading

Flooding and Its Affects on Trees: St. Paul Field Office, Northeast Area State and Private Forestry, USDA Forest Service.

Miller, P. R. 1993. Abiotic Diseases. *In* Diseases of Pacific Coast Conifers. USDA For. Serv. Ag. Handbook 521. Pacific Southwest Research Station. Albany, CA. pp.1-32.

Cite as: Jackson, M. 2004. Management guide for flooding damage. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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March 2004

Forest Health Protection and State Forestry Organizations

By Marcus Jackson
US Forest Service

Management Guide for

Spring Freeze Injury

Management In forest and landscape setting, plant cold hardy stock.	**Host:** **All trees species**

Topics

Damage

Freeze injury occurs during severe cold periods after tree growth has started in the spring. Most trees can withstand 1° or 2° below freezing even during shoot elongation, but if temperatures drop 2° to 5° below freezing, or more, during shoot elongation, damage can occur.

Young branch tips droop and turn brown on various woody and herbaceous species in an area after temperatures drop several degrees below freezing during shoot elongation.

Tips of new growth are killed by extreme cold. Death of new shoots or needles is sometimes accompanied by discoloration of older needles. Dieback, stunted growth, and abnormal tree form may be caused by terminal bud death.

Other Reading

Hiratsuka, Y. 1987. Forest Tree Diseases of the Prairie Provinces. Canadian Forest Sevice Information Report NOR-X-286. Northern Forestry Centre, Edmonton, Alberta. pp. 114-117.

Miller, P. R. 1993. Abiotic Diseases. *In* Dieases of Pacific Coast Conifers. USDA For. Serv. Ag. Handbook 521. Pacific Southwest Research Station. Albany, CA.pp.1-32.

Cite as: Jackson, M. 2004. Management guide for spring freeze injury. 1 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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April 2004

By
Marcus Jackson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Winter Injury (Red Belt)

South and west slopes are usually affected more than north and east slopes.

Hosts: All Conifers

Topics

Key Points

- Desiccation or drying of foliage.
- Early fall freeze.
- Late spring freezes.
- South and west slopes are usually affected more than north and east slopes.

Damage

Winter desiccation and rapid temperature fluctuations generally damage or kill foliage but cause less damage to buds and branches. Foliage damaged or killed by both rapid temperature fluctuations and winter desiccation often remains green as long as temperatures are cold. Damaged needles then turn brown when temperatures increase in late winter or early spring. New foliage usually emerges later in spring or early summer. Since buds and branches often survive, winter injury often only causes lost growth and aesthetic problems in conifers, but it does stress trees and occasionally kills those that are otherwise considered hardy.

Identification

Foliage turns yellow to dark brown in late winter or spring. Winter injury symptom patterns across the landscape and within individual trees vary. Snow insulates needles, so damage may occur only above the snow line. Since wind can accelerate water loss from foliage, desiccation is often directional toward prevailing winds. Winter desiccation may be greater near light colored surfaces (white building siding, white rock mulch, etc.).

The phenomenon known as "red belt" is a form of winter injury that can affect distinct patches or elevational bands of all Rocky Mountain coniferous forest tree species, but lodgepole pine forests are affected most. South and west slopes are usually affected more than north and east slopes.

Symptoms and Causes

Reddish-brown, dead foliage first seen on evergreen trees in late winter or early spring is often the result of injury sustained in the previous fall or winter. This injury may be the result of desiccation (drying of the foliage) or rapid temperature fluctuations. Desiccation occurs when the ground contains inadequate moisture due to drought or when a tree is unable to access moisture to replace water lost by the foliage. Rapid drops in temperature to below freezing can also kill evergreen foliage when it is not adequately hardened off. Discoloration can be greater when trees are improperly planted or stressed by insects, diseases, drought improper fertilization, poor soils, or when non-adapted seed sources are used.

Desiccation injury to top of trees above winter snow pack.
Photo by Jed Dewey

Management

No special management is usually necessary; however, proper watering, fertility, and pest management during the following spring and summer months may improve new growth of affected trees, helping them to recover. Well adapted seed sources should be used when planting trees.

Other Reading

Hiratsuka, Y. 1987. Forest Tree Diseases of the Prairie Provinces. Canadian Forest Service Information Report NOR-X-286. Northern Forestry Centre, Edmonton, Alberta. pp. 114-117.

Miller, P. R. 1993. Abiotic Diseases. *In* Diseases of Pacific Coast Conifers. USDA For. Serv. Ag. Handbook 521. Pacific Southwest Research Station. Albany, CA. pp.1-32.

Cite as: Jackson, M. 2004. Management guide for winter injury (red belt). 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Bark Beetles

&

Wood Borers

BARK BEETLES

Bark Beetle General Biology: Overview

Topics

Many species, but only a few are tree killers.

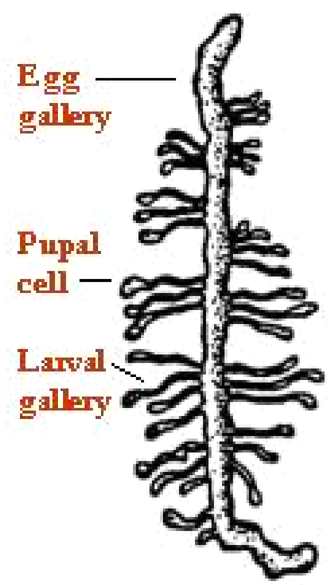
Bark beetles can be particularly destructive pests with some rather remarkable habits. Most belong to one subfamily of beetles, Scolytinae, and are represented by some 600 species in the western United States. Here, we will address the more important and commonly encountered species that actually kill trees.

Figure 1 illustrates the more common bark beetle species encountered in the Interior West with a reasonable facsimile of their galleries. Tables 1and 2 list the characteristics of the most common and destructive *Dendroctonus* beetles in the Intermountain and Northern Regions.

Life History

As a group, bark beetles have many interesting adaptations for their life under the bark of trees. One feature, which is distinctive to this family, is the habit the parent beetles have of boring tunnels under the bark for feeding and egg laying. Adults of most other insects found under tree bark lay their eggs on the outside and the small larvae bore into the bark, or the female inserts the egg through the bark with a strong ovipositor. Adult bark beetles bore directly into the bark, construct a tunnel and lay eggs. This behavior provides a strong identifying characteristic used to identify various species; such as, bark beetle gallery patterns (See figure 1 on page 3).

Many bark beetle adults construct vertical galleries in which they feed and the female beetle deposits eggs. This gallery construction, in conjunction with the introduction of xylem-infesting fungi and feeding activity of larvae, eventually girdles and kills the tree. Following egg hatch, generally a 9-14 day period, larvae feed and complete their development in galleries that usually branch out at right angles from the egg gallery. They feed within the inner bark (cambium-phloem layer),



Bark beetle galleries *generally include the egg gallery along which the eggs are deposited, the larval galleries which are mined by the developing larvae, and the pupal cells in which the larvae pupate.*

Species Guides

Mountain pine

Douglas-fir

Spruce

Western pine

Red turpentine

Roundheaded pine

Jeffrey pine

Fir engraver

Pine engraver

Six-spined Ips

Western balsam

Pinyon engraver

Cedar bark

Key Points

- Bark beetles are opportunists.
- They are generally attracted to less-vigorous hosts.
- Multiple age class trees and tree species diversity reduces impacts.

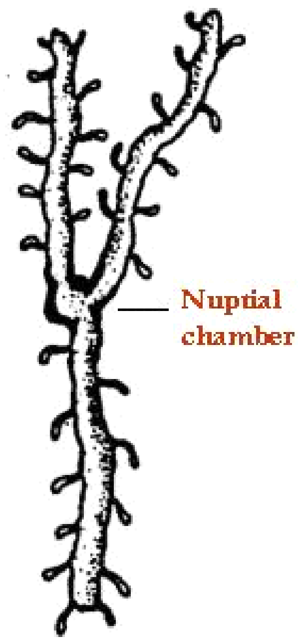
often lightly scoring the sapwood. A few species complete larval development and pupate in the outer bark.

Bark beetles undergo complete metamorphosis, passing through four stages of development during their life cycle (egg, larvae, pupa, adult). All stages are at some time of the year found under the bark of their host tree where developing beetles are protected from weather, parasites and predators. Small, white, shiny eggs are placed in niches along the side of the egg gallery. Once hatched, larvae are easily recognized from their position and appearance. They are white, wrinkled, plump grubs with distinct heads, but no legs and are usually found in a "C"-shaped posture. They are found in galleries radiating from the main or central egg gallery.

Larvae develop into pupae, typically in chambers formed at the end of their feeding galleries. Pupae are white, hairless, and reveal the formation of adult features such as eyes, legs, antennae, and wings. They are approximately the size of the adult beetle (3-8 mm).

Adult beetles are stout, cylindrical, have hard wing covers (elytra). Their membranous flying wings fold away neatly below the elytra when not in use. Adults are usually light yellow in color when first formed (callow adults), changing to reddish-brown or black when mature.

Parent bark beetles bore tunnels under the bark for feeding and egg laying.



A nuptial chamber may be constructed by a male that mates with more than one female. As the females each produce their egg gallery away from the nuptial

Mating habits influence gallery appearance

Mating habits of bark beetles differ by species, the result being various and distinctive gallery patterns. Many scolytids are polygamous—one male beetle mating with two or more females. Each female constructs her own egg gallery, starting from a central (nuptial) chamber beneath the bark. This results in a forked or radiating pattern of egg galleries, as exemplified by beetles of the genus *Ips*. (See illustration at left.) It appears that beetles mate frequently, so a common feature in the polygamous-type gallery system is that the egg tunnels are clean. These open runways allow free and easy access to all branches of the gallery. Apparently the male beetle does most of the work in cleaning the tunnels.

In the other mating arrangement, only one female is associated with each male. Monogamous beetles mate and remain together in the egg tunnel while the female deposits her eggs. Since there is no need to keep tunnels open, monogamous beetles typically allow them to fill with boring dust. *Dendroctonus* beetles are well known for this habit. Most *Dendroctonus* beetles found in the Rocky Mountain area have relatively straight egg tunnels oriented with the axis of the tree and vary in length up to 36 inches. A notable exception to this gallery pattern is the circuitous gallery constructed by *D. brevicomis*. Individual larval galleries are generally oriented perpendicular to the egg gallery and may extend from either side, usually in alternating patterns. Some of the smaller genera of monogamous beetles maintain clean galleries.

Gallery patterns and adults of some important bark beetles

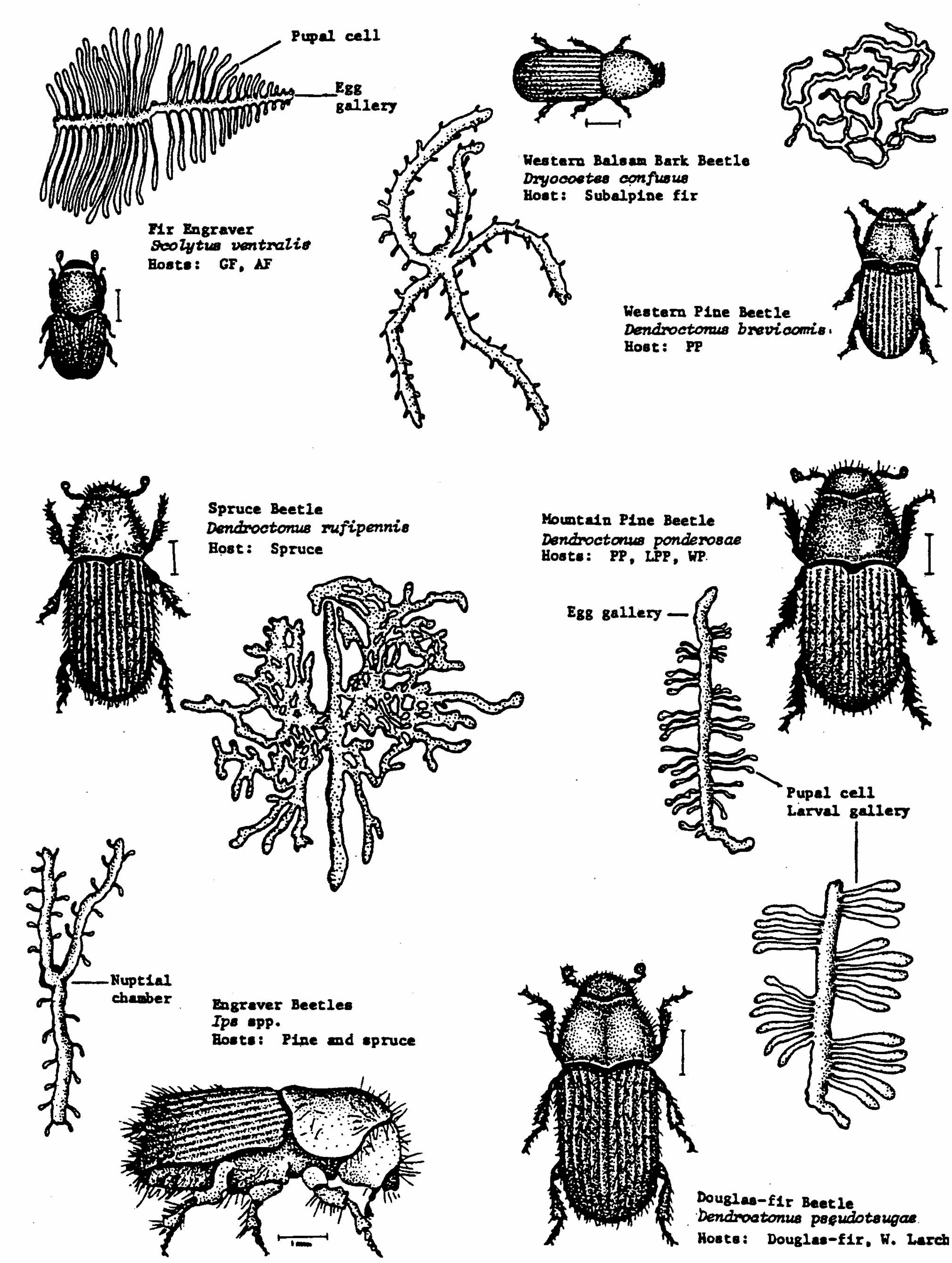


Table 1. Identification of *Dendroctonus* species -- stands and hosts.

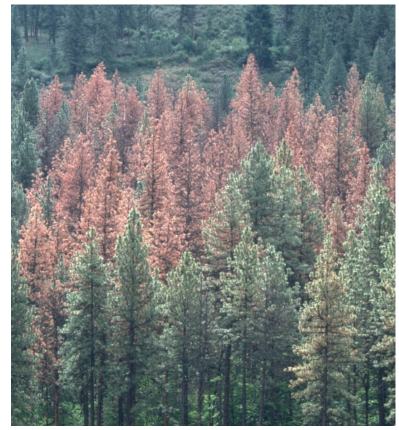
Host Tree	Bark beetle	Characteristics of Susceptible stands	Location in Tree
Ponderosa pine	Mountain pine beetle *Dendroctonus ponderosae*	Even-aged second-growth stands with BA >120 ft^2; old-growth trees with high risk rating (dbh >10") and poor sites	Trunk of trees up to 6" diameter
Ponderosa pine	Western pine beetle *Dendroctonus brevicomis*	Normally found in trees weakened by drought, lightning, fires, etc. Under epidemic conditions can be found in unmanaged stands.	Trunk of tree
Lodgepole pine	Mountain pine beetle *Dendroctonus ponderosae*	Old-growth stands (>80 years) with trees above 8" dbh, and stand BA > $120ft^2$ in the lower elevation zone for lodgepole pine	Trunk of tree up to 5" diameter
White pine species	Mountain pine beetle *Dendroctonus ponderosae*	Larger diameter western white, limber, and whitebark pines occurring in dense stands, dense stem clusters.	Trunk of tree
Engelmann spruce	Spruce beetle *Dendroctonus rufipennis*	Infestations start in logging slash, windthrow, and damaged trees. Susceptible stamds consist of BA>150, average spruce dbh >16", more than 65% of the overstory composed of spruce.	Along the bole up to 6" dbh, in shaded areas of down trees particularly along the underside of tree boles.
Douglas-fir	Douglas-fir beetle *Dendroctonus pseudotsugae*	Stressed trees weakened by drought, fires, etc. BA>$250ft^2$, dbh>14", age>120, high percentage of host trees. Windthrow creates favorable habitat for beetles.	Along the tree bole up to 5" dbh.
All pine	Red turpentine beetle *Dendroctonus valens*	Generally found at base of trees infested with other bark beetles and in stumps in a logging operation.	Attacks of beetle found in lower 10 feet of tree

Table 2. Identification of *Dendroctonus* species -- beetles.

Name of Insect	Size of Adult	Color of Adult	Insect Life Cycle	Time of Attacking New Tree
Mountain pine beetle	1/5"-1/4"	Black	1 year	July through August
Western pine beetle	1/8"-1/5"	Black	1-2 generations per year	Spring to Fall with some overlap between flights
Jeffrey pine beetle	1/4"-3/8"	Black	1 year	July through August
Spruce beetle	1/4"	Dark reddish-brown to black	1-2 years	June and July
Douglas-fir beetle	1/5"	Reddish to dark brown to black	1 year	Early spring, extending into summer
Red turpentine beetle	1/4"-3/8"	Reddish	1 to 2 per year	Mid-summer

Beetles gang up to overcome a tree's defenses

Although bark beetles derive important advantages from breeding and feeding beneath the bark of their hosts, the tree does have a method to defend itself from attacks. Attacking beetles are often in danger of being drowned in their galleries by tree pitch. In fact, the beetles must kill the host tree or at least a portion of it to stop this pitching before they can establish a brood. Gallery construction, attraction of other beetles, and introduction of fungi are all elements associated with beetles ability to overwhelm the trees' natural defense.



Bark beetles use powerful attractants to produce mass-attacks that overwhelm the original focus trees and adjacent trees in close proximity.

The importance of pitch

The effect of pitch on the beetles influences their choice of a host tree. Research has shown that beetles are more tolerant of pitch produced by their natural host trees than they are of pitch from other tree species. But, even in their natural hosts, large volumes of pitch can drown or drive the beetle from the gallery. "Pioneer" beetles apparently have the ability to select "less vigorous" trees—ones less likely to produce overwhelming amounts of pitch. Successfully attacking beetles mix pitch with boring dust and push it out of the entrance hole, forming what are called "pitch tubes" on the outside of the bark. Pitch tubes, then, typically mark the entrance hole for a pair of beetles, some of which may be successful attacks and some not. Although this attack pattern is typical for most bark beetles, not all attacks result in pitch tubes.

Chemical communication

Bark beetles communicate through the use of chemical messagers (pheromones). Attractants are complex chemicals excreted from their hindgut as they feed. These chemicals are concentrated in the frass (a combination of excrement and boring dust) and evaporate into the air as it is pushed out of the gallery. These "message-bearing" chemicals soon attract additional beetles to the tree, producing a "mass attack," which overwhelm a tree's defenses. Anti-attractant pheromones, produced mostly by male beetles, prevent a single tree from being overpopulated. A very effective combination of attractant and anti-attractant pheromones concentrates large numbers of beetles resulting in pockets of tree mortality. As the infestation increases in size, large landscapes of susceptible host trees may be affected.

Cite as: Anonymous. 2004. Bark beetle general biology: Overview. 5 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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North Dakota: (701) 228-5422	

Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Cedar Bark Beetle

Phloeosinus spp.

By Brytten Steed
US Forest Service

Beetles in this genus are native and are primarily found on Rocky Mountain and Utah junipers.

Hosts:
- Rocky Mountain and Utah junipers.

Topics

Key Points

- Most of the 25 species of *Phloeosinus* found north of Mexico are in the West.
- They are typically non-aggressive, feeding under the bark of the bole and branches of stressed, dying, or felled trees, or broken branches.

Damage

An initial yellow-green, then red-brown discoloration of sections of the tree crown (flagging) or the entire crown from adults feeding on twigs. The weakened twigs often break, producing noticeable foliage-drop on the ground. Although this foliage damage may not impact a tree's overall heath, it does indicate that adult beetles are present and active. Significant host damage or death results when adults attack live but stressed trees to produce brood. Typically, stems down to ¾" inch diameter are attacked, so risk to seedlings and small junipers is minimal..

They are typically non-aggressive, feeding under the bark of the bole and branches of stressed, dying, or felled trees, or broken branches. However, under prolonged stress conditions such as drought, intense vegetation competition or livestock damage, beetle populations may build and attack otherwise healthy trees.

Life History

Larvae overwinter under the bark. From spring through late summer, newly-emerged adults feed on the ends of branches of healthy host trees to complete their development. After mating, adults attack and bore into a susceptible host, creating a short, longitudinal gallery where eggs are uniformly deposited along the sides. After larvae hatch out, they mine perpendicular to the gallery, severing the tree's conducting tissue. One to one-half generations may be produced each year .

Egg and larval galleries. Photo by William Ciesla

Identification

Discolored sections of foliage (yellow-green to red-brown) on the tree and/or ground are caused by feeding of newly emerged adults. Small entry holes on the bole and fine boring dust in bark crevices, webbing, and around the base of the bole.

Bark removal will reveal larval galleries, with possible larvae, pupae, and adult life stages. Numerous shot-like exit holes found on boles and branches of dead, red-foliaged trees.

There are no known available systemic insecticides.

Management Considerations

There are neither existing direct chemical controls nor silvicultural options for cedar bark beetle management at a forest landscape level.

- Trees in high-value areas may be culturally managed by reducing vegetative competition, and avoiding; soil compaction, root disturbance, chemical exposure, and animal damage.
- The prompt removal and treatment (burn, chip, or bury) of infested trees may help in limiting population growth.
- High-value trees may be chemically treated with carbaryl (trade name Sevin) as a preventive mechanism. Trees are no longer considered chemically treatable if beetle populations are established under the bark (there are no known available systemic insecticides).

Other Reading

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Cite as: Steed, B. 2004. Management guide for cedar bark beetle. 3 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

Revised 2011

Forest Health Protection and State Forestry Organizations

Management Guide for

Douglas-fir Beetle

***Dendroctonus pseudotsugae* Hopkins**

Douglas-fir beetle is the most destructive bark beetle of Douglas-fir in the northern and central Rocky Mountains.

Sandra Kegley

Topics

Key Points

- Prevent outbreaks by removing windthrow and other damaged trees.
- Trap trees are effective in reducing local populations.
- Use hazard rating to identify susceptible stands.
- Pheromones can provide short-term protection of high-value trees.

Outbreaks are brief but damaging

Epidemics, though usually short-lived, may devastate susceptible stands before subsiding. Outbreaks are usually triggered by a disturbance such as wind-throw, fire scorch, or defoliation. Populations expand rapidly in such weakened material and subsequent generations of beetles attack and kill surrounding green trees. During outbreaks, groups of dead trees may total 100 or more and yearly mortality may extend into the millions of board feet. As more of the susceptible hosts are killed, and attacking beetles are forced into increasingly-less susceptible trees, populations decline. Thereafter, mortality is confined to individual trees or small groups. Low beetle populations are maintained in root diseased or other weakened trees.

Outbreaks typically last 2 to 4 years but may be prolonged during periods of drought.

Management options for Douglas-fir beetle include :

1. **Prevention. Prompt salvage of windthrown, fire damaged, or defoliated Douglas-fir; judicious timing of logging and prompt removal or disposal of logs, large slash and cull material to eliminate potential brood sites.**
2. **Hazard Rating and Stand Manipulation. Identification and silvicultural treatment of high-hazard stands to reduce susceptibility.**
3. **Trap Trees and Pheromone Tree Baits with Tree Removal. Felled trap trees and attractant pheromone baited trees are used to lure beetles into logs and trees that will be removed and processed.**
4. **Anti-aggregation Pheromones. Used to protect high-value trees and stands or prevent beetle colonization of windthrown trees.**

Recognizing Douglas-fir beetle attacks

Orange-brown boring dust is evidence of successful attack by Douglas-fir beetle.

Evidence that a tree has been successfully attacked is orange-brown boring dust found in bark crevices on the lower portion of the tree's bole or on the ground at its base. Wind and rain may remove the dust, however, and since beetle attacks are often high on the bole, careful inspection may be required to determine if beetles are present. An occasionally evident sign of infestation may be clear resin streams which have exuded from the upper level of attacks-typically 30 to 35 feet off the ground. These pitch streamers are often visible for a considerable distance. Streams of pitch lower on the bole may be evidence of unsuccessful attacks or other injury. As a rule, successful attacks can only be confirmed by removing sections of bark to reveal egg galleries, eggs, and/or developing brood.

Distinctive egg galleries are constructed beneath the bark by female beetles as they bore upward through the phloem. Galleries are parallel to wood grain and are commonly 8 to 10 inches in length, usually longer in downed logs. Eggs are laid in groups, alternately along opposite sides of galleries. After hatching, larvae mine outward from, and perpendicular to, the egg gallery as they feed in the phloem.

Several months after a tree has been attacked, its foliage begins to discolor. Needles first turn yellow, then orange, and finally a reddish brown. Discoloration rate varies with local conditions and individual trees. During dry years, trees fade more quickly-occasionally becoming yellowish-green to orange later the same year they are attacked. Typically, trees begin to fade the year following attack. Tree-to-tree fading also varies with resistance to the pathogenic fungi introduced by the beetles.

Egg galleries of Douglas-fir beetle are vertical and the larval galleries are in alternating groups.

Recognizing Douglas-fir beetle

When the larvae have completed their development, they construct pupal cells at the ends of their feeding galleries. Pupal cells may be well within the bark. Larvae are white, legless grubs with brown heads; pupae white to cream-colored. Immature beetles are light brown, becoming dark brown to black, with reddish wing covers, as they mature. Some beetles may be totally black.

Life History

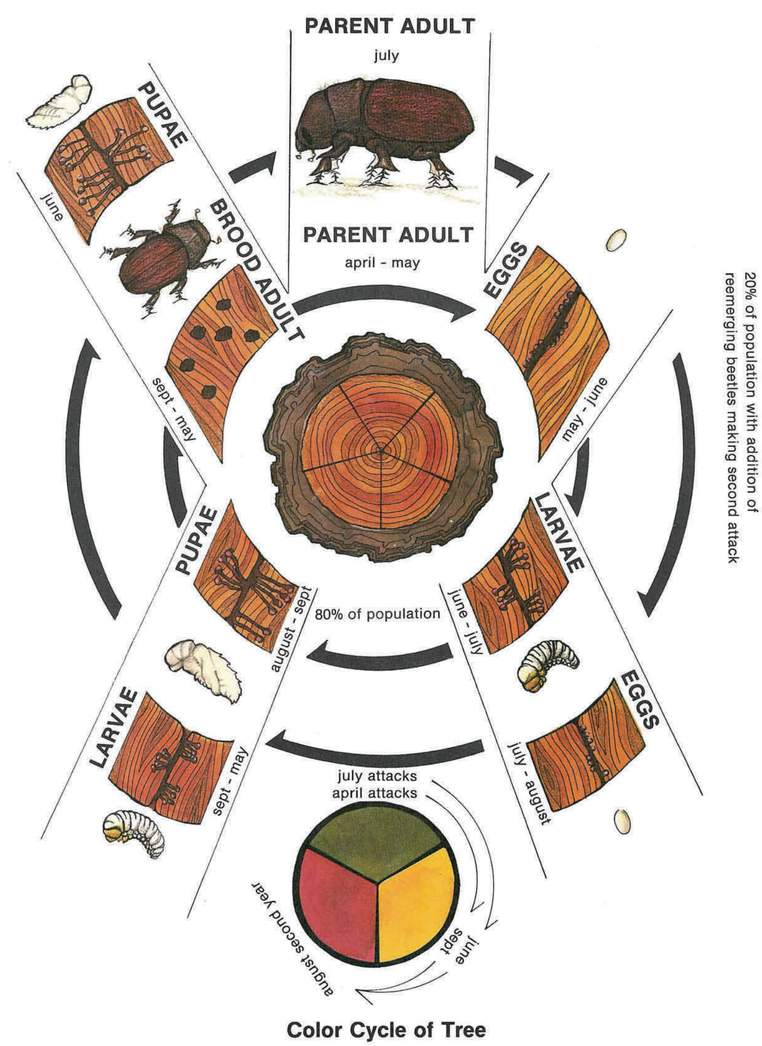
Douglas-fir beetle has one generation each year. Over wintering takes place beneath the bark of the tree in which they developed and occurs mainly as adults. A small percentage may over winter as larvae. Spring emergence of adult beetles varies with location and weather, but usually occurs from mid-April to early June. Beetles that have passed the winter as larvae complete their development in spring and early summer. Those emerge and attack host trees in mid-summer.

In addition, a few adults that made initial attacks in the spring may re-emerge to make a second attack in mid- to late-summer. This second flight (in some years nearly a continual flight) usually accounts for less than ten percent of the yearly total of attacked trees. Often, these later attacks fill in trees which were attacked during the initial spring flight.

Broods require one year to complete their development. Beetles emerging in spring are from the previous spring's brood and beetles flying later in the summer are typically from summer broods.

Western larch may occasionally be attacked, but successful brood development has only been recorded in downed trees.

Douglas-fir beetle has one generation each year.



Characteristics of Susceptible Douglas-fir Stands

Old, dense stands of large diameter Douglas-fir are highly susceptible.

Trees killed by Douglas-fir beetle will have red crowns several months after a successful attack.

Douglas-fir beetle often kills groups of adjacent trees in successive years. Older dead with a little remaining foliage are commonly found near recent mortality. Groups such as this are a good place to look for fresh attacks which will have boring dust on stems but green crowns. However, groups of beetle killed trees can also occur miles from previous-year mortality.

Density

Density-related factors reflect the importance of moisture stress and shaded-stem environment. The denser the stand, the higher the susceptibility to beetle attack. Data suggest stands over 80 percent of normal stocking are most vulnerable.

Habitat Type and Species Diversity.

No definitive correlation between habitat type and beetle- caused mortality has been developed. However, mortality is usually greatest on the more moist habitat types where Douglas-fir grows most productively. Warm, dry sites may produce susceptible stands unless they are so harsh that tree growth is sparse and slow. Little mortality has been observed on most of the subalpine fir types in which Douglas-fir is seral. The most susceptible stands have a high percentage of Douglas-fir.

Stand Age and Tree Diameter.

Average age of most Douglas-fir killed exceeds 120 years. In outbreaks and in densely-stocked stands, younger trees may be killed. Larger diameter dominant and co-dominant trees are more susceptible than intermediate and suppressed trees.

Disease.

There is a relationship between root-diseased Douglas-fir and endemic populations of beetles. That relationship is not as pronounced during outbreaks. The presence of root disease in mature trees likely contributes to their susceptibility to beetle attack by exacerbating the effects of moisture stress.

Injury.

Injuries such as wind and snow breakage, fire scorch, or defoliation predispose trees to beetle attack.

Resistance to beetle population expansion increases as:

1. susceptible trees are killed by beetles,
2. stand density is reduced through harvesting,
3. or environmental stress is reduced through improved moisture/ weather conditions.

As infested-group size declines, and a higher proportion of attacked trees survive, natural enemies of the beetle play a bigger role in population reduction. Populations are then maintained at endemic levels through host resistance and natural enemies until conditions conducive to population buildup occur once again.

Reducing Stand Susceptibility

Reducing stand susceptibility is best accomplished by changing one or more of the "high hazard" conditions through some type of stand manipulation. Alternatives include commercial thinning, or any of the several regenerative methods, which will help meet stand and site resource objectives. Any method which will ultimately reduce stocking, percent of Douglas-fir, average stand age or size, will produce stand conditions less favorable to Douglas-fir beetles.

In many Douglas-fir forests, the presence of root disease should be considered and evaluated before thinning. Any type of partial cutting in root-diseased stands can increase root disease severity, spread, and subsequent tree mortality.

A necessary first step in the prevention of beetle outbreaks is the identification of stands most likely to support an epidemic-hence, the value of a hazard-rating system.

Hazard Rating: Identifying susceptible stands

Stand susceptibility is based on characteristics associated with past outbreaks. Furniss, and others (1979), stated stand susceptibility is positively correlated with the proportion of Douglas-fir in the stand, its density, and its age.

Furniss, and others (1981), identified individual tree susceptibility characteristics as well as those factors which seem to delimit susceptible stands. Trees on which attacks are more dense and successful are those which are older, larger, more dominant, and more productive of attractant resins.

Landscape-scale hazard rating

A technique to query stand data for hazard classification has been developed by Randall and Tensmeyer (1999); stands are hazard rated according to the system of Weatherby and Thier (1993). This system provides an easy way to hazard rate stands over a landscape and can help prioritize areas for treatment.

Weatherby and Thier (1993) Hazard Rating system for the Intermountain West

Based largely on the observations of Furniss, and others (1981), but on other published and observed data as well, their hazard-rating system enumerates the following **"high hazard"** conditions for Douglas-fir stands:

Stand density:
- Stocking greater than 250 square feet basal area

Percent Douglas-fir in stand:
- Greater than 50 percent

Average stand age:
- Greater than 120 years

Average diameter Douglas-fir sawtimber:
- Greater than 14 inches

Risk Rating: Predicting levels of mortality in highly susceptible stands

Model to Predict mortality
(Negron and others 1999)

A model to predict Douglas-fir beetle-caused mortality in highly susceptible stands of Douglas-fir

For western Montana/northern Idaho, for Douglas-fir stands of otherwise high-hazard conditions this formula can be used to approximate anticipated beetle-caused tree mortality.

DF mortality = 13.2 + 0.33(DF basal area)

The following damage class levels based on Douglas-fir basal area and average basal area killed by DFB were determined

Douglas-fir Basal Area (ft^2/acre)	Risk of Tree Mortality	Average Douglas-fir Basal Area Killed by DFB (ft^2/acre)
<115	Low	37
115-230	Medium	69
>230	High	112 or more

Preventive management is the most effective and economical method of reducing mortality attributable to the beetle.

Factors initiating outbreaks

Douglas-fir beetle outbreaks are typically initiated by some type of stand disturbance-the most common being windthrow, snow breakage or other weather-related phenomena. Downed trees, logs, or other large-diameter debris are very attractive to Douglas-fir beetles. Partially burned trees after fires and trees defoliated by western spruce budworm or Douglas-fir tussock moth may also trigger outbreaks. Beetles are capable of building high populations in such material in a short period of time because of little or no host resistance. New generations emerge and attack susceptible green trees in the surrounding stand. Once an outbreak has started it normally lasts 2-4 years in an area. During droughty conditions, the beetle outbreak may be prolonged for several years.

Prompt Removal of Windthrow

Timely salvage of down, damaged or severely weakened Douglas-fir is a primary means of preventing beetle outbreaks. Such activity must be accomplished either before beetles attack it initially, or before they emerge the following spring. Beetle-infested material, hauled from the woods, must be processed prior to beetle flight to prevent new outbreaks from being initiated near mill sites.

Trap Trees

Because Douglas-fir beetles prefer freshly downed trees to standing ones, a trap-tree program can be useful in suppressing beetle populations. Beetles are so effectively attracted to felled trees that green trees in the area are rarely attacked except for a few standing trees immediately adjacent to the downed trees. Trap trees are used to lure beetles into felled trees that will be subsequently removed.

Trap trees should be cut prior to beetle flight in early spring (by April 1). Trap trees could be dropped in late fall, if done sufficiently late that they don't dry significantly before spring. Felled trees should be cut in groups of 3 to 5 trees. Diameters should be 15 inches or larger. Trees should be dropped in the shade and left unlimbed and unbucked. Trees left in the sun, or where a major portion of the bole receives direct sunlight, do not attract beetles nearly as well as those in a shaded environment. Trap trees should be left on site until about mid-July to attract beetles throughout their flight period. They should be removed as soon as practical following beetle flight but certainly before the next generation of beetles fly the following April 1. If infested logs are not subsequently removed, tree mortality will likely increase.

Trap trees must be removed as soon as practical following beetle flight to be effective.

Timing of Harvest

An adjunct to a trap tree program is the judicious timing of harvests to take advantage of the beetles' natural attraction to downed trees. Trees dropped in early spring, prior to about April 1, and left through beetle flight, can attract and hold beetles to the site being harvested. This technique can effectively prevent any beetles in the area from dispersing to other sites. Again, infested trees must be removed before subsequent beetle emergence.

A common and practical application of this technique is to cut the right-of-way trees immediately prior to, or during beetle flight and allow the cut trees to serve as trap trees. The cut trees need to be removed prior to fall snows to assure the brood is removed from the forest.

Pheromones

Attractant pheromone tree bait

Attractant pheromones to manipulate beetle populations

When contemplating harvest in Douglas-fir forests with low beetle populations, attractant pheromone tree baits can be used to keep beetles in a specific stand that is scheduled for removal. Tree baits can be used in planned clearcuts, along rights-of-way, or in any other situation where beetle populations exist and baited trees are certain to be removed following their attack. Attacked trees must be removed prior to the next generation of beetle flight or additional tree mortality is likely to occur. Tree baits effectively attract beetles not only to the baited tree, but there is almost always "spill over" to adjacent, unbaited trees. Harvest plans should include removal of all attacked trees. In partial cutting, tree baits should be used with caution to make sure that beetles do not attack any selected leave trees.

MCH provides short-term protection of high-value trees but must be applied before beetles fly in the spring.

Anti-aggregation pheromones to protect trees and stands

MCH (3-methylcyclohex-2-en-1-one) is a natural anti-aggregation pheromone produced by Douglas-fir beetles to prevent overcrowding and optimize brood survival in individual trees or logs. It gives a "no vacancy" signal to other beetles in the area, causing them to avoid an already fully colonized tree. Commercially available MCH is a tool that can be used to protect trees and stands from Douglas-fir beetle-caused mortality that would adversely impact resource management objectives. MCH can also be used to reduce beetle colonization of windthrown trees and therefore prevent population buildup and subsequent tree mortality.

MCH has been synthetically produced and formulated in two different, currently registered, releasing devises:

- plastic bubble capsules that are stapled to individual trees
- tiny polymer flakes that are aerially applied

MCH has successfully provided short -term protection of trees in campgrounds, administrative sites, and high value stands. However, this temporary approach should only be applied until stand conditions are changed to be less susceptible to Douglas-fir beetles or until beetle populations subside. To be most effective, MCH should be applied before beetles fly in the spring. For more specific information in using MCH bubble caps, see Ross et al. 2006.

Above: MCH bubble capsule

Right: MCH polymer flakes

Natural Control

According to Furniss and Orr (1978), resistance of live trees is the most important natural factor controlling Douglas-fir beetle populations. As an outbreak progresses and beetles are forced into increasingly less susceptible trees, the proportion of unsuccessful beetle attacks increase and populations decline.

Climate and weather also influence beetle populations. A sudden, severe cold snap in late fall before beetles are prepared for winter can cause significant beetle mortality. Prolonged cold, rainy spring weather may disrupt the beetles' flight period. At the other extreme, droughty conditions stress host trees and favor population buildups.

Naturally occurring parasites and predators play a role in population reduction during non-outbreak conditions, but apparently are not important regulating factors when beetle populations are extremely high during outbreaks. The most important insect parasite is a Braconid wasp which parasitizes the beetle's larval stage. Predators include Dolichopodid flies, the larvae of which prey upon beetle larvae; and Clerid and Ostomid beetles which are predaceous on both the larval and adult stages.

Woodpeckers feed on wood borers in Douglas-fir trees but have minimal effect on Douglas-fir beetle populations.

Predatory beetles that help to keep bark beetle populations in check.

The checkered beetle (Clerid) is predatory on adult bark beetles.

Ostomid adult beetle. They are predatory on adult bark beetles; attacking them on the outside of the tree.

This is the larval form of a predatory beetle. It preys on bark beetle larvae under the bark of attacked trees.

Other Reading

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January 2006

By Carol Bell Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Fir Engraver

Scolytus ventralis (LeConte)

Primary hosts:
- Grand fir (*Abies grandis*)
- White fir (*A. concolor*- Oregon, California, Idaho, Utah, Nevada, Wyoming, New Mexico, Arizona, and Colorado)
- Red fir (*A. magnifica*- Oregon and California)
- Noble fir (*A. procera*- Washington, Oregon, N. California)

Reported infesting:
- Douglas-fir (*P. menziesii*)
- Subalpine fir (*A. lasiocarpa*)
- Western hemlock *(Tsuga heterophylla)*

Rare occasions:
- Spruce (*Piceae engelmanii*)

Topics

Key Points

- Fir engraver needs only to kill a strip of cambium near its gallery to successfully reproduce.
- Fir engraver will attack trees of any size.
- Various defects such as stain, ring-shake, and decay are associated with old attack scars.
- A healthy tree can recover if sufficient areas of inner bark remain.

Damage

Unlike other bark beetles, the fir engraver needs only to kill a strip of cambium near its gallery to successfully reproduce. Because it does not necessarily kill the tree, fir engraver attacks result in a variety of tree symptoms: (1) dead branches, (2) top kill, and (3) complete tree mortality. Trees that appear healthy are rarely killed except when they are affected by root disease or by a severe, temporary stress such as drought or defoliation. Fir engraver attacks that do not kill the tree cause scars clearly visible on the outer bark.

Various defects such as stain, ring-shake, and decay are associated with old attack scars. These defects will reduce the value of true fir for solid wood markets.

Figure 1. Aerial view of the fir engraver beetle damage. Photo by William M. Ciesla

Life History

Throughout most of its range fir engraver has a one- year life cycle; two years may be required at high elevations, and during warmer years, a partial second generation may form.

Adult fir engraver are shiny black beetles about 1/5th inch long (4 mm). Viewed from the side, they have an incurved posterior with a small central bump that is more pronounced in the males (fig. 10).

There is no evidence of aggregation pheromones in fir engraver. The attack dynamics of this species can be explained solely by its sensitive primary attraction response to host volatiles.

Life History

The fir engraver (FE) is a major pest of true firs throughout the West.

Typically fir engraver leaves infested trees from June through September. Temperature probably controls when adults emerge, leading to earlier emergence during warmer springs and at lower elevations.

Female beetles initiate attacks on random standing green trees, freshly cut logs, and recent wind throws. She bores into the tree's bark and is followed by a male which she mates with. The female bores a horizontal gallery which radiates out on either side of a central nuptial chamber. The gallery is excavated between the outer wood and the inner bark, scoring the wood (hence the name "engraver beetle"). The egg gallery may be anywhere from 4 to 12 inches (10-30 cm) long. During the 5 to 7 weeks after mating the female will lay between 100 and 300 eggs along the gallery. Four to six days after the female begins boring the egg gallery, a yellowish brown discoloration appears in the surrounding area. The stain is caused by the fungus *Trichosporium symbioticum* Wright, which is carried by the beetles.

Yearly mortality attributable to the beetle is quite high in parts of its range, especially where root disease is prevalent.

Figure 2. Gallery pattern of the fir engraver is perpendicular to the grain of the wood. Photo: FE Forest Insect and Disease Leaflet

Identification

Figure 3. Red branches within the a green tree, called flagging, is sign of attack. Photo by Ken Gibson.

Fir engraver will attack trees of any size. Often fir engraver will attack the tree crown, killing individual branches in larger diameter trees. The appearance of yellowed or red branches within a green tree, called flagging, is a sign of attack (fig. 3). The branch collar is a favored attack site of these beetles. Clear streams of pitch flowing from the entrance holes down the trunk may be present- firs do not produce pitch tubes. Pitch streaming is not frequently observed in the intermountain West. Reddish brown boring dust in bark crevices of larger diameter trees or cob webs along the trunk is usually present.

Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree in a single summer. The foliage turns yellow, and then bright red over the 3 to 6 months after attack (fig. 4).

Figure 4. Red foliage stage on grand fir. Photo by Dave Powell.

Identification

Figure. 5. Signs of fir engraver attack. Bark is bubbled and rippled from outside.
Photo by Chris Schnepf.

Sometimes only strips or patches of the bole are attacked. A healthy tree can recover if sufficient areas of inner bark remain. Top-killed trees can produce new leaders. When the inner bark heals over, a brown pitch pocket marks the injury. The usual evidence of such attacks is roughened patches of bark (fig. 5) or scattered dead branches girdled at the base by the egg galleries.

The gallery pattern of the fir engraver is unique. Unlike most other bark beetles, the female fir engraver constructs a horizontal egg gallery, perpendicular to the grain of the wood (fig. 6). Eggs are deposited on each side of the gallery and the larvae tunnel at right angles to the egg gallery paralleling the wood grain. The larvae are white, legless grubs, reaching a length of about one -eighth inch at maturity (fig. 7). The pupa is also white and approximately the size of the adult (fig. 8). Adult beetles are shiny, black and about one-eighth inch in length. From the side they have an incurved abdomen, a characteristic typical of all members of the genus *Scoltus* (fig 9 and 11).

Fir engraver galleries may be confused with the gallery pattern of another bark beetle, *Pseudohylesinus sericens*. The presence of small, shiny black beetles in the galleries will confirm that the attacking insect is fir engraver, *Pseudohylesinus* are dull in appearance.

Figure 6. Fir engraver galleries. Photo by David Beckman, Idaho Dept. of Lands

Fir engraver and another bark beetle, *Pityokteines elegans*, often attack the same grand fir (*Abies grandis*) trees.

Figure 7. Fir Engraver larva.
Photo: National Agriculture Library

Figure.8. Fir engraver pupa.
Photo: National Agriculture Library

Figure 9. Fir engraver adult
Photo by Donald Owen

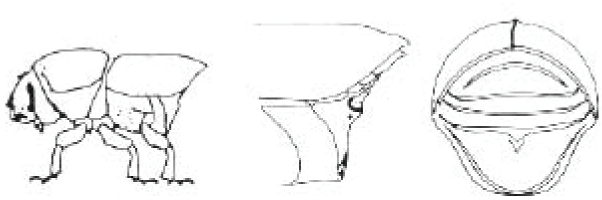

Figure 10. The characteristic incurved abdomen
Photo: FE Forest Insect and Disease Leaflet

Figure 11. Photo: University of British Columbia

Identification

Fir engraver caused fir mortality often increases in response short duration stressors, especially drought or epidemics of defoliating insects.

Recent studies show a moderate level of competition between these two bark beetles; they did not partition the bole of the host according to diameter. *P. elegans* would either colonize an area of bark before fir engraver, which would in turn not initiate attack, or in which both species would co-attack a host, but fir engraver would avoid phloem colonized by *P. elegans*.

Fir engraver is often associated with roundheaded fir borer, *Tetropium abietis* Fall, or the flatheaded fir borer, *Melanophila drummondi* Kirby; however the winding galleries of both borers are largely limited to the lower, thick barked areas of the trunk. During outbreaks, fir engraver alone is generally responsible for most of the damage.

Management Considerations

Overstocked grand fir stands have the greatest chance of beetle attack.

Overview-

Silvicultural practices aimed at maintaining healthy stand conditions appear to offer the best chance for minimizing engraver-caused losses. Overcrowding, disease, and drought often result in stress. Overcrowded trees compete with one another for limited resources, while diseased trees are unable to fully utilize the resources available to them. If a stress is of sufficient duration and severity, the tree may be unable to resist attack by fir engraver.

The Under-Story

Schenk et al. (1976) have identified groups of understory plant species which are highly correlated with moisture regimes necessary for the vigorous growth of grand fir. The presence of oceanspray (*Holodiscus discolor*), Dewey's sedge (*Carex deweyana*), sandwort (*Arenaria macrophylla*) or yerba buena (*Satureja douglasii*) on a site was strongly correlated with increased FE caused tree mortality. Sites with queencup beadlily (*Clintonia uniflora*) or pipsissewa (*Chimaphila umbellata*) experienced less FEB caused tree mortality.

Hazard rating index--

Schenk et al (1977) developed a stand hazard index to rate grand fir stands for susceptibility to beetle attack based on stand parameters measuring competitive stress and species diversity. This system, which utilizes Crown Competition Factor (CCF) as a measure of stress, and Diversity Index (DI) as a numerical rating for species diversity has shown that pure, overstocked grand fir stands have the greatest chance of beetle attack. As overstocking is relieved and the grand fir component is reduced, the risk of fir engraver infestations is reduced. Data required to derive both the CCF and DI values (species, d.b.h., number trees/plot) are routinely taken during standard timber inventories.

Silvicultural Treatment

Silvicultural treatment.--

The maintenance of vigorous stands through the elimination of competitive stress, removal of dead and dying trees, and treatment of external stressors is the best means of reducing fir engraver-caused mortality.

- If fir engraver attacks are associated with a root disease pocket, the best strategy is to follow root disease management guidelines.
- Treatment to reduce the level of defoliation caused by forest insects such as the spruce budworm and Douglas-fir tussock moth will reduce the likelihood of subsequent fir engraver mortality.
- Remove injured or decadent true fir that might provide breeding material for the fir engraver. Poor crown condition and live crown ratios have been associated with susceptibility to fir engraver attacks in white and red fir. These declining trees should be harvested whenever possible.
- Fir engraver can breed in fresh slash with a diameter >4 inches. Avoid creating large pieces of true fir slash from January-July and remove or treat wind thrown trees and logging slash before fir engraver flight.
- Overstocked fir stands should be thinned to reduce competition and increase tree vigor.
- Douglas-fir and western larch are major seral components in most grand fir habitat types. Where conditions permit, species conversion or increased species diversity should be considered.

Schenk et al (1977) developed a stand hazard index to rate grand fir stands for susceptibility to beetle attack based on stand parameters measuring competitive stress and species diversity.

Figure 12
Clerid beetle

Figure 13
Braconid wasp

Natural Controls

Natural control.--

Though a number of insect parasites and predators have been found in association with fir engraver, they are not effective in preventing outbreaks. Two species of Clerid beetles (fig. 12) found preying on various life stages of the beetle and two species of *Braconid* wasps, (fig. 13) parasitic on the larval stage, occasionally destroy large amounts of brood.

Extremely low winter temperatures can kill broods; however, normal snow depths usually protect overwintering larvae. Combinations of adverse weather and natural enemies may result in reduced fir engraver populations, though silvicultural control offers the most reasonable approach to beetle management.

Classical Biological Control. –

No classical biological control program has been mounted against the fir engraver. Although fir engraver is responsible for major losses in western forests, the potential for enhanced biological control through importation of additional natural enemies appears somewhat limited.

Clean up windthrown trees

The primary factors predisposing trees to attack appear to be related to forest health and tree vigor, not lack of natural enemies of the beetle.

Hazard Trees. —

Many living true fir tree show evidence of past attacks by fir engraver. Some signs of past attacks include: bole irregularities such as bulges and unusual bark relief, dead top, and dead branches scattered throughout the crown. Such dieback is common and may or may not have much bearing on a tree's longevity. A tree's chances for survival are inversely related to the severity of dieback in the crown.

The biggest concern with dead tops and branches is their potential to breakout and fall. Dead branches and tops should be pruned from a tree in areas where their falling presents a hazard. Dead tops in true firs are often replaced by a side branch or branches that turn up and become "volunteer tops." Such tops are not as firmly attached to the bole of the tree as the original top was and have the potential to break out under wind and snow loads.

Direct control of fir engraver populations over extensive areas in the intermountain West is usually neither warranted nor recommended. Because of the scattered nature of beetle attacks -- in tops and portions of trees -- identification and treatment of all infested trees would be impractical, if not impossible.

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Photo Credits
Figure 12. - http://www.ozanimals.com/wildlife/Insect/Beetles.html
Figure 13 - http://bugguide.net/node/view/170

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May 2004

By Darren Blackford
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Jeffrey Pine Beetle

Dendroctonus jeffreyi Hopkins

The Jeffrey pine beetle (JPB) is the primary insect that attacks and kills Jeffrey pine.

Hosts

- Jeffery Pine

Topics

Key Points

- These beetles typically breed in and kill slow-growing trees of reduced vigor.
- Tree mortality generally occurs in single-tree settings rather than in groups.

  Outbreaks occur usually during drought periods.

Damage

After JPB penetrates the bark and reaches the junction of bark and wood, they construct their egg gallery by boring diagonally upward across the grain of the wood for 2 or 3 inches, then vertically parallel to the grain for an additional 2 to 4 feet. Each egg gallery is constructed by a single pair of beetles. As construction of the gallery progresses, the female lays her eggs singly in niches along the sides (figure 3,B), and the gallery is then packed solidly with boring dust and frass.

Life History

The life cycle of JPB is ordinarily completed in 1 year in the northern part of the range, but in the southern part two generations per year may occur. Frequently, one complete and a partial second generation develop. The principal period of attack is in June and July, but attacks can also occur through September into early October. The beetle most often overwinters in the larval stage but will also overwinter in the adult stage.

The eggs hatch in 1-3 weeks. The length of the larval period varies considerably as most of the insects overwinter in the larval stage. Mature larvae pupate in cells constructed at the ends of their galleries pupate (figure 3, D).

Figure 1. Distribution of the Jeffrey pine beetle in North America.

Figure 2. Jeffrey pine killed by the Jeffrey pine beetle.

The pupae mature in about 10 days and then transform into adults. The adults emerge from the pupal cells by tunneling out through the bark.

Identification

In diagnosing JPB as the cause of mortality, it is important to establish the infested tree is Jeffrey pine. The mountain pine beetle (*Dendroctonus ponderosae* Hopk.), a closely related insect, is practically indistinguishable from the JPB, and the two species make similar galleries. One of the hosts of the mountain pine beetle is ponderosa pine (*Pinus ponderosa* Dougl. ex Laws), a tree often found growing in association with Jeffrey pine and can be incorrectly identified as Jeffrey pine. Some distinguishing characteristics between these two tree species include the bent-back prickle at the end of *P. jeffreyi* cone scales, the vanilla (and other) odors eluted by the cambial layer of *P. jeffreyi*. Jeffrey pine is also readily distinguished from *P. ponderosa* on the basis of bark, leader, needle, bud, and cone morphology (Haller, 1962).

Large, reddish pitch tubes (fig. 4) can be found projecting from the bark on all portions of the boles of infested trees. Pitch tubes mark the first points of attack and can be found long before the foliage begins to fade. Mid bole attacks are most common; however, attacks on the lower bole can be readily observed during outbreaks. Pitch tubes consist of boring dust and resin pushed out by the beetles when they bore into the tree. There are two types of pitch tubes. Pitch tubes on successfully attacked trees are pink to reddish in color and mixed with frass (a mixture of boring dust and beetle excrement). Pitch tubes resulting from unsuccessful attacks are creamy white to yellow and may lack frass. During drought years when trees produce little pitch, infested trees may lack pitch tubes and have only frass marking the points of attack. The green of the needles gives way to greenish yellow, to sorrel, and then to reddish brown.

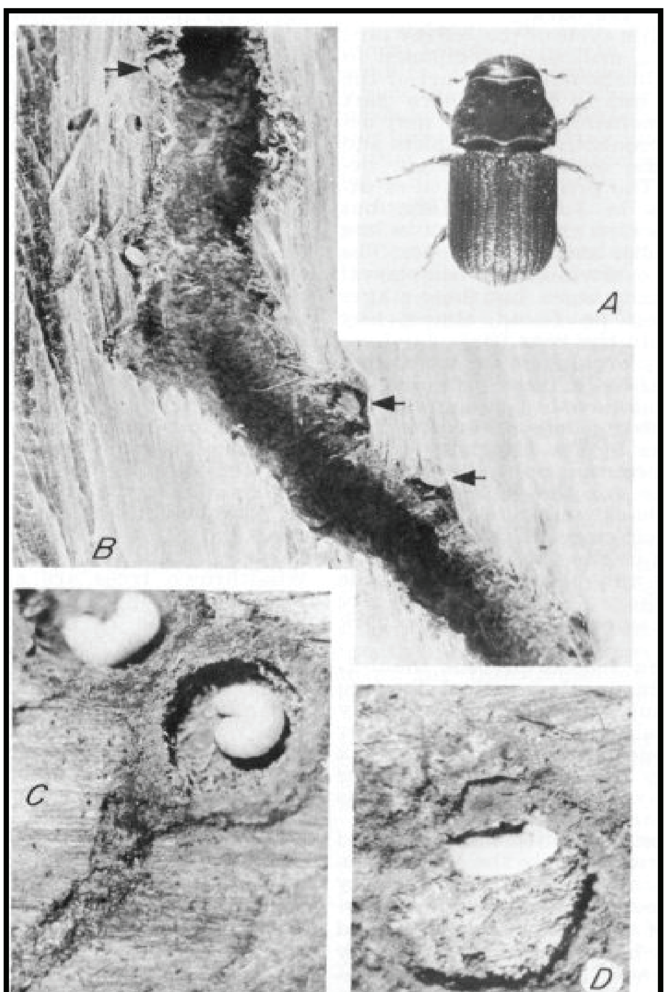

Figure 3. Life stages of the Jeffrey pine beetle:

A, Adult (5/16 in.);

B, eggs in niches in sides of egg gallery;

C, full-grown larvae;

D, pupa in pupal cell.

Figure 4. Pitch tube on outer surface of bark.

Figure 5. Egg galleries, larval galleries, and pupal cells on inner surface of bark.

Fading does not start until after the attacking beetles are well established, and their progeny partly developed. By the time the crown turns sorrel, the new broods are almost fully developed. When the foliage reaches the reddish-brown stage, the beetles have usually abandoned the tree.

The JPB is one of the larger species of *Dendroctonus* bark beetles. In the adult stage it is a stout, cylindrical beetle about five-sixteenths of an inch long and dark brown to black when mature (figure 3, A). The egg is oval and pearly-white (figure 3, B). The larva is a curved, white, legless grub with a yellow head (figure 3, C), and, when grown, it is about the same size as the adult. The pupa also is white but is slightly smaller than the mature larva (figure 3, D).

The galleries of the JPB are straight and vertical and often have a characteristic "J" shape and being packed with frass (figure 5). Galleries can range in length from about 10 inches to 30 inches. No other insect that breeds in Jeffrey pine makes galleries similar to these. If the broods are fully developed, larval mines will be seen extending across the grain and ending in open, oval-shaped pupal cells. If the beetles have matured and left the tree, the outer bark will contain many scattered, circular emergence holes. These are made when the adults burrow out from the pupal cells and disperse to attack other trees.

Management

Normally, the JPB is kept in check by its natural enemies, climatic factors, and the resistance of its host. During non-drought periods Jeffrey pine mortality caused by this beetle usually goes unnoticed.

Silvicultural

- Management activities that promote tree health and vigor will reduce the tree's susceptibility to successful attack by JPB.

- Maintaining basal areas appropriate for the site will limit tree losses during outbreak periods.

Suppression

Direct control – Direct control by removing infested trees can reduce the number of trees infested the next flight period.

- Felling and burning or peeling the bark are also useful methods if tree removal is impractical.

- Peeling the bark to expose the insects to the effects of weather and to predation by birds, ants, and other agents is should be conducted prior to the beetles reaching the pupal stage.
- Chemical treatments are also available to prevent successful JPB attacks. High value trees may be sprayed with a protective residual chemical to prevent successful attack. Protection can be gained for 1-2 years depending on the compound used. The chemical should be applied to the tree bole to run-off and should reach as high up the bole as the equipment will allow.

Prevention

Management objectives should be directed toward preventing, or at least substantially mitigating, development of epidemic beetle infestations. Once populations increase to an epidemic status and outbreaks become large, management of beetle populations, as well as other resources, becomes more complicated.

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2004

Forest Health Protection and State Forestry Organizations

Kenneth E. Gibson
USDA Forest Service,

Management Guide for

Mountain Pine Beetle

Dendroctonus ponderosae Hopkins

Topics

Most frequently killed hosts in the Northern and Central Rocky Mountains:	• Lodgepole pine • Ponderosa pine • Whitebark pine • Limber pine • Western white pine	The mountain pine beetle is the most aggressive, persistent and destructive bark beetle in the western United States and Canada.

Key Points

- Use hazard rating to set treatment priorities
- Prevent outbreaks by regenerating mature lodgepole
- Thinning can help
- High value trees are afforded temporary protection using pesticides

Manage by suppression and prevention

Because outbreaks usually develop in mature to over mature forests, especially in lodgepole pine, large reserves of these forests pose a constant hazard in areas climatically favorable for the mountain pine beetle (MPB). Thus, "storing" mature/over mature trees on the stump should be discouraged, or at least the risk of such should be realized. In addition, management plans for reserved areas, such as parks and wildernesses, should consider the need for protection against destructive outbreaks. The economic impact of tree mortality is largely dependent on the effects of epidemics on allowable cut, regeneration of affected areas, and increased fire.

Management must focus on forests and not MPB. Management should alter stand conditions that favor buildup of beetle populations. However, alternative strategies for reducing losses from MPB must emphasize biologically sound silviculture that includes concern for other resource values.

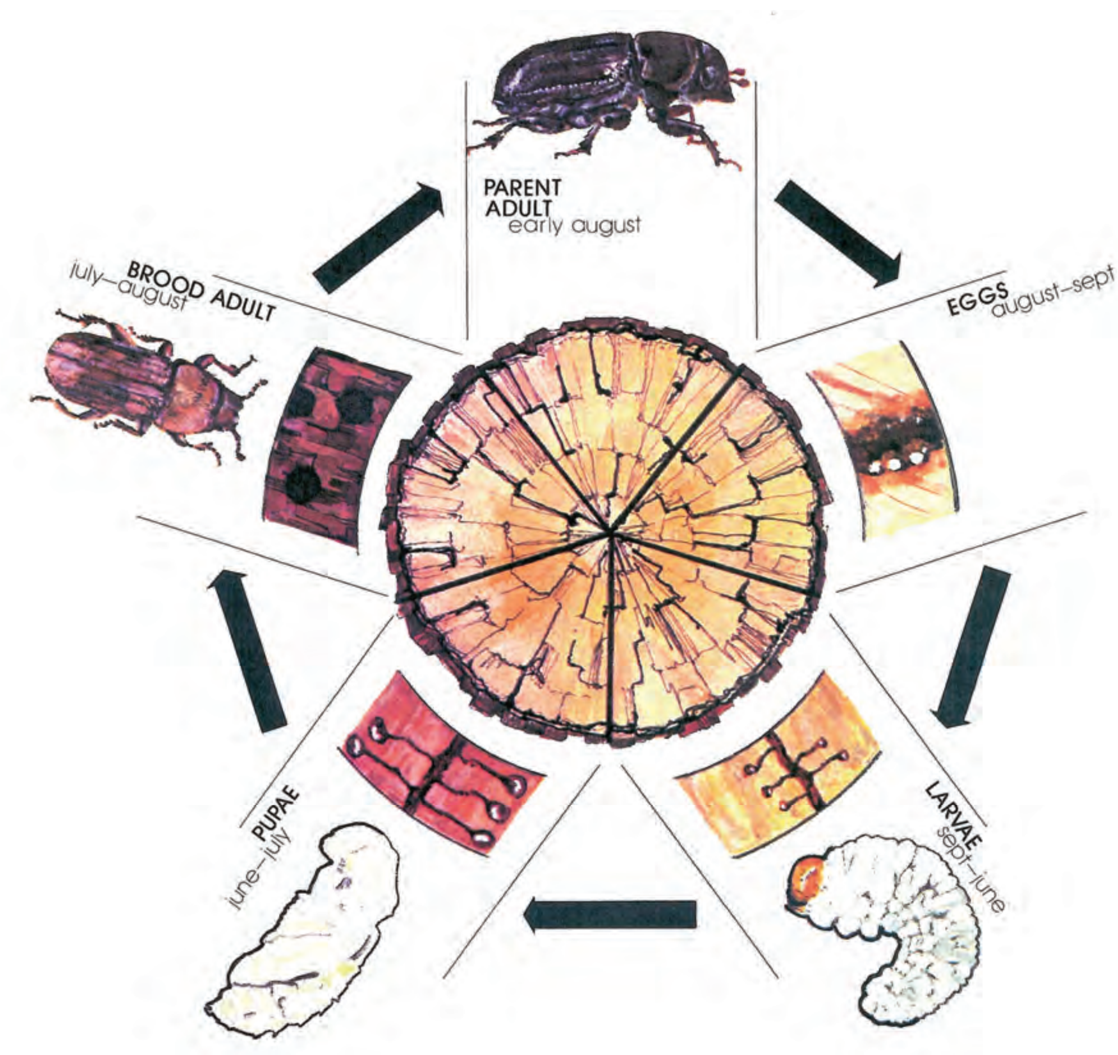
Basically, there are two approaches to reducing losses from MPB in pine forests: (1) long-term (preventive) forest management, and (2) direct control.

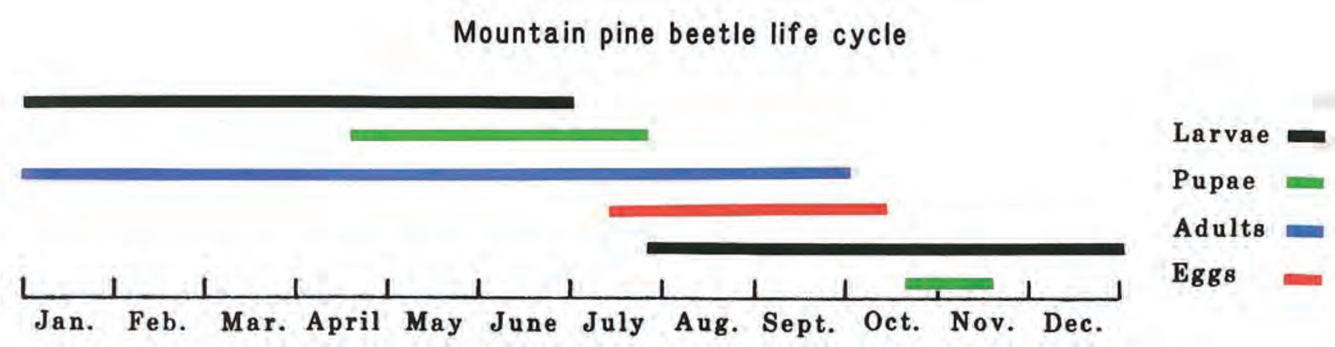
The strategy of preventive management is to keep beetle populations below injurious levels by limiting the beetles' food supply through forestry practices designed to maintain or increase tree/stand resistance. Preventive management addresses the basic cause of epidemics, which is stand susceptibility, and is considered the most satisfactory long-term solution. It includes a combination of hazard rating, priority setting, and silvicultural manipulations. protection costs. Situations where MPB instead of forest managers set priorities and dictate management options should be avoided. In contrast, suppression of MPB populations, that is killing them by various methods of direct control; treats only one symptom of the problem (too many beetles). Effects are usually, therefore, only temporary. When proper1y used, direct control might be effective both in reducing the rate of the spread and intensification of infestations; but should be considered only a “holding action” until susceptible stands can be altered silviculturally.

Life History

Mountain pine beetle over winters mostly as larvae beneath (or within) the inner bark of host trees. Occasionally, pupae and callow adults may also overwinter. In most lodgepole and ponderosa pine stands, larvae pupate at the ends of their feeding galleries in late spring. Adults emerge and attack from about early July through August depending on elevation and temperature. Egg galleries are more or less straight and vertical and may be up to 30 inches long. Eggs are laid along each side of the gallery in individual niches. Both niches and egg galleries are tightly packed with partially digested woody particles, or frass. Eggs hatch and larvae feed until freezing temperatures cause dormancy. Larvae go through four instars before pupating (Amman and Cole 1983).

Mountain Pine Beetle Life Cycle





Controlling MPB in lodgepole pine

Suppression

Direct Control

Direct control is expensive in time, effort, and resources. In spite of its long history, there is no general agreement among scientists and foresters regarding its effectiveness in reducing losses. Operational activities in Canada indicate that direct control can be a temporarily sound strategy and that tactics can be developed to implement it.

Since direct control is expensive, it is usually prohibitive to treat all infestations. Therefore, susceptible lodgepole pine stands need to be prioritized on economic, or other criteria; and control applied only to the most valuable stands. These stands must be resurveyed yearly, and as soon as newly attacked trees are discovered, a decision made on the feasibility of control action. If control action is feasible, direct treatment is applied involving sanitation cutting, controlled burning, single-tree treatment, or a combination of these methods (Safranyik 1982).

In order to be effective, suppression should be based on the following principles:

1. Early detection and control action over the entire infested area within one to two years.
2. Continue control work as long as necessary.
3. Thorough treatment and follow-up surveillance

Methods to kill beetles under the bark:

1. Pesticides (systemic, bark-penetrating) on unbaited or pheromone-baited trees. Chemical control by spraying standing and/or fallen trees provides only a holding action at best until the highly susceptible trees can be removed. Tree mortality will probably result despite any immediate success of direct control measures. Because stand susceptibility is not changed by this management option, reinfestation will occur (Cole and Amman 1980). This type of treatment might be more suitable for treating isolated spot infestations, especially in remote locations or in areas where logging is not possible.
2. Heat (burning, solar).
3. Mechanical (debarking process).
4. Water (sprinkling, submersion).

Individual Tree Protection

Preventative sprays can protect high-value trees in campgrounds, picnic areas, visitor centers, around permanent and summer homesites and administrative areas.

Shade and aesthetics can be protected for up to 2 years with one application of water-based carbaryl spray prior to beetle flight (Gibson and Bennett 1985)

Shore and Safranyik Hazard Rating System

Has three distinct facets:

- a susceptibility index,
- a beetle pressure index,
- a risk index.

Risk index is a combination of ***susceptibility index*** and ***beetle pressure index*** and is a measure of a stand's relative likelihood of sustaining damage from beetle attack in the near future. Risk index is a number, between 0 and 100. Higher numbers, represent higher probability of infestation.

Methods to protect trees from fatal attacks

1. Lethal trap trees baited with pheromone and treated with insecticide.
2. Protective chemicals. Although carbaryl treatments provided the standard preventive measures for more than 25 years, and was the only chemical registered for most of that time; pyrethroid insecticides have been recently tested and registered, and now provide an alternative to the use of carbaryl.
3. The anti-aggregative pheromone, verbenone, has been tested and registered as a preventive treatment. Results have not been as reliable as chemical insecticides, but may be a reasonable alternative in some situations.

Prevention

Management objectives should be directed toward preventing, or at least substantially mitigating, development of epidemic beetle infestations. Once populations increase to an epidemic status and outbreaks become as large as experienced during the 1970's and early 1980's, management of beetle populations, as well as other resources, becomes more complicated.

Hazard rating:

Recurrent depredations by MPB allow the forest manager less than a 50 percent (perhaps as low as 25 percent) chance of growing lodgepole pine to a 16-inch diameter in unmanaged stands. Two commonly asked questions are: (1) which lodgepole pine stands are most susceptible to mountain pine beetle outbreak, and (2) how many trees will be killed, or how much volume loss will occur, if a stand becomes infested?

Susceptibility of stands to MPB depredation is determined by hazard and risk rating stands. Generally, "hazard" is defined as the likelihood of an outbreak within a specific time period and is a function of stand conditions. “Risk" defines expected loss should an outbreak occur and is determined by proximity to beetle populations.

To date, several hazard rating systems have been developed based on climatic, tree, and stand variables that have significant effects on both beetle survival and distribution. That is, tree age, size, stand structure, phloem thickness, climatic conditions, and tree growth all determine stand susceptibility. Such site factors influence amount of tree and volume loss within stands.

The system formerly used in the Northern Region was developed by Amman and others (1977) and involves a 3-point rating of each of three factors: (1) climate (elevation/latitude), (2) average age of lodgepole pine in the stand, equal to or greater than 5 inches d.b.h., and (3) average d.b.h. of the lodgepole pine in the stand, equal to or greater than 5 inches d.b.h. Currently in our Regions, we most often recommended a hazard-rating system developed by Shore and Safranyik (1992). Similar in some respects to the one described by Amman, and others (1977), it is more definitive in its use of more detailed stand information, and it incorporates data relative to nearby beetle populations.

Calculating the Stand Susceptibility Index

To determine a stand's *risk index*, determine first its *susceptibility index* using stand data in the following relationship: The *susceptibility index* will range from 0 to 100. Highest values indicate the most susceptible stands.

Susceptibility Index (S) = P x A x D x L where:
P = Percent of susceptible pine basal area
A = Age factor
D = Stand density factor
L = Location factor

P is calculated: $\frac{\text{Average basal area per hectare of LPP} > 15 \text{ cm d.b.h.}}{\text{Average basal area per hectare all species} \geq 7.5 \text{ cm. d.b.h.}} \times 100$

(Note: Metric units must be used in formulas to assure appropriate table values are obtained.)

Susceptibility index is a measure of stand characteristics which describe their attractiveness to beetles and is based on four variables:

1. Susceptible host basal area (as percent of stand basal area),
2. Age of dominate and codominant host,
3. Stand density, and
4. Location (latitude, longitude and elevation).

Age factor from table:

Age of dominant or co-dominant LPP	Age Factor
< 60 years	0.1
61-80 years	0.6
> 80 years	1.0

Density factor from table:

Stems per Hectare (all species ≥ 7.5 cm d.b.h.)	Density Factor
≤ 250	0.1
251-750	0.5
751-1,500	1.0
1,501-2.000	0.8
2,001-2,500	0.5
> 2,500	0.1

There are three possible location factors, based on a combination of longitude, latitude and elevation. Location factor is determined from the formula Y = [24.4 longitude] -[121.9 latitude] -[elevation (in meters)]+ 4545.1. For most areas on a District, and perhaps over a Forest, the location factor, once determined, will remain constant.

Y	Location Factor
≥ 0	1.0
between 0 and -500	0.7
< -500	0.3

Calculating the Beetle Pressure Index

Beetle pressure index is related to the size and proximity of MPB population being rated. Determine first the size category from the following table:

Number infested trees outside stand (within 3 km)	Number infested trees inside stand < 10	10-100	> 1 00
< 900	Small	Medium	Large
900-9,000	Medium	Medium	Large
> 9,000	Large	Large	Large

Beetle pressure index
is related to size and proximity of nearest mountain pine beetle population. Both relative abundance of beetles and their nearness to the stand for which risk is being determined will influence that stand's likelihood of being infested.

Now, use following table to determine **beetle pressure index**:

Relative Infestation Size	Infestation Within Stand	Distance to Nearest Infestation (km) 0-1	1-2	2-3	3-4	4+
		Beetle Pressure Index (B)				
Small	0.6	0.5	0.4	0.3	0.1	0.06
Medium	0.8	0.7	0.6	0.4	0.2	0.08
Large	1.0	0.9	0.7	0.5	0.2	0.10

Risk Index:

Having determined both *susceptibility index* (S) and *beetle pressure index* (B), we can now calculate *risk index* (R) from the relationship:

$$R = 2.74\ [S^{1.77}e^{-0.0177S}][B^{2.78}e^{-2.78B}]$$

Where:
e = Base of natural logarithm = 2.718
B = *Beetle pressure index*
S = *Susceptibility index*

Alternatively, *Risk index* can be found in the table on page 6. *Risk index* will be a number between 0 and 100. The highest numbers represent stands that would receive the most damage from beetles in the near future

Risk Index Table

Based on Susceptibility Index (S) and Beetle Pressure Index (B)

S	Beetle Pressure Index (B)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
10	<1	<1	2	3	5	6	7	8	8	8
20	<1	2	6	10	14	18	20	22	24	24
30	<1	4	10	17	24	30	35	39	40	41
40	1	6	14	24	33	42	49	54	56	57
50	1	7	18	30	42	52	61	67	70	71
60	2	9	20	34	48	61	70	77	81	82
70	2	10	22	38	53	67	78	85	89	91
80	2	10	24	40	56	71	82	90	95	96
90	2	10	24	41	58	73	85	93	98	99
100	2	11	25	42	59	74	86	94	99	100

Risk index is a relative measure of a stand's likelihood of being infested in the near future -generally less than 3 years. Because it includes beetle pressure, a dynamic statistic, it should be updated every couple of years.

Models to predict stand losses

Risk index is not a predictive measure, per se, but does show a particular stand's likelihood of infestation relative to others evaluated. In a follow-up study, Shore, and others (2000) developed a predictive model that could be used to estimate percent basal area killed, based on stand *susceptibility index*. Their model is expressed as:

Percent basal area killed = 0.68 x stand *susceptibility index*

As an alternative, stands determined to be of highest risk could be subjected to analysis using the Rate of Loss Model (Cole and McGregor 1983) to determine an approximation of loss should infestation occur. This model predicts tree and volume loss over time and helps set priorities for entering high-risk stands. The model is available as part of the FINDIT program (Bentz 2000), and is also a subroutine of the Forest Vegetation Simulator (FVS).

Data used in determining stand susceptibility and risk may be obtained from surveys designed specifically for determining stand susceptibility, timber inventory, or regular stand exams.

Rate of Loss Model

To approximate mortality in high-risk stands:

- Available as part of FINDIT program
- Subroutine of the Forest Vegetation Simulator.

Silvicultural Alternatives: Even-aged lodgepole pine stands

Shortened rotation is a viable option when lodgepole pine is the desired species and a smaller tree size can be grown which would still satisfy product requirements and economics of the operation

Type conversion:

Type conversion can be an attractive choice when most objectives of management can be met equally well with different forest types. Even though the mountain pine beetle appears to infest the lodgepole component of mixed stands as readily as pure stands, the overall stocking and wood production would be higher. Achieving a mosaic of age classes and tree species in stands creates a minimum area susceptible to the beetle, making fast removal and/or application of direct control action more feasible. This operation takes careful long-range planning, good roads, markets, and above all, time.

Clearcutting in small- to moderate-sized blocks creates age and size mosaics within extensive pure even-aged stands and is a highly recommended practice (Amman 1976). Timely surveys and maps of stand growth and volume, site quality, and other risk-related factors such as phloem (inner bark) thickness, elevation, latitude, stand structure and form, composition, and forest type are essential for clearcuts to be effective. Schedules for clearcutting as a preventative measure should be coordinated with other multiple-use management objectives. In areas where probability of loss is high, future damage can be reduced by directing regeneration to alternating species among blocks or to mixed species within blocks (D. M. Cole 1978, Cole and Amman 1980, McGregor and Cole 1965).

Salvage and sanitation cutting:

In practice, salvage and sanitation logging is favored over individual tree treatment because it is more cost effective. Also, salvage operations utilize infested timber and reduce both the number of beetles and their potential food source. Individual tree treatments do not yield any salvage value and it is difficult to thoroughly treat large areas (Safranyik 1982).

Salvage and sanitation cutting should be adjusted either directly by timber economics or indirectly through protection of other resources to qualify as loss reduction practices (D. M. Cole 1978). Salvage cutting should be carefully planned and administered as a conscientious silvicultural practice to protect other resource values. Time between tree killing and salvage cutting should be minimal to prevent wood deterioration. This should be done before beetle flight or it won't be effective in protecting trees in the cutover adjacent stands.

Sanitation cutting

of highly preferred large-diameter, infested trees from high-hazard stands may slow rate of mortality. However, sanitation cutting will not significantly alter stand structure, and beetles will seek out and infest residual, preferred large-diameter lodgepole pine unless all preferred trees are cut or the stand structure is altered. Surveys to inventory stand structure, diameter-phloem distribution, and growth of residual lodgepole pine may permit successful cutting; and prevent, or greatly reduce, beetle infestation for several years. Sanitation cutting is expensive and must be carefully coordinated to prevent spread of beetles into other stands along haul roads or from infested log decks at sawmills. Sanitation cutting must also take into account the presence of dwarf mistletoe or cutting may leave too many infected residuals. Salvage, or a combination of sanitation/salvage, should be used with caution in some stands. Residual stands should be managed to meet objectives for growth, maximum stocking levels, and species composition. Salvage works best where epidemics are in early stages, in well-stocked stands with a relatively minor component of host species, and generally confined to operable ground with access in place.

Stocking control:

This is extremely important in pure, even-aged lodgepole pine stands. It allows maintenance of good stand vigor and the direction of stand growth toward moderate tree sizes and rotation objectives (D. M. Cole 1978).

Stocking control by age 25 (preferably by age 15) to a spacing of about 10 by 10 feet results in culmination of mean annual increment on medium to good sites at about age 80 with average stand diameters of about 20 inches d.b.h. Additional thinning (commercial thinning would prolong the culmination of CAI/MAI from about 80 years to probably 120-130 years. Growth decline and MPB infestation could probably be prolonged for a number of years through early thinnings.

Through stocking control, diameter/phloem thickness distributions could be managed to favor those not preferred by MPB. Alternatively, early stocking control and managed practices for increasing rate of growth (thinnings, genetic improvements, and fertilization) could increase tree vigor so that present age/ size limits of tree susceptibility would not be restrictive (Safranyik 1982).

Photo of stocking control by thinning can make a stand less attractive to MPB.

Silvicultural Alternatives

Pure, uneven-aged lodgepole pine stands and mixed-species stands

Stocking control, clearcutting, and salvage cutting

For uneven-aged and mixed species stands preventive practices mentioned for pure, even-aged lodgepole pine stands are also feasible. For example, mature uneven -aged or mixed-species stands with a significant component of large lodgepole pine in the overstory can be clearcut. If already infested, mortality can be lessened by salvage logging.

Immature, uneven-aged, and mixed-species stands are candidates for stocking control with species discrimination possible in mixed-species stands (D. M. Cole 1978).

Species discrimination

In older mixed-species stands we can discriminate against lodgepole pine by cutting only the larger lodgepole. This can be considered a valid practice in regulated forests only if the residual stand is of sufficient vigor and stocking to maintain stand growth near the yield capability level of the site. However, value of the volume removed must exceed removal costs unless indirect benefits of beetle management warrant subsidization.

Partial cutting

Partial cuts can be used to advantage in order to reduce the losses from impending outbreaks through overwood removal, shelterwood, and group selection. This method is especially attractive when environmental and visual impacts preclude clearcutting. However, dwarf mistletoe infection and windfall susceptibility can be serious drawbacks on some sites (Safranyik 1982). Amman (1976) concluded that partial cutting is an option where timber values are primary, but applies only where:

- a small portion of the lodgepole pine have larger diameter and phloem thickness categories conducive to beetle population buildup,

Partial Cutting may be useful where:

- Clearcutting is not compatible with multiple-use objectives.
- Combinations of mature forest and openings are desired.
- Regeneration after clearcutting is difficult.

Considerations for Partial Cutting in Lodgepole Pine Stands

Bollenbacher and Gibson (1986) have described additional conditions in which partial cutting may be desirable or preferable to regeneration harvests. If the decision has been made to conduct partial cuts, or "sanitation thinning," as a part of an overall management strategy, the land manager must choose stands where this technique will be most successful. Following is a list of site attributes and considerations to use when evaluating a lodgepole pine stand as a candidate for sanitation thinning.

1. Site productivity: A favorable soil moisture regime will likely add to the probability of an increase in growth and vigor of the crop trees.
2. Slope: Generally treat stands on tractor ground less than 35 percent to limit residual stand damage.
3. Average stand diameter: Choose stands where average d.b.h. exceeds 9 inches with less than 350 trees over 5 inches d.b.h. per acre. These stands will be more economical to log and will sustain less residual stand damage.
4. Age: Consider stands that are greater than 60 and less than 125 years old.
5. Current basal area: Stands should have at least 130 square feet per acre to be an economical logging chance.
6. Elevation: Consider only those stands lower than 6,000 feet. Stands at higher elevation (in northwest Montana) are generally lower risk due to a shorter growing season.
7. Wind firmness: In relation to topography, choose the most sheltered slope positions, as identified by Alexander (1975).
8. Present beetle infestation rate: Choose stands with a present infestation rate of 10 percent or less. Higher levels may result in excessive mortality in leave trees if logging is not completed prior to the next beetle flight.
9. Tree vigor: Choose stands with crop trees having a live crown ratio of 30 percent or greater.
10. Other resource objectives: Consider only those stands where other resource objectives may not be met through regeneration harvesting.

High windfall risk situations

- **Ridge top**
- **Moderate to steep middle south– and west-facing slopes not protected to windward, and all upper south-and west-facing slopes.**
- **Saddle on ridge tops.**

- residual trees would be numerically adequate and vigorous enough to maintain stand productivity.

Partial cuts in a mixed-species stand, just coming under attack, might be justified if removing high-risk lodgepole pine in mixed-species stands would protect adjacent, un-infested lodgepole pine stands. That might only be applicable in the situation where lodgepole pine in the mixed-species stand was of higher risk than that in the adjacent pure stand and infestation of the mixed-species stand posed an undue risk to adjacent stands of lower susceptibility (D. M. Cole 1978).

Windthrow in relation to prescribed cutting

Lodgepole pine is generally considered susceptible to windthrow, and the risk increases when stocking is reduced through partial cutting (Alexander 1975). Root system development varies with soil and stand conditions. On deep, well-drained soils, trees have a better root system than on shallow or poorly drained soils.

With the same conditions, the denser the stand, the less wind firm are individual trees because trees that develop together in dense stands over long periods of time, support each other and do not have roots, boles, and crowns to withstand exposure to wind if opened drastically.

The risk of windthrow is also greater on some exposures than others. The risk of windfall in these situations is increased at least one category by such factors as poor drainage, shallow soils, and defective roots and boles. All situations become high risk if exposed to special topographic situations such as gaps and saddles in ridges at higher elevations to the windward that can funnel wind into the area.

These guides should be carefully considered in assessing the efficacy of any intermediate or harvest cutting prescription for lodgepole pine stands, including those aimed at preventing or ameliorating mountain pine beetle effects.

Moderate windfall risk situations

- **Valley bottoms parallel to prevailing winds.**
- **All lower and gentle middle north- and west-facing slopes not protected to the windward.**
- **Moderate to steep middle south– and west-facing slopes protected by considerably higher ground not far to windward.**

Low windfall risk situations

- **Valley bottoms except where parallel to prevailing winds, and all flat areas.**
- **All low and gentle middle north- and east-facing slopes.**
- **All lower and gentle middle south- and west-facing slopes that are protected by considerably higher ground not far to windward.**

Semiochemicals and Baiting

Semiochemicals

Relatively recent developments by Borden, and others, (1983, 1986, 1987) have shown MPB semiochemicals ("message"-bearing chemicals) can be effectively used to augment silvicultural practices designed to reduce stand susceptibility. Semiochemicals are naturally occurring pheromones produced by attacking beetles, plus host-produced volatiles, which in combination result in mass attacks on individual trees. Taking advantage of this phenomenon, private industry has synthesized, packaged, and is marketing the complex of MPB semiochemicals in the form of aggregative "tree baits" (Phero Tech 1987).

Semiochemical tree baits are used in various strategies, in combination with logging, to essentially contain beetle populations in stands scheduled for harvest. Strategies vary with infestation intensity, size of infested stand, and susceptibility or infestation status of surrounding stands.

Spot baiting

Developed to eliminate small "spot infestations of less than about 30 trees, spot baiting will hold beetles in the infested group until that group can be removed in a small patch cut Best used for isolated infestations, effectiveness of this strategy may be diminished if heavily infested stands are closer than a few miles. In this strategy, 2-3 susceptible trees are baited in the center of the group prior to beetle flight. Following beetle flight, the entire group of dead and currently infested trees is removed.

Photo displays a funnel trap containing aggregative semiochemicals provides a means to assess populations of MPB

Mop-up baiting

This strategy is used as a follow-up action where needed in an area previously treated. By baiting susceptible trees at a 2 ½- chain interval (165 feet) around the treated spot, and any susceptible trees left within the spot, beetles can be further concentrated and removed in a post-treatment operation.

Grid baiting

Grid baiting has shown good results in containing beetles in infestations up to 50 acres in size. With this technique, susceptible trees within the infested area are baited on a 2 ½-chain (165) feet) grid throughout the stand. Care should be taken to bait no closer to cut boundary than 165 feet to avoid beetle dispersal beyond cut-block borders. Once again, trees are baited before beetle flight and the entire stand is removed in a clearcut operation following beetle flight.

Additional research with semiochemicals has involved the use of anti-aggregative pheromones for stand protection, and a combination of attractive and anti-aggregative pheromones in "diversion" tactics. Though both strategies hold promise, we are probably a couple of years or more away from their operational use. The anti-aggregation pheromone, verbenone, has shown promise as a stand or individual tree protectant in recent tests (Bentz, and others, 2002).

Managing non-timber values

The do-nothing policy may be a viable option on forested areas not included in commercial timber production. As far as aesthetics are concerned, infestations (both far and close views) may have little impact on the viewer. However, dead timber can have an enormous impact on areas relative to recreation, wildlife, build up of fuel, fire hazard, and plant succession. Therefore, a fire management program utilizing prescribed fires in combination with some "safe" wild fires, may be more appropriate and ecologically more desirable than the no-action policy (Safranyik 1982).

Natural Control Factors

While beetles are developing within a tree, many factors of mortality are reducing their numbers. These factors consist of competition among larvae, parasites and predators, pathogens, cold temperatures, drying of the bark, and pitch. Several comprehensive life table studies of the beetle and its mortality factors, including one 13-year study, showed that none of these factors, either individually or in combination, regulate beetle populations. Survival of beetles during epidemics is more closely correlated with tree diameter and phloem thickness of their hosts than any other factor.

In general, the number of beetles produced in any one tree is directly related to thickness and quality of phloem (food for developing larvae), and rate of phloem drying—which is lower in larger trees. Phloem layer is generally thicker in large-diameter trees and is a function of past growth.

Climate

Although tree diameter and phloem thickness are major factors involved in the dynamics of MPB populations, epidemics can develop only in stands located where temperatures are optimum for beetle development. Climate becomes an overriding factor at extreme northern latitudes and at high elevations. At these extremes, beetle development is out of phase with winter conditions. Consequently, stages of the beetle that are particularly vulnerable to cold temperature enter the winter and are killed. Because of reduced brood survival, infestations are not as intense and fewer trees are killed as elevation and latitude increase.

Ponderosa Pine

General site characteristics and damage

High stand density is directly related to site quality, both of which are positively correlated with damage. Intensive competition between trees in dense stands and its effect on tree resistance to beetle outbreak in the history of a second-growth stand usually occurs between ages 50 and 100 years, depending upon site quality. Stands often sustain their first serious infestation between 50 and 75 years on better sites because they grow into a susceptible condition earlier. On poorer sites, trees are usually 75 to 100 years old when an outbreak first occurs.

Direct control

Most of the philosophies, methods, and materials used to suppress MPB in lodgepole stands can be used in ponderosa pine stands. Again, most direct control efforts should be considered a holding action until silvicultural treatments can be applied.

Estimating mortality

Loveless (1981) Mortality Risk Rating system to estimate anticipated mortality in ponderosa pine stands

Number of ponderosa pine killed in an infestation increases as:

- **Average d.b.h. decreases (down to about 6-8 inches),**
- **Site index increases,**
- **age increases.**

Hazard Rating Stands

Three stand characteristics affect susceptibility to attack: (1) stand structure, (2) average d.b.h. of ponderosa pine component, and (3) stand density as expressed by average basal area per acre (Stevens et at. 1980).

(1) Stand Structure

Single-storied stands are most susceptible to severe damage. They are most likely to become attacked first and to suffer greatest mortality. Such stands are given a hazard rating of (3). Two-storied stands are rated (2) since overstory trees are generally not as susceptible. Multi- storied stands have not been given a rating, but probably could be rated (1).

(2) Average Diameter

As mean stand diameter increases, stand susceptibility increases. Stands greater than 1 10-inch average d.b.h. are high hazard (3), those 6 to 10 inches are moderate (2), and those less than 6 inches are low (1). However, more trees in the 6 - to 12-inch d.b.h. size classes will be killed once an infestation starts.

(3) Stand Density

The more dense the stand within a given average diameter, the more susceptible it will be to severe beetle-caused mortality. Hazard ratings for stands in which average d.b.h. is greater than 5 inches are: more than 150 square feet per acre = high (3); 80 to 150 square feet per acre = moderate (2); and less than 80 square feet per acre = low (1). This will vary with geographic area, with 120 BA/acre being high risk in some stands.

Computing a stand hazard category is similar to that described for lodgepole pine. The three numerical ratings above for stand characteristics are multiplied to obtain a stand risk value. The hazard value will then be assigned a rating as follows:

Schmid, and others (1994), confirmed Stevens earlier work and also demonstrated that stand hazard, a function of stocking, can effectively be reduced through commercial thinnings.

Stand Risk Value	Hazard Rating
2-6	Low
8-12	Moderate
18-27	High

Silvicultural Alternatives

Thinning of overstocked second-growth ponderosa pine stands can have a profound effect on beetle-caused mortality. An un-thinned stand stocked at a basal area of 152 square feet per acre had 8 percent of the stand killed by mountain pine beetle in a 5-year period. A similar stand, thinned to 15- by 15-feet spacing (80 square feet per acre BA) showed only 0.2 percent mortality in the same period. In addition to reduced mortality, thinned stands showed a net growth (Sartwell and Dolph 1976). Maintaining stand basal area below 150 square feet per acre has been effective in suppressing beetle outbreaks in the Black Hills (Schmid, and others, 1994). A cooperative FPM-Lolo National Forest study showed beetle-caused mortality was higher where stand basal area exceeded 120 square feet per acre.

Cautions are issued, however, where thinning is used to manage beetle populations. First, thinning has no application where trees are in a fringe area and widely spaced. Second, thinning in a small stand may not be successful if the stand is surrounded by un-thinned, infested stands. Finally, slash must be property disposed of, i.e., piled and burned or lopped and scattered to prevent population buildups of pine engraver beetles (*Ips* spp.). Where limbs or tops more than 3 inches in diameter are left, engraver beetles may develop and infest surrounding green trees.

Stevens, and others (1974), have outlined a management program to minimize losses. See the sidebar at right Using these guidelines, it may take at least 3 years to implement the program and significantly reduce mortality.

Natural control

The same factors that affect MPB in lodgepole pine pertain to ponderosa pine. However, severe low winter temperatures probably do not kill as many beetles in ponderosa pine because of its thicker bark.

Managing ponderosa pine to minimize losses to MPB

Year 1

- Determine boundaries of area to be included and arrange for handling as a unit.
- Salvage infested trees over entire area
- Locate areas in which thinning is needed (through hazard rating previously described). Begin thinning to BA of about 80 square feet per acre.

Year 2

- Continue salvage.
- Finish thinning.

Year 3

- Salvage

Year 4+

- Maintain surveillance and salvage as needed.

Year 10+

- Re-evaluate treated area. Thin where necessary to maintain low stand density.

Western White Pine

In the intermountain West, MPB is chronic in areas of residual mature western white pine. Trees over 90 years of age are susceptible and are frequently killed. Rarely does MPB attack a western white pine under 10 inches in diameter unless there are extenuating circumstances—such as blister rust infestation, extreme dry weather, or other stressing factor. Infestations in unmanaged pockets of mature western white pine usually do not spread into surrounding stands of lodgepole or neighboring ponderosa pine trees.

Surveys and observations over the years indicate that direct control, salvage logging, or partial cutting usually does not stop the beetle from killing residual mature western white pine in a stand.

Western white pine have not recently been intensively managed because of blister rust depredations; however, as rust-resistant plantations begin to mature, we may learn thinning to maintain low stand basal area will reduce mortality from MPB. At present, we recommend harvesting mature western white pine whenever feasible. It is a gamble to store such trees on the stump unless they can be salvaged easily.

Whitebark Pine

Although long known to be hosts of MPB, whitebark and limber pines have only recently begun to experience extreme amounts of beetle-caused mortality in the intermountain West. Currently, little is known about beetle life cycle at higher elevations. It may well be longer than one year.

Likewise, management efforts have been infrequently attempted on these sites. There is, however, increased interest in protecting seed-bearing trees because of their importance to wildlife species, and because of recent efforts to develop rust-resistant programs.

Mountain pine beetle can be devastating in dwindling white-bark pine forests.

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May 2004

By R. Ladd Livingston
State of Idaho

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Engraver

***Ips pini* Say**

Topics

Pine engraver will attack almost any species of pine in the West, but prefers ponderosa and lodgepole pines.

Though usually secondary attackers, *Ips pini* can become aggressive tree killers during droughts or following stand disturbances.
Outbreaks can result in considerable mortality but they are usually brief, seldom lasting more than one season.

Always present and occasionally damaging

Pine engravers maintain their populations in logging slash, wind- or storm-damaged trees, or tops of trees weakened or killed by other agents. Most frequent damage is in second-growth ponderosa pine stands where overstocked pole-size trees (2 to 10 inches dbh) are killed.

During outbreaks, group killing becomes widespread and groups may include hundreds of trees. Smaller trees are killed outright; top killing occurs in larger trees. Attacks are often associated with other bark beetles in the genus *Dendroctonus*.

Normally, there are two generations of the beetle each year, but in dry years, three or even four generations may occur. This can result in rapid buildup of populations.

Silvicultural management strategies are most effective, particularly stand thinning to maintain tree resistance to attack. Timing of pine slash creation and disposal is also of critical importance in avoiding outbreaks of pine engraver.

Key Points

- Populations build rapidly in slash and broken or damaged trees.
- Overcrowding and drought also can lead to outbreaks.
- Manage slash to minimize outbreak potential.

Thin to maintain vigor.

Management Overview

⇒ Thin to improve vigor of stands.
⇒ Avoid creating pine slash between January and June.
⇒ Dispose of slash promptly.
⇒ Provide a “green chain” of slash throughout the flight period.
⇒ Remove infested trees and destroy brood.

Life History

Each male attracts several females which, after mating, construct egg galleries radiating from the nuptial chamber.

This gives the galleries their unique Y or star-shaped appearance.

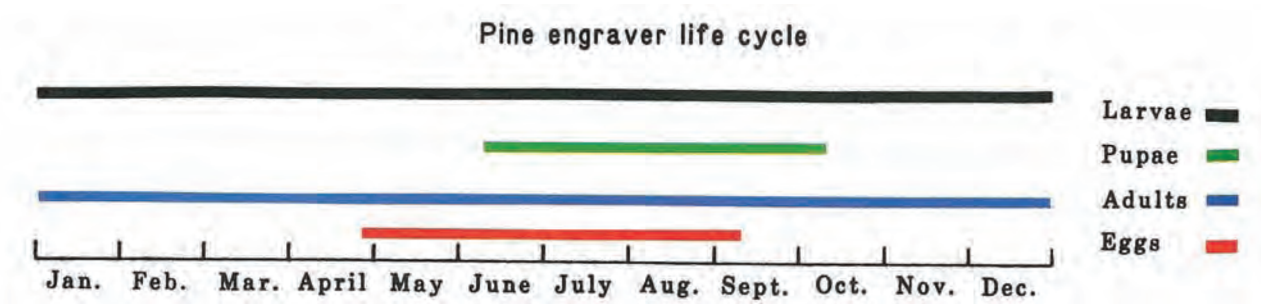
Normally, there are two generations of the beetle each year. In dry years, three or even four generations may occur. Winter is passed primarily in the adult stage, beneath the duff on the forest floor or within infested material. Adults become active early in the spring, infesting fresh slash or winter-damaged trees. Initial flights vary with weather but probably occur most often in late April to early May.

Attacks are initiated by male beetles which construct nuptial chambers beneath the bark. Each one then attracts several females which, after mating, construct egg galleries radiating from the nuptial chamber. Egg galleries are kept free of boring dust and frass-unlike those of many other bark beetles.

Eggs hatch in a short time-4 to 14 days. The larvae mine laterally, feeding on phloem tissue, for 10 to 20 days. A pupal cell is formed at the end of each gallery where pupation takes place.

New adults emerge in about 10 days, completing their development in only 40 to 55 days. This generation then seeks out new material to infest, preferring slash but attacking standing trees if none is available.

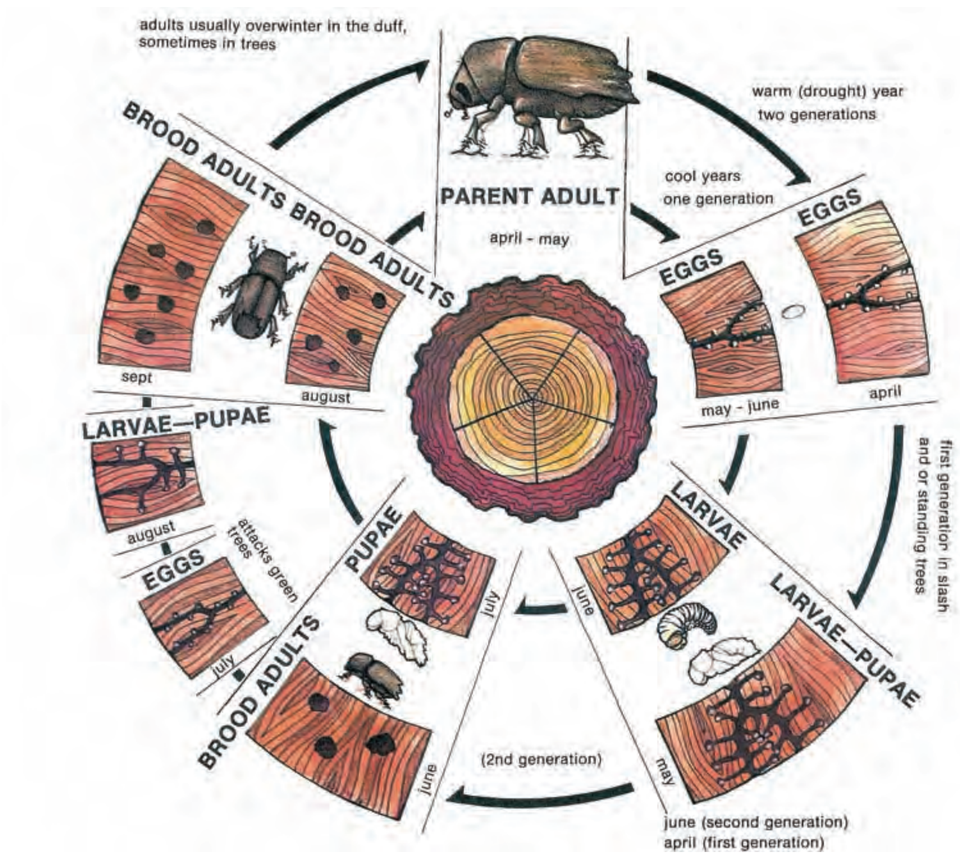
Another generation is completed in this material by mid- to late-August in a normal year. Warm, dry weather can result in an additional generation. Usually adults emerging at this time of year seek sheltered places to hibernate for the winter. Sometimes this generation makes feeding attacks prior to hibernation where no new brood is produced, but all phloem is consumed by the adult beetles.



Natural Control

Competition among developing brood often reduces adult emergence from small-diameter host material. In larger material, competition with other bark beetles and wood borers often reduces food available for engraver beetle broods. Predation by woodpeckers, beetles, flies and mites is common, as is parasitism by wasps and nematodes.

Pine Engraver Life Cycle



Conditions leading to outbreaks

Most pine engraver problems are associated with disturbances such as windthrow and ice breakage, drought in spring and early summer, thinning, logging, fires, road construction, or housing development (Livingston 1979). Logging slash, or trees weakened by such disturbances, provide ideal conditions for beetle attack and population buildup.

Pine engraver beetles overwinter in the adult stage and normally infest green slash only in the spring. Therefore, logging slash created from December through June can be especially hazardous by providing large amounts of breeding material. Slash should not be created during this time period unless it can be treated prior to beetle emergence. During years of extremely low, spring soil moisture, overwintering beetles have been known to attack and kill living trees.

The percent of normal precipitation between April and July has been used to accurately predict the intensity of beetle outbreaks in California and Oregon. If precipitation is 75 percent of normal or less, moderate to heavy tree mortality can be expected in overstocked, second-growth ponderosa pine stands. Damage may continue for 2 to 3 years.

Under conditions of extreme drought, large groups of young sawtimber have been attacked and killed (Livingston 1979).

Preventing population buildups through timely thinning and slash disposal will accomplish more than after-the-fact control measures.

Direct Suppression

Suppressive efforts directed at these beetles usually are not warranted as infestations are likely to be brief.

Several methods of brood destruction in infested material have proven to be effective. Among them are treatment with toxic chemicals, piling and burning, covering with clear plastic (or other material) which will raise temperatures to lethal levels and/or prevent adult escape.

Damage Prevention: Tips for Homeowners

In housing developments, avoid disturbing roots of trees that are to be left as ornamentals. Excessive damage will usually weaken them and render them susceptible to beetle attack. Weakened or badly damaged trees should be removed prior to completion of construction. Pine slash created near housing developments should be disposed of as soon as possible. It should not be left near residual pines as attacking beetles may overflow slash and infest standing trees. Avoid backfilling over root areas. Four inches or more of dirt over roots often stresses trees, making them attractive to attacking beetles.

When pines are cut, do not stack slash, fresh logs, or pieces against standing green trees. Beetles that develop in firewood or logs are more likely to attack adjacent or nearby trees when they emerge. Older dead wood, too dry to support beetle development, does not pose a similar threat, however (Livingston 1979).

Promptly remove trees with root disturbance, or large patches of bark torn off.

Prevent Outbreaks by Thinning Pine Stands

Thinned, vigorous stands of ponderosa pine are less attractive to pine engraver beetles. During drought years, stand vigor is even more important. Stands in which basal area has been reduced to 80- 100 square feet have been found to be less susceptible to beetle attack.

Recently thinned stands may temporarily be more attractive because of the presence of fresh slash or logging damage to leave tree.

Outbreak Prevention: A Season for Slash

The optimum time period for management activity in ponderosa pine, where slash will be created, is August to November. Activity earlier, and especially later, increases the likelihood of subsequent tree killing.

Fresh pine slash should be minimized, or not created, during approximately the period December through June. If beetles do not have fresh slash in early spring, populations will subside.

Slash created in the fall or early winter will usually dry sufficiently to be unattractive the next spring, or may be infested by competitor beetles. Slash covered by early snows, however, may still be "fresh" enough to attract pine engravers in spring.

Avoid damaging residual trees.

Fall trees into openings and use established skid trails to avoid damaging the residual stand.

Outbreak Prevention: Options for "high-risk" slash

When it is not practical to avoid creating slash during "high-risk" months, several management practices can be used to help minimize potential impacts.

Destroy slash generated in high -risk months (December to June) before brood matures. Dozer trampling of slash is effective in reducing the amount of breeding material by removing bark and drying inner bark. Chipping is a very effective means of slash disposal- perhaps more useful in developed areas. When slash is burned, avoid scorching standing trees as this makes them more attractive to numerous species of wood-boring insects.

Lop and scatter to increase drying rate Where general slash disposal is impractical, lopping into smaller pieces and scattering it into openings is effective. Exposing the slash to direct sunlight dries it faster making it unsuitable for beetle development.

Green chain to keep beetles in slash and out of trees. When beetle populations in slash constitute a threat, creating a continuous supply of fresh slash during the flight period of emerging adults will generally attract the beetles keeping them out of standing green trees. This technique is known as providing a "green chain." New slash should be produced just as the beetles enter the pupal stage. Once started, this technique should be continued for each generation of that season. An alternative to this method, more recently shown to be effective, is the early creation of very large slash piles. If piles are big enough so that interior pieces do not dry before beetles from initial generation emerge, new beetles are apparently attracted deeper into the pile (Livingston, personal communication).

Principles of Slash Management

⇒ **When possible, avoid creating slash during the high-risk months between December and June.**

⇒ **Destroy slash created during high-risk months.**

⇒ **Use a "green chain" to keep beetles in slash and out of trees.**

Pheromone Strategies

For Population monitoring— Attractant pheromones of pine engravers have been identified, synthesized, and are used to monitor beetle populations.

For prevention of attack— Anti-attractant pheromones are being tested and may soon provide valuable tools to help prevent slash from being infested until it is either dried or otherwise treated.

Pine engraver egg gallery.

Recognizing Pine Engraver Attacks

The first indication of a pine engraver attack in slash or standing trees is the characteristic reddish-orange boring dust which emanates from the beetle's point of entry. In slash or logs, this boring dust appears as mounds around an entrance hole on the upper surface of the host material. On standing trees, the dust is most notable in bark crevices and around the base of the infested tree. Removing the bark reveals a Y -or a star-shaped gallery pattern usually running with the grain of the wood.

Adult beetles are cylindrical, dark reddish-brown to black and one -eight to three-sixteenths inch long. All members of the genus *Ips* are characterized by an elytral declivity- a dish-shaped depression at their posterior end. On each side of this depression the species pini has four small spines.

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No FIDL for this damage-agent

May 2004

By Liz Hebertson
US Forest Service

Forest Health and State and Private Forestry Organizations

Management Guide for

Pinyon Engraver Beetle

Ips confusus LeConte
(Coleoptera: Scolytidae)

The pinyon engraver beetle is the most important insect mortality agent in pinyon pines in Regions 1 and 4.

Hosts:

- Colorado pinyon
- Singleleaf pinyon
- Other pinyon species

Topics

Key Points

- Drought may increase a tree's susceptibility to engraver beetle attack.
- Egg galleries have forked or star-shaped patterns.
- Beetles introduce a 'blue stain' fungus that plugs up conductive tissues.
- Adults overwinter in groups at the base of infested trees.

Damage

In healthy pinyon-juniper woodlands, endemic levels of the pinyon engraver work in association with other insects and diseases to kill weakened and stressed trees. Tree mortality thins the forest reducing competition for light, water, and nutrients. Population levels may build when ample host material is available. This material may consist of green pruned branches and recently broken, uprooted, or downed trees. Outbreaks of pinyon engravers may continue for one to several years killing large groups of trees over the landscape.

Drought, disease, or injuries by other insects are often important in weakening trees, thus increasing the potential for successful engraver attacks. Moisture stress may increase tree susceptibility in two ways. The first way is by reducing the production of sap. Vigorous trees can produce enough sap to push or 'pitch' attacking beetles out of entrance holes. Beetles often become trapped in the sap and die. The second way is by increasing the nutritional quality of the tree for the beetles. Moisture stress has been found to increase soluble nitrogenous compounds and sugars in living cells of trees. Both of these substances are important for the development of beetles. Pinyon engraver activity is often associated with black stain root disease (*Leptographium wageneri*). The beetle also favors pinyons with heavy dwarf mistletoe (*Arceuthobium divaricatum*) infections.

Tree damage occurs when adult beetles colonize and reproduce in the conductive tissues of suitable host trees. Conductive tissues transport water and nutrients throughout the tree.

Pinyon engraver populations may build when ample host material is available.

The life cycle of pinyon engraver beetles last from 6-8 weeks with up to 5 generations in one season.

Life History

Adult beetles generally overwinter in groups at the base of infested trees. Adults emerge in the spring to infest suitable host material often re-attacking uninfested portions of the same tree or attacking another susceptible host tree. In Utah and Nevada, pinyon engravers normally begin flight in mid-April. A male beetle locates and attacks host material emitting a pheromone that attracts females and other males. The male mates with one or more females in a nuptial chamber constructed within the tree phloem. The females construct galleries to lay their eggs. These egg galleries initially radiate outward from the nuptial chamber then generally follow the grain of the wood resulting in a forked or star-shaped gallery pattern. Unlike *Dendroctonus* beetles, pinyon engravers do not pack their galleries with frass and travel freely along the entire gallery length. Females lay eggs singly along both gallery walls. These eggs hatch into small larvae and create larval galleries extending perpendicular to the egg gallery. Larvae eventually pupate and transform into new adults. The life cycle of pinyon engraver beetles generally lasts from 6 - 8 weeks with up to 5 generations produced in one season depending on climate and elevation. With multiple generations produced every year infested trees may contain beetles of various life stages.

Identification

Adult beetles are cylindrical, ranging in size from about three to seven millimeters long. They are reddish-brown to black in color and often shiny. As with other *Ips* species, pinyon engraver beetles have a pronounced depression at the rear end of their wing covers. Five spines occur along the margins of each side of this depression.

Foliar symptoms provide initial evidence of pinyon engraver beetle attack. Pinyon pine needles on branches or trees killed by the beetle will generally turn yellow (fade) to orange/red within a few days or weeks. Before long, the needles begin to fall. Successfully attacked trees will also have red or orange boring dust (frass) in bark crevices and/or around the base of the tree. Boring dust is produced when beetle chews through the bark. Small, inconspicuous tubes of pitch containing boring dust may also be visible on the bark surface around entrance holes.

Adult engraver beetle on dime.

Pitch tubes on pinyon pine. Photo courtesy of USDA Region 3 FHP

Water stress, diseases and the presence of other insects can increase a tree's susceptibility to pinyon engraver attack.

Susceptibility:

1. Characteristic. The most susceptible trees are relatively old with average root collar diameters (drc) between seven and eleven inches.
2. Climate. During intense drought years, pinyon pines may be susceptible to attack even in stands with low densities and small tree diameters (2 inches drc) .
3. Density The probability of beetle attack also increases with increasing pinyon density even when pinyon represents a minor portion of the stand (Negron and Wilson 2003).

Management

High value trees such as those in recreation sites may be sprayed with a registered insecticide to protect them from attack.

High value trees such as those in recreation sites may be sprayed with a registered insecticide to protect them from attack. Insecticides with the active ingredient Carbaryl are quite effective and several brand names are registered engraver beetles. These sprays, when applied as a 2% solution, provide protection from attacking engraver beetles for 16-18 months. The insecticide must saturate all sides of the trunk and larger branches (≥ 1 inch in diameter). If any portion of the trunk or susceptible branches is missed, then beetles can successfully attack the non-treated area.

Thinning offers the best long-term management strategy for the pinyon engraver beetle. To maximize effectiveness, thin the pinyon component to an SDI of 20 or less (~6% of maximum SDI; 360 for pure stands (pinyon or juniper) and 415 for mixed stands). Where stands are composed of mixed pinyon and juniper, a total SDI of 24 may be appropriate and will approximate the same competitive conditions. Table 1 shows traditional measures of stand density for an SDI of 24 for given size classes. Multi-aged/sized stands should have the total SDI apportioned among size classes (Table 2).

Table 1.
TPA, BA, and Spacing Between Trees based on SDI and Diameter
(Stand SDI = 24 or 5.6% of maximum SDI)

SDI	DRC	TPA	BA	Spacing
24	6	54	10.7	28.3
24	8	34	12.0	35.6
24	10	24	13.1	42.6
24	12	18	14.1	49.3
24	14	14	15.0	55.8
24	16	11	15.8	62.0
24	18	9	16.6	68.2
24	20	8	17.3	74.2
24	22	7	17.9	80.1

Table 2. Target After-Treatment Stand (at 5.6% of max SDI)				
Size Class	**SDI**	**TPA**	**BA**	**Spacing**
Regen (<3”)	6.5	45	2.2	31.2
Small (3-6”)	6.5	15	2.9	54.4
Mid (6-9”)	6.5	8	3.4	75.2
Large (>9”)	6.5	14	15.0	55.8
Total	***26***	***82***	***23.5***	--

Thinning offers the best long-term management strategy for the pinyon engraver beetle.

Various factors should be taken into account in the selection of trees to retain on the site (“leave trees”). Damaging agents, such as disease or physical damage (including logging damage), can weaken and stress trees, making them more susceptible to pinyon engraver. Leave trees should be those that appear the healthiest trees with the least damage. If dwarf mistletoe (a parasitic plant species) is present on individual trees, these trees should not be favored for leave trees over adjacent uninfected and otherwise healthy trees. Pinyon engraver beetles prefer trees with somewhat reduced crown ratios. Pinyon leave trees should be those with the higher percentage of crown-to-height ratio. The beetles also prefer larger diameter pinyon trees, thus it may be desirable to retain older juniper “legacy” trees and remove any older/ larger pinyon trees that show signs of declining vigor.

Stand Composition

Stand susceptibility to pinyon engravers is also influenced by stand composition, and those stands with a higher percentage of pinyon-to-juniper tend to be more susceptible to beetle-caused mortality. Thus it is desirable to maintain a good mix of species. Additionally, treatments may vary by size of pinyon leave trees and percentage of pinyon-to-juniper leave trees.

Timing of Treatment

Timing of implementation and treatment of pinyon slash can be critical factors when pinyon engraver beetles are present in the general area. Green pinyon slash can serve as an attractant to beetles. Beetles can colonize slash during the spring and summer months and maturing beetles can emerge from this slash seeking new hosts, which will tend to be the nearest available suitable pinyon trees. Even chipped pinyon debris can attract beetles during the beetles’ flight periods. Pinyon engravers cannot colonize chips but may attack nearby pinyon trees. If chips or slash are to be left on the site, then treatment is best done in late fall, allowing the winter months for material to dry and become less attractive to beetles. Larger green pinyon material that is not chipped should be removed or disposed of before the next beetle flight (March).

If green pinyon material greater than 3 inches in diameter can be removed from the site within four to six weeks of cutting, then operations may be done at any time without risking increasing the incidence of beetles. If neither can be practically accomplished, then mitigation for increased beetle activity may be either to leave more junipers and fewer pinyon or to leave more pinyon, realizing that many of these trees may be subsequently killed by beetle attack. If retention of pinyon trees on the site is of prime concern, it may be best to delay thinning pinyon stands when populations are high in the drainage where the treatment is to take place.

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January 2006

By
Carol Bell Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Red Turpentine Beetle

Dendroctonus valens LeConte (Coleoptera: Scolytidae)

Hosts (primarily):
- **Ponderosa pine**
- **Lodgepole pine**
- **Monterey pine**
- **Coulter pine**

Red turpentine beetle is not considered to be a tree killer, but its attacks may indicate that the tree is stressed and at increased risk of dying.

Topics

Key Points

- Not usually a tree killer
- Usually associated with damage from other insects or diseases or acute tree stress
- Prevent attack by limiting predisposing factors

Introduction

The red turpentine beetle (RTB) is the largest (1/4 – 3/8th inch long) and most widely distributed bark beetle in North America. It is a common pest of forest, shade, and park trees 8 inches or larger in diameter. It has been recorded from at least 40 species of domestic and foreign conifers, but is most commonly found on ponderosa, Monterey, and Coulter pines. It is not considered to be a tree killer, but its attacks may indicate that the tree is stressed and at increased risk of dying. There is evidence that red turpentine beetle can kill Monterey pines.

Outbreaks of this beetle have not been extensive or severe. red turpentine beetle is most frequently found in individual trees or in groups of trees in localized areas. Stressed pines are the most common host.

Adults are attracted by the odor of tree pitch or resin. Adults primarily attack freshly cut stumps or the bases of trees that are dying. Freshly cut logs with thick bark may be attacked, but they will not produce large numbers of beetles. Red turpentine beetle may be attracted to healthy trees near freshly cut logs and lumber and to stands attacked by other bark beetles.

Red turpentine beetle has been destructive in areas disturbed by fire, logging, land clearing, or construction. In some stands up to 3% of pines remaining after logging have been attacked. On construction sites, injured trees or those adjacent to fresh lumber frequently become infested.

Red Turpentine Beetle Management

1. **Prevention.** **Thin pine stands to maintain tree vigor. Avoid damaging trees. Salvage promptly any trees that are damaged or diseased.**
2. **Chemical pesticides.** **Can be used to temporarily protect high-value trees during periods of drought or other stresses.**
3. **Pheromones.** **Reduce beetle populations using attractant -baited funnel traps.**

Seldom are healthy trees damaged

Damage

All serious damage by red turpentine beetle has been to pines. Monterey pine is the tree most frequently killed and ponderosa pine is the most frequently attacked. Attacks on other genera of conifers- spruce, larch, true fir, and Douglas-fir- are infrequent and have never led to serious losses.

Seldom are healthy trees killed. Usually trees of poor vigor or those infested with other bark beetles are attacked. However, populations may build up in areas disturbed by fire, logging, or land clearing. Injured trees, stumps, or trees near fresh lumber or slash can be infested and residual healthy trees nearby may be killed.

Red turpentine beetle attack trees wounded or stressed by construction activities, like paving, grading, trenching or root smothering. Damage from red turpentine beetle can be prevented by not conducting any of these activities within 40-50 feet of the large pines.

Host Range

In the Northern and Intermountain Regions most frequently attacked:

- **Ponderosa pine (*Pinus ponderosae*)**
- **Lodgepole pine (*Pinus contorta*)**

In North America the most frequently attacked:

- **Ponderosa pine**
- **Monterey pine (*Pinus radiata*)**
- **Coulter pine (*Pinus coulteri*)**

Red Turpentine Beetle has been found on over 40 species of conifer including larch (*Larix* sp.), spruce (*Picea* sp,) and white fir (*Abies concolor*).

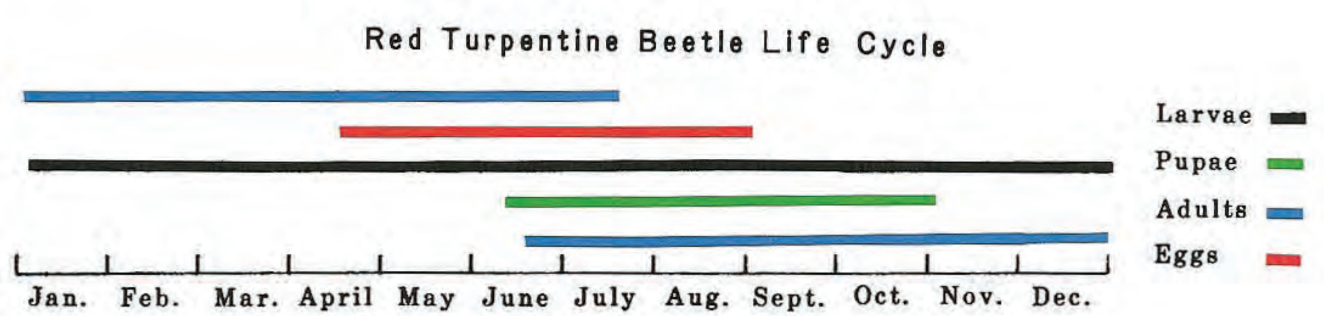
Life History

Adult beetles initiate new attacks

Red turpentine beetle peak flight and attack activity usually occur in the spring. Beetles emerging from recently cut stumps and dying trees and attack trees, exposed roots, or freshly cut stumps. The female bores inward through the outer corky bark and inner, spongy phloem to the surface of the wood where she is quickly joined by a male. The pair generally bore downward, although at first the gallery usually has a lateral or even slightly upward direction. Where attacks are made just above the ground line, the gallery may extend below the ground line and along the larger roots. Boring may exceed an inch a day. Typically one pair of beetles is found per gallery, but 1, 3, or 4 adult red turpentine beetles may be present.

Egg galleries

Eggs are laid in an elongate mass along the side of the gallery and are partitioned off from the adult gallery by a wall of pitchy borings. The egg mass may extend from 1 to several inches along the gallery; the number of eggs in it varies from a few to more than a hundred. A single female may deposit one or more groups of eggs farther along the gallery, usually several inches or more below the previous group.



The parent beetles continue to feed in the gallery for several weeks, and then they either bore out through the bark and make additional attacks or die within the gallery.

Larval feeding

In summer eggs hatch in 1-3 weeks. A unique feature of red turpentine beetle is that the small larvae feed gregariously where as most other bark beetle larvae maintain separate feeding tunnels. red turpentine beetle larvae tunnel away from the adult gallery. As they grow they feed more extensively and make an irregularly margined, fan shaped gallery. Larvae feed side by side in an irregular line, steadily moving forward into fresh tissue. Their feeding kills patches of cambium which may vary from a few inches to more than a foot wide.

Pupation

As larvae complete their feeding they scoop out bits of wood or bark to make separate pupation cells. The cells are located between the bark and the wood, either in the area of the gallery or a short distance forward in the fresh inner bark. Here the larvae pupate then emerge as adults.

New adults emerge from galleries

New adults move around in the gallery area for a few days to several months. In warm weather they soon bore outwards through the bark and fly to new host material. Several adults may use the same exit hole. The adult beetles are capable of flying more than 10 miles.

The rate of development and number of generations per year are largely dependent upon temperature. In most areas there is at least one generation of red turpentine beetle per year. In northern areas and at high elevations, 2 years may be required for a single generation. In southern areas at low elevations, there may be as many as three generations per year.

In the warmer parts of their range, the beetles' flight may occur during intermittent warm periods in the winter and new attacks may occur at nearly any time of the year. In the colder parts winter is passed in hibernation, chiefly in the adult stage and to a lesser extent in the larval stage. Pupae and eggs rarely overwinter.

A unique feature of Red Turpentine Beetle is that the small larvae feed gregariously where as most other bark beetle larvae maintain separate feeding tunnels.

Attacking adults are attracted by the odor of tree pitch or resin

Assessing Red Turpentine Beetle Damage

Signs of Attack

Red turpentine beetle attacks generally start near ground level and rarely occur above eight feet. Attacks are often accompanied by the presence of light pink to reddish brown pitch tubes around the base of the tree and/or white granular material on the ground.

Pitch tubes vary in size, texture, and color depending on the kind of tree and the relative amounts of bark borings and frass embedded in the resin. The resin is usually white to yellow and the borings are red. On pines red turpentine beetle pitch tubes may be as large as 2 inches in diameter, much larger than the pitch tubes of other pine infesting bark beetles. On other species of trees which produce little resin (such as fir or spruce) the pitch tubes may be small or absent, but boring dust or small pitch pellets may be found on the ground around the base of the tree.

Red Turpentine Beetle Attacks—

- Generally start near ground level and rarely occur above eight feet
- May occur over a period of two years or more, especially on vigorous trees.
- Have been destructive in areas disturbed by fire, logging, land clearing, or construction

Pitch masses of an inch or more in diameter that occur higher on the trunk or on the branches are probably due to attacks by the Sequoia Pitch Moth.

Red turpentine beetle is the largest (1/4-3/8th inch long) and most widely distributed bark beetle in North America.

Red turpentine beetle attacks, especially on vigorous trees, may occur over a period of two years or more.

Often crown fading from green to yellow to sorrel and red lead to the discovery of red turpentine beetle attacks. In most cases crown fading is a direct result of associated attacks by other insects, primarily bark beetles, not red turpentine beetle.

Evaluating Attacks

Pitch tubes are the result of the trees defensive reaction to red turpentine beetle attack. As long as the tree continues to release resin, pitch tubes are formed and the tree is resisting attack. A few pitch tubes on an otherwise healthy tree or old pitch tubes that are hard and have turned yellow are generally not a reason for concern.

The appearance of 5 or more new pitch tubes over a one to two month period warrants a more careful inspection of the tree to determine why it is being attacked. Injury, disease, or attacks by other bark beetles are likely causes for repeated red turpentine beetle attacks. A tree that exhibits symptoms of stress and has many red turpentine beetle attacks is at high risk for mortality.

In vigorous trees the flow of resin apparently prevents egg-laying. Beetles may remain in these trees expanding their galleries laterally or vertically but they seldom deposit eggs.

Factors that may help red turpentine beetle by decreasing resin production—

The introduction or invasion of blue stain fungi which grow in the sapwood surface of the gallery.

Lowering of the sapwood moisture content as a result of beetle feeding activity.

When Assessing Tree Vigor Consider:

Stressed trees often exhibit crown symptoms such as:

- Needles shorter than normal.
- Poor needle retention, resulting in tufts of foliage at branch ends lion's tail) and a thin crown that is easy to see through.
- Off-color, chlorotic foliage.
- Slow height growth, resulting in a flattened, rounded top.
- Excessive amounts of dead or dying branches.

In contrast, a vigorous fast growing tree will have a pointed top and a full green crown.

Wounding can attract red turpentine beetle:

- Has there been any major wounding to the trunk or roots of the tree? Have roots been cut?
- Have the roots been disturbed by soil compaction, sidewalks or pavement ?

Management Considerations

Prevention

The most effective way to prevent red turpentine beetle attacks is to maintain tree vigor and avoid practices that attract beetles.

Tree disease

Red turpentine beetle activity is often associated with tree diseases, including root diseases. If disease is present, it will be important to learn about the disease and how it can be managed.

Wounds and site factors

Wounding has the potential to attract red turpentine beetle. If portions of the root system are cut or paved over, the vigor of the tree may be seriously impacted. Any sudden or dramatic change in the soil/root environment e.g. compaction, grade changes, flooding, etc. will adversely affect the trees health. When building near trees special precautions need to be taken to maintain the integrity of the tree's environment and health.

Fire damage

Red turpentine beetle attacks frequently occur on pines that have been damaged by fire.

Actions to prevent red turpentine beetle attacks

Preventative measures can be taken to make your property fire safe and reduce the potential for fire damage to your trees.

- **Thin**— In forest situations, thinning trees to achieve wider spacing can help alleviate stress and reduce the possibility of tree mortality.
- **Avoid damage**— Damage to stands or individual trees should be minimized through improved logging, construction, and management practices. Fresh stumps, slow-dying trees, fire-scorched trees, exposed roots of live trees, and trees with compacted soil around them should be treated or removed

Pesticides

Certain pesticide formulations containing carbaryl, chlorpyrifos, or permethrin when applied to the bark of a tree have been proven effective at preventing bark beetle attacks. Pesticide applied to the lower 6-8 feet of the tree trunk can be used to prevent red turpentine beetle attacks, but it must be realized that other species of bark beetles may pose a threat to the tree as well.

Pesticide treatments can be useful at protecting high value trees during drought or other periods of acute stress.

Factors to consider before choosing to use a pesticide for this purpose:

- Only those portions of the main stem of the tree that are sprayed will be safe from bark beetle attack.
- It is important to use a pesticide specifically formulated for use against bark beetles. All pesticides must be applied according to label instructions, and if the pesticide is a restricted material it must be applied by a certified applicator or under their direct supervision.

The most effective way to prevent red turpentine beetle attacks is to maintain tree vigor and avoid practices that attract beetles.

Natural Control

There is little information available on the biological or natural control of red turpentine beetle.

- Insect parasites and predators have been observed destroying some stages of the beetles beneath the bark.
- Many beetles die in their attempts to attack healthy trees.
- Woodpeckers feed on larvae and pupae.
- The competition for food within and between broods may result in reducing beetle populations.

None of these natural or biological means can be counted on to control the beetle.

The use of pesticides against bark beetles is best viewed as a temporary measure for protecting trees during periods of temporary stress.

- Pesticides that are injected into trees have not been proven effective against bark beetles.
- One treatment in the spring before bark beetle flight begins is usually sufficient to protect trees for the duration of the beetles' flight.
- A common mistake is to spray pesticides on a tree that is already dead or dying.
- The use of pesticides against bark beetles is best viewed as a temporary measure for protecting trees during periods of temporary stress.
- Trees that have little or no chance of recovering from the effects of chronic stress should not be treated with pesticides, as such attempts to save them eventually fail.

Warning- remember, when using pesticides, always read and follow the label!

Pheromones

Baited funnel traps need to be placed well away from host trees (over 20 yards) to avoid unwanted attacks.

Attractant pheromone baited 8 or 12 unit Lindgren funnel traps have been used to reduce local populations of red turpentine beetle. The standard red turpentine beetle pheromone blend used in North America is a 1:1:1 blend of (+)-alpha-pinene, (-)-beta-pinene, and (+)-3-carene.

Baited funnel traps need to be placed well away from host trees (over 20 yards) to avoid unwanted attacks.

NOTE

Red turpentine beetle is a recent New World introduction to the People's Republic of China.

An outbreak of these beetles has infested over 1.25 million acres of pine forests and has killed several million Chinese pines in the Taihang Mountain region in North China's Shanxi Province.

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Forest Insect & Disease Leaflet

May 2004

Forest Health Protection and State Forestry Organizations

By Darren Blackford
US Forest Service

Mangement Guide for

Roundheaded Pine Beetle

Dendroctonus adjunctus Blandford

The roundheaded pine beetle *Dendroctonus adjunctus* Blandford (= *convexifrons* Hopkins) (Chansler 1967, Stevens and Flake 1974, Wood 1963), occurs and kills pine trees in Colorado, Utah, Nevada, Arizona, New Mexico, and southward into Mexico. Periodic outbreaks, although sporadic and short-lived, have killed large numbers of ponderosa pines *(Pinus ponderosa* Lawson) in southern New Mexico and Nevada during the last three decades (Massey, 1977).

Hosts:
In the United States, roundheaded pine beetle principally attacks *P. ponderosa* but have also been collected from limber pine *(P. flexilis* James). From Mexico southward, it infests several pines, including Mexican white pine *(Pinus ayacahuite* Ehr.), Chihuahua pine (P. *chihuahuana* Engelm.) Montezuma pine (P. *montezumae Lamb.),* and Nicaragua pine *(P. pseudostrobus* Lindl.).

Topics

Key Points

- Roundheaded pine beetle is destructive in stands of overstocked, pole-sized ponderosa pines.
- In southern Nevada, mature and overmature ponderosa pines have been extensively killed by this beetle on high-use areas.
- Attacks by roundheaded pine beetle are made in the basal portion of the bole.

Damage

Attacks by roundheaded pine beetle are made in the basal portion of the bole, often in trees previously attacked by other species of *Dendroctonus* or by species of *Ips*. In dense young stands, trees usually are killed in groups of 3 to 15; sometimes up to 100 (figure 1). Recently felled trees are also commonly attacked. Roundheaded pine beetle may kill up to 50 percent of the trees in pure stands of ponderosa pine, including both small- and large-diameter trees. In mixed conifer stands, roundheaded pine beetle may also kill up to 50 percent of the pine, thereby leaving Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) as the dominant species.

Figure 1. Ponderosa pines infested by the roundheaded pine beetle (Massey, 1977).

Life History

Egg hatch generally begins in mid-March and is essentially complete by late April.

The larvae mine across the grain in the cambium region.

Most roundheaded pine beetle in the United States complete their life cycle in 1 year, although about 10 percent of the brood may take 2 years. In Nevada, a larger percentage may take more than 1 year to complete development. Attacks are made principally in October and November to green trees within a few days of emergence. The foliage of attacked trees fades the following May or June.

The females bore through the outer bark into the phloem, where the egg gallery is constructed; the outer wood (xylem) is also lightly scored. From this entrance hole, the egg gallery extends horizontally in the cambium region, either left or right, for 2.5 to 5 cm and then winds longitudinally with the grain an average distance of 30 cm (figure 2). Galleries of neighboring pairs often cross, but retain an overall longitudinal pattern. Eggs are laid individually in niches on alternate sides of the egg gallery (figures 2,5). The egg gallery is initially kept clean of boring dust, but as the gallery lengthens, the male packs the first few inches with boring dust. Galleries are usually about 30.5 cm long, although they may extend to 1.2 m. Beetles that attack trees early in the flight period will have their galleries essentially completed by early December; galleries in trees attacked in November will only be partly completed by December. Between December and February, gallery construction is limited to times when bark temperatures are favorable. A minor amount of gallery construction resumes in March and April.

Figure 2. Long, vertical egg galleries with eggs deposited at intervals along their lengths

The youngest larvae form small feeding galleries in the phloem (figure 3). Older larvae bore into the drier outer bark, broadening the feeding tunnels that eventually end in pupal chambers (figure 4). Brood densities are highly variable between aspects and heights on the tree.

Egg hatch generally begins in mid-March and is essentially complete by late April. A few eggs from the early attacks will hatch before winter but many of these die during that period.

Figure 3. Larval mines radiating horizontally (USDA, 2005)

Figure 4. Larvae mining in the bark of a ponderosa pine in the later stages of development.

The larvae mine across the grain in the cambium region until the third instar, then they bore into the outer bark to complete development. Larvae develop rapidly through the third instar. Fourth-instar larvae develop more slowly and do not pupate until late July and early August; in exceptional cases, pupae may be found as early as June and as late as mid-September. Adult beetles are present after the middle of August and remain in the tree for a period of 2 to 3 months.

Identification

Figure 5. Pitch tubes formed after attack by the round-headed pine beetle (Massey, 1977).

Resin mixed with boring dust may exude from the entrance holes in the first trees attacked by roundheaded pine beetle. On most trees, boring dust collects in the bark crevices and accumulates around the base of the tree. This dust ranges in color from a brownish red to almost white. Pitch tubes (figure 5) are usually formed on the surface of the tree trunk when the resin solidifies. On trees with relatively few attacks, pitch tubes are larger than those on trees with many attacks. Boring dust and pitch tubes are freshest and most noticeable during the attack period of late September to early November. Foliage on the trees attacked by the beetle begins to fade to a light green as early as May of the year following attack; by mid-July, the foliage is straw brown. By December, 14 months after attack, most of the trees have dropped their needles. A few trees may remain green for 12 to 16 months despite the presence of boring dust and pitch tubes on the bark.

Newly emerged adult beetles are a shiny dark brown to black, about 6 mm long and 3 mm wide (figure 6). Females are slightly larger than males.

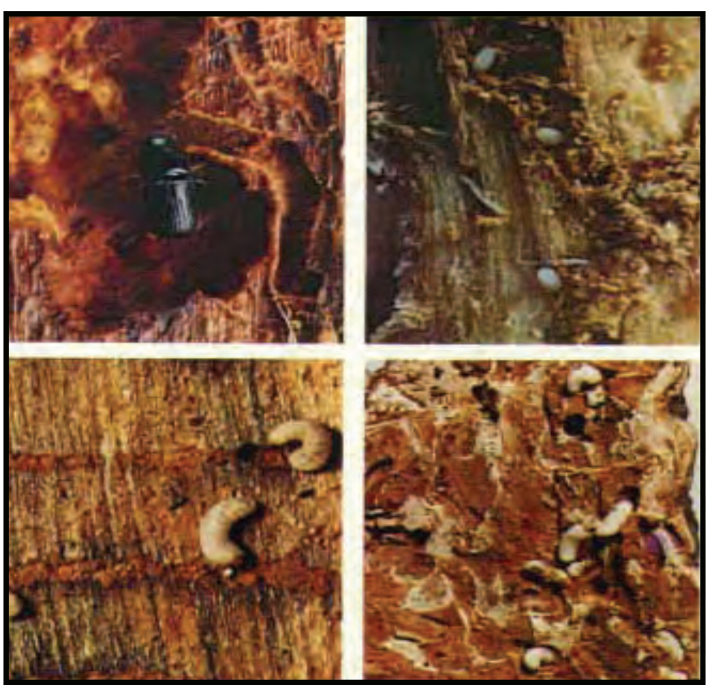

Figure 6. Stages in development of roundheaded pine beetles: top left, adult; top right, eggs; bottom left, larvae; bottom right, larvae and pupae in outer bark (Massey, 1977).

Eggs are oblong and pearly white, less than 1.5 mm in length and width (figure 6). Larvae are grublike, legless, and more or less translucent, although the contents of the abdomen may impart a reddish-brown hue (figure 6). Depending on the instar, the size of the larvae may range from the dimensions of the egg to those of the adult. The pupae are white and bear adult characteristics such as antennae, wing covers, and legs (figure 6).

Management

Management objectives should be directed toward preventing, or at least substantially mitigating, development of epidemic beetle infestations. Once populations increase to an epidemic status and outbreaks become large, management of beetle populations, as well as other resources, becomes more complicated.

Biological control:

- The red-bellied cleric *(Enoclerus sphegeus* Fab.) is the most important predator of roundheaded pine beetle in New Mexico and plays an important role in regulating beetle populations. The red-bellied cleric larvae consume the larvae, pupae, and callow adults of roundheaded pine beetle.
- A predaceous ostomid beetle *(Temnochila virescens*Fab.) commonly feeds on roundheaded pine beetle eggs and larvae. A braconid wasp *(Coeloides sp.)* is the most abundant insect parasite. Numerous other arthropods are associated with roundheaded pine beetle, but little is known of their relationships.
- Two common internal nematode parasites, *Parasitylenchus stipatus* Massey and *Parasitaphelenchus dendroctoni* Massey, frequently reduce egg production of infested females by 50 percent.
- Woodpeckers may reduce populations of the beetle during spring and summer on individual trees. Woodpeckers have consumed over 90 percent of the brood of other *Dendroctonus* beetles on individual trees, so it is probable that they do the same with roundheaded pine beetle.

Low winter temperatures appear to have little effect on the insect. The overwintering eggs survive temperatures as low as minus 25° F. (minus 32° C). These temperatures do, however, cause high mortality among the larvae that hatch before the low temperatures occur.

Management

Cultural control: Thinning and control of dwarf mistletoe in dense young stands of commercial forest likely will minimize potential killing by this beetle. Private landowners can minimize the number of trees killed on their property and protect especially high-value trees by (1) thinning their stands, and (2) eliminating infested trees by felling and then burning or treating chemically. Trap trees felled in late September may be effective but the technique needs more study.

Chemical control: Direct control is expensive in time, effort, and resources and therefore usually applied to high value areas. The need for insecticidal control measures should be based upon environmental risk assessments and surveys of population abundance (egg band or post-hatch larval surveys).

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Damage-agent is not in field guide.

Forest Insect & Disease Leaflet

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Forest Health Protection and State Forestry Organizations

By Carl Jorgensen
US Forest Service

Management Guide for
Six-spined Ips

***Ips calligraphus* (Germar)**

Topics

Next to *Ips pini, Ips calligraphus* is the most economically important engraver beetle attacking pines.

Hosts:
- **Ponderosa pine**
- **Limber pine**

Damage

During 1970, these two species killed an average of 63 ponderosa pine trees per ace that had been severely defoliated by a pine looper in southeastern Montana. It is commonly found infesting ponderosa pine stands throughout eastern Montana, and has been found across North America.

Low populations of *Ips calligraphus* maintain themselves in slash, weather-damaged trees or in trees attacked by other bark beetles.

Populations build up in abundant logging and thinning slash, trees damaged by floods, fire and injury, and trees weakened by droughts or defoliating insects.

Preferring thicker barked, deeply fissured, larger stems, this bark beetle attacks the lower boles of large trees or entire boles of smaller ones. Sometimes limbs of large trees are infested. Trees may be killed singly or in groups.

Key Points

- Populations build up in slash and damaged or weakened trees.
- Treat logging slash and remove damaged trees promptly.

Management

Sanitation and salvage are the best preventative measures. Logging slash or other breeding material should be chipped, burned, or scattered in the sun. Trees damaged by weather or logging and trees weakened by defoliators or disease should be removed. During drought years, populations may increase to damaging levels despite management efforts.

The life cycle and habits of *Ips calligraphus* are quite similar to those of *Ips pini* and it is often found in association with *Ips pini*.

Life History

There are two and sometimes three generations per year depending on locality. Larvae, pupae, and adults overwinter under the bark of infested trees or logs. In the spring, males bore into suitable host material, construct a nuptial chamber, and mate with three to six females. Each female constructs an egg gallery radiating from this chamber often deeply scoring the xylem tissue. Larvae feed and pupate in their galleries. Adults emerge to start a second generation during the summer months. It takes about 50 days for the spring generation to complete its development and from 30 to 40 days for the summer generation.

Identifying Sixspined Ips

Reddish-brown boring dust will be in bark crevices of newly attacked trees and occasionally, pitch tubes of the same color will be present. This is a large *Ips* species, and the brown adults can be 6 mm long and easily identified by six spines on their posterior declivity. Egg galleries are Y- or H-shaped and up to 38 cm. in length.

Other Reading

Ciesla, W. M. 1973. Six-spined engraver beetle. USDA For. Serv., Forest Pest Leaflet 141, 6 pp. illus.

Dewey, J. E., W. M. Ciesla, and H. E. Meyer. 1971. Evaluation of an engraver beetle, *Ips calligraphus* (Germar) following pine looper defoliation on the Ashland District, Custer NF, Montana. USDA For. Serv., Div. of State and Private For., Rept. 71-5, 5 pp. illus.

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May 2005

Forest Health Protection and State Forestry Organizations

By Steve Munson
US Forest Service

Management Guide for

Spruce Beetle

Dendroctonus rufipennis Kirby

Topics

Host: Engelmann spruce
Occasionally Lodgepole pine

Since the mid 1980's, large stand-replacing spruce beetle epidemics have occurred in southern and central Utah, south central Idaho, north central Washington, northwestern Wyoming and on the Kenai Peninsula in Alaska.

Outbreaks often start with wind or fire damage

Population increases are often associated with blowdown, landslides, stumps, residual large slash, and occasionally fire-weakened trees. If this susceptible host material is not available when adults emerge, they will attack and kill standing trees. As spruce beetle populations increase, susceptible landscapes can be adversely affected by spruce beetle epidemics.

Outbreaks can develop at any time in mature spruce stands throughout the susceptible Engelmann spruce component following blowdown (Holsten et al. 1999), landslides, winter damage, and improper treatment of logging residuals (Wygant & Lejeune 1967; McCambridge & Knight 1972). Epidemics are most common in overmature stands but may be sustained in large pole and immature stands (Wygant & Lejeune 1967). Spruce beetles will attack and kill trees 4-inch diameter and larger (Schmid & Mata 1996). Periodic epidemics have occurred throughout the west over the last 100 years.

Key Points

- Blowdown events are often associated with spruce beetle epidemics.
- Use hazard rating to anticipate damage.
- Reduce hazard by altering stand conditions.
- Trap trees are effective in reducing local populations.

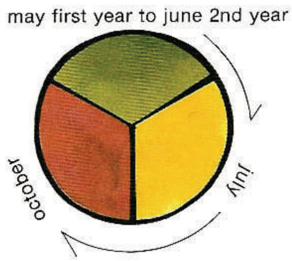
Management Brief

⇒ Prevention; Partial harvest treatments to reduce the proportion of spruce, reduce the average diameter of spruce, reduce stand density to create uneven-aged conditions.

⇒ Suppression; using trap trees, pheromone baits and lures, insecticidal sprays, sanitation and salvage harvests

⇒ Clean up spruce logging residue and blowdown.

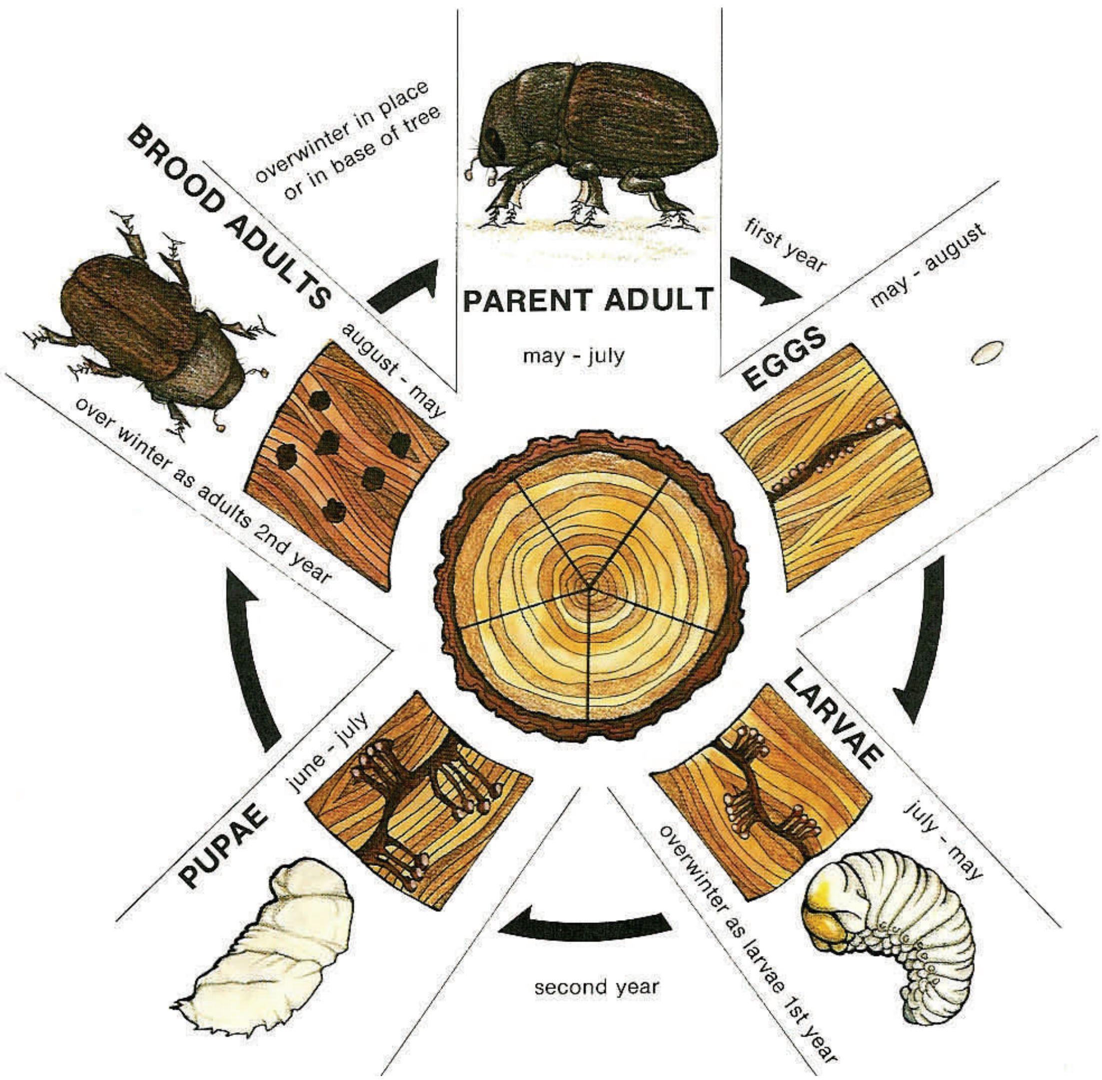
Life History

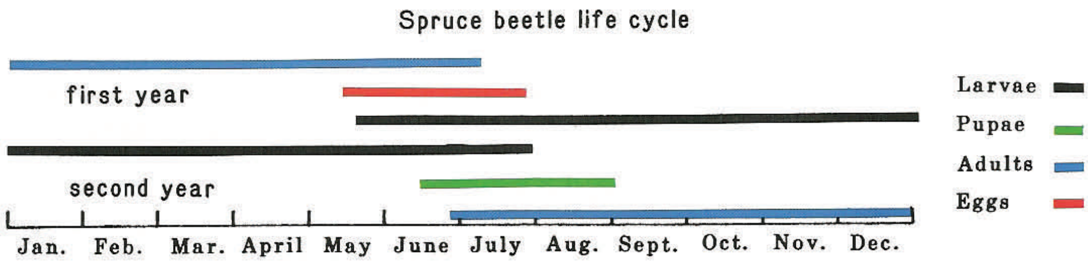


Color Cycle of Tree

Spruce beetle can have a 1 or 2-year life cycle. In the one-year cycle, larvae complete their development over the summer and overwinter as callow (teneral) adults under the outer bark. They complete their development the following spring emerging as sexually mature adults (Hansen et al. 2001). In the two-year cycle most of the beetles overwinter as larvae, although parent adults and eggs may also be present under the bark (Schmid & Frye 1977). Larvae resume feeding in the spring, then pupate in galleries during late spring-early summer of their second year. A small number of female adult beetles may reemerge and attack green trees from August through October, however most of the maturing brood adults overwinter under the outer bark. Although it varies from tree to tree, a percentage of the adults reemerge and move to the base of the tree to overwinter. Adult populations then emerge the following spring attacking host material. Beetles in downed material do not emerge and move to another site for hibernation. Most of the adult emergence occurs from mid-May to mid-July.

Spruce Beetle— typical 2-year life cycle





Management Considerations: An overview

Historically suppression efforts usually began after an infestation had caused substantial tree mortality. Suppression activities emphasized sanitation cutting, trap trees, pheromone deployment and chemical spraying. Most spruce beetle susceptible spruce stands were unmanaged with few pre-outbreak treatments designed to mitigate the effects of a spruce beetle outbreak.

Forest managers can alter these post mortem activities by initiating treatments designed to reduce the effects of a spruce beetle outbreak. Depending on resource objectives, spruce stands should be designated as a beetle-management or no-management area. Stands designated as no management sites would not be subject to silvicultural or suppression treatments. Spruce beetle populations would be allowed to fluctuate within these no management sites.

Alter stand conditions to minimize outbreak potential

Spruce stands designated as beetle management areas should be managed to minimize the effects of a spruce beetle outbreak. In beetle management areas, resource managers should hazard rate stands to determine stand susceptibility to spruce beetle which will assist them with setting treatment priorities. Suppression activities would occur within these sites if spruce beetle populations began to increase. Spruce stands with multiple use objectives (i.e. recreation, wildlife and wood fiber production) are excellent candidates as spruce beetle management areas.

Suppress beetle populations

Suppression activities may still occur in stands where preventative treatments occurred. Treatments designed to mitigate spruce beetle impacts often result in stands with some level of spruce beetle susceptibility. Not all beetle management designated areas will receive silvicultural treatments before insect populations increase in susceptible stands. Thus, suppression activities could become an integral part of a spruce beetle management strategy. Suppression activities may also be an option in treating sites near no management treatment areas if spruce beetle populations increase in no management zones. Wherever appropriate, suppression treatments should be linked to a silvicultural treatment to modify stand conditions that contribute to an infestation.

The effectiveness of suppression treatments varies depending upon the action taken and the scale of the infestation. Because spruce beetle attacked trees do not fade until the following year, ground and aerial surveys may not identify all the infested sites requiring treatment. In which case, spruce beetle populations would continue to expand in these non-treated sites. Suppression treatments are most effective when most, if not all of the infested areas are addressed and the suppression treatments are administered correctly.

Spruce stands should be designated as a beetle management or no-management areas, depending on resource objectives.

No-management sites are generally associated with wilderness areas, National Parks, experimental forests and some roadless areas.

Hazard Rating

Determine stand susceptibility to spruce beetle.

Develop treatment priorities.

Example:

Step One: To calculate the hazard rating for a hypothetical stand assume the following stand and site attributes:

Site Index = 100

Avg. spruce dbh =17 in.

Spruce in canopy = 70%

Evaluating these site and stand characteristics in Table 1, values of 2, 3, 3, and 3 are obtained .

Step Two: Adding these together results in a hazard rating value of 11. This is a "highly " susceptible stand and therefore at risk of sustaining significant mortality if spruce populations increased.

High Stand Risk: Indicates that the stand and site has attributes that can contribute to population increases.

Medium Stand Risk: Indicates the stand has some attributes that can contribute to significant spruce mortality. Generally stands rated moderate risk may or may not contribute to population increases, however during spruce beetle outbreaks most of the susceptible hosts within these intermediate rated stands will be killed.

Hazard/Susceptibility Rating (Schmid and Frye 1976)

Step one : To identify spruce stands susceptible to spruce beetle population increases, several stand and site attributes are used for the evaluation. The rating system is useful to determine what stand conditions could be altered to mitigate spruce beetle population increases.

Table 1	**Stand Hazard**		
	3	**2**	**1**
Physiographic Location	Well-drained sites in creek bottoms	Sites with site index of 80-120	Sites with site index of 40-80
Average diameter of live spruce >10 inches dbh	>16"	12-16"	<12"
Percent of spruce in canopy	>65	50-65	<50

Step two: The potential risk rating is based on the summarized hazard rating obtained from the table. Risk indicates the amount of tree mortality that could occur if spruce beetle populations increased within the rated stand.

Table 2	**Stand Hazard**
Summary of Hazard Rating	**Potential Hazard Rating**
11-12	High
7-9	Medium
4-5	Low

Although this tree characteristic is not important in the lower 48 states, in Alaska large diameter spruce trees with slower than average growth rates were more likely to be attacked and killed by spruce beetle than trees with growth equal to or greater than the stand average (Hard et al. 1983, Hard 1985, Holsten 1984, Doak 20).

Silvicultural Treatments

Stands with epidemic spruce beetle

Alexander (1973) suggests the following silvicultural options if spruce beetle populations pose a threat to susceptible stands.

- If spruce beetle populations are present in the stand to be cut or in adjacent stands affecting clumps of spruce

AND

- less than the recommended percentage of basal area to be removed is in susceptible trees,

Action: Any attacked and all susceptible trees should be removed in the first cut.

This silvicultural option will remove most of the larger spruce thus affecting wind firmness of the residual spruce. Non-hosts and smaller diameter spruce (<10-12" dbh) should be left on site to minimize windthrow.

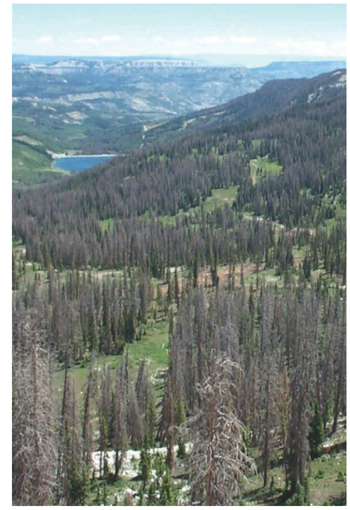
OR

- If more than the recommended percentage of basal area to be removed is in susceptible trees, three options are available:

(1) **Remove all the susceptible trees,**

(2) **Remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses**

(3) **Leave the stand uncut.** If the stand is left uncut and a spruce beetle outbreak occurs, most of the susceptible spruce basal area will be lost and surviving spruce would be smaller diameter (<5" dbh) (Dymerski et al. 2001).



Engelmann spruce killed by spruce beetle on the Manti-LaSal NF in Utah.

Stands with endemic spruce beetle

Uneven aged prescriptions for spruce-fir stands will not prevent losses caused by spruce beetle but they will mitigate the effects of an outbreak within a treated area. Table 3 summarizes post-harvest diameter class distribution where a full range of diameter classes is the objective for an uneven-aged prescription.

The uneven-aged prescription provides an average diameter of 7.5 inches, a stand density index (SDI) of 35 percent of maximum and a basal area of 134 ft^2 per acre. This spruce-fir prescription will generally meet visual and wildlife objectives while reducing stand density to a lower degree of full site utilization (thus allowing for maximum individual tree growth).

Small, ¼ acre openings will promote spruce regeneration within these uneven aged systems. Stand entry should occur before the stand reaches 60 percent maximum SDI to sustain a lower spruce beetle stand hazard rating.

Table 3	**Example: Uneven-aged stand with low spruce beetle potential**		
Mid-point dbh	**Stand Density Index**	**Basal Area**	**Trees/ acre**
2	15	4	197
6	50	25	125
10	60	33	60
14	60	37	35
18	50	35	20
Total	235	134	437

Treat Logging Residuals

Log Wizard is used to remove outer bark of spruce beetle infested logs.

Any infested down or standing material should be removed, burned or peeled following adult beetle flight.

Guidelines for addressing logging residuals were developed by Schmid (1977) to minimize spruce beetle populations increases.

- Minimize stump heights leaving stump heights of no more than 1.5 feet.
- Cull logs and tops should be limbed and the branches moved to reduce shade on bole surfaces.
- After limbing, cull logs and tops should be moved from shady sites to sunny areas and not piled unless they will be burned.
- Cutting logs and tops into short lengths (18-inches) will promote drying of the phloem reducing the amount of suitable habitat for developing larvae.
- While full-length logging removes the merchantable host material, complete removal or destruction of all cull logs and tops would eliminate suitable host material for developing life stages. If trees are logged full length, the diameter of the small end should be 4 inches.

Except for complete elimination of host material, even the previous recommendations will not keep beetles from inhabiting the bottom surfaces of logs and tops. If high beetle populations are subsequently found in these surfaces, they should be treated by removing the outer bark (peeling knife or log wizard) or burned.

If a significant spruce beetle population exists in the adjacent forest (clumps of infested trees), the logging residuals could be used to trap dispersing adults. Adult beetles prefer downed host material; however there could be a spillover effect, as some adult insects will attack adjacent standing hosts. Any infested down or standing material should be removed, burned or peeled following adult beetle flight.

The logging residual guidelines are applicable under selective, shelterwood, or clearcut silvicultural systems. The selective system provides more shade than the other treatments. Under a selective system prompt removal or destruction of suitable host material is the best strategy to minimize spruce beetle population increases.

Clean up windthrown trees

Remove infested windthrown trees from moderate to high hazard sites.

Windthrown susceptible spruce are the most important contributors to spruce beetle population increases (Schmid & Mata 1996). Windthrow events that occur in stands rated moderate to high hazard may result in outbreak populations of the insect. Not all windthrow events lead to spruce beetle population increases. Scattered windthrow in late winter or spring is the most conducive to population increases.

Windthrown trees should be sampled in late July-August following adult flight to determine attack densities in the downed material using the sampling scheme developed by Schmid (1981).

If the windthrown trees are infested, removing infested trees from susceptible sites is the preferred option. Salvage programs in Utah have used a variety of treatments to suppress spruce beetle populations in sites where windthrow occurred, including; salvage of infested trees, using Lindgren funnel traps baited with the 3-component spruce beetle attractant pheromone and trap trees (Bentz & Munson 2000).

Direct Suppression

Preventative Sprays

Carbaryl - Carbaryl (Sevin) is registered as a preventive insecticide treatment for spruce beetle. Several flowable formulations are commonly used including, Carbaryl 4L, Carbaryl 4F, Sevin XLR Plus and Sevin SL. Do not use wettable powders; they are ineffective with low residual efficacy. Carbaryl applications applied correctly, are effective for two years following treatment.

Other Insecticides - Pyrethroid field trials are currently being conducted in central Utah. Various rates of the pyrethroid formulations are being evaluated for efficacy. There are no registered pyrethroids for spruce beetle at this time.

Preventive insecticide applications must be applied before adult beetles attack the tree. Because of application costs associated with individual trees, preventative treatments are generally reserved for high value trees, i.e. recreation areas, administrative sites and ornamentals.

Preventative sprays are applied using hydraulic sprayers with pump pressures that reach 350-450 psi (pounds per square inch). Nozzle orifice sizes range from #8 to #10. The higher pump pressures are necessary to reach up to 50 feet on the tree bole of large diameter trees. Trees with abundant branching on the lower portions of the bole should be pruned up to 10-12 feet to enhance treatment performance. All bole surfaces must be sprayed to the point of runoff, including the root collar and exposed surface roots.

Remedial Sprays

Although chemical insecticides have been used in the past to kill developing larvae in infested trees, no products are currently registered for this type of treatment.

Trapping

During endemic population phases, spruce beetles maintain populations in windthrown trees. They prefer downed material to standing green trees. Trap trees are used as a suppression tactic because of this preference for downed trees. Trees selected as trap trees, are green large-diameter trees (>16 inches dbh) felled to attract attacking adult spruce beetles.

Trap trees are either burned, peeled or removed before beetle emergence the following spring to ensure that no one year brood adults will disperse to standing trees.

Trap trees should be felled in the shade and left intact and unlimbed (Hodgkinson 1985, Nagel et al. 1957, Wygant 1960). They are most effective if felled in the spring before adult beetle flight (Hebertson 2004, McComb 1955). Felled trap trees often attract 10 times or more the number of adult beetles that attack standing trees (Wygant 1960). The number of trap trees felled depends on the level of infestation and size of the infested trees. In static infestations, the number can range from 1-10 depending on the diameter of standing infested trees and the diameter of trap trees, larger diameter trap trees absorb more beetles (McComb 1953). In building infestations, the number of trap trees ranges from 1-5 based on the same parameters used for determining number of trap trees for static infestations (Nagel et al. 1957, Wygant 1960).

Standing trap trees baited with an attractant pheromone (tree bait) are effective but attract fewer beetles than downed trap trees. Adjacent to felled or standing trap trees, other susceptible host trees will often be attacked. To suppress beetle populations, all standing and down infested trees should be treated before beetle emergence the following spring.

Removing the bark from spruce beetle infested trap trees is an effective, if time-consuming, means to destroy the brood.

Trapping (continued)

Trap trees not treated by the following spring before adult flight, will add to further tree mortality. Forest entomologists can assist resource managers with determining the number and placement of trap trees necessary to mitigate spruce beetle population increases.

Non-host trees baited with the attractant pheromone are also potential trap trees because reproduction is prevented and many parent adults die due to the pitch produced by the non-host baited tree (Dyer & Safranyik 1977). Lethal trap trees, which are felled or standing host trees baited with the spruce beetle lure and sprayed with a preventative insecticide, have not been as effective at suppressing populations compared to the traditional trap tree approach described previously.

Non-host trees baited with the attractant pheromone are potential trap trees.

Pheromone strategies

Spruce beetle attractant pheromones have been used to suppress localized populations of the insect. There are two methods of deploying attractant pheromones: tree baits and spruce beetle lures.

Tree Baits –

Polymer bubble caps containing the attractant pheromone are stapled to green susceptible host trees. Tree baits are an effective tactic if used in sites where spruce beetle populations are endemic or low. Baiting tactics are as follows:

- Spot Baiting – Used to suppress small pockets of infested trees (<30 trees). Bait 2-3 susceptible trees in the center of each spot spaced 30 to 50 feet apart.
- Mop-Up Baiting – Used to concentrate residual beetle populations following harvest. Bait trees within or surrounding the treated area at 75-150 foot intervals. Baits should be deployed for two years to effectively cover the 2-year life cycle spruce beetles.
- Grid Baiting – Used in infested sites up to 50 acres to contain beetles within currently infested boundaries. Bait single standing trees at 75 foot intervals.
- Cluster Baiting – A tree bait is placed in 3-bait clusters at 330 foot (5 chain intervals). Within each cluster, place individual baits 30-50 feet apart. This is an effective technique for low or endemic spruce beetle populations to concentrate dispersing adults.

All baited trees and adjacent attacked trees must be removed, burned or peeled to eliminate the developing life cycles from the treated areas. Because of the possibility of a one-year life cycle, the trees must be treated the same year the baits were installed following adult spruce beetle dispersal.

Spruce Beetle Lures —

Spruce beetle attractants are used for monitoring purposes and to supplement suppression efforts. Recent attractant studies in Utah indicate that the 3-component lure is a more effective attractant for spruce beetle (Ross et al. 2005). However, spillover effects on adjacent host trees are greater when the 3-component lure is used. To minimize this effect, funnel traps with lures should be placed at least 100 feet from a susceptible host tree. Trap placement should occur in clumps of non-hosts or dead spruce. Trap placement in open areas without shade, is not very effective.

MCH
(3-methyl-2-cyclohexen-1-one)
The natural antiaggregant pheromone for Douglas-fir beetle repels spruce beetle attacks, particularly if populations are endemic or just beginning to increase.

Previous field studies indicate MCH can reduce attacks on MCH treated windthrown trees and logs (Rudinsky et al. 1974). MCH used as a repellent in outbreak populations of spruce beetle, is not an effective treatment (Ross et al. 2004).

Pheromone strategies (continued)

A funnel trap containing aggregative semiochemicals provides a means to assess and reduce local populations of spruce beetle.

Monitoring –
Spruce beetle lures are used in combination with Lindgren funnel traps to determine flight periodicity and population densities. A Lindgren funnel trap baited with the 2-component lure is an effective monitoring technique. Single traps placed in sites with spruce beetle activity will effectively monitor flight activity and population densities.

Suppression –
Lindgren funnel traps baited with the 3-component lure is an effective strategy to reduce local populations of the insect. This technique is most effective if used in combination with other suppression treatments (i.e. sanitation, trap trees). Traps should be placed in 3 trap clusters at 330-foot intervals (5 chains) in clumps of non-hosts or dead spruce. Distance between traps within a cluster should range between 50-75 feet.

Natural Controls

- *Temperature extremes*
- *Woodpeckers*
- *Insect predators and parasites*

Temperature extremes

Temperature is one of the most critical factors in the life of the spruce beetle; the extremes are lethal, and the intermediates influence development.

Extreme cold—
Laboratory tests showed that subcortical temperatures of -15°F will kill all adults, while -30°F will kill all larvae (Massey & Wygant 1954). Extremely low temperatures in Colorado in 1951 are frequently cited as a major factor in terminating the White River outbreak (Wygant 1956). In the northern Rocky Mountains, an average of 42 percent of the brood was killed during an unusually cold spell (Terrell 1954).

Extreme heat—
At the opposite extreme, temperatures exceeding 130°F for 30 minutes will kill all the brood in the bark subjected to such conditions. Temperatures above 110°F will kill varying percentages of the brood depending on the length of exposure (Mitchell & Schmid 1973).

Adaptation to cold—
The overwintering behavior of a percentage of the adults may have evolved in response to cold winter temperatures. When beetles leave the upper bole and reenter the bark near the base, their survival is enhanced. Under normal conditions, 6 feet or more of snow accumulates on the ground in the high elevation spruce-fir forest covering the tree base. Below this snow line, temperatures are near 32°F while above the snow line ambient air temperatures exist. Thus, beetles in the bark below the snow line are not subjected to lethal sub-freezing temperatures (Schmid & Frye 1977).

Extremely low spring temperatures in Colorado in 1951 are frequently cited as a major factor in terminating the White River outbreak

Woodpeckers

During an outbreak, woodpeckers can consume as much as 55% of the spruce beetle brood.

Three species of woodpeckers, the northern three-toed, the hairy, and the downy, are important predators of the spruce beetle and are listed in decreasing order of importance (Knight 1958).

Three important bird species—

- The northern three-toed is most effective because it feeds exclusively on the boles of trees, primarily on trunks of freshly attacked trees rather than old snags (Koplin 1969) and is indigenous to the spruce-fir habitat (Baldwin 1960). Its effectiveness is also greater because this species aggregates in infested areas (Koplin 1969).
- The hairy woodpecker feeds on the trunks of trees including old snags in addition to freshly attacked trees (Koplin 1969).
- The downy is the least effective spruce beetle predator of these three species of woodpeckers. It feeds mainly on the branches of infested trees (Koplin 1969) and has the least pronounced functional response to infestations (Koplin 1972).

Natural Controls

- **Weather: temperature extremes have been credited with ending some spruce beetle outbreaks**
- **Woodpeckers: such as the northern three-toed woodpecker, feed exclusively on insects in the bole of trees.**
- **Insect predators and parasites: Effects are quite variable, from minimal to more than 60 percent.**

Impact on bark beetle populations—

Woodpecker effects on beetle populations are influenced by host material, density of beetle brood and extent of woodpecker feeding. During outbreak conditions in standing trees, woodpeckers may destroy 55 percent of the brood (Hutchison 1951) although beetle mortality may vary from 45 to 98 percent (Knight 1958).

During low-level infestations woodpeckers may only take about 20 percent of the brood in standing trees. In trap trees or downed material woodpeckers may consume 2 to 26 percent of the brood (Koplin & Baldwin 1970). Feeding activity on trap trees or downed material may be influenced by the presence or absence of adjacent infested standing trees. When present, feeding activity on the downed material may be reduced. When absent, woodpeckers may concentrate on the downed material.

Feeding activity of woodpeckers fluctuates with the season, day, weather, and the type and amount of infested host material. Feeding on infested standing trees is generally highest during December through March; feeding is greatly reduced on such trees from late May to September (Koplin & Baldwin 1970).

Despite high-energy needs and exclusive feeding on spruce beetle in winter, woodpeckers would be unable to eliminate all the beetles in each tree because of the overwintering behavior of a percentage of the adults in the base of the tree beneath the protective snow cover.

Natural Controls

Insect Predators and Parasites

The effects of insect parasites and predators on spruce beetle populations are quite variable. These agents are a tremendous mortality factor in some infestations; perhaps accounting for more than 60 percent beetle mortality. In other cases, the entomophagous species kill a large number of spruce beetles, but their effect on the population is minimal.

Impact on spruce beetle outbreaks—
Some forest entomologists believe insect parasites and predators are primarily responsible for keeping beetle populations at endemic levels. However, the fact remains that infestations develop from a low level to outbreak status with these organisms present. Furthermore, under outbreak conditions these organisms seldom cause a rapid reduction of the beetle population to pre-outbreak levels even though they may kill a large number of beetles.

Based on these observations, it is difficult to conclude that natural populations of insect parasites and predators regulate spruce beetle populations.

Important species—
Generally the important parasitic and predacious species are known (Massey & Wygant 1954, Jensen 1967). Their life cycles, habits, and mortality effects of some species are known either from studies of the spruce beetle or other *Dendroctonus* beetles (Schmid and Frey 1977).

- The most important *Braconid* wasp parasite is *Coeloides dendroctoni*. Two other parasitic wasps have been observed feeding on spruce beetle larvae. Both are *Pteromalididae* wasps with little known about their life history or habits. Neither species are considered to be important contributors at suppressing spruce beetle populations.

- The second most important biological mortality agent of spruce beetle besides woodpeckers is a parasitic fly *Medetera aldrichii*. Its effectiveness may be lessened by indiscriminate feeding habits because larvae feed on a variety of other insects (Massey & Wygant 1954).

- Three species of clerid beetles also feed on spruce beetle life stages, *Thanasimus undatulus, Enoclerus lecontei* and *Enoclerus sphegeus*.

- Other insect species have been observed feeding on various developmental stages of the beetle. Few of these have been adequately studied and their effectiveness as predators is not known.

Insect parasites and predators

These agents are a tremendous mortality factor in some infestations; perhaps accounting for more than 60 percent beetle mortality.

Parasitic wasps help to keep bark beetle populations in check.

Effects of Spruce Beetle

Significant succession effects of spruce beetle include rapid conversion to fir cover types, and increased density and diversity of grasses and forbs.

Vegetation—

When epidemic spruce beetle populations change stand structure, they also simultaneously alter species composition. Stands composed of 90 percent spruce and 10 percent fir in the overstory before the White River outbreak became 20 percent spruce and 80 percent fir in the overstory after the epidemic (Schmid & Hinds 1974).

In Utah on the Wasatch Plateau, the spruce beetle outbreak reduced spruce basal area more than 90 percent and decreased average spruce diameters from 14.1 inches to 8.6 inches (Dymerski et al. 2001). Affected stands become predominately fir for the next 125-175 years or until the fir begins to die (Schmid & Hinds 1974).

Forage production in beetle-killed stands is much greater than in green unaffected stands. Grasses and sedges showed increased density in beetle-killed stands and forbs were 2.3 times more numerous but browse plants decreased. In general, the greatest density, number of species, and index of occurrence of plants were found in beetle-killed stands (Yeager & Riordan 1953).

Elk and deer may find improved forage after a spruce beetle epidemic.

Wildlife—

The influence of spruce beetle epidemics on animal populations inhabiting spruce-fir forests has not been determined but would depend on the species requirements and the intensity and range of the epidemic (Schmid & Frye 1977). Insectivorous birds such as woodpeckers would initially increase because of the abundant food supply, however as insect populations decreased these predators would have to emigrate thus declining in abundance.

Seed eating birds and mammals are adversely affected because of the loss of spruce seed (Yeager & Riordan 1953). Spruce grouse would also decline in numbers because of the loss of suitable habitat and winter food. In contrast, elk and deer benefit from the increased forage production, although the loss of thermal cover can be detrimental to both species (Schmid & Mata 1996).

In the aftermath of a spruce beetle epidemic, the risk of increased fire intensity remains high for several decades because the large dead fuels are slow to decay.

Fire—

Spruce beetle epidemics can influence both fire hazard and fire intensity. Increased fire hazard (probability of a fire starting) created by the killing of spruce by beetles is limited to the first two years after beetle attack when the dead and dying needles increase the fine fuel component. Once these fuels fall from the dead trees, fire hazard is essentially similar to the period before the trees were attacked and killed by spruce beetle (Schmid & Mata 1996).

In contrast, fire intensity (the destructive nature of a fire) would increase after a spruce beetle infestation and remain at a higher level for decades because of the increased amount of dead fuels that are slow to decay (Schmid & Mata 1996). The probability for stand replacing fires in a spruce beetle affected site remains small because fires are infrequent in spruce-fir forests (Veblen et al. 1994). However, if a fire started under favorable or extreme fire weather coniditons the abundant fuel loads would increase fire intensity.

Effects of Spruce Beetle (continued)

Hydrology—

Spruce beetle epidemics influence tree-water relationships and if the epidemic is large enough, streamflow. A long-term streamflow study in Colorado following a spruce beetle epidemic found that a major increase in streamflow occurred after the epidemic (Bethlahmy 1974). Following the White River spruce beetle outbreak in Colorado, streamflow for the affected watershed increased 1.6-1.9 inches (Mitchell and Love 1973).

Loss of riparian forest canopy following a spruce beetle epidemic can result in increased stream flows.

Deterioration of Spruce—

Mielke (1950) studied the rate of tree deterioration in beetle killed Engelmann spruce. In southern Utah, 85 percent of the spruce beetle killed trees were still standing after 25 years. Mielke also studied this effect in Colorado and noted that the moisture content of heartwood and sapwood had reached such a low level in the dead spruce that decay fungi were unable to develop.

In the White River spruce beetle outbreak in Colorado (1941-1952), Hinds et al. (1965) found that about 40 percent of the original cubic volume had been lost 20 years after the trees died. About one-third of this loss was due to decay in standing trees, two-thirds to windthrow. As time passed, windthrow was a progressively more important deterioration factor.

Boring dust on the bark is often the most obvious sign of successful spruce beetle attacks. Pitch tubes may occur on the bark of attacked trees.

Recognizing Trees attacked by Spruce Beetle

Reddish-brown boring dust on bark, in bark crevices, and on the ground around the root collar from mid-May to mid-July is the most obvious sign of beetle attack. Pitch tubes may also occur around entrance sites. Boring dust and pitch tubes are most visible the first summer following initial attacks (Holsten et al. 1999). During winter, woodpeckers feeding on overwintering life stages produce bark flakes that accumulate on the ground or snow around infested trees. Egg galleries average about 6-8 inches in length, have a slight crook at the start, and extend vertically in standing trees. Eggs are deposited on alternate sides of the gallery, which is packed with frass and boring dust. Larvae feed in the phloem outward from the egg gallery, often in a radiating pattern. The needles on infested trees usually do not turn yellowish-green until the following summer, one year after the initial attacks. Needle discoloration generally takes place in late July and August. Needles drop soon after fading as a result of wind and rain. Adult beetles are dark brown to black with reddish-brown or black wing covers and are about 1/4 inch long and 1/8 inch wide (Holsten et al. 1999).

Pitch tubes may occur around beetle entrance sites on the bark.

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No FIDL for this damage-agent

March 2006

By
Sandra Kegley
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Balsam Bark Beetle

Dryocoetes confusus Swaine

Host:

- **Subalpine fir**

Windthrow can touch off outbreaks of this beetle, killing hundreds of large trees.

Topics

Key Points

- **Very common and often damaging insect.**
- **Usually accompanies damage from other insects or diseases or acute tree stress.**
- **Beetles can build up in windthrow or logging slash.**

Introduction

The western balsam bark beetle is the most conspicuous of a complex of pests which are responsible for high amounts of tree mortality in subalpine fir forests throughout the host range. Infestations are chronic in some areas. Other agents responsible for the decline of subalpine fir include root diseases (figure 1) and balsam woolly adeglid.

Figure 1.Trees attacked by western balsam bark beetle are often infected with root disease such as *Armillaria* shown here.

Root disease, old age, and weather damage may contribute to success of western balsam bark beetle in stands.

Damage

Low populations maintain themselves in trees weakened by old age or root disease, and in windthrow or slash. During periods of drought or other environmental stress, infestations can build up over large areas. Outbreaks often occur after windthrow events. Groups of 100 to 1,000 large diameter trees may be killed (Figure 2).

Even in outbreaks, weakened trees are more likely to be attacked. Successfully attacked trees have less crown (lower percent of the bole covered with constant crown and lower crown volume), slower growth, and are older than unattacked trees (Bleiker et al, 2003, 2005).

Western Balsam Bark Beetle Management

1. **Prevention: Destroy logging slash and remove infested trees.**
2. **Pheromones: Although still under development, anti-aggregation pheromones have potential for protecting stands from outbreaks.**

Western balsam bark beetle female adult. Note thick patch of hair on her head.

Western Balsam Bark Beetle Adult

Adult beetles are glossy, dark brown and cylindrical. They range from 3.4 to 4.3 mm long. Their thorax is evenly convex above; their posterior is abruptly rounded and without spines. The front of their head is covered with a distinct brush of hair. Females have a denser brush of hair than do males.

A male initiates the attack and attracts several females to the nuptial chamber to mate and begin excaving egg galleries.

In British Columbia, an estimated 35 percent of subalpine fir mortality is due directly to attack by beetles. The remainder is attributed to a beetle-introduced lesion-causing fungus, *Ceratocystis dryocoetidis*, and other unidentified fungi. Initial beetle attacks may be pitched out, but subsequent attacks on trees weakened by lesions are often successful. Coalescing lesions may kill trees without further beetle activity (Molnar 1965, Doidge 1981). Often, other secondary bark beetles become a part of this tree-killing association.

Figure 2. Mortality caused by western balsam bark beetle often occurs in groups.

Life History

Overwinter as larvae and then nearly mature adults

Western balsam bark beetle normally has a 2-year life cycle. However, they may develop in one year under the right weather conditions. Normally, they overwinter as larvae under the bark the first year, continue development during spring and early summer, and overwinter the second year as nearly mature adults.

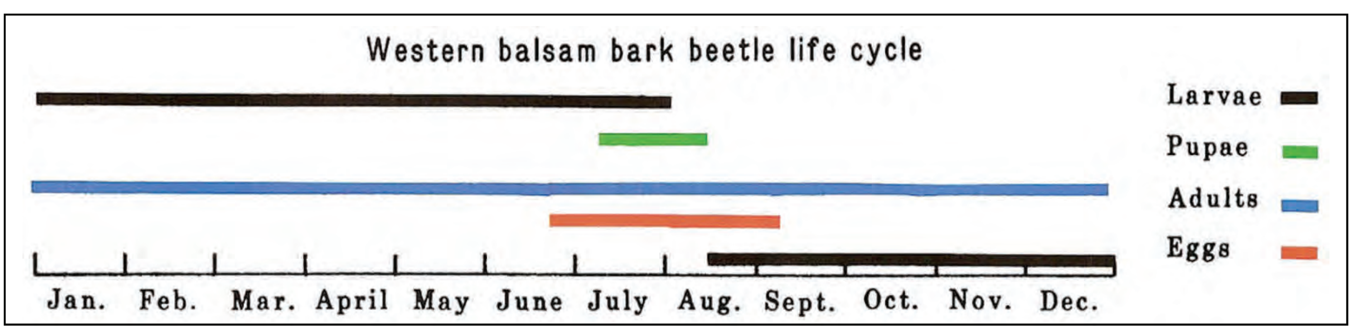
Adult beetles initiate new attacks

Males initiate attacks on trees, excavate a nuptial chamber in the phloem, and attract several females. Female beetles can lay eggs for 2 years, either in the same tree they initially attacked or in different trees. Solitary females can successfully initiate galleries and brood production (Stock 1981).

Egg galleries and larval feeding

Egg galleries radiate from the central nuptial chamber in a random pattern (figure 3). Larvae extend their mines from the main egg galleries until freezing weather and then become dormant.

Figure 3. Gallery pattern of western balsam bark beetle consisting of egg galleries radiating out from a central nuptial chamber and larval galleries extending beyond the egg galleries.



New adults emerge from galleries

Pheromone trapping conducted in northern Idaho and western Montana indicates initial flights begin in early- to mid-June and continue through September. Peak flights occurred in late June/ early July and in late July/ early August (Gibson et al. 1997). Two main flight periods have also occurred in British Columbia (Stock 1991) and Utah (Hansen 1996).

Evidence of attack

External evidence of attack on the boles of standing trees is hard to detect. Entrance holes and boring dust on the bark or around the base of the tree may be visible during late summer. Pitch flow may be evident and often indicates an unsuccessful attack (figure 4). Attacked trees generally turn yellowish-red within a year and can stay bright red for a year or two after death (figure 5).

Figure 4. Pitch flow on the bole of subalpine fir indicating an unsuccessful western balsam bark beetle attack.

Management Considerations

Silvicultural methods

Because of the high elevation and sensitivity of sites on which subalpine fir grows, silvicultural control is seldom possible. To keep epidemics from developing, logging slash should be destroyed. Weakened and beetle-infested trees or windthrow should be salvage logged when feasible.

Pheromones

Aggregative pheromones (exo-brevicomin) have been developed which can help concentrate beetles into stands scheduled for harvest (Stock et al. 1994).

An antiaggregation pheromone, endo-brevicomin, has been shown to reduce the response of beetles to the aggregation pheromone in laboratory and field studies. It also prevented attack on subalpine fir trees baited with the attractant pheromone. Although not yet recommended operationally, the antiaggregation pheromone has potential for protecting individual trees from attack or suppressing western balsam bark beetle activity in high hazard or infested stands (Stock et al. 1990).

Figure 6. Dense stand of subalpine fir susceptible to western balsam bark beetle.

Figure 5. Bright red crowns often indicate western balsam bark beetle attack. Trees may retain red needs for a year or two after death.

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Forest Insect & Disease Leaflet

May 2004

By
Carol Bell Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for
Western Pine Beetle

Dendroctonus brevicomis LeConte

The western pine beetle is an aggressive killer of ponderosa pine throughout its range.
It also attacks Coulter pine.

Topics

Damaged and diseased trees are most vulnerable

Beetle populations often attain outbreak levels when host pines are moisture stressed during drought or following forest fire. Between 1987 and 1993, western pine beetle killed over 165,000 trees in south central Idaho.

The beetle devastated stands of large, over-mature, decadent pines in the first half of the twentieth century. Western pine beetles will still infest these stands where they occur. Single, large, old, slow growing or diseased pines are very susceptible to attack. Large old ponderosa pines surrounded by second growth mixed conifer stands are often at risk, a result of fires suppression and excessive competition from younger trees.

Over the last couple of decades the western pine beetle has become especially aggressive in second growth stands, killing trees six inches or larger in diameter, including apparently healthy trees.

Trees are characteristically killed in groups, primarily in dense, over-stocked stands of pure, even-aged pines, but mortality also occurs among dense clumps of ponderosa pines in stagnating mixed-conifer stands.

Key Points

- Old age, drought, fire damage and disease make trees vulnerable.
- Use hazard rating to anticipate problems. Reduce hazard by removing high-risk trees.
- Thin to maintain vigor.
- Trap trees are effective in reducing local populations.

Management

⇒ Silvicultural treatment; remove high-risk trees and thin to improve vigor of stands.

⇒ Preventative sprays can protect high-value trees, temporarily.

⇒ Remove and destroy brood in infested trees.

⇒ Pheromones can be used to lure beetles into traps or trap trees.

Life History

Female western pine beetles carry spores of blue stain fungi. The combination of blue stain fungus growth in the sapwood, and beetles tunneling in the phloem, blocks the conductive vessels of the inner bark and sapwood, resulting in tree death.

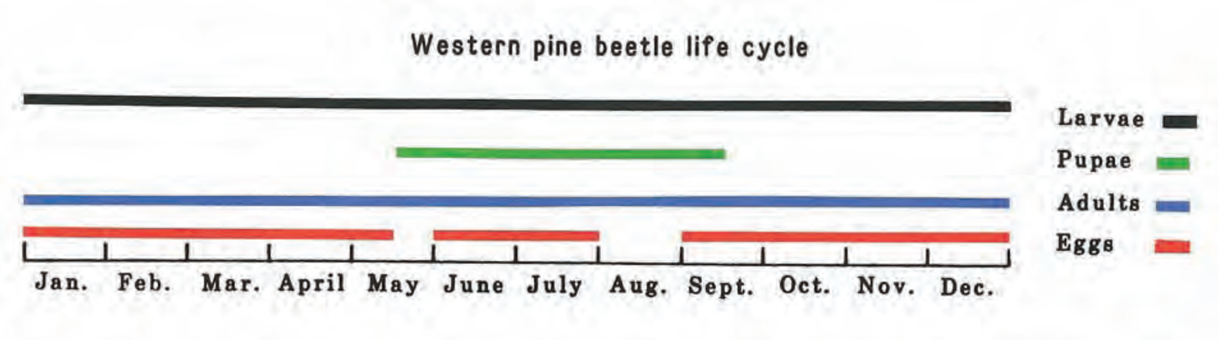
Normal attack and development occur only in ponderosa and Coulter pine. Initial attacks on a standing tree are made about midbole and subsequent attacks fill in above and below. The beetles may take from 2 to 10 months to pass through egg, larval, pupal, and adult stages. All stages are completed beneath or in the bark of infested trees, except for a brief period when adults fly to find new trees to attack.

In the northern part of their range (including Idaho and Montana) and at higher elevations, the beetles produce two generations each year, with attacks concentrated in early June and late August.

During an attack period, which may last 3 weeks, each female lays about 60 tiny pearl-white eggs individually in niches cut into the sides of the egg gallery. Some of these parent females may emerge and re attack to establish additional galleries on the same tree or in other host trees.

After incubating for 1 to 2 weeks, the eggs hatch. The larvae are small white grubs. Larvae initially feed in the phloem, where they construct a short gallery, but then mine into the middle bark where most of their development takes place.

Adults mine through the middle and outer bark, accumulating fungal spores in their mycangia (special pouches near the beetles' mouth). These fungal spores contain blue stain fungi which assist the beetles in overcoming host defenses during attack.



Recognizing Trees attacked by Western Pine Beetle

Fading foliage is the first evidence of damage to the tree that is visible at a distance. Trees attacked during the summer may fade even before the beetles emerge, depending on weather conditions in any given year. In trees attacked in late summer or fall the fungus develops more slowly and many infested trees do not fade until the following spring. Woodpeckers may flake off the outer bark of these green, infested trees as they search for and feed on developing beetle larvae. This flaking exposes the bright orange inner bark, making trees visible from as far away as 300 feet (100 m). Under the bark, the pattern of the egg gallery is distinctive.

Damage Prevention: The Silvicultural Approach

Damage prevention is best accomplished by reducing hazard associated with one or more of the "high hazard" conditions through some type of stand manipulation. Alternatives include commercial thinning, or any of the several regenerative methods, which will help meet stand and site resource objectives. Any method which will ultimately reduce stocking, stand senescence (old age) or tree damage will produce stand conditions less favorable to western pine beetle.

A necessary first step in the prevention of beetle attacks is the identification of trees and stands most likely to support heavy populations of beetles-hence, the value of a hazard-rating system.

Hazard Rating: Identifying susceptible trees and stands

Hazard rating systems are used to help identify individual trees likely to be killed or stands more likely to experience high levels of tree mortality in the event of elevated western pine beetle populations. Two systems have been developed for western pine beetle, one focusing on individual mature ponderosa pine trees and the other on stands of ponderosa pine.

Individual Tree Hazard (Miller and Keen 1960)

A hazard rating system based on a combination of individual tree characteristics is used to rate mature ponderosa pines according to their susceptibility to western pine beetle attack.

⇒ Age

⇒ Crown size

⇒ Dominance

Applying these hazard-rating criteria, one of four levels of risk is assigned to each tree: low, moderate, high, very high. Older trees with poor thin crowns and slow growth rates are considered most likely to be attacked and killed by the beetle. Though this system was developed in California, Johnson (1972) determined it works equally well when applied to ponderosa pine stands in western Montana.

It is important to note that hazard does not imply imminent mortality.

Many risk 4 (very high) trees have survived multiple periods of elevated beetle populations.

Stand level hazard ratings are best when multiple stands are rated across a landscape, to identify areas of concentrated hazard.

Stand Hazard
(Steele et al. 1996)

A combined mountain pine beetle/ western pine beetle hazard rating system for ponderosa pine.

It uses the average diameter of ponderosa pine >5" dbh (12.5 cm dbh), the basal area (ft^2/acre) of the stand (all species), stand structure, and the percent basal area of host in stand.

If all ponderosa pine is < 5 inches dbh or if ponderosa pine is absent, hazard = 0. Else, assign the stand a value of high (3), moderate (2), or low (1), for each of the three parameters.

	Stand Hazard; Step one		
Parameters	**1**	**2**	**3**
Average dbh of ponderosa pine*	< 8 in. <20 cm	8-10 in. 20-25 cm	>10 in. >25 cm
Basal area of stand (all species)	<90 ft^2/acre	90-120 ft^2/acre	> 120 ft^2/acre
Stand Structure	Multi-aged (> 2 stories)	Dual-aged (two storied)	Even-aged (single storied)

* average diameter at breast height (3.5 ft.) of ponderosa pines that are at least 5 in. dbh.

Step two: Add the stand hazard values for each parameter, then multiply by the percentage of ponderosa pine > 5" (10 cm) dbh in the stand.

Hazard rating can be displayed using maps to detect areas of concentrated hazard, especially areas where beetle caused mortality would adversely impact ability to achieve management goals. Such hazard maps enable land managers to prioritize areas for treatment to reduce hazard.

Silvicultural Treatments

Old Growth Stands

The most effective means of educing losses to the western pine beetle in old growth ponderosa pine stands is through the application of individual tree hazard rating techniques (Miller and Keen 1960) with subsequent removal of high-risk trees. In stands where high-risk tree removal strategies have been implemented, beetle-caused mortality has been reduced by as much as 70 percent.

Second Growth Stands

Management strategies that reduce stand hazard ratings often increase the vigor of residual trees and result in lower losses to the western pine beetle. The one stand characteristic used in hazard rating most amenable to silvicultural manipulation is density. Thinning the trees will increase tree vigor and reduce the risk of beetle attack in remaining trees. Reducing the basal area to 90-100 square feet per acre is an effective guideline. A general rule of thumb is the remove enough trees so that the tree crowns do not touch.

Rapid vigorous growth increases host resistance and reduces the likelihood of outbreaks.

In both old growth and second growth stands, trees weakened by defoliation, root disease, lightning, fire, mechanical injury, breakage, soil disturbances, or attack by other bark beetles are very susceptible and should be removed as quickly as possible.

Natural Control

Climatic conditions and host resistance most often determine western pine beetle abundance. Winter temperatures of –20 F and lower for a few days have been found to cause heavy mortality to over wintering broods. Drought, which stresses trees, promotes beetle survival and the development of outbreaks. Rapid, vigorous tree growth increases host resistance and reduces the likelihood of outbreaks.

While woodpeckers and insect enemies of the western pine beetle do exert pressure on western pine beetle populations, these natural enemies have not been shown to effectively cause an outbreak population of the beetle to collapse.

Predatory beetles help to keep bark beetle populations in check. The first sign of attack may be predacious checkered beetles seen at eye level scurrying over the bark in search of western pine beetle prey.

Direct Control

Direct control measures focus on killing beetles and may be justified in areas where beetle caused tree mortality is incompatible with management objectives such as home sites, campgrounds, or recreational areas. Felling the infested tree and immediately burning, debarking, or spraying it with toxic chemicals can kill beetle broods.

If the larvae are well developed, debarking alone will not kill them, the bark would need to be burned or otherwise destroyed. If western pine beetle infested ponderosa pine is used for fire wood, the fire wood needs to be used (at least the bark) before the adults can emerge in the spring or they may attack and kill nearby pines.

Preventative Sprays

Certain insecticides may be applied to susceptible trees prior to beetle flight and will successfully protect trees from attack. Check with your local Forest Health Protection Office or State/County officials to determine which insecticides are currently registered for this application.

Beetles initially attack a standing tree about midway up the bole with subsequent attacks filling in above and below- so preventative sprays need to cover as much of the trunk as possible.

Pheromone Strategies

The aggregation pheromone for the western pine beetle has been identified and synthesized for use in management strategies.

Aggregation pheromones are compounds produced by the beetles which call to other beetles in the vicinity to aggregate to facilitate successful mass attacks on hosts. Western pine beetle baits have numerous potential applications including:

⇒ **Trap out Strategies**: pheromone baited traps or trap trees are used to concentrate beetles in an area slated for management. Traps are routinely maintained/ emptied or trap trees are promptly removed to prevent beetles from completing their lifecycle and attacking additional trees.

⇒ **Tree baiting**: in certain areas tree baits are being used to selectively remove certain ponderosa pine. In the Northern Region tests are ongoing to determine the potential to use western pine beetle tree baits to kill off site ponderosa pine.

⇒ **Baited toxic trap trees**: in this scenario a tree is treated with an insecticide than baited. Beetles fly to the bait and then ingest the insecticide and die.

Recognizing Western Pine Beetle

Inconspicuous white to reddish brown pitch tubes ¼ to ½ inch (6 – 13 mm) in diameter, may be formed on the tree trunk around entry holes made by attacking female beetles. More frequently the first visible sign of successful attack is reddish boring dust that accumulates in bark crevices and around the base of trees. Egg galleries wind both laterally and longitudinally, crossing and recrossing each other in a maze-like pattern which is unique among bark beetles infesting ponderosa and Coulter pine. The life stages are similar to other species in the genus, the adult being dark brown to black and slightly less than one-quarter inch long.

Western pine beetle gallery in cambium.

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WOOD BORERS

March 2004

By Ken Gibson
US Forest Service

Forest Health Protection and State Forestry Organizations

Wood Borer Management: Overview

Wood borers take many forms. Among the common boring insects are:

- **Beetles**
- **Wasps**
- **Moths**

Boring insects feed within the woody portions of trees and shrubs or within the phloem and pith of shoots.

Topics

Key Points

- Several kinds of insects may cause boring damage in wood
- Damaged and dying trees often are attacked
- Improve vigor of potentially damaged trees
- Use pheromones to disrupt mating or trap adults
- Chemical control to prevent attacks

Borers invade a variety of tissues

Boring insects may spend most of their life cycle feeding inside a host or spend part of their life cycle as borers and part as a defoliator on the same host. Beetles, wasps, and moths that are borers, undergo complete metamorphosis and pass through egg, larva, pupa, and adult stages of development.

Boring insects, while feeding, construct tunnels (galleries) in plant tissue. Feeding by borers may deform, weaken, or stunt tree growth. Their galleries may girdle a portion of or an entire tree, or involve an entire bud, branch tip, seed, or fruit. Recovery of a tree from boring damage or replacement of a dead or damaged tree is slow and may take years.

Weak or damaged trees may attract borers

Many borer insects are attracted to trees that are weakened by crowding, stem and trunk diseases, or other insect damage. Chemicals, mechanical activities, rodents and extremes in temperature, sunlight, and moisture may also produce damage that attracts boring insects.

Cultural Control of Boring Insects

Attraction of boring insects may be avoided by maintaining health of high-value trees should through cultivating, fertilizing, watering, and thinning when necessary. Removing infested, dead, or dying branches is also beneficial.

Chemical Control

While some systemic insecticides have proven effective against some boring insects, most will not kill larvae already in the tree. This is especially true for some of the more destructive wood-boring larvae. Chemical control is usually limited to the short period of time when the adult or newly hatched larvae are exposed on the bark and before they enter the tree.

Mating Disruption and trapping

Males of many species of boring insects, especially moths, are attracted to a chemical produced by females (pheromones). A few of these synthetically produced chemicals have been used successfully to survey for, evaluate, or control a pest species.

Mating disruption strategies, using synthetic pheromones, have been used successfully to reduce harmful populations of some stem-boring insects. In some cases, males are "trapped" out of naturally occurring populations. In others, pheromones saturate an area with attractant, confuse searching males, and render mating less successful.

Cite as: Gibson, K. 2004. Wood borer management: Overview. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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May 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Ambrosia Beetle

By R. Ladd Livingston
State of Idaho

Topics

***Trypodendron* spp.**

Ambrosia beetles are chronic pests in stored conifer and hardwood logs; at times reducing the market value as much as 50 percent.

Beetles in the genera *Platypus, Gnathotrichus* and *Xyleborus* cause similar damage but are not as economically important as Trypodendron, especially *T. lineatum*.

Boring holes in stored logs and fresh lumber

Four species of *Trypodendron* occur in the West along with species in the genera Platypus, Gnathotrichus and Xyleborus.

They cause economic damage in true firs, spruce, Douglas-fir, and hemlock. Larch and pines are also attacked. Some breed in aspen, poplar, birch, and alder.

Populations build up in wind throw, fire-killed trees, logging slash, trees killed by other beetles, and logs.

Their galleries within the sapwood cause defect in logs stored for long periods and may reduce market value as much as 50 percent. Some species extend galleries into the heartwood, and freshly cut lumber may be attacked before it has dried. Damage is not usually sufficient to cause structural weakening of the wood.

Key Points

- Only dead trees and logs are attacked.
- Many species of conifers and hardwoods are damaged.
- Damage from stain and decay fungi carried by beetles in addition to bore holes.
- Process logs promptly.
- Protect by keeping logs wet.
- Trap out beetles from log storage areas.

Management

- Time harvest to avoid *Trypodendron* flight periods.
- Process logs promptly after harvest.
- Avoid moving infested logs to storage areas.
- Use water misting to protect log decks from attack.
- Use low-value logs such as pulp logs to trap out beetles.
- Use pheromone traps around storage facilities to reduce populations.

They are called ambrosia beetles because brood in chambers along the galleries feed on a cultivated ambrosia fungus.

Life History

The following is for *T. lineatum* (Oliver) which is the most damaging ambrosia beetle in western conifers. Adults hibernate in the duff and start emerging in the spring, after most of the snow has melted, when temperatures reach 16° C (above 60° F). Attacks can occur from May until August.

Females bore through the bark and straight into the wood and construct compound galleries. They cut niches in series above and below these tunnels to lay eggs. Larvae develop in these cradles for 6 to 8 weeks, then pupate.

New adults emerge from June into September and go into hibernation in the forest litter. There is only one generation a year, but re-emergence of some adults in late summer could result in a second brood.

Alternatives for Control

A variety of procedures can be employed to minimize infestation and decrease damage in infested logs. A combination of methods used congruently are likely to produce the best results.

Nijholt (1978) recommended the following procedures to decrease damage:

At the Logging Site——

- Avoid having susceptible logs available to beetles.
- Utilize logs as soon as possible after felling. "Hot logging".
- Avoid leaving fall- and winter-cut logs until the spring flight period.
- If any logs have to be left in woods during attack period, leave the pulpwood.
- Do not transport infested logs to dry land storage facilities during spring and summer. This will increase the resident beetle population there.
- Low-grade logs can be used as trap logs to help reduce populations.

In the Dry Land Storage Areas—

Avoid conditions that will increase populations:

- Reduce spring and summer log inventories.
- Avoid storage of fall- and winter-felled logs.
- Do not store freshly infested logs that brood can emerge from and over- winter in nearby forest.
- Water misting can completely protect log decks from attacks in dry land operations.
- Dispose of debris. Beetles can build up in it.

In addition to Nijholt's recommendations, timing of harvests and use of pheromones for direct trapping can protect logs and reduce populations.

Timing of harvest—

Logs cut in autumn and early winter are most susceptible to, attack by *Trypodendron* in the spring. Logs cut by February through May are not too attractive to *Trypodendron* but can be infested by other genera, mainly *Gnathotrichus*.

Trapping out——

Trapping of adult beetles at log storage sites (typically mill yards) using pheromone-baited traps deployed every 100 feet around decks is effective. Traps have to be serviced at least weekly to empty the catch basin.

Pheromone traps

Pheromones produced by female ambrosia beetles boring into logs attract others and stimulate mass attacks on a log or within a log deck.

Work is being done to develop a method of baiting "sticky traps" with this pheromone to capture a large portion of an attacking population during peak flight periods.

Recognizing Ambrosia Beetle Damage

Entrance holes (pin holes) are marked by piles of fine, granular, white boring dust in bark crevices. The main entrance gallery penetrates sapwood from 2.6 to 5 cm before branching. Tunnels branch in a horizontal plane and cut across grain of the wood. Holes and galleries are surrounded by a dark brown or black fungus stain. Adult *Trypodendron* are stubby, 3 to 4.5 mm long, and are generally shiny and dark brown to black.

Other genera have different body shapes, gallery dimensions, gallery patterns (see drawing), life cycles, and feed on different fungus species.

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No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

By Ken Gibson
US Forest Service

Management Guide for

Flatheaded Fir Borers

Topics

Melanophila drummondi (Kirby)

Family Buprestidae

Found extensively throughout the western United States and Canada.

Hosts:

- **Douglas-fir**
- **True firs**
- **Spruce**
- **Western hemlock**
- **Western larch**

Key Points

- Mostly attack weakened, damaged or recently felled trees.
- Symptoms similar to bark beetle –killed trees.
- Sanitation during logging operations prevents buildup of populations.

Damage

The flatheaded fir borer usually attacks trees in poor vigor resulting from mechanical injury, mistletoe infection, fire damage, or drought stress. They are also readily attracted to recently felled trees.

However, they also attack and kill apparently healthy trees, especially on dry sites or during unusually droughty conditions.

Most economic damage occurs when it kills apparently healthy Douglas-fir and western larch, which often occurs during extremely dry conditions.

Life History

A one-year life cycle is typical, but may be extended in some circumstances. Overwintering usually occurs as larvae in galleries, beneath host bark. Pupation takes place in spring. Adults emerge and lay eggs in bark cracks or crevices during the summer. Larvae mine and feed in the phloem, barely scoring the sapwood. When attacks are unusually heavy, trees may be killed in one season. If healthier trees are attacked, and do not die, larvae seldom survive.

Foliage on dying trees will fade from yellowish to red, typical of a beetle-killed tree.

Identifying the flatheaded fir borer

Typical flatheaded wood borer galleries (tightly packed with boring dust and frass in concentric rings) and larvae will be found beneath the bark. Adults are bronzy black and usually have three small yellow spots on each wing cover. They are a little less than one-half inch long. Woodpecker feeding will cause recognizable holes in the bark of flatheaded fir borer attacked Douglas-fir.

Management

Sanitation and salvage of infested and severely weakened trees is the best defense against damage. During harvest operations, cull logs and other large materials, suitable for colonization, should be removed or burned.

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<u>Cite as</u>: Gibson, K. 2004. Management guide for flatheaded fir borers. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

February 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Flatheaded Borers of Pines

Flatheaded Pine Borer
Melanophila gentilis Le Conte

California Flatheaded Borer
Melanophila californica Van Dyke

By Ken Gibson
US Forest Service

Topics

Family Buprestidae

These wood borers mostly attack old, decadent, or unhealthy trees.

- **Usually found in Ponderosa pine.** May attack other pine species in California and Nevada.

Key Points

- Mostly attack weakened or damaged trees.
- Symptoms similar to bark beetle –killed trees.
- Larvae may feed in a tree for as long as long as four years.
- Prevent attacks by maintaining stand vigor and removing dead and dying trees.

Damage

The California flatheaded borer has been found killing large -diameter, older ponderosa pines throughout the state of Idaho and in pine stands south and west of there. The flatheaded pine borer is more generally distributed throughout the western States. They are often found attacking trees in concert. Although outbreaks are rare, trees weakened by drought or other damage are common hosts.

Some trees may be killed outright, but primary importance seems to be weakening trees, causing them to become susceptible to bark beetle attack.

Life History

Adults feed on pine foliage during the spring, then lay clusters of eggs in bark crevices of host trees during the summer. Larvae bore into the phloem and feed in meandering galleries, lightly scoring the sapwood. Their life cycle is quite variable, with larvae feeding from a few months to as long as four years. If the infested tree is not ultimately killed, larvae typically will not survive. In dying trees, pre-pupal larvae appear in the outer bark in July and August; but new adults do not appear unti1 April or May the following year.

Foliage on dying trees will fade from yellowish to red, as do many bark beetle-killed trees.

Identifying flatheaded borers of pines

Flatheaded borer larval galleries are packed with chewed wood fibers and frass that is laid down in sort of half-rings (resembling a finger print). Larvae of flatheaded borers have a flattened head and thorax, having a shape something like a horseshoe nail. Adult California borers are greenish-bronze above and brassy-green below, a little less than one-half inch long. Many have one to three small yellow spots on each wing cover. Pine borer adults are bright bluish green and have no spots. The two species are often mistaken for each other.

Management

Attacks by flatheaded borers may be prevented by maintaining stands and trees in healthy, vigorous conditions. "High-risk" trees—ones with dead or dying tops, and ones infested by borers or bark beetles—should be removed.

Other Reading

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March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Sawyer Beetles

Spotted pine sawyer
Monochamus maculosus Haldeman

Whitespotted sawyer
Monochamus scutellatus (Say)

By Ken Gibson
US Forest Service,

Topics

Family Cerambycidae:

Sawyers are roundheaded wood borers, or long-horned beetles

Hosts:

- **Pines, Predominantly**
- **Also Spruce, True Firs, Douglas-fir**

Key Points

- Degrade dying, recently killed and felled trees.
- Larvae also introduce wood decay fungi.
- Prevent attacks by removing logs before egg-laying in late summer.
- Minimize damage by processing logs promptly.

Damage

Sawyer beetles, or more accurately, their larvae, are responsible for extensive damage to dying, recently killed, and felled conifers of various species—but especially pines, spruce, true firs, and Douglas-fir. They rarely, if ever, attack vigorously growing green trees.

They damage infested trees and logs through series of extensive mines that introduce degrade and entry courts for decay-causing fungi.

Life History

Sawyers typically have one generation per year, but may extend to two years in the northern part of their range. Susceptible material is infested in mid- to late-summer. Eggs are deposited in slit-like niches in the bark. Larvae feed for several weeks in the inner bark before entering the sapwood. Tunnels extend through the sapwood and often deep into the heartwood. Pupation, however, takes place near the surface of the log, and when mature, the adult beetles emerge by gnawing a round hole through to the surface.

Identifying sawyer beetles and their larvae

Larvae are legless, with generally round heads about the same diameter as the rest of the body. Their heads slant strongly downward in later instars. They are cream-colored with well-defined body segments. Larval mines between the bark and wood contain long, fibrous borings.

Sawyer beetle larvae introduce wood decaying fungi which further degrade borer-infested logs.

Adult whitespotted sawyers are shiny black beetles, about an inch long, with a tooth-like projection on each side of the prothorax, and a white spot between the elytra at their base. Spotted pine saywer adults are about the same size, also shiny black, but with scattered tufts of white hairs in irregular bands across the elytra. Both species have very long antennae, often longer than their body, with the male's antennae being longer than the female's.

Management

Prevention is the best control. Logs should not be exposed to attack during the July-September egg-laying period. If logs are infested, they should be promptly processed.

Other Reading

Furniss, R.L.; Carolin, V.M. 1977. Western forest insects. Misc. Publication Number 1339. Washington, D.C.: USDA Forest Service. 654 p.

Cite as: Gibson, K. 2004. Management guide for sawyer beetles. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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March 2004

By Ken Gibson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for Western Larch Borer

Tetropium velutinum **LeConte**

Family Cerambycidae

The western larch borer is a roundheaded wood borer or long-horned beetle.

Hosts:
- **Western Larch**
- **Douglas-fir**
- **Western hemlock**

Topics

Key Points

- Mostly attack weakened or damaged trees.
- Symptoms similar to bark beetle – killed trees.
- Larvae initially feed in inner bark and penetrate the wood in late summer.
- Remove logs before adults attack in June or before larvae bore into wood in August.

Damage

Drought-weakened, insect-defoliated, and fire-scorched trees are attacked and sometimes killed. Extensive mortality has been recorded during extremely droughty conditions.

Foliage on dying trees will fade within a year.

Life History

Western larch borer normally has one generation per year. Overwintering takes place as larvae in mines in host sapwood. Larvae pupate in cells made at ends of feeding mines by June.

Adults emerge in late June, mate, and lay eggs in bark crevices of susceptible hosts. Larvae feed initially in inner bark, but by August begin to penetrate the sapwood.

Identifying western larch borer

Larvae have round heads, cylindrical bodies of about the same width from back of head to posterior, are cream co1ored, and each body segment is well-defined. Larval mines contain finer wood particles and frass, often more loosely packed, than galleries made by flatheaded wood borers.

Photo of roundheaded wood borer larvae. Photo by William Ciesla

Adults have very long antennae ("long horns"), often nearly as long as their body. They are dark brown, close to three-quarters of an inch long, and have divided eyes.

Management

Weakened trees should be salvaged as soon as possible. To prevent degrade, decked logs should be processed before adults attack in June; or if infested, before larvae bore into wood.

Other Reading

Furniss, R.L.; Carolin, V.M. 1977. Western forest insects. Misc. Publication Number 1339. Washington, D.C.: USDA Forest Service. 654 p.

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Cite as: Gibson, K. 2004. Management guide for western larch borer. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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March 2004

By Ken Gibson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Horntails (Wood Wasp)

Horntails (wood wasps) are common throughout western United States and Canada.	**Horntails attack a wide range of weakened hosts—mostly conifers.**

Topics

Key Points

- Mostly attack fire damaged or felled trees.
- Larvae may survive a year or two in lumber after milling.
- Prompt removal of logs may prevent infestation.
- Kiln drying will kill developing larvae.

Damage

Horntails develop in trees that are damaged or killed by fire, wind, insects, disease, or mechanical operations. They are quickly attracted to recently killed or cut trees and are commonly seen by both loggers and fire fighters. Because of the ovipositing behavior of female horntails, the group has acquired a somewhat unflattering name. It is best left unmentioned!

Their mines degrade lumber cut from infested trees, but normally only attract attention when lumber from large burns or windthrow events is marketed in large amounts. In the first year or two after homes are built using such lumber, horntails may immerge in high numbers—causing holes in walls, floors, and ceilings—and an undue amount of homeowner distress!

In other parts of the world, some species of horntails have killed trees in young plantations. Such activity has never been recorded in western North America.

Life History

Life history of most horntails is not well known. Females insert their long ovipositor deep into the wood to lay their eggs. As they feed, larvae construct nearly circular galleries that wind extensively throughout the wood. Galleries are packed with fine boring dust. Completion of their life cycle may take two or more years. Pupal cells are constructed near the wood's surface. Upon completion of their development, adults bore round holes through which they emerge. It is believed, in at least some species, larvae feed upon introduced fungi rather than wood.

Horntails may emerge from lumber in use a year or two after it was milled—particularly if the trees had been fire-killed or windthrown.

Identifying horntail larvae and adults

Larvae are cylindrical and yellowish white, with a small spine at the posterior end. In profile, their body resembles a shallow letter "S."

Adults are large, thick-waisted, cylindrical insects. Both sexes have a short, horn-like process at the end of their body. Females have a long, stinger-like ovipositor that extends straight back when not in use. Adults are typically bold colors—dark blue, black, and reddish brown, often with a metallic sheen. Bodies are often marked with ivory, yellow, or red bands. Size and color vary widely, even within species.

Management

Prevention, in the form of prompt salvage of damaged trees, or rapid utilization of cut ones would forestall most degrade introduced into lumber products by horntails. Kiln drying of processed lumber will kill developing larvae and prevent their emergence from finished products.

Other Reading

Furniss, R.L.; Carolin, V.M. 1977. Western forest insects. Misc. Publication Number 1339. Washington, D.C.: USDA Forest Service. 654 p.

Cite as: Gibson, L. 2004. Management guide for horntails (wood wasp). 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Branch & Terminal

Branch & Terminal

Diseases

Related section in field guide.

March 2005

Forest Health Protection and State Forestry Organizations

By John Schwandt
US Forest Service

Management Guide for

Fir Broom Rust

Melampsorella caryophyllacearum Schroet.

This fungus causes conspicuous yellow witches brooms on fir.

Primary Host:
- Grand fir and subalpine fir
- All firs (*Abies sp.)* are susceptible

Alternate host:
Chickweeds, *Stellaria* spp., and *Cerastium* spp.

Topics

Damage

Although mortality is rare, this disease may cause some growth loss and localized volume loss as well as reduced value of infected ornamental trees. Amount of damage depends on the number and size of brooms and their position within the crown.

Key Points

- Principal damage from this disease is volume and growth loss.
- Amount of damage depends on the number and size of brooms and their position within the crown.
- Diseased trees should be eliminated through selective thinning.

Life History

Broom rust alternates between true firs and chickweeds. Spores from chickweed infect young fir needles. The fungus then spreads into the woody tissues of branches and stems where witches brooms form. The yellow color of these brooms is due to yellow-orange fungal structures and spores produced on infected foliage. These spores complete the life cycle by spreading to chickweed.

Fir broom rust produces witches broom displaying yellow fungal structures on firs. Photo by John Schwandt.

Fir broom rust. From Forest Service Archives.

Identification

Presence of witches'-brooms and production of yellow rust pustules on needles. Infected needles are dwarfed, and chlorotic, and twigs in the brooms are shorter and thicker than normal. At the base of the broom, infected branches and stems are swollen, forming an elongate canker or gall. Brooms and stem swellings may be observed after brooms have been shaded out.

Spores produced on needles within the broom during the summer. Photo by John Schwandt.

Management Considerations

Diseased trees should be eliminated through selective thinning, and infected branches can be pruned from high value trees.

Other Reading

Allen, E.A., D.J. Morrison, and G.W. Wallis. 1996. Common Tree Diseases of British Columbia. Natural Resources Canada, Canadian Forest Service.

Peterson, R.S. 1963. Effects of broom rusts on spruce and fir. USDA For. Serv., Int. For. Range Exp. Stn., Ogden, UT. Res. Pap. INT-7. 10 p.

Ziller, W. G.1974. The tree rusts of western Canada. Canadian Forestry Service, Dept. of the Environment, Victoria, B.C. Publication No. 1329.

Cite as: Schwandt, J. 2005. Management guide for fir broom rust. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

No FIDL for this damage-agent

January 2006

Forest Health Protection and State Forestry Organizations

By John Schwandt
US Forest Service

Management Guide for

Spruce Broom Rust

Chrysomyxa arctostaphyli Diet

Topics

This fungus causes conspicuous yellow witches brooms on spruce.

Primary Host:
- Engelmann spruce
- All spruce are susceptible

Alternate host:
Kinnikinnick, *Arctostaphylos uva-ursi*

Key Points

- Principal damage from this disease is volume and growth loss.
- Amount of damage depends on the number and size of brooms and their position within the crown.
- Diseased trees should be eliminated through selective thinning.

Damage

The principal damage from this disease is volume and growth loss. Little tree mortality occurs although topkill and dead branches are common. Amount of damage depends on the number and size of brooms and their position within the crown. Infection and damage may also provide infection courts for decay fungi.

Life History

Broom rust alternates between spruce and kinnikinnick. Spores from the kinnikinnick infect young spruce needles. The fungus then spreads into the woody tissues of branches and stems where witches'-brooms form. The yellow color of these brooms is due to yellow-orange fungal structures and spores produced on infected foliage. These spores complete the life cycle by spreading to kinnikinnick.

Broom rust displaying yellow fungal structures on spruce. Photos from Common Tree Diseases of British Columbia.

Alternate host, kinnikinnik.

Identification

Presence of witches brooms and production of yellow rust pustules on needles. Infected needles are dwarfed and chlorotic, and are often shed annually. Twigs in the brooms are shorter and thicker than normal. At the base of the broom, infected branches and stems are swollen, forming an elongate canker or gall. Brooms and stem swellings may be observed after brooms have been shaded out.

Infected needles are dwarfed and chlorotic. Photo from Common Tree Diseases of British Columbia.

Management Considerations

Diseased trees should be eliminated through selective thinning, and infected branches can be pruned from high value trees, such as those around dwellings and in concentrated recreation sites.

Other Reading

Baranyay J. A. and Ziller W. G. 1972. Broom Rusts of Conifers in British Columbia. Forestry Canada, Forest Insect and Disease Survey, Forest Pest Leaflet No. 48 6p.

Allen, E.A., D.J. Morrison, and G.W. Wallis. 1996. Common Tree Diseases of British Columbia. Natural Resources Canada, Canadian Forest Service.

Ziller, W. G.1974. The tree rusts of western Canada. Canadian Forestry Service, Dept. of the Environment, Victoria, B.C. Publication No. 1329.

Photos from **Canadian Forestry Services**
http://forestry-dev.org/diseases/ctd/Group/Rust/rust1_e.html

Cite as: Schwandt, J. 2006. Management guide for spruce broom rust. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Comandra Blister Rust

Cronartium comandrae **Pk.**

By Jim Hoffman
US Forest Service

Lodgepole pine and ponderosa pine are the primary hosts.	**Bastard toadflax, *Comandra umbellata*, is the herbaceous alternate host.**	This fungus causes spindle-shaped cankers that are generally two- to four-times as long as wide on branches and main stems.

Topics

Damage

Comandra blister rust disease is widely distributed, infecting over 30 pine species in 45 States. Despite almost nationwide distribution, disease damage is generally severe in only a few localized areas.

On lodgepole pine, Comandra blister rust is found in southern Montana, Wyoming, and southeastern Idaho. In Utah it occurs rarely in lodgepole pine stands on the north slopes of the Uinta Mountains.

It is occasionally damaging on ponderosa pine in southern Montana. Curiously, disease incidence on ponderosa pine in southern Idaho and Nevada is restricted to plantations established with off-site seed sources.

The fungus can infect the branches and stems of all sizes and ages of host trees. Infected seedlings are easily killed within a few years.

On pole-sized and mature trees infections on the branches either girdle and kill the branch distal to the canker, or grow into the stem tissues resulting in a stem canker.

Girdling stem cankers cause top-kill and thus loss of growth potential. Alternatively, the whole tree may die if stem cankers are below most of the tree crown.

Porcupines, squirrels and other rodents often chew the bark at the edges of cankers. They are attracted by sweet exudates from pycnia (see *Life History* on next page) in the canker margins. In some cases, the animals can completely excise all fungal tissues rendering the canker inactive.

Key Points

- Cankers girdle stems of trees of all sizes.
- Squirrels and porcupines often chew at the edges of cankers.
- Manage by removing infected trees.

Life History

Four spore stages and two types of hosts typify macrocyclic rust fungi, such as *C. comandrae*. Both conifer and herbaceous hosts are necessary for the fungus to complete its life cycle.

The fungus increases by on the herbaceous host, bastard toadflax, by reinfecting this species throughout the summer. These spores are produced by uredinia on the leaves and stems. They are windborne and reinfect bastard toadflax causing pale yellow spots.

In late summer to early fall during moist periods, the second stage is produced on bastard toadflax. In this stage, telia produce windborne spores that infect pine needles and shoots. Fungal vegetative tissues develop from germinating spores and spread from pine needles into twigs and stems.

One to three years later sticky reddish-orange drops appear on the twig or stem bark. In this third spore stage, haploid spores are produced by pycnia (also called spermagonia).

This spore stage is followed the next spring or early summer by the final, diploid spore stage. Orange spores are released from white to tawny-colored paper-like "blisters". These fungal fruiting bodies are aecia. The "aeciospores" are also windborne and infect toadflax to complete the cycle.

Managing Comandra Blister Rust

Recommendations are generally aimed at reducing the disease incidence on the conifer hosts to both reduce the potential for infection of nearby toadflax and to improve stand vigor by culling out genetically susceptible individuals. Heavily infected mature stands should be harvested and regenerated to species other than lodgepole or ponderosa pine. Young trees with stem cankers should be removed during precommercial thinning. Trees with multiple stem cankers, spike tops, and girdling stem cankers in the lower third of the crown should be removed in timber stand improvement work.

Other Reading

Johnson, D. W. 1986. Comandra blister rust. USDA Forest Service, Forest Insect and Disease Leaflet 62. 8p.

Krebill, R. G. 1968. Comandra rust outbreaks in lodgepole pine. Journal of Forestry 63:519-522.

Ziller, W. G. 1974. The tree rusts of western Canada. Environment Canada, Canadian Forestry Service, Publication No. 1329. Victoria, B.C. 272p.

Cite as: Hoffman, J. 2004. Management guide for Comandra blister rust. 3 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

FIDL - Douglas-fir dwarf mistletoe

FIDL - Lodgepole pine dwarf mistletoe

FIDL - Limber pine dwarf mistletoe

FIDL - Western larch dwarf mistletoe

May 2004

By James T. Hoffman
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Dwarf Mistletoe

Arceuthobium spp.

Dwarf mistletoe parasitism reduces the growth, wood quality, seed production ability, and life span of infected host trees. Most western conifer species are host to one or more species of dwarf mistletoe.

Topics

Parasitic Plants that cause significant damage to trees

Dwarf mistletoes are small, leafless plants. They are entirely dependent upon their hosts for water, nutrients, and support. These parasites can infect trees of all sizes and ages. They are generally host specific, but the eight dwarf mistletoe species present in the forests of the Northern and Intermountain Regions can infect 21 tree species (See page 12). While they are generally host specific (occur on one principal host species), cross-over does occur into other tree species.

Dwarf mistletoes are the most widely dispersed pathogens in the western United States. Several forces have influenced their distribution across the landscape. Historically, fire has been the foremost factor in affecting dwarf mistletoe population dynamics.

In terms of acres affected, the major tree species impacted by dwarf mistletoes in the Northern and Intermountain Regions are lodgepole pine, Douglas-fir, and western larch (See page 11).

Key Points

- Dwarf mistletoes affect tree growth and form.
- Dwarf mistletoe plants and brooms may be important ecosystem components.
- Control is accomplished by killing infected trees and preventing spread to young trees.

Features of dwarf mistletoes that make them relatively easy to control.

⇒ **Dwarf mistletoes are obligate parasites, always requiring a living host in order to survive.**

⇒ **They are generally host specific.**

⇒ **Dwarf mistletoes have long life cycles (2 to 8 years).**

⇒ **Spread and intensification of dwarf mistletoes is slow in a newly infected stand averaging 1 to 2 feet / year.**

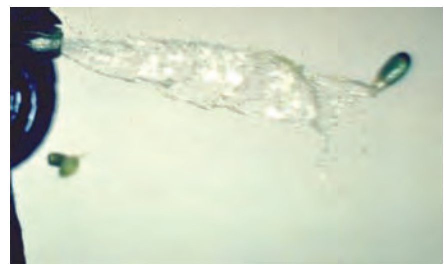
⇒ **Dwarf mistletoe infections in both trees and stands are easy to detect because of the presence of witches' brooms, branch and stem swellings, and presence of the mistletoe shoots.**

According to fossil records, dwarf mistletoes have co-evolved with their hosts for at least the past 40-million years, meaning they have likely filled many ecological niches in many forest landscapes over time.

Life History

Both male and female plants can be produced upon the same host tree. Mature fertilized female shoots produce fruits from which seeds are explosively discharged in the late summer and early fall. The average horizontal distance of seed flight is about 20 feet with 90% of the seed landing within 30-feet. The seeds have a sticky coating that enables them to adhere to any surface they contact. Seeds that land on needles and twigs of susceptible species may germinate the following spring and penetrate the bark resulting in new infections.

The equivalent of a dwarf mistletoe root system that develops within the host is called the endophytic system. Growth of this “root-like”system gives rise to specialized structures called “sinkers” that develop within the host wood, providing the parasite with nutrients and water. Success and spread of the sinkers causes a visible swelling on the twig due to distortion of the annual rings and cambial tissues. Several years after infection, dwarf mistletoe shoots emerge on the twig. New shoots require a couple years of maturity to produce seeds.



Dwarf mistletoe seed is explosively discharged.

Management objectives determine desirability of dwarf mistletoes

We are just beginning to value dwarf mistletoes as unique biological species in their own right and to recognize and define their roles as functional components of ecosystems.

It is only during the last 100 years that the roles of dwarf mistletoes in forest ecosystems were defined by humans as being counter to the predominant forest management goal of maximizing timber production.

Dwarf mistletoe parasitism reduces the growth, wood quality, seed production ability, and life span of infected host trees. Stem infections also provide entrance points for decay fungi. For these reasons, and the fact that they infect so many acres, dwarf mistletoes are considered serious pathogens of the forests in the Northern and Intermountain Regions.

Wildfire risk is greatly increased because of dwarf mistletoe infestations, especially in Douglas-fir stands. The large, pendulous brooms usually occur in the lower portion of the crown and are filled with small twigs and dead needles that provide a fuel ladder for upward spread into tree crowns. Brooms broken off by winter storms accumulate around the base of infected trees and increase the fuels on site. It has also been reported by firefighters that large witches’ brooms can fall off burning trees on steep hillsides and quickly spread fire downhill via “flaming pinwheels.”

On the positive side, dwarf mistletoe seeds and shoots and dwarf mistletoe–affected branches are used in a variety of ways by many animal species.

Ecology: Fire and Dwarf Mistletoes

Fire is the foremost factor in affecting dwarf mistletoe population dynamics. Generally any fire event that kills their host trees will reduce the population of dwarf mistletoes, at least in the short term. Large, high intensity burns will greatly reduce dwarf mistletoe populations across a landscape and may even eliminate small, localized populations. Smaller, but more frequent light intensity fires will temporarily reduce segments of a dwarf mistletoe population. However, infected residual trees that survive a fire provide a source of dwarf mistletoe seeds to infect newly developing regeneration. Large and numerous brooms in dwarf mistletoe infected-stands increases the fire potential on a site, greatly increasing the likelihood of returning the forest to an early successional stage through a stand-replacing fire event.

Human influences, including fire suppression and logging have affected dwarf mistletoe distribution and disease severity.

Ecology: Successional Effects

In areas where dwarf mistletoes infect trees that are early seral species, dwarf mistletoe-related mortality will advance forest succession toward the climax species. Mortality of large, mature seral individuals provides an opportunity for the release of the shade-tolerant species. Significant mortality generally does not occur until trees are 100+ years of age, when height growth has slowed, allowing infections to move upward and intensify throughout the entire tree crown. Seedlings and saplings of seral species growing under a heavily infected overstory of the same species will be killed at an accelerated rate, further increasing the rate of stand succession toward the climax species.

Dwarf mistletoe shoots and seeds are consumed by a variety of birds, mammals and insects.

Ecology: Animal Utilization

There is increasing evidence that important interactions exist between dwarf mistletoes and animals living in the forested ecosystems where the parasitic plants occur. Bird species, including black-capped chickadees, sparrows, ruffed grouse and blue grouse, are reported to eat dwarf mistletoe seeds, and porcupines and squirrels preferentially eat the bark associated with dwarf mistletoe infection. Dwarf mistletoe shoots can be an important winter food source for many animals including porcupines, mule deer, elk, Abert's squirrels, ruffed grouse and blue grouse. Several insect species are also reported to feed on various parts of dwarf mistletoe plants. Cavity-nesting birds utilize trees killed by dwarf mistletoe, and witches' brooms provide cover and nesting sites for many different birds and mammals. Many species of songbirds and owls are attracted to mistletoe brooms for nesting.

Western larch with brooms caused by dwarf mistletoe infection.

Dwarf mistletoes affect tree growth and mortality

Dwarf mistletoe witches' brooms extract water and nutrients from their hosts thereby reducing the amount of available stored photosynthetic energy that is necessary for tree maintenance and growth. Consequently, witches' brooms grow at a faster rate than the rest of the tree, causing reduction in both tree stem diameter growth and height. Ultimately the witches' brooms become such a drain on the host tree that both the vegetative and reproductive tissues die from the top down.

The more severely infected a tree, the more severe the growth impacts are. Once the dwarf mistletoe has spread throughout the entire tree crown, it usually takes 10+ years for tree mortality to occur. Growth effects and mortality rates generally increase as site quality decreases. Growth loss, as expressed in terms of cubic foot volume, can be quite significant. In addition to direct tree mortality, infected trees are predisposed to attack by other pathogens and/or insects.

Management Strategies

Dwarf mistletoe impacts can be effectively reduced through timing the use of any silvicultural treatments that emphasize the removal or killing of infected branches or trees.

- ⇒ **Regeneration operations**: The greatest opportunity to control dwarf mistletoes is by the removal of infested stands and replacement with mistletoe-free regeneration.
- ⇒ **Precommercial thinning**: Lightly infested precommercial stands can be brought through to rotation age using sanitation thinning operations but heavily infested stands may not benefit from sanitation thinning.
- ⇒ **Commercial thinning**: Select leave trees with a dwarf mistletoe rating (DMR) of 3 or less, preferably those with infections in the lower crown.
- ⇒ **Chemical control**: The chemical, Florel ® is registered for dwarf mistletoe control. It doesn't kill the parasite but prevents seed production for a short period of time(one to three years).
- ⇒ **Prescribed fire**: Western dwarf mistletoe (*A. campylopodum*) has been reduced somewhat in ponderosa pine stands using prescribed underburning. Heavily infested trees were less than half as likely to survive underburning than their healthy counterparts.

Assessing Dwarf Mistletoe Infection in Stands

Dwarf mistletoe management should only be considered after an analysis of the impacts that the parasite has in the trees, stands, and ecosystems they inhabit. One tool has been used for over 25-years to standardize the quantity of dwarf mistletoe parasitism within a stand. The Hawksworth 6-class dwarf mistletoe rating system (DMR) provides a quantitative reference scale for determining the relative population status of a dwarf mistletoe infestation within a stand and its potential for spread and intensification.

Partial cutting creates multi-storied stands, which serves to increase the distribution and intensity of dwarf mistletoe.

The 6-class dwarf mistletoe rating system (DMR)

(Hawksworth 1977)

Instructions

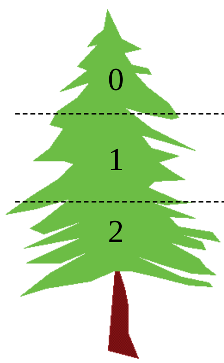
STEP 1. Divide live crown into thirds.

STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.

- (**0**) No visible infections.
- (**1**) Light infection (1/2 or less of total number of branches in the third infected).
- (**2**) Heavy infection (more than ½ of total number of branches in the third infected).

STEP 3. Finally, add ratings of thirds to obtain rating for total tree.

Example



If this third has no visible infections, it's rating is (**0**)

If this third is lightly infected, it's rating is (**1**)

If this third is heavily infected, it's rating is (**2**)

The tree in this example will receive A rating of **0+1+2=3**.

Management of Dwarf Mistletoe in Stands

Human influences, including fire suppression and logging have also affected dwarf mistletoe population dynamics. In many cases, dwarf mistletoe intensity has been increased by partial cutting. Conversely, dwarf mistletoe populations may have been reduced in certain age-classes, habitat types, elevation zones, or topographic positions that have been intensively managed. Fire suppression and cutting practices that encouraged shifts in species composition may increase or decrease disease severity depending on the species of trees and dwarf mistletoes present on the site.

Dwarf mistletoe impacts can be effectively reduced through timing the use of any silvicultural treatments that emphasize the removal or killing of infected branches or trees. Direct control is usually only necessary when the parasite interferes with accomplishment of clearly defined land management goals.

Dwarf mistletoe management is based on the five biological characteristics of this parasite

See "Features of Dwarf Mistletoes" on page 1.

Management

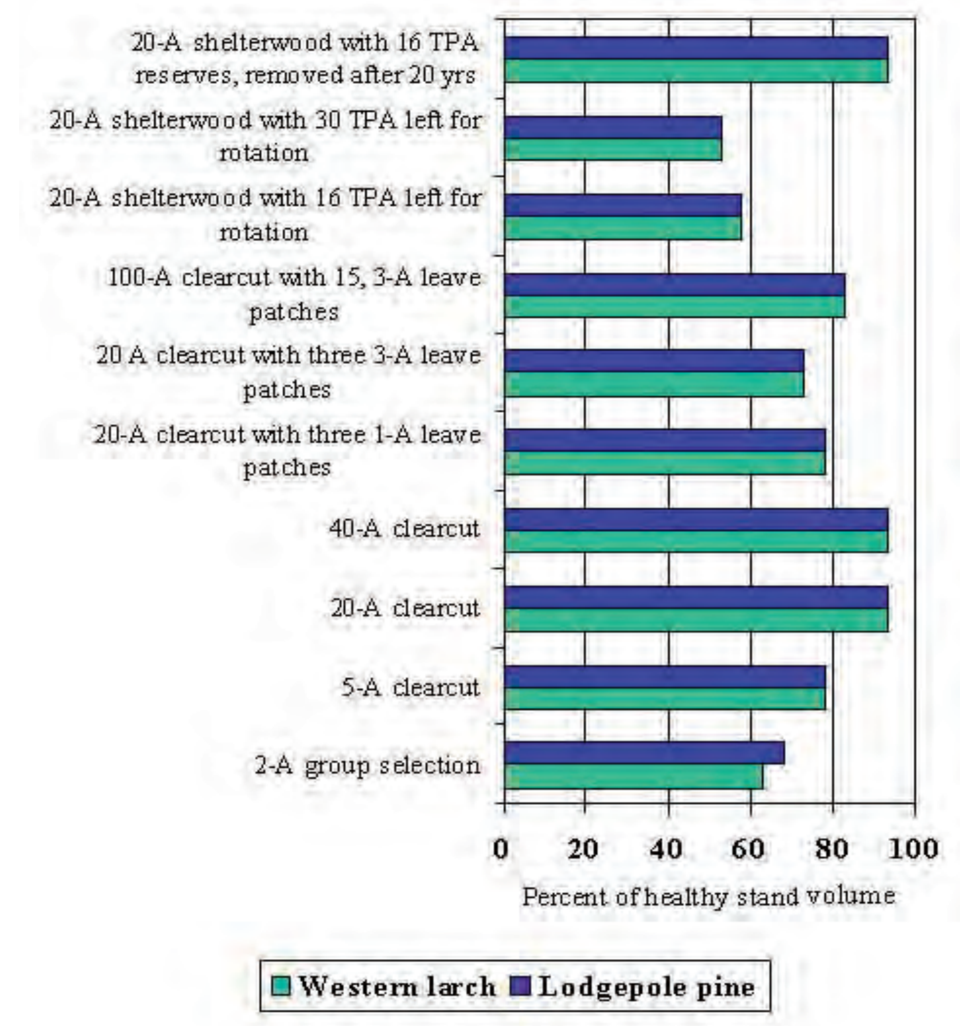
The dwarf mistletoe spread rate is fastest in multi-storied stand conditions where mistletoe seeds from infected overstory trees "rain down" on susceptible understory trees.

In evenaged stands, the spread rate is faster in single species stands than in mixed species stands, and the rate decreases as stand density increases.

Regeneration Operations -

These methods include the use of clear cuts, and seed tree and shelterwood operations. A possible downside of clearcutting in some ecosystems is that it leads to the establishment of an even-aged stand. However, if mistletoe control is successful at time of regeneration, it is usually possible to convert the stand to an uneven-aged state in subsequent rotations.

Clear cuts in infested stands should have as large of an area/perimeter ratio as possible to minimize edge effects and reinvasion from bordering stands (see graph below). Preferably, the harvest unit should be at least 20-acres in size, and narrow strips should be avoided.



Expected productivity of western larch and lodgepole pine stands with moderate initial dwarf mistletoe infection rates with a variety of management methods. Analysis results for western larch using northern Idaho variant of the Forest Vegetation Simulator (Wykoff and others 1982), and for lodgepole pine using the eastern Montana variant. Percent of non-infected stand merchantable cubic-foot volume at 120 years of age.

The Forest Vegetation Simulator (Wykoff and others 1982) is a stand based tree growth regeneration and mortality model developed by the US Forest Service.

This model is widely used to predict forest productivity and composition under a variety of site and management conditions.

Wykoff, W. R., N. L. Crookston, A.R. Stage. 1982 User's guide to the Stand Prognosis Model. USDA-Forest Service, Intermountain For. And Range Exp. Sta., Gen. **Tech. Rep. INT-133. 112P.**

Management: Regeneration Operations

Whenever possible, cutting unit boundaries should be located in non-infested stands, and take advantage of natural and/or manmade barriers such as roads, meadows, natural openings and species type changes.

In shelterwood and seed tree operations, it is essential to leave non-infected trees. However, if only infected trees are in the treated stand, silvicultural objectives may be met by retaining trees with a dwarf mistletoe rating (DMR) of 3 or less, providing they are felled, girdled, or removed before the regeneration is 3 feet tall or 10-years old. If non-susceptible species are present, it may be desirable to favor these species as leave trees for shelter, to meet management objectives, or for regeneration purposes. Infected overstory trees may be left if the site is regenerated with a non-susceptible species. This is frequently the best option in recreation or riparian areas.

It is essential to leave only uninifected seed trees or shelterwood trees unless they will be removed before the regeneration is three feet tall or ten years of age.

Management: Thinning Operations

Precommercial Thinning

Lightly infested precommercial stands can be brought through to rotation age using sanitation thinning operations. The stand should be surveyed to determine the degree of infestation when deciding whether or not sanitation thinning is practical. If an acceptable stocking level of noninfected trees will be left following thinning little growth loss will occur. If heavily infested stands remain, severe growth losses may occur. It is generally recommended that sanitation thinning should be attempted only if < 40% of the trees of the susceptible species are infected and the average stand DMR is 3 or less. In stands with higher infection levels, the removal of infected trees will reduce stocking below acceptable levels. In these cases, it would be better to adjust the spacing guidelines to retain more trees per acre on the site. A denser stand will slow both individual tree growth and the expansion of dwarf mistletoe intensity within the stand.

Commercial Thinning

Stands should be surveyed for the level of dwarf mistletoe infestation before treatment is prescribed. If timber growth and yield are not the objectives of the stand, it is possible that control measures will not be warranted at this time. However, if growth and yield are major concerns, the following guidelines can be followed. It is known that significant growth losses do not occur until trees reach a DMR >3. Therefore, it is advisable to select trees for removal that have a DMR > 3. Trees with DMR 3 and less, especially those with infections limited to the lower 1/3 of the crown, will probably not incur major growth effects, as the anticipated growth of the thinned trees should exceed the dwarf mistletoe impacts. It is also important to consider the time of harvest and site quality. If time until harvest is short, or if the site is good, leave trees with moderate levels of dwarf mistletoe infection to maintain stocking.

Management: Chemical Control

Florel ® (active ingredient, ethephon) doesn't kill dwarf mistletoe but does slow the spread.

The only chemical approved by the Environmental Protection Agency (EPA) for use in controlling dwarf mistletoes is Florel (the active ingredient is ethephon), an ethylene-releasing growth regulator that causes mistletoe shoot abscission. Unfortunately ethephon doesn't kill the root-like endophytic system of the dwarf mistletoe, and the parasite resprouts quickly. However, the chemical does delay production of dwarf mistletoe seeds, which postpones spread of the parasite by 2 - to 4-years. High-valued trees in recreation, residential, or commercial sites may benefit from applications of ethephon to control dwarf mistletoe spread and intensification.

Management: Prescribed Fire

Fire has long been recognized as the most important single factor governing the natural distribution and abundance of dwarf mistletoes, however, there are few studies and papers on fire-mistletoe interactions. Dwarf mistletoe-infested stands have been measured and demonstrated to have higher total fuel loadings compared to un-infested stands. Moreover, dwarf mistletoe-infected branches are larger, more resinous, and persist longer than healthy branches. In these ways dwarf mistletoe infections increase the fire risk within an infected stand.

Dwarf mistletoe brooms may provide fuel ladders to move fire from the ground to the crown.

Direct Control by fire:

Western dwarf mistletoe can be partially sanitized from both thinned and unthinned ponderosa pine stands using prescribed understory fires. It is essential, though, to attain scorch heights 30- to 60% of the crown length to significantly reduce dwarf mistletoe infestations. On ponderosa pine on the south rim of the Grand Canyon infected with southwestern dwarf mistletoe, it was found that a larger proportion of tree crowns were scorched because infected trees have highly flammable witches' brooms in the lower portion of the live crown. With equal amounts of crown scorch in the 40 to 90% range, the probability of survival of heavily infested trees was less than half that of healthy trees. Mortality of dwarf mistletoe infected trees following the prescribed fires ranged from 9% to 36%.

Indirect effects of fire:

The effects of heat and smoke from fires need additional study. One study found southwestern dwarf mistletoe seed germination was reduced to almost zero by exposure to smoke for 60-minutes or longer, but exposing seeds to smoke for 30-minutes had little effect on their germination. Seeds of lodgepole pine dwarf mistletoe were unaffected by 40-minutes of exposure to smoke from fuels with a high moisture content, and germination was even enhanced by 30-minutes of smoke exposure from dry fuels.

Modeling Dwarf Mistletoe Spread and Effects

Growth and yield simulation models have been developed which can be used in the planning of silvicultural decisions. One of the most widely used models throughout the USDA Forest Service in the western United States is the Forest Vegetation Simulator (FVS) model. The dwarf mistletoe impact model is initiated through FVS automatically when mistletoe data is encountered. This process allows the user to estimate dwarf mistletoe effects on yield in stands under different silvicultural treatments.

Analyses of the effects of silvicultural treatments on the estimated volume reduction from dwarf mistletoe in infected western larch and lodgepole pine were presented in the graph on page 6. For the comparison, certain conditions were assumed: 120-year rotation, regenerated stand is 90-100 percent host species, cutting unit edge contains infected residuals, leave-patches and reserve trees are infected, and no sanitation treatments occur during the rotation.

Projected Productivity of Dwarf Mistletoe-infected Stands

	Percent of non-infected stand volume (merchantable cubic feet) at 120 years	
Treatment	**Western larch**	**Lodgepole pine**
2-acre group selection	60-65	65-70
5-acre clear cut	75-80	75-80
20-acre clear cut	90-95	90-95
40-acre clear cut	90-95	90-95
20-acre clear cut with reserves (Three 1-acre leave patches)	75-80	75-80
20-acre clear cut with reserves (Three 3-acre leave patches)	70-75	70-75
100-acre clear cut with reserves (Fifteen 3-acre leave patches)	80-85	80-85
20-acre shelterwood with reserves (16 trees/acre left for rotation)	55-60	55-60
20-acre shelterwood with reserves (30 trees/acre left for rotation)	50-55	55-60
20-acre shelterwood with reserves (16 trees/acre, removed after 20 years)	90-95	90-95

Analysis for larch was done using the northern Idaho variant of the Forest Vegetation Simulator. For lodgepole pine, the eastern Montana variant was used.

Modeling Dwarf Mistletoe Spread and Effects

These simulations suggest that the impacts of dwarf mistletoe on merchantable cubic foot volume increase as the size of the cutting unit decreases and if infected residuals are left standing throughout the rotation. If cutting units are at least 20-acres in size, and residual trees are removed before the regeneration is 10- years old, growth losses may be reduced to as little as 5-10 percent when compared to volume produced in a non-infected stand growing under similar conditions.

Dwarf mistletoes are widespread and damaging in many forest types throughout the northern and central Rocky Mountains.

Distribution of Dwarf Mistletoes

Surveys in the northern and central Rocky Mountains have demonstrated the widepread distribution and, often, damaging effects of dwarf mistletoes in conifer forests. The overall distribution and intensity of these parasites changes slowly through time as host age and abundance changes. The following tables show the estimated percent of area by forest types on National Forest lands which are infested by dwarf mistletoes.

Distribution of dwarf mistletoes in northern and central Rockies national forests

	Percent Acres Affected by Forest Type			
UTAH	**Lodgepole pine**	**Ponderosa pine**	**Douglas-fir**	**Western larch**
Ashley	45	0	8	0
Dixie	—	20	10	—
Fishlake	—	0	9	—
Uinta	12	0	10	—
Wasatch-Cashe	34	0	9	—
WYOMING	**Lodgepole pine**	**Ponderosa pine**	**Douglas-fir**	**Western larch**
Bridger-Teton	53	—	14	—
NEVADA	**Lodgepole pine**	**Ponderosa pine**	**Douglas-fir**	**Western larch**
Humboldt	*	*	*	*
Toiyabe	17	20	15	—
IDAHO	**Lodgepole pine**	**Ponderosa pine**	**Douglas-fir**	**Western larch**
Boise	40	20	30	10
Caribou	52	—	21	—
Clearwater	9	*	1	55
Idaho Panhandle	10	*	10	55
Nez Perce	40	*	55	50
Payette	40	28	30	21
Salmon	49	0	45	—
Sawtooth	70	0	53	—
Targhee	60	—	40	—
MONTANA	**Lodgepole pine**	**Ponderosa pine**	**Douglas-fir**	**Western larch**
Beaverhead	52	*	—	—
Bitterroot	44	*	43	40
Custer	28	*	—	—
Deerlodge	47	*	—	—
Flathead	18	*	1	34
Gallatin	42	*	—	—
Helena	35	*	1	15
Kootenai	23	*	10	50
Lewis & Clark	37	*	—	—
Lolo	23	*	17	30

*** insufficient survey data available; — dwarf mistletoe not found on this Forest**

Dwarf mistletoes in the Northern and Central Rockies

Dwarf mistletoe species	General location	Principal Host	Secondary Host	Occasional (o) or Rare (r) hosts
A. abietinus, f.sp. concoloris White fir dwarf mistletoe	Southern Utah and Nevada	White fir		Subalpine fire (o)
A. americanum Lodgepole pine dwarf mistletoe	Idaho, Montana, Wyoming, Northern Utah and far western Nevada.	Lodgepole pine		Ponderosa pine (o) Whitebark pine (o) Limber pine (o) Engelmann spruce (o) Blue spruce (r) White spruce (r) Douglas-fir (r)
A. campylopodum Western dwarf mistletoe	Western Nevada and, rarely, in northern Idaho.	Ponderosa pine and Jeffrey pine		Lodgepole pine (o)
A. cyanocarpum Limber pine dwarf mistletoe	Dispersed in Idaho, Montana, Utah, Wyoming and Nevada	Limber pine, Whitebark pine, Great Basin bristlecone pine	Western white pine Mountain hemlock	Engelmann spruce (r) Lodgepole pine (r) Ponderosa pine (r)
A. divaricatum Pinyon pine dwarf mistletoe	Nevada and Utah	Singleleaf pinyon and common pinyon pines		
A. douglasii Douglas-fir dwarf misteltoe	Idaho, western Montana, Utah and one location in eastern Nevada	Douglas-fir		Grand fir (o) Subalpine fir (r) Engelmann spruce (r) Blue spruce (r) Limber pine (r)
A. laricis Larch dwarf mistletoe	Northern Idaho and western Montana	Western larch	Lodgepole pine Mountain hemlock Subalpine fir	Grand fir (r) Engelmann spruce (r) Ponderosa pine (o) Western white pine (r) Whitebark pine (o)
A. vaginatum, subsp. ***cryptopodum*** Southwestern dwarf mistletoe	Southern Utah	Southwestern ponderosa pine		Rocky Mountain bristlecone pine (o) Southwestern white pine (r) Limber pine (r)

Recognizing Dwarf Mistletoe infections

Dwarf mistletoe plants appear as perennial shoots, either simple or branched. Length varies from less than 1-inch in the case of Douglas-fir dwarf mistletoe, to nearly a foot-long in the case of southwestern dwarf mistletoe in Utah. They may occur as tufts or be scattered along the young twigs. Shoots are jointed with opposite pairs of scale-like leaves at the top of each segment. Color varies from yellow to purple to brownish-green or olive-green. If the shoots have dropped, the small basal cups from which they developed often remain on the bark.

It is far easier to identify dwarf mistletoe infections from the symptoms they cause to their host trees than to look for the plants. Even from a long distance, infected stands can be noticed by the presence of deformed, stunted, spike-topped, dead and dying trees. Infected trees are most easily recognized by witches' brooms, a pendulous dense cluster of small twigs on a branch, and/or swellings or other abnormalities on the branches and tree stems.

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May 2004

Forest Health Protection and State Forestry Organizations

By Jim Hoffman
US Forest Service

Management Guide for

Elytroderma Needle Cast

Elytroderma deformans (Weir) Darker

Topics

Elytroderma rarely kills trees but growth loss may occur and severely defoliated trees may be attacked by bark beetles.

Primary host:
- **Ponderosa pine**

Minor hosts:
- **Pinyon pine**
- **Lodgepole pine**

Key Points

- Growth rate and form are affected but trees are seldom killed by Elytroderma.
- Moist, stagnant air increases infection rates.
- Seed and crop trees should be selected for apparent resistance.
- Increase air flow by thinning or, perhaps underburning.

Damage

Elytroderma needle cast causes browning and eventual loss of needles similar to other foliage diseases. The fungus also causes witches' brooms by growing systemically within perennial infections in the branch tips. Infections are heaviest in the lower crowns of sapling and pole-sized ponderosa pine in dense stands on gentle slopes near reservoirs, lakes, or stream bottoms where moist air accumulates. Direct killing is rare, but infected trees are weakened and more susceptible to bark beetle attacks.

Management

Maintaining open stand spacing to allow airflow reduces moisture retention on an infected site and can minimize Elytroderma damage in young stands. Uninfected, or lightly infected trees (more than a three-fifths of the crown without symptoms) should be selected as crop trees. Logging in heavily infected mature stands should be accelerated to salvage valuable timber and prevent losses from secondary causes.

Since Elytroderma needle cast incidence is highest where moist environmental conditions prevail there has been speculation that underburning infected pine stands every 10-15 years will greatly reduce stand incidence and damage by consuming infected needles on the ground and by killing all branches in the lower portion of the crown.

Life History

Spores are disseminated by wind to the current-years needles and germinate if there is rain or heavy dew.

Spores mature in small linear black fungal fruiting bodies during mid- to late- summer on needles that were infected the previous year. Alternatively, fruiting bodies can also form on new needles that emerged from perennial infections on the buds and twigs. In both cases, spores are disseminated by wind to the current-years needles and germinate if there is rain or heavy dew. After germination the fungus grows rapidly through the needle tissues and into the twigs without initially killing the needle. Needles die the next spring, turn reddish-brown, develop fungal fruiting bodies in the summer, and then are shed from the tree during fall rains.

Compact witches broom with red needles.

Identification

Elytroderma needle cast is a perennial disease easily recognized by dramatic reddening of last years foliage in early spring, coupled with numerous compact and globose witches' brooms that are present all year. In smaller trees, the effect of several years of defoliation results in a “lion's tail” appearance of the twigs and branches. Brown dead lesions develop in the inner bark of twigs and branches. The characteristic thin black fruiting bodies are produced on dead and dying needles of the previous year's growth.

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No FIDL for this damage-agent

January 2006

By John Guyon
US Forest Service

Management Guide for

Limb Rusts

Cronartium arizonicum Cummins
(aecial stage *Peridermium filamentosum* Peck)

Primary hosts:

- **Ponderosa pine**
- **Jeffrey pines**

Alternate Hosts:
various species of *Castelleja* (paintbrush), *Othocarpus* (cow-wheat) and *Pedicularis* (lousewort).

Pines of all sizes can be infected, but limb rust is most evident on mature trees.

The fungi involved belong to several species, only one of which is completely described.

Topics

Key Points

- Trees of all size classes can be infected.
- Once inside the host, the rust can move around systemically in xylem tissues.
- The fungus only sporulates on small branches on the pine host.
- Infected trees are reservoirs for bark beetles.
- Remove infected trees during thinnings.
- Limb rust appears to be decreasing in occurrence in many areas.

Distribution and Damage

The limb rusts are widely distributed, ranging from the Black Hills of South Dakota, through the western United States and south through Mexico and even into Guatemala. When present they are some of the most destructive diseases of ponderosa and Jeffery pines in the western U.S.

Trees of all size classes can be infected, but limb rust is most evident on mature pines. These fungi are unusual for rust diseases in that they are capable of extensive growth in the sapwood after first infecting needle bearing branches. Mycelium of the fungus spreads at a rate of about 18–21 cm/year, either up or down the stem, a rate of growth substantially slower than most stem rusts. When a tree is infected in the center of its crown this growth pattern leads to a distinctive “hole in the crown” type symptom (Figure 1).

The slow growth of the fungus leads to slower damage than most rust diseases, and host trees usually aren’t killed until 80% or more of the crown has been killed.

Endemic bark beetle populations frequently attack limb rust infected trees hastening tree death. There is evidence that there is less limb rust now than there was 30–40 years ago due to reduced infection rates and silvicultural discrimination against infected trees.

Limb rusts cause gradual, progressive crown dieback due to systemic movement in the xylem.

Figure 1. Trees infected with limb rust sometimes develop a distinctive “hole in crown” symptom.

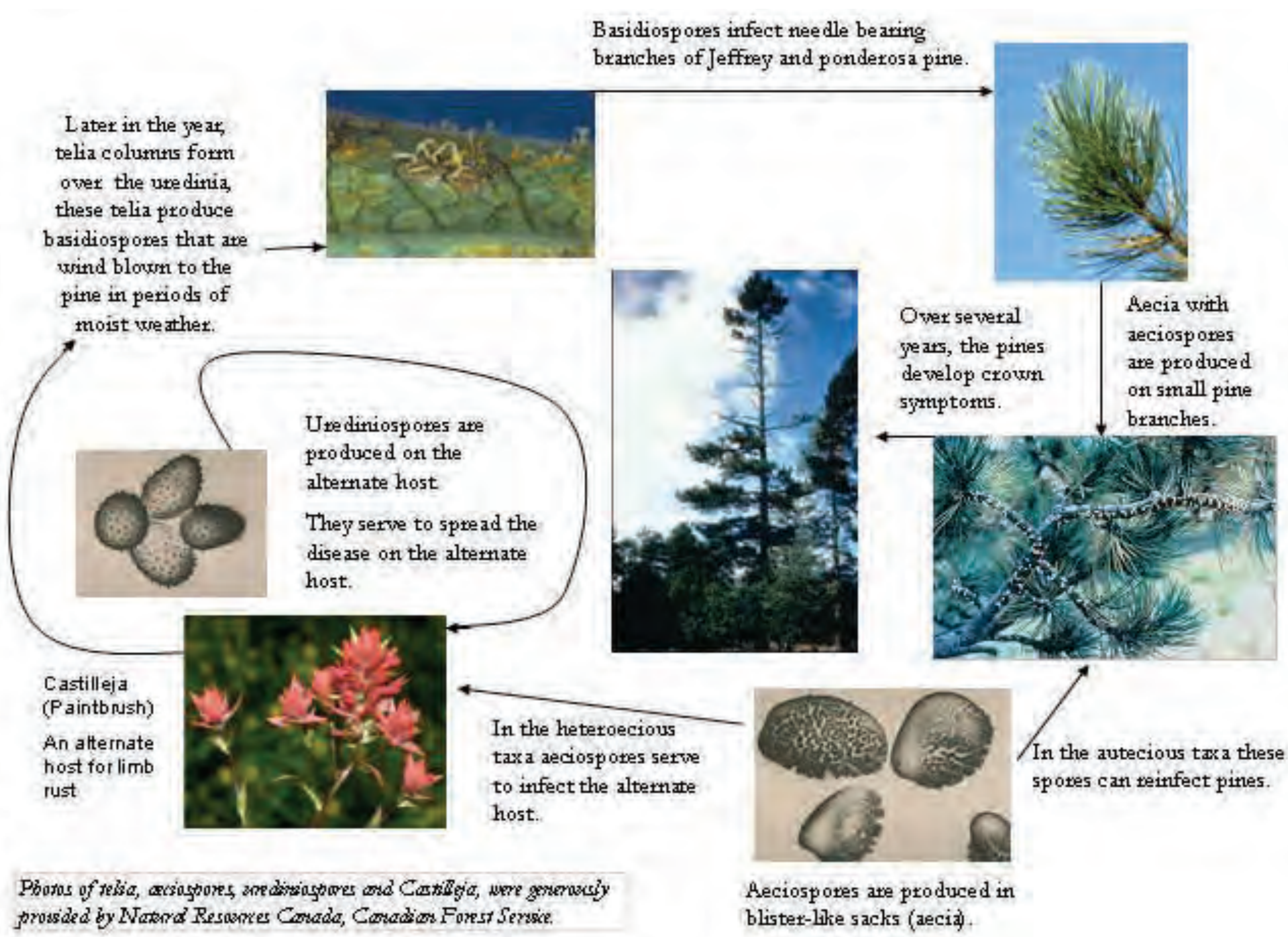
Limb rusts are easy to tell from the other stem rusts in that they only sporulate on small branches.

Life History

The fungi involved belong to several species, only one of which is completely described. *Cronartium arizonicum* Cummins (aecial stage *Peridermium filamentosum* Peck) is the best known causal fungus of limb rust, but there are at least 4 other incompletely described taxa involved.

At least 2 of the races of *Peridermium* that cause limb rust appear to be heteroecious, with 2 hosts, the pine and an alternate host such as *Castilleja* (Figure 2). Two other limb rust fungi appear to be autoecious; they don't need an alternate host to complete their life cycle. It may be that we are seeing some interesting evolution in action. In other words, have some of the races of the rust lost the need for an alternate host thus simplifying their life cycle?

Figure 2. Limb Rusts Life Cycle



After aeciospores from the pine host infect *Castilleja miniata*. (common name: giant red paintbrush, one alternate host) it takes about 18–20 days for the spore stage (urediniospores) that can re-infect the alternate host to be produced. After 39–50 days the telia that produce the basidiospores that infect the pine host are produced. In periods of moist weather, the basidiospores that can infect the pine host are produced, completing the life cycle. In some races of limb rust the aecia are persistent and still contain aeciospores well into the fall, and in some cases aecia can persist for 2 or even 3 years on the same small branch, which is unusual for stem rusts.

Once the fungus infects small branches it moves into the xylem tissues. This means of growth allows the disease to become systemic in the host, spreading throughout the crown rather than being restricted to a gall or canker. Mycelium of limb rust have been found in wood as much as 60 years old, and mycelium from a single infection can be over 100 feet in length. The disease can then move out from the sapwood and sporulate on and kill small branches resulting in gradual, progressive crown dieback and tree death.

Limb Rust Management

- **Limit damage.** Select against infected trees during stand management activities and keep cutting cycles short.
- **Inoculum reduction.** Eradicate infected trees around nurseries.
- **Chemical.** Apply fungicides to protect seedlings.

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March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Stalactiform Blister Rust

Cronartium coleosporioides Arthur
(=*Cronartium stalactiforme*, =*Peridermium stalactiforme*)

By James T. Hoffman
US Forest Service

Topics

Lodgepole pine is the principal conifer host, while ponderosa pine is a rare host.

Alternate hosts include several broadleaved plants, but mainly Indian paintbrush (*Castilleja*).

Stalactiform rust causes perennial cankers on the stems of hard pines (two- and three-needled pines). Generally Stalactiform rust cankers are visually distinguished from other stem cankers, like Comandra blister rust (*Cronartium comandrae*), by being 10 or more times longer than broad in shape.

Management

- **Frequency of Stalactiform rust infections is not known.**
- **Rust out-breaks often involve a burst of infection during a single season or even a single moist period, then years of tapering off as the infections die out.**
- **Removal of infected trees during partial cuts is the only practical means of reducing losses.**

Damage

Stalactiform rust affects the form, lumber content, and growth rate of trees. Although the fungus kills individual trees, it does not kill whole stands. Infected seedlings are usually killed, and significant mortality may occur in nurseries.

On mature trees, long stem cankers may develop from branch infections that grew into the bole, resulting in non-merchantablity of the main log. Frequently the bark is gnawed off by porcupines or squirrels, which causes extensive resinous. Infections by Atropellis canker (*Atropellis piniphila*) cause similar damage.

Since Stalactiform rust fruiting bodies (blisters) are sparse and difficult to detect on old stem cankers and rodent-chewed branches, such damage is often attributed entirely to causes other than rust.

Life History

Needle infection on pine takes place in late spring from spores produced by the alternate host. Fungal development progresses from within the needle tissues, spreading to the twigs, branches, and eventually into the main stem.

Elongate cankers develop around the infected branch, and eventually the branch stub, and produce white-orange blisters filled with spores in early summer that infect the alternate hosts, completing the fungal life cycle.

Recognizing Stalactiform Blister Rust

The perennial stem cankers are many times longer than they are wide, often approximating a diamond shape. Branch infections cause death of branch tissues distal to the branch canker resulting in a symptom known as " flagging." Main stem infections may cause top-kill or even tree death. Rodent chewing of the infected bark and cambium near the canker edges is evident by areas of exposed stem wood, often accompanied with heavy resin flow.

Other Reading

Ziller, W. G. 1974. The tree rusts of western Canada. Environment Canada, Canadian Forestry Service, Publication No. 1329. Victoria, B.C. 272p.

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2011

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Gall Rust

Endocronartium harknessii **(J.P.Moore)Y. Hiratsuka**

James Hoffman and
Susan Hagle

Forest Pathologists
Forest Health Protection
USDA Forest Service

Hosts:
Lodgepole pine
Ponderosa pine
Ornamental pines (Austrian, Mugo, Scots)

Western gall rust is the most common stem rust found on "hard pines" (2-3 needled pines) in the Northern and Intermountain Regions.

Topics

Key Points

- Trees of all ages are affected.
- Infections in young trees are most damaging.
- Cankers on stems of seedlings and saplings are usually lethal.
- Branch infections do not move into stem and die when the branch dies.
- Stem cankers on larger trees contribute to stem breakage.

Damage

Lodgepole and ponderosa pines are the principal hosts in the western United States; however, ornamental plantings of Austrian, Mugo, and Scots pines in proximity to forested areas can become infected. Unlike other stem rusts, western gall rust doesn't require an alternate host to complete its life cycle.

Perennial infections of the cambial tissues in branches and twigs cause globose swellings called galls. Galls that develop on the main stems can cause somewhat concentric ridges in the stem sapwood called "hip" cankers which affect form, lumber content, and growth rate.

Stem cankers on pole or larger trees rarely kill the trees directly but often contribute to stem breakage.

The rust infects pines of all ages, causing the most severe damage to seedlings/saplings in tree nurseries, Christmas tree plantations, and/or progeny test areas. Infected trees are more commonly found in drainage bottoms or near bodies of water.

WHERE GALL RUST IS SEVERE:

Promote tree species diversity and control tree density

OVERVIEW OF WESTERN GALL RUST MANAGEMENT

1. **Sanitize ornamental trees.** Prune infected branches to improve appearance and limit local inoculum.
2. **Seed sources.** Select apparently resistant trees as seed sources.
3. **Remove infected trees.** Cull infected seedlings in nurseries. Select against infected trees in stand thinning operations after 10 years of age.
4. **Limit local inoculum.** Sanitize stands surrounding nurseries by removing infected trees.

Figure 1. Trees with stem galls should be cut during precommercial thinning and stand improvement harvests.

Figure 2. An infection on just one side of the stem probably will not kill the tree directly but will lead to a hip canker as the tree matures.

Figure 3. A hip canker (arrow) caused deformation of the lower stem which pre-disposed the tree to wind breakage.

Life History

Spores produced on infected pines in the spring are windborne and infect emerging shoots and/or cone-flowers on pines. Infections are most common in the lower third of the crown, likely owing to better moisture retention close to the ground. The fungus grows within the cambial tissues. Round swellings (galls) are produced on branches, twigs, and stems and eventually girdle and kill the branch or stem. The canker does not spread beyond the gall. Alternatively, galls on main stems enlarge and cause "hip" cankers, which may exist for decades.

One or two years after infection, blisters containing spore pustules appear under the bark scales, completing the disease cycle. The orange-colored spores form in paper-thin blister-like pustules on the galls during the spring or early summer.

Unlike other stem rusts of pines, the fungus causing western gall rust does not require an alternate host to complete it's life cycle.

Impact

Branch galls commonly result in branch death, especially when infested by insects or infected by secondary canker fungi. High rates of branch infection may reduce growth and predispose trees to attack by pine engraver beetles (*Ips pini*). Stem infections are far more serious. Galls restrict water conductivity (Wolken and others 2010) which often results in tree death, especially in dense stands where trees are competing for water. Young trees are commonly killed outright by the restriction of water and nutrients caused by stem galls (Figure 1) or by subsequent infestation of the gall by insects or secondary canker-causing fungi. Deformation from hip galls predispose trees to stem breakage (Figures 2 and 3).

The tissue around the edges of a stem canker are common sites for sequoia pitch moth (*Synanthedon sequoia*) infestation which increases the extent of dead cambium.

Management

On sites with a history of severe gall rust, promote tree species diversity and control stand density for optimum growth.

In nurseries, seedlings with galls should be destroyed. Detection of seedling galls is difficult; often there is only a slight swelling on the main stem. Infected pines within 300 yards of nursery beds should be removed to prevent seedling infection.

Genetically controlled resistance to infection is evident; infected trees generally occur in groups of the same age-class and seed source. When thinning infected stands, remove trees with stem galls or more than six branch galls. Aggressive, early thinning for gall rust that will leave stands understocked is not recommended. Infection rates decrease dramatically over the first 10 years as trees rapidly gain resistance (Blenis and others 2005). Incidence of infection decreases further as the trees reach maturity (van der Kamp and Spence 1987).

Branch infections generally die within ten years after thinning. This is likely due to increased vigor and growth of the host and the consequential shading -out of the lower branches, where most of the infections occur.

The pathogen requires live host tissue to survive so it is not necessary to dispose of infected trees or branches after cutting.

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2013

Forest Health Protection and State Forestry Organizations

White Pine Blister Rust

General Ecology and Management

John Schwandt and Holly Kearns

Forest Pathologists
Forest Health Protection
USDA Forest Service

Topics

Key Points

- The cause of this disease is an invasive species
- Forests have been dramatically altered by this disease.
- Pruning can save stands.
- Monitor to schedule treatment and assess resistance.
- Hazard rate sites to select the best management.

Cronartium ribicola Fisch.

- **Conifer Hosts** - All native five-needled pines
- **Alternate hosts** - *Ribes* spp. (currants and gooseberries) are the main alternate hosts.

This fungus disease was accidentally introduced from Europe in 1910. Since then, it has devastated western white pine and whitebark pine forests in the northern and central Rocky Mountains.

Introduction

Management of western white pine has been confounded by the introduction of white pine blister rust, caused by the fungus *Cronartium ribicola* Fisch. This disease was introduced into western North America from Europe in 1910 on infected eastern white pine seedlings grown in France and planted near Vancouver, BC. Western white pine proved to be highly susceptible to blister rust with mortality rates of 90 percent or more in what were once vigorous, well-stocked stands. The disease is now distributed throughout the range of the pine hosts in the northern and central Rocky Mountain region.

This fungus has two host types that are both required to complete its life cycle. One host is a five-needled pine and the other is a shrub or herbaceous host, referred to as the alternative host.

On pines, the fungus causes branch flagging and stem cankers that eventually cause top kill or death. All sizes of trees are attacked and small seedlings can be killed rapidly. Generally, the larger the tree is at the time it becomes infected, the longer it survives after infection. On the alternate hosts, damage is usually confined to small leaf spots but minor defoliation ay occur if severely infected.

White Pine Blister rust Management summary

Four major goals for integrated management of western white pines:

1. **Breed for resistance.** Use breeding programs that will incorporate desirable silvical characteristics as well as rust resistance while minimizing selection pressure on the rust.
2. **Prune and thin.** Prune and thin to remove and minimize infections.
3. **Hazard rate sites.** Rate sites for potential blister rust damage.
4. **Maintain genetic diversity.** Maintain genetic diversity by encouraging white pine leave trees.

Life History

White pine blister rust requires two host types to complete its life cycle.

Conifer hosts—
All native five-needled pines including western white pine (Figure 1), limber pine, whitebark pine, sugar pine, and bristlecone pine.

Figure 1. Rust stem canker.

Alternate hosts—
Mostly *Ribes* spp.(currants and gooseberries). Research has recently shown some species of *Pedicularis* (lousewort) and *Castilleja* (Indian paint brush) can also be infected, but their role has yet to be determined.

Figure 2. Spots on a Ribes leaf.

The white pine blister rust fungus is an obligate parasite which means it can only survive on living host tissue. It has a complex life cycle that includes five spore stages on two different hosts. Cankers on white pine produce characteristic yellow-orange blister-like aecia that erupt through the bark in spring.

Figure 3. Aecia on a whitebark pine branch. [Photo by J. Schwandt]

Aeciospores from these blisters can travel long distances to infect leaves of the alternate hosts.

During summer, pycniospores are produced near canker margins in watery droplets which insects carry from canker to canker resulting in fertilization of the rust fungus.

Figure 4. Pycniospores exuding from an infected pine twig. [Photo by J. Schwandt]

The fungus builds up on the alternate hosts through the summer by producing spores (urediospores) which reinfect alternate hosts nearby. In late summer the fungus produces teliospores on small hair-like projections on the underside of leaves of the alternate hosts. These soon produce very fragile spores (basidiospores) which usually travel very short distances to infect current- and one year-old needles of

Figure 5. Telia on underside of ribes leaf in the fall. [Photo by J. Schwandt]

white pines.

During spring, the fungus kills leaf tissue resulting in small leaf spots, then grows into adjacent twigs and branches. The fungus grows along branches about 2-4 inches per year toward the main stem, killing tissue as it advances. Cankers within six

Figure 6. New canker (orange discoloration) in a twig. [Photo by J. Schwandt]

inches of the bole may continue to grow several years, even in branches that have no live foliage remaining. Cankers on branches and young stems generally produce aecia 3-5 years after needle infection, but sporulation can be very sporadic.

Recognizing rust infections

New infections

Although the fungus causes small needle spots the spring after infection, the earliest obvious symptom is usually discoloration, swelling, or pitch flow on an infected twig or branch. As the fungus girdles the branch, the needles beyond the canker die creating distinctive "flags" (figure 7). The bark at the canker center becomes sunken or cracked while the leading margin of a canker is

Figure 7. Branch flag caused by a canker girdling the branch. [Photo by J. Schwandt]

yellow to brown. (The canker margin can usually be made more visible by washing and lightly scrubbing with water).

Sporulation

Characteristic sporulating yellow blisters near the canker margins are produced in the spring, but may not occur until many years after infection, and may not occur every year. During the summer, cankers may produce watery droplets of pycniospores that ooze out from inside canker margins and leave dark brown spots (pycnial scars) which can aid in canker identification.

Other fungi and rodent chewing

During periods of high moisture cankers may be partially covered with a pink-purple weakly parasitic fungus called *Tuberculina*. This fungus only has minimal effects on the rust, but may help to identify rust cankers.

Rodent chewing on western white pine (figure 9) has almost always been an indicator of rust infection since rodents are attracted to high sugar concentrations in cankers.

Figure 8. Rodent chewing on white pine bark is almost always an indication of a blister rust canker. [Photo by J. Schwandt]

Stem cankers

Infected trees may appear vigorous until shortly before death (> 90% girdle), although stem cankers usually have abundant resin flow on the outer bark.

Abnormal cankers may also be found, especially on trees with some level of natural resistance. These can appear as slow growing cankers with swollen callus ridges and sunken centers or misshapened areas at the base of small trees that can easily be mistaken for mechanical damage or root disease infection (figure 10). Trees with basal cankers may be bent by snow or chewed by rodents which may make identification difficult. Trees with root disease usually have an irregular "canker" margin without any yellow discoloration at the top and copious resin that increases below ground line.

Figure 9. Wetting makes cankers easier to see.

A branch canker showing more distinct discoloration after wetting with water.

Figure 10. Abnormal stem cankers.

Management Considerations

Figure 11. White pine blister rust resistance offers the best long term solution for the restoration of white pines. [Photo by S. Hagle]

There are four major goals for integrated management of western white pines: (1) use breeding programs that will incorporate desirable silvical characteristics as well as rust resistance while minimizing selection pressure on the rust, (2) use silvicultural practices such as pruning and thinning to remove and minimize infections (3) develop hazard rating systems that will help rate sites for infection potential, and (4) maintain genetic diversity by encouraging leave trees.

Breeding for resistance

A cooperative western white pine tree improvement program to capture and concentrate naturally occurring resistance mechanisms was started in 1959. The early crosses proved resistance traits could be successfully passed on through breeding and nearly 15 years later seed was operationally available from this first generation (F1) of selectively bred trees (Sandpoint, Idaho seed orchard). The best candidates from the first breeding were crossed to create a second generation (F2) to further improve resistance. F2 seed orchards were established at Moscow, Lone Mountain, and Coeur d'Alene, Idaho. Most of the white pine planted since the mid 1980s have been F2 stock from these seed orchards (Moscow was phased out in the early 1990s). A single green house test of this stock reported that 66% of this stock would remain canker free. Genetic resistance to blister rust is not infallible since the fungus can make genetic adjustments which overcome host resistance. Strains of *C. ribicola* that have overcome resistance in western white pine have been discovered in Oregon and California. These populations are being closely monitored and so far have not spread far from their origin. Because of the potential for the rust to change, there is an ongoing program to select and test additional parent trees exhibiting resistance. The testing is conducted at the Coeur d'Alene nursery where seedlings from potentially resistant trees are subjected to an intense spore load under favorable infection conditions. Trees are checked for resistance and good growth characteristics for 3 years and the best performers are being added to a new seed orchard established in 1986 at Grouse Creek, Idaho. The goal is to produce seedlings that have good silvical characteristics as well as resistance levels that will provide good survival while minimizing selection pressure on the rust.

White Pine Tree Improvement Program Goals

- **Produce seedlings that have good silvical characteristics**
- **Resistance levels that will provide good survival while minimizing selection pressure on the rust.**

Because of the potential for the rust to change, the program to select and test additional parent trees exhibiting resistance is ongoing.

Silvicultural practices to minimize infection and mortality

Although white pine has only been planted on a small fraction of its historical range, thousands of acres have been planted, and natural white pine regeneration is present on many cutting units. However, infection levels in many plantations are high enough that additional treatments may be necessary to prevent white pine stocking from falling below (acceptable levels. In spite of the early test indicating 66% resistance for the life of the F2 stock, we found about half of 60 surveyed plantations had over 50% infection, and some had over 90% infection after only 15-20 years. However, the F2 stock at all sites had lower infection and mortality levels than F1 or natural regeneration. We are continuing to monitor stands to see if the higher than expected infection levels result in higher than expected mortality.

There are several management practices that can help minimize levels of infection and mortality in white pine plantations. These practices use biological concepts to create an environment less favorable to the rust, so the trees have a better chance of surviving. These practices include lower branch pruning, canker excision, judicious use of thinning, and practices that minimize ribes populations.

Survey of F_2 plantations has found higher rust infection rates than expected.

- **Half of 60 surveyed plantations had over 50% infection,**
- **Some had over 90% infection after only 15-20 years.**

Pruning

Basal and lower stem cankers are most often the cause of mortality of blister rust-killed white pines. Since blister rust can only infect through needles, these infections must occur through needles on small branches when trees are young. Therefore, pruning lower branches before cankers can develop or spread into the bole may prolong survival and reduce mortality (figure 12).

A test of pruning lower branches from young white pine greatly reduced mortality and infection from blister rust over the next thirty years. Thirty years after treatment, survival of white pine in 15-year old stands of unimproved stock that were pruned and thinned, was 70% versus 40% in thinned only and untreated control plots. In addition, the number of trees without obvious infections ("clean") in the pruned and thinned plots was nearly twice the number of clean trees in the controls and thinned only plots. We have no long-term pruning efficacy data available for F2 stock, but since F2 has always out-preformed naturals and F1, we expect pruning to be at least as effective in F2 as in naturals. (We are currently establishing plots to monitor effects of prune only as well as pruning and thinning on F2 stock.)

It is important to remember that pruning does not change the rust susceptibility of white pine. A tree with a branch canker is still susceptible to future infections, but pruning has greatly increased its chances of survival. In fact, some geneticists are concerned that if these trees live long enough to contribute to future natural regeneration, resistance levels in off-spring may be watered down. Careful monitoring of stands is recommended in order to apply pruning at the most beneficial time. This depends largely on management objectives regarding the amount of white pine desired in a stand so it is crucial to look at both the infection levels and stocking levels when making pruning decisions. It is preferable to allow the rust to have time to infect the most susceptible trees, but to

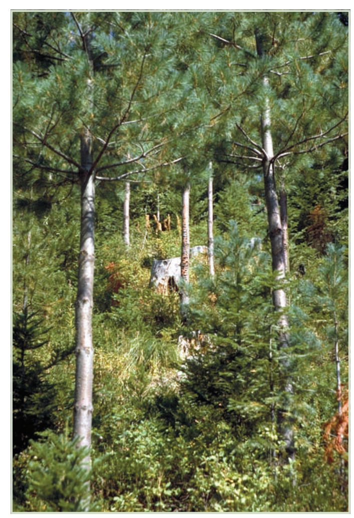

Figure 12. Pruning removes the branches nearest the ground where most infections occur. [Photo by J. Schwandt]

Stands that are at least 10 years of age, and average less than 35 feet tall are the best candidates for pruning.

Figure 14. (top) Damage has occurred early in stand development. Figure 15. (bottom) Pruned seedling. Early pruning may be the only option for saving young trees on hazardous sites. [Photos by J. Schwandt]

prune a stand while enough trees are still prunable or clean to maintain acceptable stocking levels. For this reason, decisions to prune or excise should always be preceded by a rust status survey. Rust status is the current status of white pine blister rust infection in a stand. Stands that are at least 10 years of age, but average less than 35 feet in height offer the greatest opportunity for pruning to reduce infection and mortality. A rust status sample should include at least 100 white pines. Infection can vary across a stand, so the survey should cover the entire stand and fixed area plots are required to calculate trees per acre. Additional tallies of other species may also be beneficial to determine total stand density of all species. A sample rust status survey form can be found at the end of this section.

Each white pine is rated by the most lethal canker observed. Trees with no obvious cankers are considered "clean", while those with only branch cankers more than 24 inches from the bole are considered to be "safe", since the branch will likely die before the canker can grow into the bole. If the canker is on or within six inches of the bole, it is considered lethal. If the most lethal canker is on a branch between 6 and 24 inches of the bole and within easy reach from the ground, trees are considered prunable. Since the fungus grows 2-4 inches per year, if the margin of a branch canker is four to six inches from the bole, it could probably be safely pruned immediately, but if pruning will be not be conducted for at least a year, six inches is a safer distance to use for surveys. (Moistening and lightly scrubbing the canker with water will usually assist in defining the margins of the canker).

Even if a stand has some blister rust infection, it may not need to be pruned. The rust status survey will tell you how many trees per acre are uninfected as well as number of trees with prunable and lethal cankers so you can make a much wiser decision about pruning. In a dense stand, there may be many infected trees, but the number of clean trees may still be high enough to satisfy management objectives, so pruning may be unnecessary (or delayed). In lightly stocked stands, every white pine may be needed to maintain management objectives for trees desired per acre, so it may warrant pruning even if the number of infected trees is small.

A single pruning to a height of eight feet or the lower 50 percent of the tree height (whichever is less) is recommended. Individual infected branches above this height should also be pruned ("pathological pruning"). Pruning above eight feet in trees greater than 16 feet tall has not been justified for blister rust, but may be considered if pruning for clear wood. Both dead and live branches should be cut since infections on "dead" branches may continue to grow towards the bole for several years. Cuts can be flush with the branch collar since white pine has very little tendency to develop decay from wounds. Pruning is accomplished using hand pruners, shears with 2-foot handles, or pruning saws, and there have never been reports of transferring the fungus on pruning tools.

Prune the desired number of white pine crop trees per acre whether they appear to be infected or not.

Other species should not be pruned as their shade will help prevent sunscald and reduce *ribes*, plus impede movement of rust spores. Live branches near the base are often partially buried in duff or brush and may be overlooked so crews should be instructed to check carefully for hidden branches and basal cankers. (More detailed information regarding pruning is available in Schnepf and Schwandt, 2006).

Figure 16. Excising around a small branch canker will effectively kill this canker.

Excising Cankers

Excising cankers

Small bole cankers on valuable trees or branch cankers within six inches of the bole can be "excised" to eliminate individual cankers. Excision consists of cutting a channel completely through the bark and cambium at two inches beyond the visible margin of the canker. This essentially creates an island of tissue that dies along with the infection. Excision is very time consuming (expensive), and far more difficult than pruning, so it is generally not recommended for operational forest use.

Excising is best accomplished from mid-April through early June when bark is soft and canker margins are most obvious. Excisable cankers girdle no more than 50 percent of the tree circumference, have their upper edge no more than six feet from the ground, and lower edge no less than six inches from the ground. (This includes the discolored area beyond the obvious edge of the canker.) Branch cankers that are within six inches of the bole can be treated by pruning the branch and then excising the bole around the branch collar.

Figure 17. A successful excision may leave a large scar that will eventually heal.

Thinning

Precommercial thinning is often used in the white pine type to release dominant and co-dominant trees by removing trees in the lower crown classes. Recent research has found that while white pine responds to thinning, it does not need release unless over-topped by other species. We recommend leaving all white pine regardless of infection or spacing (often referred to as "ghosting") and allow blister rust to thin the white pine.

Timing and intensity of precommercial thinning of other species may also affect blister rust infection. Blister rust infection levels and mortality in five precommercially thinned 10-15 year old white pine stands were significantly higher than unthinned plots in the same stands 30 years after treatment. The higher losses in the thinned only treatments are probably due to increased retention of lower live branches where many infections occur and increased vigor of *Ribes* populations which may increase local inoculum levels. Plots that were pruned as well as thinned had significantly lower rust infection and mortality than both the thinned only and untreated plots, so pruning of lower branches appeared to be more important than the increase in *Ribes*

We recommend leaving all white pine regardless of infection or spacing to allow blister rust to thin the white pine.

Figure 18.
Two important local Ribes species.

Ribes lacustre (top) and Ribes viscosissimum (bottom) are two common and important alternate hosts for white pine blister rust. [Photos by S. Hagle]

populations due to thinning. Thinning should be delayed as long as possible to allow the rust to thin the most susceptible trees, and to enhance shading out of lower branches along with the shade intolerant *Ribes* plants.

Ribes Management

Although spores from white pine can travel many miles to *Ribes* plants, spores produced on *Ribes* that infect white pines are very fragile and do not survive very long. Recent surveys have not found as high a correlation between local *ribes* and infection levels as was once thought, but high populations of *Ribes* could still be a major factor in local inoculum levels.

Most *Ribes* species are shade intolerant, so any management activity that increases shade will help reduce *Ribes* abundance, and any activity that increases sunlight will encourage *Ribes* populations. Since *Ribes* seed can remain dormant if undisturbed in the forest floor many decades, activities that disturb the duff layer can activate dormant seed. Studies have found that light partial cutting can activate the dormant seed, but close before the plants can produce seed. Site preparation can also be a factor; burning generally increases *Ribes* production (except for hot burns), compared to unburned sites.

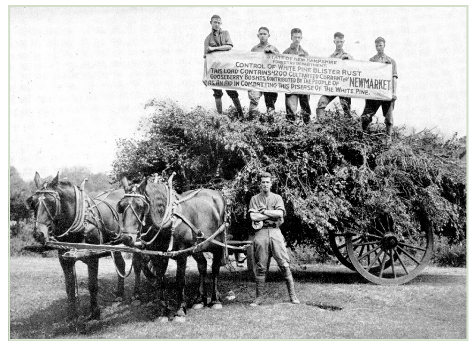

Figure 19. Early blister rust control efforts included eradication of wild currants and gooseberries from forest lands, but cultivated plants also were removed from gardens.

Rust Hazard—
The favorableness of a site for the development of the rust.

Rust hazard rating is still under development, but several factors have been implicated by a University of Idaho study of 60 white pine plantations (citation).

- Infection levels increased with elevation above 3500 feet, slopes greater than 15 percent, *Ribes* bushes/acre greater than 100, and stand age.
- Infection levels also were higher on sites with tall brush (> 4.5 feet), southern aspects, cedar-wild ginger habitat types or sites that had been broadcast burned.
- Additional testing of these relationships is needed.
- Local weather patterns and micro-site environment are also important factors contributing to rust hazard but are currently poorly understood.

Prioritizing Stands for Treatment

If several stands are being considered for pruning or thinning, it may be necessary to prioritize them to insure the proper stands are treated. Prioritization will depend on many factors such as access, thinning plans, and other species present, as well as average age, height, and rust infection levels of white pine.

Prescriptions involving stocking reduction in young mixed stands should take into account white pine stock type (natural, F1 or F2), rust hazard, and level of rust infection as well as the stocking density of all species. Grand fir, western hemlock, and western redcedar more effectively suppress *Ribes* than do Douglas-fir, western larch, and pines. Therefore, *Ribes* populations will decline most rapidly in heavily stocked stands with high proportions of grand fir, western hemlock, and western redcedar. Stands with large amounts of grand fir and Douglas-fir may suffer increasing mortality from root disease so retention of less susceptible white pine may be increasingly important.

Priority for treatment depends on:

- **Thinning plans,**
- **Other species present,**
- **Average age and height,**
- **Rust infection levels,**
- **Relative site hazard.**

Monitoring

The importance of monitoring stands for blister rust can not be stressed enough. Even after silvicultural treatments, stands should be monitored to evaluate treatment effectiveness. Rust infection and mortality levels can increase dramatically in a few years, even in plantations with initially low levels of rust.

Table 1 shows survey results in seven young plantations surveyed in 1992, 1998, and 2004. Infection levels in five F2 stands increased dramatically in the first six years and all but one doubled in 12 years while infection levels in the two F1 plantations doubled to 80% during the first six years of monitoring. Mortality rates in all but the youngest F2 plantation were already 30-46% and over 70% in both F1 plantations during a 12 year period 3-8 years after planting.

Monitor stands

- **For changes in rust infection and mortality levels.**
- **For treatment effectiveness after thinning, pruning and excising.**

Table 1. Change in percent infection and mortality in seven plantations of improved stock over a 12-year interval.

Stock Type	Year Planted	Stand Name	% Infection			% Mortality		
			1992	1998	2004	1992	1998	2004
F_2	1986	Copper 1	37.7	49.7	60.0	10.3	32.0	46.3
F_2	1986	Copper 2	11.5	34.4	45.9	9.8	18.0	29.6
F_2	1984	Copper 21	29.9	42.7	47.6	13.4	28.7	38.4
F_2	1989	Varnum 2	1.9	14.2	28.3	0.0	3.8	7.5
F_2	1988	Varnum 11	1.8	36.0	45.9	1.8	10.8	45.0
F_1	1988	Varnum 23a	43.1	80.2	88.8	6.0	61.2	79.5
F_1	1988	Varnum 23b	43.8	83.8	90.8	19.2	46.2	71.5

Figure 20. Top-kill from two blister rust cankers at different levels on the stem.

Leave Trees

In stands with mature live white pine, it is advisable to leave some of the best trees to help maintain the genetic diversity. These trees have been exposed to many years of spores, and may possess resistance traits not yet incorporated into the breeding program.

Guidelines for leaving up to 10 trees per acre are provided in Schwandt and Zack (1996). The Inland Empire Tree Improvement Cooperative encourages foresters to look for and document possible rust free "plus" trees for addition to the breeding program.

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Data form for field surveys to determine the status of stands with respect to white pine blister rust infection.

WHITE PINE RUST STATUS

Area Name:____________________ Forest _____________ Seed Lot ________ Date ________
Stand No: ____________________ Acres ________ Plant Date _________ TPA___________
Location: T____ R. ___ Sec____ Plot size: _________ Crew: ______________________________

Plot#	Clean	Safe	Prune	Lethal	Dead Rust --	RR --	Unk	Ribes
Total	Clean	Safe	Prune	Lethal	DR	RR	D	Ribes

Summary

______ % Clean	_____ TPA
______ % Prunable	_____ TPA
______ % Lethal	_____ TPA
Total % live _____	____ Total Live WP
______ % Dead	_____ TPA

Other Sp. TPA: L____, DF/GF______ _____

Ave Crop Tree Ht.: ___________

TPA = #trees X inverse of plot size / # plots

Plot Size: 1/10 ac. = 37.2' radius
1/20 ac. = 26.3'
1/50 ac. = 16.7'
1/100 ac. = 11.78'
1/300 ac. = 6.8'

Definitions/Codes:

Clean: (C)	No visible cankers
Safe: (S)	All cankers > 24" from bole
Prunable:(P)	Branch cankers 6-24" from bole
Lethal: (L)	Stem canker or <6" from bole
Dead rust (DR)	Dead with rust cankers
Dead (RR)	Dead with evidence of root rot
Dead (DU)	Dead from unknown cause

1/24/06

Comments and recommendations:

Cite as: Schwandt, J.; and Kearns, H. 2013. Management guide for white pine blister rust. 12 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Branch & Terminal

Insects

Related section in field guide.

No FIDL for this damage-agent

April 2004

By
Dwight Scarbrough
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Native Aphids

Family: Aphididae

Topics

Aphids can be found almost anywhere on a tree, particularly on new growth.

Often, the first evidence noticed is the sticky "honeydew" excrement on affected plants.

Key Points

- Weather and other natural controls usually keep aphids in check.
- A forceful water spray may remove aphids.
- Insecticides are most effective in nymph stage.
- Several beneficial insects that are important in aphid control are harmed by insecticide treatments.

Damage is usually seen on ornamentals

Aphids infest hardwoods, conifers and many other plant species throughout the United States. They are common, though rarely noticed, in forest settings. Aphids are usually of greatest concern in nurseries, seed orchards, and shade and ornamental trees.

They have piercing mouth parts through which they fed on sap from nearly all parts of host plants-foliage, buds, flowers, fruits, twigs, and roots. Damage on needles may result in necrotic spots similar to some diseases or feeding by other insects.

Aphids excrete a sticky substance known as "honeydew" which is feed upon by ants and other insects. It may also provide growth medium for black fungus molds (sooty molds). Honeydew and sooty mold, associated with aphids, usually mar the beauty of ornamentals.

Heavy infestations distort foliage, cause terminal dieback, reduce tree vitality, weaken the tree, and cause branch and crown dieback. In young trees and seedlings, mortality can occur from heavy infestations.

Aphids are usually controlled effectively by nature.

Adverse weather conditions such as beating rains and low temperatures, as well as fungus diseases, insect predators and parasites keep the aphids in check.

Life History

Some aphids require alternate hosts in alternate generations.

Overwintering can occur in any life stage, but the most common is the adult or egg. Eggs hatch and live births usually occur in the spring, and nymphs begin feeding on selected parts of the plant. Some aphids migrate as nymphs; others spend their life in one place. Some aphids have only one generation per year; others have several. Some aphids require alternate hosts in alternate generations.

Recognizing plant aphids

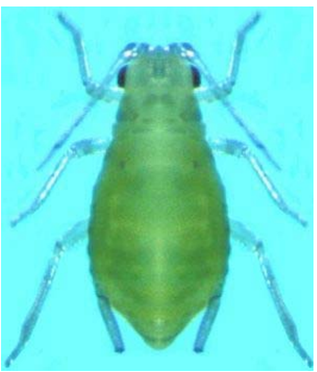

Figure 1. Magnified view of adult aphid.

Aphids vary in bodycovering and range in size from 1/5 to 1/4 inch long. They are all soft-bodied and are usually gregarious insects. Most aphids are pear-shaped, with a pair of cornicles (tubes) at the posterior of the abdomen. They may be transparent, yellow, green, pink, brown, almost black, or spotted. Some species may be covered with white woolly wax.

Most aphids that are seen are wingless; however, winged adults may be observed at various times during the summer.

The presence of sticky exudates (honeydew), sooty mold, and large numbers of ants probably indicate that aphids are also present.

Management

Warning:

Insecticide applications can destroy beneficial insects as well as pests and leave trees or shrubs unprotected if pest resurgence occurs.

Adverse weather conditions such as beating rains and low temperatures, as well as fungus diseases, insect predators and parasites keep the aphids in check. Aphid enemies include lady beetles, syrphid fly larvae, aphis lions and small wasp parasites known as braconids.

When control measures are warranted careful concideration should be given to the choices of whether to use cultural, biological, or chemical measures. Insecticide applications can destroy beneficial insects as well as pests and leave trees or shrubs unprotected if pest resurgence occurs. Several beneficial insects play an important role in natural aphid control.

If this is a concern, try washing aphids away with a forceful stream of water before using insecticide sprays. However, insecticides are often used to protect high value trees and are most effective against the nymphs.

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Related section in field guide.

March 2010

R. Ladd Livingston
Idaho Dept of Lands (ret.)
and
Lee Pederson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Balsam Woolly Adelgid

Adelges piceae (Ratzeburg)

Topics

Subalpine fir is most susceptible.
Grand fir is most resistant to damage.
All true firs may be hosts.

This European invader was first found in northern Idaho in 1983. It has expanded south to the Sawtooth National Forest, killing substantial numbers of subalpine fir.

Key Points

- It is a non-native species that has only been known in Idaho since 1983.
- We know little about its real potential for ecological damage.
- Natural and environmental influences have not stopped its spread.
- Silvicultural management may reduce damage.

Damage depends on population density

Balsam woolly adelgid was discovered in northern Idaho in 1983 feeding predominantly on subalpine fir and to a less extent, grand fir. Since that time, it has been found from the Canadian border to as for south as the Sawtooth National Forest in Idaho. It has caused extensive mortality of subalpine fir, especially in low-elevation drainage bottoms.

Nymphs feed on the bark of stems, branches, and twigs, and at the base of new shoots and buds, but never on needles. Their feeding causes stunting of terminal growth with distinct swellings (gouting) around the buds and branch nodes.

All sizes of trees are attacked. but the infestations may be concentrated on the stems or in the crowns. Stem-attacked trees can die after only 2-3 years of heavy infestation and without any apparent gouting.

In the crowns, gouts occur on the fastest growing parts of the tree, and on trees that have been lightly infested for a long time. These trees decline slowly, growth is reduced, and the dead and dying upper stem is often infected by wood-destroying fungi.

An Invasive Species

- **This insect is still advancing in Idaho and mortality is increasing.**
- **It causes tremendous ecological changes on low elevation subalpine fir sites.**
- **Control at stand or landscape levels is not feasible with insecticides. Individual tree protection with an approved insecticide can provide effective control.**

- Balsam woolly adelgids insert their mouthparts into the cortical parenchyma of the bark.
- A chemical in their saliva affects the hormonal action of the tree.
- This causes abnormal cell division and differentiation in the bark and newly formed wood.
- Abnormally wide annual rings are produced in the stem, which are composed of thick cells (compression wood).
- Stunting of terminal growth also occurs, with distinct swellings around the buds and branch nodes.
- The abnormal swelling is called "gouting".

Life History

Balsam woolly adelgid generally overwinters in the first instar (neosistens) of the hiemosistens generation. They are about 0.35 mm long, amber colored, flattened. and fringed with wax. They can be found on any part of the tree where the bark is thin enough for them to reach the conductive tissue (cortical parenchyma). About May they start feeding, go through two more instars, and change into adults by June.

Adults are all females and are about 1 mm long, dark purple to black, wingless, and become covered with whitish "wool". Up to 250 eggs can be laid under the wool. The egg laying period can last about 6 weeks.

Crawlers (first instar nymphs) emerge from the eggs and settle on the bark during July. These neosistens of the new aestivosistens (summer) generation go into a dormant period for several weeks then start feeding and develop into adults by late summer.

Egg laying can occur from late August to late October. and nymphs from these eggs overwinter. Two generations a year commonly occur in the mountainous areas of the West. Three to four generations can occur in milder climates.

Natural Control

Hosts: Heavy balsam woolly adelgid feeding modifies the bark and after a few years they can't penetrate the thicker layers. Attractive feeding space on the tree diminishes and populations die out. If a tree survives the initial infestaton, mortality will likely be avoided.

Weather: Freezing is fatal and chances are increased as temperatures fall below -5° F. There are no survivors at –30° F. Adelgids below the snowline usually survive. Cold, wet springs can reduce populations of developing nymphs. Abnormally cold periods in the fall will also decimate populations.

Biological: North American predators are not very efficient, so three beetles and three flies were introduced from Europe and have become established. Balsam woolly adelgid populations increase so rapidly that these predators have been shown to be virtually ineffective.

Silvicultural Alternatives

Along the West Coast the most severe outbreaks occurred at the lower end of the host species elevation range, i.e.. from 3,000-5,500 feet in subalpine fir and below 1,000 feet in grand fir. Although we do not have anything below 1000 feet, elevational restrictions may exist in the Northern Rocky Mountains also.

The literature indicates there are not many effective measures of prevention through forest management practices. Under intensive forest management, the following measures may reduce damage:

1. Slow the rate of infestation spread that is caused by crawlers being transported by the wind or carried on logs and vehicles, and nursery stock:

- Refrain from moving infested logs through non-infested stands.
- Take into account prevailing wind direction when establishing cutting boundaries.
- Fall infested trees away from non -infested ones.
- Clean all logging equipment before moving it to new areas.
- Cut and remove infested trees in winter when nymphs are not motile.
- Don't establish nurseries in the vicinity of infested stands. Inspect outgoing seedlings for aphids.

2. Grow fir on short rotation cycles.

3. Favor other non-host species.

4. Selective cutting and removal of heavily infested trees.

5. Maintain full stocking and increase vigor of stands.

6. Introduce or develop less susceptible species of firs, and genetically resistant strains or hybrids.

There are few effective measures for prevention through forest management practices.

Chemical Control

Insecticidal sprays have to drench this insect which is fairly well hidden on the tree. Thus, aerial spraying is unfeasible.

There are five insecticides registered for balsam woolly adelgid control in Idaho (as listed in the Pacific Northwest Insect Management Handbook 2009).

- Carbaryl
- Chlorpyrifos (Lorsban 4E): A restricted use pesticide.
- Endosulfan (Thionex 3EC, Thionex 50W): Nursery use only.
- Imidacloprid (Provado 1.6F)
- Sucrose octanoate (SucraShield): A sugar based insecticide/ miticide/ovicide that quickly acts to desiccate or suffocate the target insect.

Always check for current registration and restrictions before using any of the chemicals listed above.

White "wool"- covered female balsam woolly adelgid on the bark of a subalpine fir.

Recognizing Balsam Woolly Adelgid

The most obvious indicator of balsam woolly adelgid presence is the white "wool" covered females on the bark of stems or branches. This is most noticeable during summer months.

Swellings of the outer branch nodes and terminal buds (gouting) with a concurrent stunting of growth is another symptom. If the gouts enclose reproductive buds, no new shoots or needles are produced.

Dying or dead branches and crowns are other symptoms.

Internet Resources

http://insects.ippc.orst.edu/pnw/insects
http://www.oregon.gov/fh/BalsamWoollyAdelgid.pdf
http://www.fs.fed.us/r6/nr/fid/fidls/fidl-118.pdf
http://cru.cahe.wsu.edu/CEPublications/eb1456/eb1456.html

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March 2004

By
Carol Bell Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Gouty Pitch Midge

Cecidomyia piniinopis Osten Sacken
(Diptera: *Cecidomyiidae*)

In the West on it's principal host, ponderosa pine, it is known as the bird's-eye pine midge (although it does not cause the "bird's-eye" figure in pine lumber) or ponderosa pine resin midge.

Hosts:
- **Pines (Pinus spp.)**

(Particularly Ponderosa pine)

Topics

Key Points

- It attacks only the current year's shoots.
- Young trees are particularly susceptible.
- Wounds caused by gouty pitch midge may later be attractive to other insects, such as the pinyon pitch mass borer.

Damage

Midge larvae feed under the bark of shoots, in small resin filled pockets.

Light infestations may cause little damage or minor distortion of the bark around the pitch pocket.

Heavy infestations can girdle and kill the terminals. Evidence of dieback progresses throughout the summer and by late summer needles or entire terminals may be killed.

Damage first noticeable in early summer when the new shoots fade, droop, and gradually turn yellow and die. On some trees nearly every new shoot is affected.

If there are not enough pockets to kill the terminal, the injury heals over but for many years the annual rings are distorted into a peculiar whorl until the pocket is completely covered.

Severe attacks retard tree growth and repeated attacks sometimes kill trees. Young trees are particularly susceptible.

Attacks are heaviest on trees with sticky twigs and lightest on trees with dry, powdery twigs.

Life History

This insect occurs from coast to coast. In California, Oregon, Washington, Idaho, and Montana it commonly infests young, open grown pines, especially in plantations.

The larvae spends the winter within pitch pockets on the bark of twigs. In the spring they move to the base of needles and spin a cocoon in which they pupate.

Adult midges emerge in spring shortly after the new shoots have emerged. Adults are small, delicate flies- typical midges. Adults mate and females lay eggs on the surface of the shoot.

Eggs hatch and newly hatched larvae first tunnel into resin droplets that form at the base of the needles and later migrate to resin pockets in the bark for further development.

The gouty pitch midge has one generation per year.

Populations fluctuate widely from year to year due to natural control.

Identification

The gouty pitch midge has one generation per year.

Signs of Attack—Needles on infested shoots die in tufts which soon droop, turn yellow and later reddish-brown. These flags are scattered over part or all of the crown and appear by summer.

Extensive twig killing, stunted or distorted growth, and sparse, off-color foliage are symptoms of persistent, heavy infestations.

Infested shoots will have slight swellings on their surface. When the bark is removed, infested tips will be pitted with small, resinous pockets with bright red to orange red maggots, often found in groups, within pockets of pitch on twigs or small branches.

Infested shoots with gouty pitch midge larvae. Photo by: Scott Tunnock

Management Considerations

Controls have not been developed. Populations fluctuate greatly under normal conditions due to natural controls. There is also great variability in genetic susceptibility to this insect among individual pines.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Juniper Twig Pruner

Styloxus bicolor (Champlain and Knull)

By Brytten Steed
US Forest Service

Topics

This insect is found on junipers throughout parts of Utah, Nevada and California.

Host:

Junipers

Key Points

- Foliage and twig damage may occur over the crown.
- Overall damage to juniper stands is usually considered minor.
- Mortality of small trees is possible.

Damage

Twig dieback, and stunting of growth and leaf development occurs from pith mining by larvae. Repeated attacks and heavy populations may limit growth, but overall damage to juniper stands is usually minimal. Mortality of small trees is possible.

Life History

Adults often lay eggs under the bark near the junction of branch twigs one to two feet back from the branch tip. Small, white, cylindrical larvae kill twigs by boring through and feeding on the twig pith. It may take up to two years for the juniper twig pruner to complete its life cycle.

Identification

Conspicuous yellow, red, or brown foliage “flagging” occurs midsummer as twigs are girdled and die. Damage may be mistaken as caused by adult cedar bark beetles, but the juniper twig borer creates a distinct, round boring tunnel through the center of the stem. Adults have the typical “long-horned” beetle form and are about ¼ to ½” long, have a brownish to black-colored slender body with a reddish-orange head. They have narrow, tapered wing covers that only partially cover the abdomen. Larvae are long and cylindrical in shape, and have a round head. Several body segments directly behind the head are somewhat larger than those following.

Juniper twig borer creates a distinct, round boring tunnel through the center of the stem.

Management Considerations

There are no registered insecticides for control for this insect nor any recommended silvicultural options at a landscape level.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

June 2005

By Lee Pederson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Lodgepole Terminal Weevil

Pissodes terminalis (Hopping) (Coleoptera: Curculionidae)

Feeding and larval mining by this weevil kills terminal growth in lodgepole pine.

Hosts:

- Lodgepole pine, with distribution throughout range of hosts.

Topics

Key Points

- They prefer open-growing young pines.
- Larval mining kills terminal growth in lodgepole pine.
- The damage does not directly result in tree mortality, but can inflict various growth malformations.

Damage

It attacks and kills or badly injures terminal leaders on lodgepole reproduction (to the first whorl) from 1 to 30 feet in height. This may result in dieback, height growth loss, or deformity of the main stem. Repeated attacks can produce multiple leaders, and may also result in tree mortality.

Lodgepole terminal weevil damage. Photo by Ken Gibson

Life History

There is only one generation a year, but brood development overlaps. Most stages can be found at any time from spring to fall, and all stages except the egg can overwinter. They typically overwinter as adults in debris on the forest floor. Adults emerge and make feeding punctures in the bark of newly expanding terminal shoots in May, and by June females lay eggs in the punctures. Newly hatched larvae feed down the terminal just under the bark and become mature about midsummer. During that time, the current year's leader will distort and wilt to form a "shepherd's crook", which gradually fades to yellow, red, and then gray or brown. Oval-shaped pupal cells are constructed in the wood and covered with shredded wood fiber (chip cocoons). Emergence of new adults continues from August until fall. They feed at random on bark and then drop to the ground to overwinter. The lodgepole pine terminal weevil tends to suffer high egg and larvae mortality, and often will not produce any adults from an attacked terminal. However, significant damage can still occur prior to larval death from mining activity.

Photo of adult lodgepole terminal weevil. Photo by Ron Long

Identification

Mature larvae can be found boring and pupating in the pith.

Leaders and terminals begin to droop (Shepherd's crook) when girdled, then die and turn gray or brown. Mature larvae can be found boring and pupating in the pith. Look for oval-shaped "chip cocoons" under the bark of lodgepole terminals. These remain imbedded in the wood long after the beetles emerge and are characteristic of their presence.

They prefer open-growing young pines. Adults are of typical weevil form, having a well-developed snout and clubbed antennae, 5-7 mm in length, and are mottled yellowish-brown in color.

Management Considerations

Direct Control. – Chemical insecticide registrations for insect control change frequently. Contact County, State, or Federal pesticide coordinators for updates on current insecticide registrations and application methods.

Natural control. -- Several species of flies in the genus *Lonchaea* have been reported as predators. Birds have been found to feed on larvae and pupae, and small rodents will feed on hibernating adults in forest floor litter. Other factors include food competition between larvae, the drowning of larvae in pitch, and conditions affecting overwintering adults.

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Related section in field guide.

No FIDL for this damage-agent

March 2004

By
Lee Pederson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

White Pine Weevil

Pissodes strobi (Peck)

Topics

Key Points

- Damage is dieback, height growth loss, or deformity of main stem.
- Only one generation a year.
- Newly hatched larvae feed down the terminal just under the bark.

This is the most significant pest of spruce reproduction in the Northern Region.	**Host:** Engelmann spruce and occasionally lodgepole pine

Damage

It attacks and kills or badly injures terminal leaders on spruce reproduction from 1 to 30 feet in height. This may result in dieback, height growth loss, or deformity of the main stem.

Repeated attacks can produce multiple leaders, and may also result in tree mortality.

White pine weevil damage on the main leader. Photo by William Ciesla

Life History

There is only one generation a year, but brood development overlaps. Most stages can be found at any time from spring to fall, and all stages except the egg can overwinter. They typically overwinter as adults in debris on the forest floor. Adults emerge and make feeding punctures (resin droplets are usually associated with these wounds) in the bark of the previous year's leader in May, and by June females lay eggs in the punctures. Newly hatched larvae feed down the terminal just under the bark and become mature about midsummer. During that time, the current year's leader will distort and wilt to form a "shepherd's crook". This gradually fades to yellow, red, and then gray or brown, which indicates weevil attack. Oval-shaped pupal cells are constructed in the wood and covered with shredded wood fiber (chip cocoons). Emergence of new adults continues from August until fall. They feed at random on bark and then drop to the ground to overwinter.

Identification

The adults feed at random on bark and then drop to the ground to overwinter.

Leaders and terminals begin to droop (shepherd's crook) when girdled, then die and turn gray or brown. Resin droplets on the previous year's leader usually indicate adult weevil puncture wounds. Look for oval-shaped "chip cocoons" under the bark of terminals. These remain imbedded in the wood long after the beetles emerge and are characteristic of their presence. Adults are of typical weevil form, with well-developed, curved snouts and clubbed antennae. They are about 6mm long and have rough wing covers mottled reddish-brown to black with cream-colored markings.

Adult white pine weevil and adjacent puncture wounds. Photo by James Hanson

Management Considerations

Direct Control. -- The insecticides Dimilin 4L and Metasystox R have been used for management in the past. However, chemical registrations change frequently, so it is advisable to contact County, State, or Federal pesticide coordinators for updates on current registrations and application methods.

Silvicultural alternatives.-- Some silvicultural practices can reduce weevil damage. Heaviest weevil damage occurs on trees from 5 to 20 feet in height in even-aged, open-grown spruce stands. Plant spruce in closely spaced, well-stocked stands or small blocks. In some areas, large blocks of young, even-aged spruce should not be planted. Douglas-fir may be substituted.

Natural control. -- Several species of flies in the genus *Lonchaea* have been reported as predators. Birds have been found to feed on larvae and pupae, and small rodents will feed on hibernating adults in forest floor litter. Other factors include food competition between larvae, the drowning of larvae in pitch, and conditions affecting overwintering adults.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

March 2004

By Ken Gibson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Pine Tip Moth

***Rhyacionia bushnelli* Busck**

Larvae distort and kill both terminal and lateral shoots.

Host: Ponderosa pine

Topics

Key Points

- Damage occurs in young ponderosa pine, generally less than ten feet tall.
- Trees are not killed but may be stunted or deformed.
- Experimental control uses insecticide to kill moths as they emerge from pupae in soil under damaged trees.

Damage

Outbreaks of western pine tip moth have occurred periodically in areas of eastern Montana with an abundance of young ponderosa pines. Tip moths present persistent problems in field and farmstead windbreaks in Montana and North Dakota.

Damage is seen in upper- and mid-crowns of young ponderosa pines. The feeding activity of larvae distorts and kills both terminal and lateral shoots. This often stunts growth and deforms trees.

Life History

A single generation per year occurs in most parts of the intermountain West. Winter is passed as pupae in cocoons in the litter or soil beneath infested trees.

Adult moths emerge by late May or early June, mate, then females deposit eggs on needles, buds, and shoots of young trees. Newly hatched larvae either feed between needles or mine them. Later instars feed inside needle sheaths or buds, then enter new shoots, and mine within developing shoots.

Larvae complete growth by midsummer or fall, emerge from shoots, and drop to the ground to pupate, where they spend the winter.

Identification

In June, larvae can be found in resinous pitch tents near bases of new needle fascicles or in needle sheaths. Recently damaged or currently infested shoots are covered with matted frass, dead needles, and webbing. New shoots are greatly shortened and rapidly turn yellow, then brown. Shoots are packed with large amounts of coarse, loose frass but pith is generally intact. Larvae are yellowish with black heads, and less than one-half inch long.

Adults, though rarely seen, have forewings mottled with yellowish gray and reddish brown. Hind wings are gray. Wingspan extends to about three-quarters inch.

Management

- Experimentally, a systemic insecticide applied to the soil in the spring has protected young pines for two growing seasons.
- Work needs to be directed at protecting young ponderosa pines until they reach a height of about 10 feet.
- Very few attacks occur on trees over 10 feet in height.

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Related section in field guide.

No FIDL for this damage-agent

April 2005

Forest Health Protection and State Forestry Organizations

By Carol Bell Randall
US Forest Service

Management Guide for

Western Pine Shoot Borer

Eucosma sonomana (Kearfott)
(Lepidoptera: Olethreutidae)

Topics

Young, open grown ponderosa pine the western pine-shoot borer is a significant pest that stunts or sometimes kills the terminal shoot by boring down through its center.

Hosts:

- Ponderosa pine (*Pinus ponderosae*)
- Lodgepole pine (*Pinus contorta*)
- Jeffrey pine (*Pinus jeffreyi*)
- Engelmann spruce (*Picea engelmanii*).

Key Points

- Western pine shoot borer attacks start when pines are approximately breast height (4.5 feet) and gradually increase over the next 25- 30 years.
- In older plantations it is common for 50% of the trees to be attacked on an annual basis.
- Fast growing pines are more likely to be attacked than slow growing pines.
- Frequently the tip of infested lodgepole pine terminals will die back by late fall.

Damage

Larval mining in the terminal shoots reduces or stops shoot and needle elongation and can effect the development of new buds.

Larval mining in lateral shoots usually kills shoots.

Each attack of the terminal shoot reduces annual height growth by 25% and sometimes damages tree form.

Life History

Eggs hatch and young larvae enter shoots near terminal buds and mine downward in the pith leaving little evidence of attack. Larvae complete development by midsummer. Usually there is only one larva per shoot and it chews a circular exit hole in the lower part of the shoot, falls to the ground, and pupates for the winter.

Shoot borer overwinters as pupae in cocoons in ground litter under infested trees.

Signs of Attack

Western pine shoot borer mining within the pith of an infested shoot. Photo by Jed Dewey. www.forestryimages.org

- This moth does not leave feeding scars, webbing or frass on the surface of infested shoots.
- Borer infestations can usually be diagnosed by examining the form of the current year's terminal shoot.
- Attacked shoots become thickened but do not wilt and their needles usually remain green, but are shorter than normal giving the terminal a "shaving brush" appearance.
- The upper third of attacked pine shoots (laterals and terminals) will be tightly packed with frass (a combination of boring dust andinsect excrement). On terminal shoots the xylem and phloem are not usually damaged.
- Because the infested terminal does not fully elongate, lateral shoots are often longer than the infested terminal. A normal, un-infested terminal is usually 25-40% longer than lateral shoots on the same tree.
- Exit holes from the pith are visible near the middle of the shoot where the larva has bored out from the pith.
- Infested lodgepole pine is less obvious from a distance than infested ponderosa pine. Larval feeding is more destructive in small diameter lodgepole terminals and emergence holes can weaken the stem resulting in breakage.
- Frequently the tip of infested lodgepole pine terminals will die back by late fall. Laterals will then compete with terminals for dominance but the effects on tree form are usually minor.

Management Considerations

Prevention—Intensive site preparation and brush control designed to increase growth in pine plantations result in higher levels of shoot borer infestations.

Ponderosa pines grown on drier sites often suffer higher levels of infestations.

When pine plantations are planted at higher elevations, shoot borer damage is either minor or absent.

Plantations on some habitat types are not infested heavily. Stoszek (1973) determined three hazard categories:

1. Low hazard = sites with *Abies* species on mesic mixed conifer sites.

2. Medium hazard (about 40 percent of leaders infested yearly)= snowbrush-manzanita habitat types within mixed conifer zone and ponderosa climax zone.

3. High hazard (50 to 70 percent leaders infested yearly)= Bitterbrush habitat types within ponderosa zone and grassy types of the mixed conifer zone.

Developing stands having a mixture of Douglas-fir and pine tend to suffer less damage.

Indirect Control—Tree genetics affect susceptibility to western pine-shoot borer attacks. Certain site and stand characteristis have also been found to influence the rate of attack (see prevention).

Pheromones— Susceptible pine plantations can be monitored for western pine shoot borer with the male sex pheromone in a wing type pheromone trap. The current recommendation is to use at least 3 traps at each location, separated by at least 20 yards. For large sites consider 1 trap per 2.5 acres (hectare).

Mating disruption has proven effective at reducing damage, but a commercial supplier of pheromones for this use is not currently available. Contact your local Forest Health Specialist for current information.

Pesticides—Insecticides, contact or systemic, have proven ineffective at controlling western pine shoot borer damage.

A new technique using synthetic pheromone baits to attract male moths and kill them has proven effective at reducing damage in pine plantations and is registered for use. Pines must be treated with this hand-applied formulation by mid-march, before any moth flight has occurred. The product is named Last Call™ EucosmaAK and is available through Advanced Pheromone Technologies, Inc. of Portland, Oregon.

Warning- remember, when using pesticides, always read and follow the label!

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<u>Decays & Heartrots</u>

January 2006

(Scientific names updated April 2015.)

By Gregg DeNitto
US Forest Service

Forest Health Protection and State Forestry Organizations

Stem Decay Management: Overview

Decays may be classed as sap rots or heart rots, depending on the fungus involved and the part of the tree affected. Many decays are restricted to a few principal tree species, all native trees are subject to decay by one or more fungi.

Topics

Key Points

- The type of decay produced is determined by the fungus involved.
- Younger trees are practically free from decay, but the likelihood of occurrence of decay and the amount of decay increases with age.
- Once a tree dies, decay may advance throughout the tree.

Damage

Stem and butt decay fungi enter living trees through trunk wounds, dead twigs, broken branches and tops, or wounded roots. The fungi develop within the tree, often with no external signs of defect. They may eventually produce fruiting bodies that produce spores capable of spreading the decay to other trees. In old-growth stands, these decay fungi cause more volume loss than all other diseases combined.

Two types of decay occur, depending on how physical and chemical properties of wood are altered. Brown rots destroy cellulose, leaving the brown lignin that usually cracks into cubical blocks; white rots destroy both cellulose and lignin, leaving only a bleached residue in late stages of decay. The type of decay produced is determined by the fungus involved.

Life History

Two stages describe the degree of wood decay. In the earliest or incipient stage, the predominant feature is discoloration or stain without an accompanying strength loss; the advanced stage is characterized by both cell breakdown and strength loss. Occasionally, an intermediate stage occurs between the two stages. All stages are often present in a tree, the incipient stage at the advancing margins of a zone of decay, and the more advanced stages near the center.

Decays may be classed as sap rots or heart rots, depending on the fungus involved and the part of the tree affected. Usually sap rots are limited to the sapwood, while heart rots are found only in the heartwood. For some decay fungi, though, they may cross the boundary. Also, once a tree dies, decay may advance throughout the tree.

Figure 1, Phellinus pini conk on western larch. USDA, Forest Service, Northern Region Forest Health Protection photo files.

Identification

Most decay fungi produce one of two types of reproductive structures, either a mushroom or a conk. Mushrooms are fleshy and ephemeral, lasting less than a single season. Conks are harder and more woody (Fig 1). They may be annual or perennial, but usually are evident more than a single season. Absence of fruiting bodies does not mean that a tree is without decay. Some fungi rarely produce conks on living trees, although fruiting may be prolific after the tree dies. Presence of conks on some trees is a reliable indicator of the amount of cull, or volume reduction, to be expected. These cull factors are included in Table 1.

Although many decays are restricted to a few principal tree species, all native trees are subject to decay by one or more fungi. Hosts for the more common and significant decay fungi in Region 1 are shown in Table 1.

Table 1. Common decays in the Northern and Intermountain Regions.

SCIENTIFIC - COMMON NAME	HOSTS	INCIPIENT DECAY	ADVANCED DECAY	SPOROPHORE	CULL INDICATORS
Echinodontium tinctorium (Ell. & Ev.) Ell. & Ev. Indian paint fungus	Heartwood of true firs and hemlock.	Slightly darkened, light brown or tan water-soaked spots or larger areas.	Wood tan to reddish, soft and stringy, often brown to red zone lines; reddish, stringy.	Large, woody, hoof-shaped. Upper surface black, roughly cracked. Lower surface with hard gray teeth. Conk brick red inside. Often below branch stubs or knots.	3-4 punk knots or 2-3 scattered conks indicate extensive cull. 1 conk indicates 16’ decay in either direction.
Phellinus pini (Thore.: Fr.) A. Ames Red ring rot	Heartwood of most living conifers. Most common in larch, pines, spruce, and Douglas-fir.	Wood reddish to purplish.	Pockets white, spindle-shaped, well-defined, separated by firm red wood. Black lines termed “zone lines” may be present.	Conk about 3” diameter, shelving, shape variable. Top: dark, concentric furrows. Underside: pores yellow-brown.	2-3’ up and 3-5’ down from each punk knot, swollen knot or conk; 100% cull if several present
Dichomitus squalens (Karst.) Reid Red ray rot	Heartwood of living conifers, particularly ponderosa pine. Also an important decayer of slash.	Reddish to purplish color in radial or circular pattern (easily confused with *P. pini*)	Pockets white, elongate, with square ends; margins not well defined, run together. Wood eventually crumbles. No zone lines. Black flecks may be present in pockets.	Conk white, crust-like, with pores, on underside of logs.	Sporophores on logs or dead branches of living trees indicate extensive cull. Difficult to detect in living trees since sporophores rare. Length of decay column variable.
Phellinus sulphurascens Pilat Laminated butt rot *P. weirii* (Murr.) Gilb. Laminated root rot	Butt and root rot in Douglas-fir, grand fir, and hemlock. Stem rot in cedar.	Yellowish-brownish discolored areas.	Yellow-brown flaky, riddled with tiny pockets, delaminates easily along annual rings; some traces of brown fungal tissue present.	Extremely rare; brown crust-like on underside of logs or exposed roots.	Sporophores indicate 6-12’ in Douglas-fir, grand fir, and hemlock. 8’ or more in cedar. Basal wounds indicate probable cull in stands where the fungus is known to be present.

Table 1. Common decays in the Northern and Intermountain Regions (cont.)

SCIENTIFIC - COMMON NAME	HOSTS	INCIPIENT DECAY	ADVANCED DECAY	SPOROPHORE	CULL INDICATORS
Postia sericeomollis (Rom.) Julich Brown pocket rot of cedar	Western red cedar.	Yellow-brown elongate areas.	Large pockets develop containing brown cubical rot; pockets unite to form solid mass of decay; some white fungal tissue present.	Very rare on live trees; white crust-like patches with pores.	Too irregular of column; assume cylinder.
Fomitopsis officinalis (Vill.: Fr.) Bond et Singer Brown trunk rot Quinine fungus	Larch, Douglas-fir, and ponderosa pine.	Slightly darkened areas	Cubically cracked dark red-brown wood. Thick white mats of fungal tissue present in cracks.	Rare; large, hoof-shaped to pendant, chalky.	1 conk indicates entire tree is cull (but conks are rare). Decay columnar if detected in log.
Laetiporus sulphureus (Bull.: Fr.) Murr. Brown cubical rot Sulfur fungus	True firs, Douglas-fir, white and ponderosa pines, larch, spruce, and hemlock.	Slightly darkened areas	Cubically cracked dark red-brown wood. Thick white mats of fungal tissue present in cracks.	Large clusters of overlapping soft shelves, somewhat fleshy. Top: orange. Underside: yellow. Becomes chalky with age.	Total cull if conk on log; usually butt log on trees.
Fomitopsis pinicola (Schwartz: Fr.) Karst Brown crumbly rot	All conifers (dead only).	Yellow-brown areas develop.	Wood becomes red-brown or yellow-brown and cubically cracked; some white fungal tissue present.	Large, perennial, flat to hoof shaped. Top: smooth gray with red band at edge. Underside: white pores.	Entire log cull if conks present. Entire log cull if decay at one end.
Phaeolus schweintizii (Fr.) Pat. Red-brown butt rot (Brown cubical butt rot)	Butts and roots of western conifers; most common in Douglas-fir, true firs, spruce, and hemlock.	Faint yellow to red-brown spires of discoloration in heartwood. Very inconspicuous.	Heartwood becomes red-brown, with some tendency toward large cubical cracking. This white mycelium may occur in shrinkage cracks. Decayed wood very brittle and crumbles easily to fine powder.	Irregular shelving; annual conk with thick short stalk grows in soil. Top: Velvety, dark red-brown. Underside: Yellow-green turning brown when old or bruised.	Conk in or near base of tree indicates 3' of tapered decay in butt log. May extend to 32' in ponderosa pine.
Hericium abietis (Weir ex Hubert) K. Harrison Yellow pitted rot	True firs, spruce, and hemlock. Continues in logs or fallen trees.	Elongate, spindle-shaped yellow-white spots form where pockets will develop.	Long-spindle-shaped pockets, separated by firm, natural colored wood. Pockets usually empty, but may contain a few white fibers.	White, soft, coral-like conks produced annually; rare on live trees.	Conk indicates complete cull; decay detected on log butt may extend 14' with irregular taper.
Cryptoporus volvatus (Pk.) Shear. Gray-brown sap rot	True firs, Douglas-fir, pines, larch, and hemlock (dead only).	Indistinct gray areas appear in sapwood.	Sapwood only; small, pale brown cubical, crumbly areas beneath conks.	Small, soft, round, yellow-white conks produced profusely for 2-3 years following tree death caused by bark beetles.	None; most of decay is outside the scaling cylinder.

Table 1. Common decays in the Northern and Intermountain Regions (cont.)

SCIENTIFIC - COMMON NAME	HOSTS	INCIPIENT DECAY	ADVANCED DECAY	SPOROPHORE	CULL INDICATORS
Haematostereum sanguinolentum (Alb. & Schw. ex Fr.) Pouz. Red heart rot	Heart rot of living conifers. Also common in slash.	Wood water-soaked, reddish-brown.	Wood light, yellow-brown, dry, stringy, thin white fungal mats in shrinkage cracks.	Crust-like with shelving margins, pores underneath. Grayish, red fluid when bruised. Mainly fruits on dead trees.	Cull estimates not established, but is usually minor; localized.
Fomitopsis rosea (Alb. & Schw.:Fr.) Karst. Brown top rot Rose-colored fungus	Upper stems of true firs, larch, spruce, pines, Douglas-fir and hemlock.	Faint brown to yellow-brown color, grades into the color of surrounding wood.	Wood light yellowish to reddish brown and usually breaks into irregular cubes. A pinkish tinge barely discernible in decayed wood. Shrinkage cracks often have thin, whitish to rose-colored mycelial mats.	Small, bracket-like, abundant. Upper surface gray or black, rough. Lower surface finely pored and rose-tipped. Rare on living trees	Probably less than a total of 6' indicated by single conk or bunched conks.
Heterobasidion occidentale Otrosina & Garbel. (fir-type) *H. irregulare* Garbel. & Otrosina (pine-type) White spongy rot (Annosus root and butt rot)	Western conifers; most common as a butt rot of true firs and hemlock. Also causes a root disease, particularly in pines.	Small, elongate, shallow pockets, often with black specks. Pockets slightly whiter than surrounding bleached wood.	Pockets merge, producing a very spongy white mass flecked with black. Zone lines occasionally appear in decayed wood.	Irregular in outline, usually less than 3" across, may shelve or be mostly crust like. Upper surface dark and concentrically furrowed. Lower surface white with small round pores Rarely produced except inside rotted stumps and on tree parts below ground level.	Conks on older trees, especially hemlock, indicate 8 to 10' of cull. Generally confined to butt log and deduction made by length cut.

Benefits for wildlife habitat

Numerous species of wildlife use decayed trees, live and dead, for habitation and foraging. The most common uses are nesting and roosting by various bird species, especially woodpeckers. Woodpeckers generally nest and roost in dead or partially dead trees and take advantage of the presence of fungal decay. Generally, some tree species are preferred for cavity construction. In the Pacific Northwest, preferred species include ponderosa pine, grand fir, lodgepole pine, western larch, and western red cedar (Parks, Bull, Torgersen 1997). Heartrot fungi are the typical decay group associated with woodpecker cavity excavation.

Both white rots and brown rots are associated with cavities, but white rots appear to provide most opportunities (Jackson and Jackson 2004).

Figure 2. Cavity excavated in a tree with white pocket rot. USDA, Forest Service, Northern Region Forest Health Protection photo files.

Management to reduce stem and butt decay impact

A concept known as "pathological rotation" has been developed that indicates the maximum age at which a stand should be harvested if economic loss is to be avoided. Geographic location and tree species are determinants of pathological rotation.

This age may not agree with other rotation ages, such as culmination of mean annual increment.

Younger trees are practically free from decay, but the likelihood of occurrence of decay and the amount of decay increases with age. Sapwood decay can start at any age, but heart rots cannot start until heartwood formation begins. From that time on, trees are liable to decay, but it is usually many years later before decay of consequence is evident. Under managed conditions we expect the age at which decay causes consequential loss will be well beyond the actual rotation set by other considerations. Some exceptions will occur; advanced decay may be found occasionally in 20-year-old trees.

Management actions during the pre-planning stage

Some of the decay fungi are known to infect trees through branchlets at an early age and become dormant. These spores become incorporated into a tree as it grows. At later times when trunk wounds occur, these infections can become active and result in decay columns. Open wounds may be avenues for entrance of decay; the wound must be completely grown over before the tree is no longer exposed to infection. Wounds are caused by many agents; some of which can be controlled. Logging commonly wounds leave trees so that serious decay may result, particularly in thin-barked species such as hemlock and true firs.

Reducing injuries to residuals during thinning or partial cuts will help reduce the impact of decay fungi. In thin-barked species, and in some cases even thicker-barked species, this may mean special care in designing operations. The following pre-operation planning actions have been found to decrease damage.

Management

General management recommendations include:

- Restrict the logging season during the spring and early summer
- Match the size and type of equipment to the site, tree size, and soil type
- Match the type of equipment to the size of the material being removed
- Lay out skid trails in advance using straight line skid trails
- Mark the residual or leave trees
- Leave buffer trees or cull logs along the edges of skid trails and remove after the last turn
- Match log lengths with the final spacing of the residual stand
- During the operation, the following can help to minimize damage:
    - Gain the cooperation of the operator
    - Log skid trails first
    - Require directional felling
    - Limb and top prior to skidding

Management: Other operations

During partial cutting, remove all trees with decay indicators, large fire scars, and logging wounds. Consider the "pathological" rotation along with other factors when developing stand prescriptions.

Fire wounds can also be an entry point for decay fungi. During prescribed burning operations, prescriptions can be developed to limit the amount of heat that desired trees are exposed to so that cambium damage is minimized. In some cases with high value trees this may mean the actual mechanical removal of the litter and duff layer from around the base of trees before firing to limit smoldering and heating of the tree's base.

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May 2005

Forest Health Protection and State Forestry Organizations

By Liz Hebertson
US Forest Service

Topics

Management Guide for

Aspen Heart Rot

Phellinus tremulae **(Bondartsev) Bondartsev and Borisov in Bondartzev**
(= *Phellinus igniarius* [Linnaeus: Frie]
Quellet, *Fomes ignarius* [Linnaeus: Fries]
J. Kickx fil. *F. tremulae* Bondartsev)
(=*Fomes igniarius* var. *populinus* (Neuman) Camp.)

Aspen heart rot caused by *Phellinus tremulae* is distributed throughout the range of quaking aspen in Regions 1 and 4. Advanced decay results in tree defects and cull and widespread infection causes extensive aspen damage.

Host:

Quaking Aspen

Key Points

- Aspen heart rot decays the heartwood of infected trees.
- Tree wounding constitutes the main avenue of fungal entry.
- In advance infections the heart wood decomposes and the tree loses structural strength.
- Aspen heart rot benefits ecosystems by creating gaps in forest canopies.

Damage

Aspen heart rot decays the heartwood of infected trees. In early stages of disease development (incipient decay), the heartwood begins to show patterns of discoloration, but remains hard and firm. As the decay advances, the heartwood decomposes and the tree loses structural strength. Trees with advanced decay are often predisposed to windsnap, blowdown, and other damaging agents. This damage may lead to tree mortality. Undesirable levels of damage may conflict with some recreation, wildlife, economic, and other resource management objectives. The loss of trees in recreation settings reduces shade, screening, and aesthetics thus compromising visitor experiences (Helm and Johnson 1995). Although heart rot does not affect all uses of aspen, decayed wood has undesirable pulping qualities and stained wood is not suitable for veneers. *Phellinus tremu1ae* may continue in logs after trees are dead, decay will cease once wood has been milled. Aspen heart rot benefits ecosystems by creating gaps in forest canopies that enhance species succession and biodiversity, by providing critical habitat for cavity nesting birds, and by facilitating nutrient cycling.

Susceptibility

Younger age classes comprised of fast-growing trees are least susceptible to infection by this disease and typically experience only minor decay. The percentage of decay increases as trees age with the greatest amount of damage present in old-growth stands (> 120 years). Resilience to decay has also been linked to the genetic differences of aspen clones.

The presence of conks is indicative of significant stem decay.

Susceptibility

Site characteristics have not been correlated to decay, although generally less volume is lost in vigorous stands on good sites. Tree wounding constitutes the main avenue of fungal entry in the heartwood of aspen and primarily contributes to increased rates of infection. Successful germination of the fungus only occurs in fresh wounds (< 2 days old) during the summer. Spores will not typically germinate in wounds older than one week.

Figure 1. A large *Phellinus tremulae* conk on an aspen.

Life History

Phellinus tremulae produces perennia1 fruiting bodies (conks) at branch stubs or wounds on the bole of the tree. Sporulation probably begins in late winter or early spring and may continue throughout the summer and fall when moist weather prevails. Airborne spores typically infect dead branch stubs and fresh wounds. Fungal growth results in the development of decay columns that enlarge in both vertical directions, and radially until live wood (sapwood) is reached. Conks are produced at intervals along decay columns, emerging through branch stubs or wounds.

Identification

A yellow-white rot is produced with brown or black zone lines traversing decayed wood (Fig.2). A brown or yellow-brown stain is produced irregularly throughout decayed heartwood. Conks are hoof -shaped with a gray, or brown upper surface and tan to white lower pore surface (Fig. 1). Because conks are perennial they also bares concentric growth rings on upper surface. The interior of the conk is brown or gold with white flecks and appears layered. Most trees with large amounts of decay have conks.

Figure 2. Discoloration and patterns of decay associated with infection by *Phellinus tremulae* in aspen.

Management Considerations

Historically, aspen was a major component of western forests. Lower elevation, drier stands tended to burn more frequently serving to rejuvenate aspen stands and reduce the incidence and extent of fungal diseases, wood borers, and other damaging agents throughout the type (Bartos and Campbell 1998). As a consequence of fire suppression, many aspen stands have exceeded their pathological rotation age with trees losing as much volume to decay as they gain from incremental growth. In western forests, aspen stands begin to deteriorate between 80-120 years, particularly if trees are stressed by other environmental factors such as drought.

Management Considerations

Regenerating stands every 80 to 100 years is the most effective method to minimize losses due to heart rot.

Decay pathogens, however, are an integral part of forest ecosystems and can be both beneficial and detrimental to the health, proper function and productivity of forests.

Managing for aspen heart rot should begin by :

- assessing the percentages of decay within a project area and developing a vegetation management plan with prescriptions written to meet resource objectives.
- Crown symptoms of heart rot may not be apparent during site evaluations.
- Conks, cavities, cracks, wounds, and exposed decay are good indications of heart rot, but are not always visible.
- Destructively sampling several trees would provide the most reliable means for estimating percentages of decay.

Recreation Sites

No direct control strategies (i.e. fungicides) are available to protect high value aspen in recreation sites from infection by heart rot.

- **Pruning**—Dead branches does not reduce infection rates of heart rot.
- **Thinning**—Maintaining vigorous aspen can be accomplished by removing all trees exceeding 5 inches diameter at breast height and those with wounds or other indications of poor health. This treatment would also encourage the growth of new aspen suckers while providing some shading and screening.
- **Avoid damage**—Measures to avoid tree wounding can reduce infection rates. Protecting aspen regeneration from animal damage may require erecting enclosures until suckers have reached a sufficient height to escape ungulate grazing. Depending upon site conditions, this could require 2 to 5 years. Tree removal could occur in stages, treating portions of the recreation site over a number of years.

A second alternative for aspen management in recreation areas would include:

- **Removal**—selectively removing severely decayed trees and leaving any healthy aspen on site to meet recreational needs. Decayed and dead trees directly threaten picnic areas, structures, and trails and pose a potential hazard to public safety requiring routine tree hazard inspections and maintenance (Johnson 1981).

Recreation Sites

The presence of a conk on the bole of a tree indicates high failure potential warranting consideration for removal.

- In the absence of conks, or other defects, consider removing trees with less than 20% circumference of sound wood. Although hazard tree assessments and costs associated with hazard tree removal are high, the money lost in tort claims due to accidents is even greater (Johnson 1981). This treatment may encourage aspen regeneration, improve the vigor of residual trees and reduce hazards, but would not be as effective with respect to the management of decay and other damaging agents.

Silvicultural Treatments

Decay fungi do not spread via root-to-root contact, heart rot poses little threat to regeneration.

In stands outside of recreation areas, aspen heart rot can be managed using silvicultural methods (Hinds and Shepperd 1987). It is important to consider that harvesting, regeneration and stand management activities can affect the competitive behavior of decay pathogens in ecosystems. Thus, the management objectives of the prescription should determine how decay fungi are managed in the stand.

Regenerating stands every 80 to 100 years is the most effective method to minimize losses due to heart rot. Clearcutting systems that remove all trees within a clone result in the growth of healthy and vigorous root suckers. Treatments should occur prior to spring flush to achieve the greatest amount of suckering. Because decay fungi do not spread via root-to-root contact, heart rot poses little threat to regeneration. With no damage to residual trees, the potential of infection through wounds is low. Managing aspen in uniform well-stocked stands to encourage natural pruning will also reduce the number of infection sites. Harvest stands damaged by fire, wind, and other stands earlier in the rotation. Where management objectives necessitate retaining trees such as in riparian areas, or for some wildlife habitat, cut the best trees to propagate the next crop. Leave some decayed trees if the objective is for nesting birds.

Good planning and logging practices—Managing aspen heart rot in stands where thinning and partial cutting systems will be used requires good planning and logging practices, experience and well-trained personnel.

- Stands should be managed on short rotations. Harvest operations should not occur in the spring and early summer. During this period, the sap is flowing and the bark is not tight. Thus, trees wound more easily and the injuries are often larger. Wounding can also be minimized by matching the size and type of logging equipment to the size and type of topography, tree size, soil type and soil condition.

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Related section in field guide.

No FIDL for this damage-agent

April 2006

By Susan Hagle
US Forest Service

Management Guide for

Cedar Brown Pocket Rot

Postia sericeomollis (Rom.) Julich [*Poria asiatica*]

Topics

Hosts: Living western redcedar and incense-cedar

Dead conifers of other species may be decayed by this fungus.

Once commonly known as "Pecky Rot", this brown cubical decay is an important source of cull in western redcedar and incense-cedar.

Key Points

- Alters the integrity of wood in last stages of decay
- Develops and increases with age
- Wounds increase decay rate in infected stems
- Cavity nest sites used by many wildlife species.

Introduction

Although western redcedar heartwood is considered to be highly resistant to decay, standing trees often have a high rate of decay defect. *Postia sericeomollis* is among the most common causes of heartrot in western redcedar, second only to *Phellinus weirii* in decay volumes. In dead wood, *P. sericeomollis* has a broad host range, but seldom infects any live trees other than western redcedar. Stem and butt decay can develop in living trees without external signs of defect.

Little is know about the mode of infection by this pathogen. The butt log is the typical site of decay but are seen with decay at all levels. Old age and stem wounding increase the severity of this disease.

Figure 1. Living cedar trees with brown pocket rot are commonly selected by wood peckers and sapsuckers to develop nest sites. The cavities excavated by these birds are used by many cavity-nesting birds and animals.

Cedar Brown Pocket Rot

A very common and destructive disease of western redcedar and incense cedar.

Quick Facts:

- Brown rot
- Large and small pockets in the heart wood.
- Common nest site for cavity-nesting birds.
- No external indicators of this disease on trees.
- Increases with age and with stem wounding.
- Some sites are more prone to this disease than others.

Life History

Infection

The mode of entry of *P. sericeomollis* into the stem heartwood of trees remains unknown. Wounds are apparently not necessary for establishment of infections but may contribute to expansion of decay by aerating the heart wood.

Spores are produced in abundance by annual fruiting bodies on dead logs and slash of a variety of tree species but the means by which the fungus establishes itself in the heartwood of living western redcedar has not been studied. The presence of the most advanced decay in the butt of the tree may indicate root-infection as a mode. Such infections are commonly the source of other butt rots, including those caused by *Phellinus weirii*, *Heterobasidion annosum*, and *Phaeolus schweinitzii*.

Other common heartrot fungi are thought to be infected via dead branchlets. Latent (inactive) infections in these tiny dead branches remain viable until the branches are incorporated into heartwood as the tree grows. Once surrounded by heartwood, the fungus mycelium is able to actively grow and produce decay. This mode also may be employed by *P. sericeomollis*.

Development of decay

Pockets of decay are initially small and isolated in the heartwood, often separated by several inches of solid wood. Inside the pockets, the decay is a typical brown cubical rot. At first, the wood is light brown and dull in appearance. In the advanced stages, the decay becomes brown or red-brown with cubical cracking. Thin felts of white mycelium may develop in some of the cracks.

In time, the pockets may merge forming larger pockets of brown, cubically-cracked decay. In cross-section, the decay may appear in concentric rings or arcs as pockets merge. Decay may eventually involved the entire heartwood of the butt log. Although it is most common and extensive in the butt log, cedar brown pocket rot can develop at all levels in the stem.

There is little loss of structural integrity of western redcedar wood until very late in the decay process (Harvey and others 1989).

Figure 2. Cedar brown pocket rot producing small pockets (arrow) and large pockets of brown cubical decay in cedar heart wood.

Fruiting structures

Fruiting bodies form on dead logs and slash but are not seen on live trees. They are white or cream-colored, annual, resupinate, poroid sporophores. Though they are not a species normally consumed, they have a characteristic bitter flavor. They form as thin crusts on the outer surface of log ends or dead wood, 6- 10 inches across.

Scaling logs for defect

Scaling for cedar brown pocket rot is made difficult by the irregular distribution of decay in the stem. Cahill and others 1987) compared actual defect to several scaling methods in incense-cedar logs with cedar brown pocket rot. They found that all standard methods tended to overestimate this type of decay unless the decay was in the late stages in which the pockets have merged in to a cylinder. The overestimation of defect was several times greater than actual defect if the decay was visible in both ends of the log.

MANAGEMENT OVERVIEW

1. **Appreciate its value as wildlife habitat.** Cavity nest sites are often in short supply. If heartrot is uncommon in your forest, consider leaving a few infected trees for their ecological value.
2. **Prevent wounding.** Even if wounds are not the source of infection, they probably increase decay rates by aerating the heartwood.
3. **Pathological rotation.** Harvest trees before they a old enough for the fungus to have done much damage.

Management

"Stem Decays; General Ecology and Management" by Gregg Denitto provides a full discussion of management considerations and methods for conifer stem decays. Of the methods discussed by Denitto, *harvesting trees before they are old* and *avoiding wounding* are the most applicable methods for management cedar brown pocket rot.

Harvest before trees are old

This method is referred to as "pathological rotation", that is, the stand is harvested, or rotated, before stem decay becomes a significant. The age may vary by location but in general, once a stands has reached maturity, it can be expected to begin decaying at increasingly greater rates with each passing decade. Wounding can considerably accelerate the rate at which decay develops even in relatively young trees.

Avoid wounding

Cedars are thin-barked trees and easily wounded by falling trees, fire and machinery. Wounds that remove bark and expose sapwood may provide entry courts for *P. sericiomollis* spores. They may also aerate the wood beneath the wound and increase growth of heart rots already present in the wood.

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Related section in field guide.

No FIDL for this damage-agent

June 2006

Forest Health Protection and State Forestry Organizations

By Susan Hagle
US Forest Service

Management Guide for

Cedar Laminated Butt Rot

Phellinus weirii (Murr.) Gilbertson

Host: **Western redcedar**	**Also known as yellow ring rot. The majority of heartwood decay in western redcedar in inland forests is caused by this fungus.**

Topics

Key Points

- Decays the heartwood of both roots and stems, especially the butt log
- Develops and increases with age
- Wounds increase decay rate in infected stems
- Cavity nest sites used by many wildlife species.

Introduction

Although western redcedar heartwood is considered to be highly resistant to decay, standing trees often have a high rate of decay defect. *Phellinus weirii* is the most common cause of heartrot in western redcedar in inland (non-coastal) forests. Alaska yellow cedar is a significant host in high elevation stands.

The butt log is usually most damaged and decay extends into root heartwood, commonly rendering them hollow as well. Extensive decay can develop in living trees without external signs of defect. The butt log and roots are most damaged, although decay can extend to considerable heights in a tree.

Decay can be extensive in old trees. Cedar trees are rarely killed by this disease, and this fungus is not known to cause disease in other tree species.

Management Overview

1. **Appreciate its value as wildlife habitat.** Cavity nest sites are often in short supply. If heartrot is uncommon in your forest, consider leaving a few infected trees for their ecological value.
2. **Prevent wounding.** Fires, logging and other activities in the forest can result in basal wounds. Even if wounds are not the source of an infection, they can increase decay rates by aerating the heartwood.
3. **Pathological rotation.** Harvest trees before they a old enough for the fungus to have done much damage.

Cedar laminated root and butt rot

Quick Facts:

- Yellowish laminated rot
- Western redcedar is the only significant host in inland stands
- Common nest site for cavity-nesting birds.
- Basal cankers (catfaces) commonly are associated with severe infections
- Wounding may increase damage.

Identifying *Phellinus weirii* in culture and in wood

New methods have been developed for the differentiation of *P. weirii* (cedar pathogen) and *P. sulphurascens* (Douglas-fir pathogen) using molecular analysis (Lim and others 2005). This method is able to detect *P. weirii* genetic material (DNA) in cultures and even in cedar decay samples.

Though not currently commercially available, it has the potential to be a cheap and rapid method of detecting and differentiating *P. weirii* in western redcedar stands.

Life History

Infection

Little is know about how this pathogen infects and spreads. Sporophores produce abundant spores on the outer bark of the lower stem and roots. Trees with no evidence of prior wounding commonly have extensive columns of decay. The presence of extensive root decay suggests that roots may be a site of infection from which the decay extends into the stem heartwood.

Although wounds are apparently not necessary for establishment of infections, they may contribute to expansion of decay by aerating the heart wood. Carpenter ants also are commonly found building nests in this type of decay but they are unlikely to have caused the infections.

Development of decay

Phellinus weirii produces a white-rot type of decay in which both lignin and cellulose are degraded. Even in the early stages, the integrity of the wood is significantly reduced.

At first, the decayed wood is light tan or yellowish. In advanced stages of decay the wood becomes red-brown in color. It delaminates, separating easily into sheets as the springwood is decayed in preference to the denser summer-wood. Shallow pits develop on the springwood side of delaminated sheets. These pits often are filled with fuzzy cinnamon-colored mycelium.

In old infections, the stem and main roots may become hollow, with delaminating decay at the edges of the cavities. Although mostly confined to the butt-log, decay columns occasionally extend up the stem 30 feet or more.

Fruiting structures

This fungus is often seen fruiting at the base of infected trees, generally between buttress roots. They will occasionally occur up to six feet high on the outer bark of trees.

The conks (Figure 1) are thin (usually less than 1/4 inch), resupinate (crust-like), and highly variable in size, from less than 1 inch to several inches across. These perennial conks have irregular, somewhat elongate pores that are typically about 1/100th inch in diameter.

Figure 1. *Phellinus weirii* conk close-up. The new pore layer (light brown) can be seen developing over the dark brown pore layer from the previous season. The presence of new and old pore layers produces the characteristic mottled appearance of this species. This conk is perennial, having survived more than one season. [Photo by S. Hagle]

The older pore layers of a conk are dark brown with lighter brown, newer growth in irregular patches on top.

These conks are common in cedar stands that have a high rate of infection. It appears that most conks survive two, or perhaps three years.

Management

Phellinus weirii is the most common cause of laminated decay in cedar trees in inland forests. It is especially common in mature trees, at least 100 years of age. In coastal forests Buckland (1946) found *Poria albipellucida* to be the most common cause of cedar decay in forests of coastal British Columbia, Canada. It produces a similar decay (yellow, laminate) to that produced by *P. weirii* and is also most common in mature age classes of cedar. Although this fungus occurs in inland stands, it is far less common here.

Cedar brown pocket rot is also a common heartrot of cedar and can occur in the same stands and even the same tress as cedar laminated rot. The management for these two diseases is similar.

The publication included in this guide entitled 'Stem decays; General ecology and management' by Gregg Denitto provides a more complete discussion of management recommendations for stem and butt decays. For cedar butt rots, avoiding wounding and harvesting before the trees are old are recommended.

Avoid wounding

Cedars are thin-barked trees and easily wounded by falling trees, fire and machinery. Wounds that remove bark, exposing wood, may provide entry courts for *P. weirii* spores. They may also aerate the wood beneath the wound and increase growth of heart rots already present in the wood.

Harvest before trees are old

The most effective means of managing cedar butt rot is to harvest trees before stem decay becomes significant. The age may vary by location but in general, once a stand has reached maturity, it can be expected to begin decaying at an increasingly greater rate with each passing decade. Stands with a great deal of wounding can be expected to accumulate decay at an even faster rate, necessitating earlier harvest to avoid excessive loss.

For a full discussion of management considerations and methods for conifer stem and butt decays, go to:

"Management guide for stem decays"

Other Reading

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Related section in field guide.

FIDL - Decays of white, grand, and red firs

FIDL - Heart rots of western hemlock

January 2006

By Holly Kearns
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Indian Paint Fungus

Echinodontium tinctorium (Ellis & Everh.) (= *Fomes tinctorius*)

Indian Paint Fungus is a major cause of decay in true firs (*Abies* spp.) and hemlocks (*Tsuga* spp.).	Hosts: • Grand fir • Subalpine fir • Western hemlock Mountain hemlock	Occasional hosts: • Engelmann spruce • Douglas-fir

Topics

Key Points

- Presence of two to three scattered conks typically indicates complete cull.
- Maintain vigorous stands to promote rapid healing of branchlet stubs.
- Trees without signs of infection and non-susceptible species should be favored as leave trees.

Damage

The amount of decay is usually greatest on north-facing, lower slopes with slow growing, dense stands. Decay may extend up to 16 feet above and below a single conk. The presence of two to three scattered conks typically indicates complete cull.

Life History

As trees reach about 40 years of age, very small (<0.1 inch diameter) branchlet stubs are formed when shade-suppressed branchlets are broken off. Spores infect the exposed ends of these branchlet stubs in late fall or early spring. Once the branchlet stub heals over, the fungus enters a dormant state, which can last for more than 50 years. Dormant infections are activated when wounds from mechanical injuries, breakage of old limbs, frost cracks, insect attacks, etc. occur within 1 foot of the dormant infection.

Identification

Woody, perennial, hoof-shaped conks as large as one foot in diameter are usually formed on the underside of dead branch stubs. The upper surface is black, rough and cracked. The lower surface consists of gray to black teeth or spines. The inside of the conk is brick red. In the early stages, the decay appears as a light brown or water soaked stain in the heartwood. Later, the wood becomes yellow-brown to orange-red and stringy or fibrous. The wood often separates into reddish stringy concentric rings.

Cross-section of tree. USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Photo shows conks have an orange-red context and gray teeth projecting down. They form beneath branches. USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Management

General management recommendations include:

- Maintaining vigorous stands to promote rapid healing of small branchlet stubs.
- Keeping rotations short (less than 150 years) as the volume of decay increases with age.
- In recreation areas, mature trees with wounds should be monitored for decay and trees with conks removed.
- Thinning of young stands can increase vigor and airflow minimizing infection and decay column size.
- Minimize wounding when thinning, prescribed burning, or partial cutting to prevent activation of dormant infections.
- Trees without signs of infection and non-susceptible species should be favored as leave trees.
- Small, suppressed trees older than 40 years should be removed from stands with infected overstories when thinning or regenerating.
- Removal, or sanitation, of old, infected trees may reduce the amount of infection in residual trees. Spores can be produced for 10 or more years on dead trees, both standing and downed.

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November 2005

Forest Health Protection and State Forestry Organizations

By Blakey Lockman
US Forest Service

Management Guide for

Brown Trunk Rot

Fomitopsis officinalis (Vill.:Fr.) Bond. et Singer

Topics

Brown trunk rot is one of the three most important sources of defect in conifer forests throughout its range.

Primary Host:

- Western larch
- Douglas-fir

Occasional host:

- Ponderosa pine
- Spruce
- True firs
- Western white pine
- Lodgepole pine
- Western hemlock

Key Points

- A major decay throughout older forests.
- One of the three most important sources of defect in conifer forests throughout its range.

The only indicator of decay is the presence of the fungal fruiting body or conk.

History and Distribution

Brown trunk rot is a major decay throughout older forests of the western United States and Canada. It is considered one of the three most important sources of defect in conifer forests throughout its range (Overholts 1967). Although it causes significant amounts of damage, it is considered rare in occurrence (Overholts 1967). It is known historically as a source of agaricin which is used to reduce fevers and in the treatment of certain diseases such as tuberculosis (Gilbertson and Ryvarden 1986). The first century Greek physician Diosorides recognized the medicinal properties of this fungus in treating "consumption" and called it agaricum or agarikon (Stamets 2002). The Haida peoples of British Columbia also used it medicinally and spiritually, personifying it as "Fungus man" and including it as part of their creation story (Stamets 2002).

Damage

Fomitopsis officinalis causes a brown cubical rot of the heartwood of affected trees. It is more commonly found in the trunk and upper bole, and only occasionally in the butt portion (Scharpf 1993). The only indicator of decay is the presence of the fungal fruiting body or conk. When a conk is present, the tree is generally considered to not have useable wood volume or to be a cull for timber production (Allen, Morrison, and Wallis 1996). Trees with conks in recreation areas should be considered high hazards (Allen, Morrison, and Wallis 1996).

Life History

It is not known how the fungus enters living trees. However, wounds, broken tops, and branch stubs have been mentioned as common entry points (Scharpf 1993). Conks occur infrequently on trees, but once they develop they can last for many years and become quite large.

Trees with conks in recreation areas should be considered high hazards

Identification

The conk of brown trunk rot is very distinctive when present, but is generally rare especially on living trees. It is most commonly seen in old-growth western larch and Douglas-fir. The conks become quite large and are white to yellow-white in color. The inside of the conk is chalky, crumbly, and bitter to the taste. The fungus produces a brown cubical decay of the heartwood. The decay is not limited to any particular part of a tree, but is more commonly found in the trunk and upper bole rather than the butt. Between the cracks in the decay are thick white felts or sheets of fungal material which are also bitter to the taste.

Known historically as a source of agaricin which is used to reduce fevers and in the treatment of certain diseases such as tuberculosis.

Photo to the right: Typical quinine conk fruiting high on the stem of a tree. Photo by John Schwandt.

Management Considerations

Alternatives for reducing the amount of brown trunk rot in a stand are limited to managing for younger age classes. Removing weakened or damaged trees through sanitation cuttings may limit the amount of decay in a stand. Cull factors of the amount of decay present in an affected tree have been determined for northwestern California (Kimmey 1950). Factors for the intermountain states have not been determined, but are likely similar.

In general, a tree with a conk present is usually considered to be completely decayed. Trees with conks in developed areas and heavily used sites should be considered for removal to reduce the risk to users of the facilities and area.

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Related section in field guide.

FIDL - Decays of white, grand, and red firs

April 2007

Forest Health Protection and State Forestry Organizations

By James T. Hoffman
US Forest Service

Management Guide for

Red Belt Fungus

Fomitopsis pinicola (Swartz: Fr.) P. Karst.

Topics

The red belt fungus is one of the most common and important wood decay fungi in North America. It is almost exclusively a saprophyte, decaying both the heartwood and sapwood of many recently killed conifer and hardwood tree species.

Hosts:

Recently killed conifer and hardwood tree species

Key Points

- Red belt fungus destroys cellulose and leaves the brown lignin which fractures into cubical blocks.
- Reddish-orange band forms on the rim of the upper surface of the conk during the annual production of a new pore layer.

Damage

The red belt fungus is one of the most common and important wood decay fungi in North America. It is almost exclusively a saprophyte, decaying both the heartwood and sapwood of many recently killed conifer and hardwood tree species. For this reason it performs an important ecological role in the degradation of woody material necessary for nutrient recycling in a forest. *Fomitopsis pinicola* can cause a heartrot in living conifers, but only rarely such as when a large wound or broken top has allowed the fungus an opportunity to colonize the physiologically "dead" heartwood.

Identification

The red belt fungus is a brown rotter, destroying cellulose and leaving the brown lignin which fractures into cubical blocks that easily crumble. Timber scalers called this symptom of the wood decay fungus, brown crumbly rot. In later stages, the spaces between the cubical cracks become filled with white felts of mycelium which exude out through cracks or insect bore holes forming fruiting bodies of the fungus called conks.

Young conks are amorphous masses of white or cream-colored tissue. Later the fruiting body develops into the typical perennial shelf conk from 3- to 18-inches wide with a white lower surface of minute pores filled with reproductive spores.

Red belt fungus conks has a distinctive red band along the perimeter when mature and fresh. Photo by Susan K. Hagle

Identification

The top of the conk is leathery to woody and ranges in color from gray -brown to almost black. Usually a reddish-orange band forms on the rim of the upper surface of the conk during the annual production of a new pore layer. It is this distinctive coloring that gives the fungus the common name of the red-belt fungus.

Red velvet fungus, conk on a dead black spruce stem, photo taken in northern MN, St. Louis Co.
Photo by Steven Katovich.

These are young fruiting bodies, which harden and turn darker with age.
Joseph O'Brien, USDA Forest Service.

Management

There is no empirical data to indicate the amounts and rates of Red Belt Fungus decay development in managed forests. Intuitively, because second-, or third-growth stands are younger they should have fewer decay problems than unmanaged stands. On the other hand, because of more frequent thinning entries, there is an opportunity for the fungus to become established in standing trees via injuries caused by frequent tree felling or entries of mechanized equipment.

Thinning slash and stumps also provide the ubiquitous fungus a supply of wood to colonize and decay. Slash burning is one means to release the energy stored in wood and prevent the potential buildup of decay caused by Red Belt Fungus. However, the ecological effects of wood decays are just beginning to be studied and appreciated. For instance, decayed wood is like a sponge, trapping and storing moisture for use by tree seedlings, shrubs, and forbs. Decayed snags and fallen trees are also used as habitat by many amphibians, birds, and mammals.

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FIDL - Heart rots of Douglas-fir
FIDL - Decays of Engelmann spruce & subalpine fir
FIDL - Decays of white, grand, and red firs
FIDL - Heart rots of western hemlock

April 2005

By Gregg DeNitto
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Red Ring Rot

Phellinus pini (Thore.: Fr.) A. Ames. (=*Fomes pini* (Thore.:Fr.) Karst.)

Red ring rot is the most common and destructive decay in the western United States.

Host:
- most living conifers
- western larch
- pines
- Engelmann spruce
- Douglas-fir

Topics

Key Points

- Primarily a concern in forests that are aging.
- The most common decays found in conifers in the Rocky Mountains.
- Loss to decay limited in early stages of infection.
- Indicators such as conks and punk knots are readily produced on infected trees.

Damage

Phellinus pini is one of the more common stem and butt decay fungi in conifers. Although estimates for the Rocky Mountains have not been made, it was estimated that 17% of overmature Douglas-fir in the Pacific Northwest were decayed, and of this over three-fourths was from red ring rot (Harvey 1962).

Decay extends 2 to 4 feet above and 4 to 5 feet below each punk knot, swollen knot, or conk (Partridge 1973). If several swollen/punk knots or conks are present and separated by 10 feet or more, the cull factor will be 100 percent. It is rare for an individual tree to have significant decay without having an external indicator.

Life History

Colonization by *P. pini* appears to depend on the host involved. In western conifers decay is associated with branch stubs and dead branches (Sinclair, Lyon, and Johnson 1987). The fungus apparently enters living trees mainly through branch stubs and knots. It develops within the tree, usually with no visible signs of defect for many years. The fungus eventually produces conks that produce spores capable of spreading the decay to other trees.

Identification

In the incipient decay stage, wood is reddish to purplish. In the advanced decay stage, spindle-shaped, well-defined white pockets separated by firm red wood form. Black zone lines may be present.

Photo by Minnesota Department of Natural Resources Archives.

Identification

Provides ecological benefits such as wildlife habitat and early recycling of standing wood.

Conks occur commonly on infected trees, usually emerging from branch stubs or knots. Conks are variable-shaped and shelving, usually about 3 inches wide. The tops of conks are dark with concentric furrows; underside is yellow-brown with pores. Swollen knots and punk knots are additional indicators.

Pini rot is often indicated by swollen knots on the stem which have a brown, punky interior.
Photo by USDA Forest Service Archives.

Recognize the positive ecological functions of the pathogen—

Decayed trees are used by cavity nesting birds and mammals. The decay caused by this fungus is important in the southeastern US for the nesting of the red cockaded woodpecker.

Management options should be based on objectives to be achieved, not on the presence or absence of red ring rot.

Management

Limiting the damage from red ring rot in stands is most readily achieved by **managing stands to younger ages.** Red ring rot normally becomes a significant loss factor only in very old stands. Even when red ring rot is present in younger stands, the volume of wood added due to growth usually exceeds that lost to decay.

Managing to limit red ring rot should not usually be an objective. Other objectives, such as economics, visual quality, old growth characteristics, wildlife habitat, and recreational safety, are more important in determining the appropriate silvicultural treatments and timing. These objectives may actually benefit from the retention of trees with decay from red ring rot.

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Related section in field guide.

April 2004

By Jim Hoffman
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Pouch Fungus

Cryptoporus volvatus (Pk.) Shear (= *Polyporus volvatus*)

Topics

Pouch fungus is the major cause of sapwood decay in trees killed by bark

Most conifers are host to the fungus except for western redcedar and the five-needle pines (western, whitebark, and limber pines).

Once bark beetles attack, it's a race to recover log volumes

The pouch fungus causes extensive and rapid sapwood decay that results in timber volume loss in bark beetle-attacked trees, or fire-killed ponderosa pine colonized by woodborers. Initial observations and studies of the decay caused by this fungus over 80-years ago indicated little volume loss. However, the faster and better growth rates of managed forests produce logs with far greater sapwood to heartwood ratio than in natural stands. Consequently, timber losses due to the pouch fungus can approach 30% of the scaleable volume of the log.

Key Points

- Bark beetles carry the fungus into trees they attack.
- Up to 30% of log volumes may be lost to pouch fungus decay if salvage of beetle-killed trees is delayed.

Prompt salvage is the only means of damage control.

Timber volume loss caused by pouch fungus decay is substantial. The rapid decay of sapwood necessitates timely harvest of bark beetle and/or fire-killed trees.

Occasionally pouch conks appear on trees with green foliage following a light intensity fire or bark beetle strip attack. Usually these trees die by the following year and should be marked for salvage removal if consistent with the project guidelines.

Fairly accurate estimates of the year of tree death can be made based on the condition of pouch fungus conks on the tree.

Life History

Pouch fungus is intimately associated with bark beetles and woodborers. Insects bore holes through the bark of trees and either carry the fungus into the cambial layer on their bodies or create an opening for wind-disseminated spores to initiate the decay process in the moist sapwood.

On recently killed trees conks issue from bark beetle tunnels to fruit on the outer bark of trees. Often several hundred conks appear the year after bark beetles attack a tree.

The rounded, whitish-tan conks are usually less than two inches in diameter. Initially the conks are leathery and completely cover the spore-bearing layer in the fungal fruiting body. Later a small hole develops allowing release of the spores.

Conks can be produced annually on a stem for up to 3 years, but deteriorate after their first year. Fairly accurate estimates of the year of tree death can be made if new and/or old pouch conks are present.

The fungus causes a grayish white rot of the sapwood only. In the advanced stage the decayed wood is light brown, cubical, and crumbly.

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Cite as: Hoffman, J. 2004. Management guide for pouch fungus. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

FIDL - Schweinitzii root & butt rot

FIDL - Heart rots of Douglas-fir

FIDL - Decays of white, grand, and red firs

May 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Schweinitzii Root and Butt Rot

Phaeolus schweinitzii (Fr.) Pat.

By James T. Hoffman
US Forest Service

Primary hosts—

- **Douglas-fir**
- **Engelmann spruce**
- **Ponderosa pine**

The most common heartwood decay organism of conifers in Montana and Idaho.

As a root disease, it results in little direct tree mortality except on the poorest sites.

Topics

Butt decay and windthrow are common effects

Butt rot from this fungus is common and can be seen in virtually all western conifers but is considered economically significant in only a few situations— mature and overmature Douglas-fir stands in Idaho and Montana; spruce stands infected with *tomentosus* root rot; and ponderosa pine but in Nevada around Lake Tahoe.

The fungus causes extensive decay of host root and butt heartwood. In addition, root ends are killed causing them to terminate in gall-like swellings, which greatly reduces structural support of roots. Consequently infected trees are more susceptible to uprooting and lower-stem breakage. Brown cubical decay in the structural roots often extends about 8 feet up the tree stem causing significant cull of the commercially important butt log.

As a root parasite on Douglas-fir, it predisposes trees to infection by *Armillaria ostoyae*, or attack by Douglas-fir beetle. Root disease caused solely by this fungus results in little direct tree mortality except on the poorest sites.

Although trees typically become infected at a very young age, they seldom show significant effect until they are 100 years-old or more. Generally, if one tree in a stand is infected, nearly all others are as well.

Key Points

- Douglas-fir is the most commonly damaged species in western United States and Canada.
- Cull from butt rot and windthrow cause most losses.
- Direct mortality is rare.
- Trees may be predisposed to Douglas-fir beetle and Armillaria root disease.

Management Overview

⇒ **Prevent over maturity**
⇒ **Avoid basal stem damage**
⇒ **Maintain growth and vigor**
⇒ **Favor less-susceptible species**
⇒ **Accept damage as a natural occurrence that can have positive effects**

Life History

Schweinitzii root and butt rot generally is considered a disease of old trees.

Infections can be detected in saplings but little damage is evident in young trees.

Basal wounding, including fire scars, can greatly increase severity of butt decay.

Infection occurs through small roots, in laboratory tests. Growth of the mycelium through duff and, perhaps direct infection by germinating spores probably accounts for most infections. Field evidence suggests that this may be the most important means of infection of Douglas-fir and grand fir.

Infections are also thought to occur directly though deep basal stem, or root wounds associated with a stand disturbance such as fire or logging. Even if the infection didn't originate with the wound, such scars almost certainly increase the extent of decay, presumably by aerating the infected heartwood, as seen in other heartrot diseases .

Incidence of Schweinitzii root and butt rot is very high in fire-scarred Douglas-fir stands. Old basal wounds, often mined by carpenter ants, are a fairly reliable indication that the tree also has brown cubical root and butt rot.

After infection, the fungus grows directly into the center of roots and is seldom found in the outer tissues. It decays the root heartwood and spreads from root to root through heartwood, also using grafted roots to move from tree to tree.

In the early stages the decay is punky and only slightly discolored. In the advanced stages, the decay is red-brown with cubical cracking.

Terminal ends of many of the larger roots eventually become stubbed; forming large gall-like swellings which can be diagnostic of this disease. These are particularly evident in trees uprooted because of their compromised root systems. Trees infected with *P. schweinitzii* display above-ground symptoms, such as thinning crowns with branch dieback and shortened terminal growth, only after the root system has been seriously degraded. Trees on very poor sites, such as at the margins of forest and grasslands, are most likely to display crown symptoms typical of other root diseases. Decades after root infection, decay may become evident in the lower stem.

Fruiting bodies produced by the fungus area annual, spongy to leathery conks. They develop during periods of moist weather in late summer. The upper surface of conks are reddish-brown and velvety with concentric rings; the lower surface is pored, green when fresh and becoming brown with age. Conks on the ground emanate from either decaying roots, or from the base of severely infected stems. Conks occasionally form on the cut end of logs with brown cubical heartrot.

Silvicultural Alternatives

Prevent overmaturity—

For existing Douglas-fir stands on affected sites, plan stand rotations of 100- to 120-years to both minimize Schweinitzii root disease severity and subsequent attacks by Douglas-fir beetle.

Prevent basal stem damage—

Avoid basal stem and root damage to residual trees to reduce the disease and decay hazards

Maintain growth and vigor—

Thin stands early, particularly on poor sites which can not support dense tree growth.

Favor less-susceptible species—Management should be planned to favor less-susceptible species, especially seral species like pines and western larch, whenever and wherever possible.

Appreciate the positive ecological functions of the pathogen—

Realize that *P. schweinitzii* is a common, native pathogen that can not be removed from infested sites. The fungus plays an ecological role in recycling aging trees. It also produces habitat for cavity nesting birds and other animals, and for decay-inhabiting insects. Each of these roles and many others have evolved with the evolution of conifer forests and contribute to ecological diversity and stability.

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Foliage & Shoot

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Biotic Diseases

Related section in field guide.

No FIDL for this damage-agent

Forest Health Protection and State Forestry Organizations

January 2006

By John Schwandt
US Forest Service

Management Guide for

Brown Felt Blight

Herpotrichia juniperi (Duby) Petr. *(= H. nigra* R. Hartig) and *Neopeckia coulteri* (Pk.) Sacc. (= *Herpotrichia coulteri* (Peck) Bose)

Snow mold, often called "Brown felt blight", develops on seedlings or lower branches of small trees under snow at high elevations.

Host:
All conifers at high elevations

Neopeckia coulteri is generally found only on pines at high elevations, while *Herpotrichia coulteri* is most common of firs, hemlock, cedar, and spruce but can be found on other conifer species including pines and has a broader elevational range.

Topics

Key Points

- Develops on seedlings or lower branches of small trees under snow at high elevations.
- Fungi develop under prolonged snow cover during periods of high relative humidity and mild temperatures.
- Damage is so slight that no controls have been needed.

Damage

Brown felt blight covers small branches and twigs smothering the foliage. If buds are smothered branches or small trees may die, but they may survive and resume growth if the buds are not coved by the felts.

Life History

Brown felt blight, develops on seedlings or lower branches of small trees under snow at high elevations. It is also called "snow mold", but this should be avoided as it may be confused with "snow blight" which is an entirely different disease (caused by *Phacidium abietis*) with entirely different symptoms and damage.

Little is known about the life history of these fungi except that they develop under prolonged snow cover during periods of high relative humidity and mild temperatures. They grow rapidly at 10^{o} C (*N. coulteri*) and 15-18^{o}C (*H. juniperi*) but have grown in culture at as low as -3^{o} C. *N. coulteri* penetrates the cuticle of needles, producing haustoria (feeding structures) in cells under the cuticle. *H. juniperi* seems to remain superficial on live foliage, smothering the foliage, and penetrating cells after the foliage is dead.

Life History (cont.)

As the snow melts and felts are exposed, rapid growth ceases. The felts turn dark and often somewhat shiny as the hyphae become thick-walled to resist sunlight and drying. They produce small (0.25-0.5 mm) pear shaped fruiting bodies that are embedded in the mycelial mats with their tips protruding (to facilitate spore release). These become conspicuous as the felt weathers away and produce ascospores during summer and early autumn. Infection is apparently by ascospores and by fragments of mycelium that remain viable as the felts disintegrate. Branches that are bent by snow to touch the ground are apparently infected by mycelium spreading from duff under the snow.

Management

Damage is so slight that no controls have been needed.

Identification

Needles are matted together and covered by heavy brown felt-like masses of mycelia, usually on lower parts of the crown. Fungal growth is prolific on branches that are buried under snow. Under the snow, the mycelium is grey in color. Freshly exposed felts are dark brown-black, weathering to grey-brown. The macroscopic signs and symptoms of both diseases are very similar; the two are differentiated by host preference and microscopic features.

Brown felt blight produces a thick mat of gray to dark brown mycelium on foliage that was buried under snow.

Other Reading

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May 2007

Forest Health Protection and State Forestry Organizations

By Robert James
US Forest Service

Management Guide for

Dothistroma Needle Blight

Dothistroma septosporum **(Dorog.) Morelet.**
= ***Dosthistroma pini*** **Hulb.**
= Sexual stage [teleomorph]: ***Scirrhia pini*** **Funk & A.K. Parker**

Topics

Primary hosts:	Ponderosa pine; Lodgepole pine
Minor Host:	Western white pine

Recent unprecedented high levels of this disease have been found in lodgepole pine in British Columbia, Canada and ponderosa pine in central Montana.

Key Points

- Growth is adversely affected but infected trees are seldom killed.
- High rainfall and prolonged periods of humidity are conducive to infection and disease severity
- Recent epidemics may be related to climate change that has altered traditional rainfall patterns.

Introduction

The major impact of Dothistroma needle blight is growth reduction which may result from excessive defoliation. Tree mortality is rare, although severely-infected young trees may be killed during years when environmental conditions are conducive to infection and buildup of the pathogen. Large-diameter trees with severe foliage infection may be predisposed to attack by bark beetles.

The most serious disease often occurs near rivers, especially in canyons where high humidity occurs for prolonged periods. Damage is most noticeable in the early spring before new foliage is produced.

Management Overview

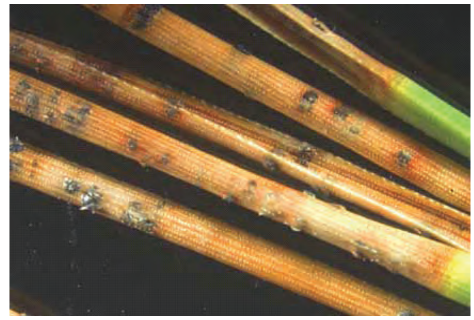
1. **Damage potential rarely warrants control efforts.** In most situations, *Dothistroma* infection will result in little growth loss or mortality.
2. **Recognize hazardous sites.** Sites that are prone to prolonged periods of high humidity provide ample opportunity for fungus sporulation and infection.
3. **Thin favoring resistant trees or species.** Individual resistance to needle blight often varies considerably within a species on a site providing opportunities to remove the most damaged trees during routine thinnings. Non-susceptible species may also be selected for retention.

Life History

Dothistroma needle blight of Ponderosa pine results in a needle discoloration and loss of two-year old foliage. With repeated infections, trees may have no foliage older than two years.

Infected needles produce spores that are disseminated primarily via rain splash onto uninfected foliage. Infection occurs on previous years' needles during the spring when weather conditions (rain and high humidity) are conducive; some current year needles may be infected during mid summer.

The pathogen requires two growing seasons to complete its life cycle. Infected needles characteristically have reddish-brown bands that often contain black fruiting bodies. The base of infected needles often remains green; they often turn yellow to brown and drop prematurely.



Black, erumpent fruiting bodies of *Dothistroma* needle blight

Distinctive banding pattern of *Dothistroma* needle blight

Unusually severe infections

Trees that are off-site may be particularly susceptible to infection. Some sites are especially favorable for the fungus, for example river canyons where moisture lingers in the air after rain and the western shores of Flathead Lake in Montana. There is even some evidence that climate changes have favored the fungus by increasing summer precipitation. Under each of these conditions, infection can be chronically severe, leading to tree death.

Management

This disease can be managed by favoring less-susceptible species in areas of high disease potential. However, since tree mortality is usually rare, little is often done to manage Dothistroma needle blight in the inland Northwest.

Recent unprecedented high levels of this disease have been found in lodgepole pine in British Columbia, Canada and ponderosa pine in central Montana. These outbreaks may be related to climate change, particularly increased summer precipitation, that has traditionally been rare. Situations such as these could eventually alter the traditional hands-off approach to managing the disease.

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Related section in field guide.

May 2004

By Jim Hoffman
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Elytroderma Needle Cast

Elytroderma deformans (Weir) Darker

Topics

Elytroderma rarely kills trees but growth loss may occur and severely defoliated trees may be attacked by bark beetles.

Primary host:
- **Ponderosa pine**

Minor hosts:
- **Pinyon pine**
- **Lodgepole pine**

Damage

Elytroderma needle cast causes browning and eventual loss of needles similar to other foliage diseases. The fungus also causes witches' brooms by growing systemically within perennial infections in the branch tips. Infections are heaviest in the lower crowns of sapling and pole-sized ponderosa pine in dense stands on gentle slopes near reservoirs, lakes, or stream bottoms where moist air accumulates. Direct killing is rare, but infected trees are weakened and more susceptible to bark beetle attacks.

Key Points

- Growth rate and form are affected but trees are seldom killed by Elytroderma.
- Moist, stagnant air increases infection rates.
- Seed and crop trees should be selected for apparent resistance.
- Increase air flow by thinning or, perhaps underburning.

Management

Maintaining open stand spacing to allow airflow reduces moisture retention on an infected site and can minimize Elytroderma damage in young stands. Uninfected, or lightly infected trees (more than a three-fifths of the crown without symptoms) should be selected as crop trees. Logging in heavily infected mature stands should be accelerated to salvage valuable timber and prevent losses from secondary causes.

Since Elytroderma needle cast incidence is highest where moist environmental conditions prevail there has been speculation that underburning infected pine stands every 10-15 years will greatly reduce stand incidence and damage by consuming infected needles on the ground and by killing all branches in the lower portion of the crown.

Life History

Spores are disseminated by wind to the current-years needles and germinate if there is rain or heavy dew.

Spores mature in small linear black fungal fruiting bodies during mid- to late- summer on needles that were infected the previous year. Alternatively, fruiting bodies can also form on new needles that emerged from perennial infections on the buds and twigs. In both cases, spores are disseminated by wind to the current-years needles and germinate if there is rain or heavy dew. After germination the fungus grows rapidly through the needle tissues and into the twigs without initially killing the needle. Needles die the next spring, turn reddish-brown, develop fungal fruiting bodies in the summer, and then are shed from the tree during fall rains.


Compact witches broom with red needles.

Identification

Elytroderma needle cast is a perennial disease easily recognized by dramatic reddening of last years foliage in early spring, coupled with numerous compact and globose witches' brooms that are present all year. In smaller trees, the effect of several years of defoliation results in a "lion's tail" appearance of the twigs and branches. Brown dead lesions develop in the inner bark of twigs and branches. The characteristic thin black fruiting bodies are produced on dead and dying needles of the previous year's growth.

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Forest Insect & Disease Leaflet

2004

Forest Health Protection and State Forestry Organizations

Susan K. Hagle
Plant Pathologist
Forest Health Protection
USDA Forest Service

Management Guide for

Larch Needle Blight

***Hypodermella laricis* Tub.**

Western larch trees of all ages and sizes are infected by this pathogen

Topics

Key Points

- Impact is rarely as significant in the long term as it appears during an outbreak.
- Select for resistance during precommercial thinning.
- Select resistant seed trees.
- Protect ornamentals and nursery stock with well-timed fungicide treatments.

Three main types of impact

In years of severe outbreaks of larch needle blight, trees of all sizes may be affected. Defoliation varies from slight in some trees to complete in others. In larger trees, most infection occurs in the lower two thirds of the crown. Severe infections occurring in two or more years in succession can result in significant impacts, especially in young trees.

1. **Growth loss** resulting from severe infection is the most common effect.

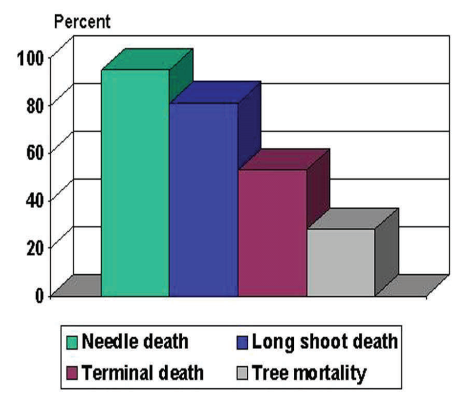
2. **Terminal shoot death** results in direct loss of height growth and may result in double-leader formation.

3. **Some seedlings may be killed** after two or three successive years of severe defoliation.

Based on artificial defoliation trials (Graham 1931), radial growth loss may be roughly proportionate to the amount of defoliation.

A single year's infection weakens spur shoots as evidenced by late bud burst, fewer leaves per spur, stunting and chlorosis of foliage (Weir 1912, Cohen 1967).

Spur shoots often are killed by two successive years' infection by *Hypodermella* (Cohen 1967). Long shoot mortality with resulting loss in height growth occurs when long shoots are heavily infected (Weir 1913).



Damage to wild western larch seedlings in the second year of a larch needle blight outbreak on Red Ives Ranger District, northern Idaho, in 1981. Percent of foliage, long shoots, terminals and trees killed.

Long and short shoots

Western larch produces long shoots and short (spur) shoots.

Long shoots are responsible for height growth and branch extension.

Spur shoots bear the majority of the foliage.

It's all a matter of timing

Hypodermella laricis produces spores in the spring. If the timing of spore maturity coincides with prolonged periods of rain to help with the release of spores and with larch foliage being at their susceptible, immature stage of growth, an epidemic may be in the making. If there is also an abundance of spores resulting from infections in the previous season, the epidemic may be severe.

In spring, foliage typically begins to emerge first on the spur shoots. Long shoot elongation follows bud break with individual needles produced at intervals along the immature shoot.

The differences in timing of foliage production on the two types of shoots can result in much different levels of infection.

Disease Resistance

Allow nature to select for disease resistance or incorporate disease resistance into your tree improvement program.

Control Strategies

Impact is rarely as significant in the long term as it appears during an outbreak. Consideration should be given to the probability that control is not warranted. The control method selected should match the setting.

Considerable variation in susceptibility to *H. laricis* is evident in native populations of larch.

In the forest, silvicultural controls are recommended, emphasizing enhancement of natural resistance of some larch trees to infection by *Hypodermella*.

- Select for resistance during precommercial thinning. To some extent this will happen by default when the better-growing trees are selected as leave-trees.
- Select resistant seed trees.

In ornamentals and nurseries,

- *Hypodermella laricis* (larch needle blight) is rarely observed in nursery settings. (*Meria laricis*, the cause of larch needle cast, is common and very damaging in *Larix* species in nurseries.) Ornamentals can be protected with fungicide treatments.
- Chlorothalonil, generally under the trade name Bravo®, is commonly used to control needle diseases on ornamentals and in nurseries. **Always follow label instructions carefully when using chemicals.**
- Spray to protect foliage from *H. laricis* just prior to bud break. Reapplication may be necessary after rain. Protect the foliage for two weeks after needles emerge.

Life History

Leaves (needles) that were killed in the previous season, are the inoculum source for the fungus. *Hypodermella laricis* produces a plant hormone (indoleacetic acid) that inhibits formation of an abscission layer (Cohen 1967). This prevents normal leaf abscission and allows the fungus to fruit the following season on leaves still attached to the spur. Fruiting bodies will be produced in this way for as long as two years.

The spores of *H. laricis* are mature in February in western Montana (Cohen 1967). During spring rain, usually in mid-April or early May, the walls of the hysterothecium(Figure 1) absorb water and split the fruiting body open length-wise exposing the asci containing the spores.

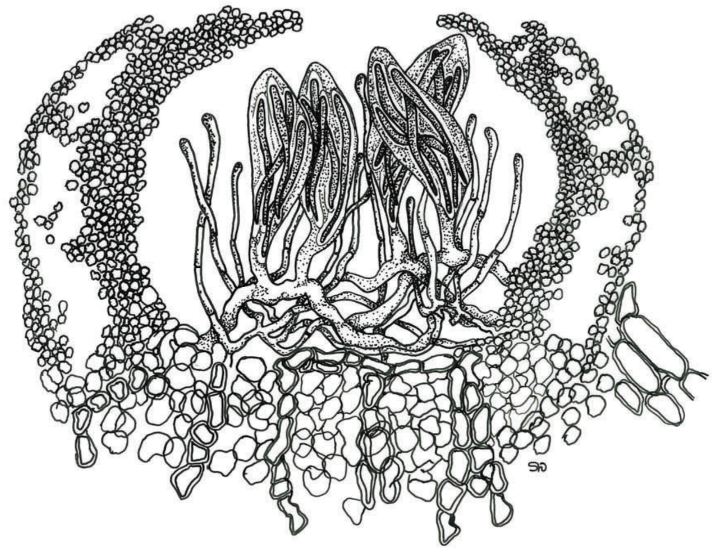
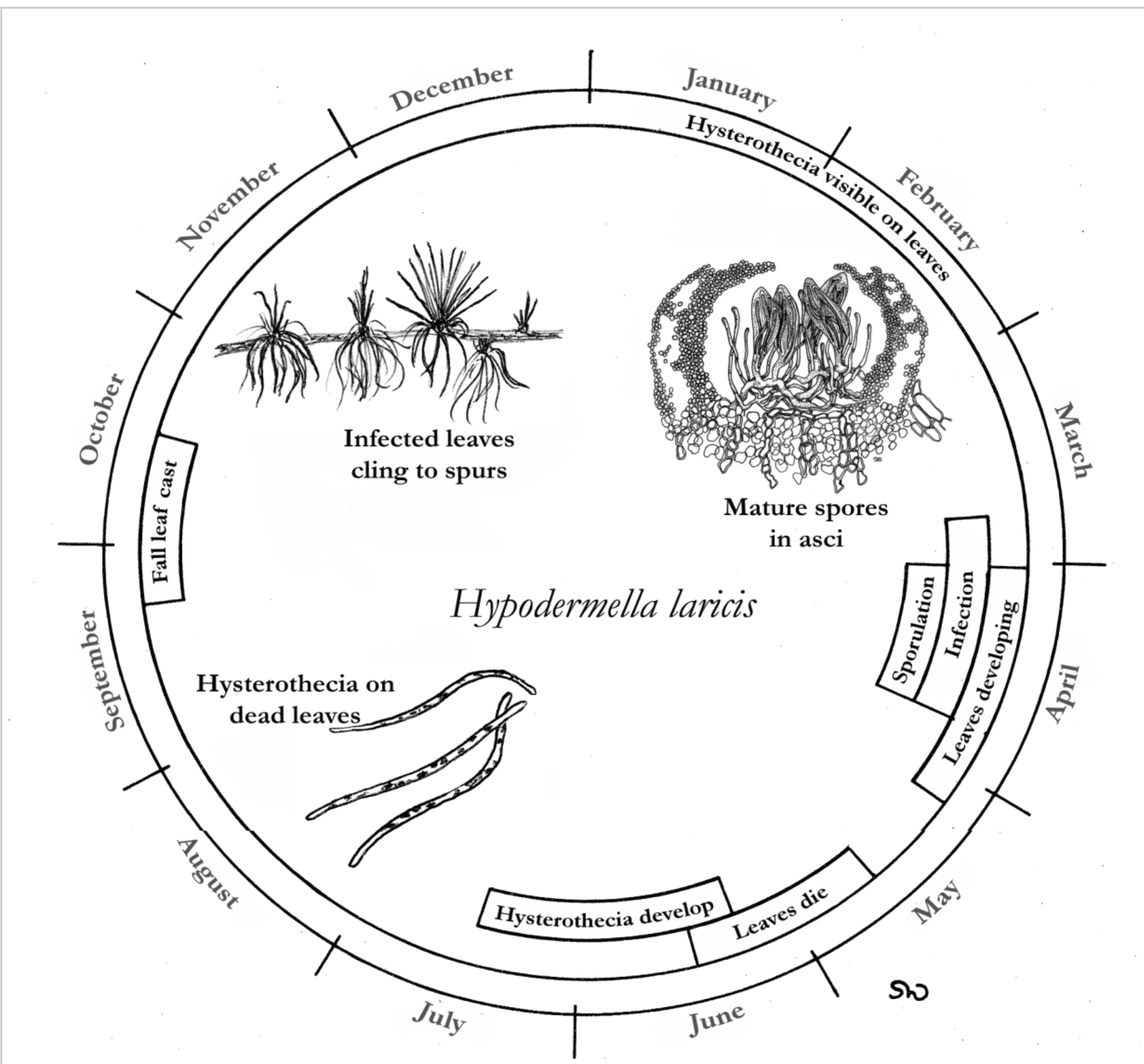


Figure 1. Hypodermella laricis is an Ascomycete of the order Phacidiales. This drawing illustrates a cross-section of the fruiting body. Elongate spores are contained within sac-like asci inside the cavity of the black hysterothecium on the undersides of leaves.



The process of leaf death may take only three days, giving the appearance that entire stands of larch have suddenly died.

Life History *(continued)*

Timing for infection is important

The asci burst open and the spores are released. If the larch buds have begun to open and the leaves are exposed, the spores that land on the leaves will germinate and penetrate the leaf surface. By two weeks following bud break, leaves are much more resistant to infection. Thickening of the waxy outer cuticle of the foliage apparently prevents penetration by hyphae of the germinating spores (Garbutt 1985). If rainfall does not coincide with early leaf growth, few of the spores will survive to infect.

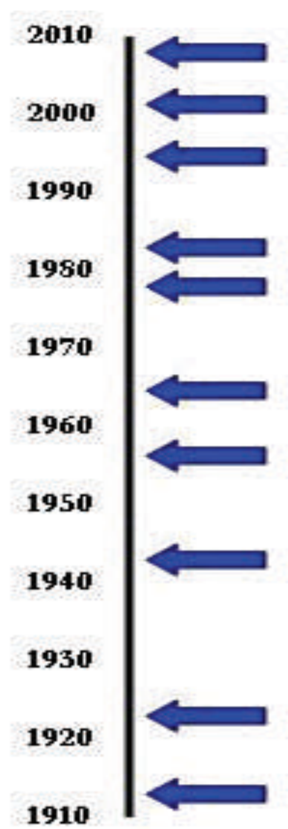
Symptom development

Approximately a month following infection, usually mid-May to mid-June, the needles turn brown and droop, remaining attached to the spur shoots. Spur shoots are not invaded by Hypodermella (Cohen 1967), but it is uncertain whether long shoots become infected.

Elongate, black fruiting bodies appear on the undersides of leaves in July or August. Spores within them are still immature in October. By January, however the spores have matured and are ready for above-freezing temperature and rain in the spring (Cohen 1967).

Previously-infected shoots continue to bear symptoms

When buds resume growth in the spring, differences become apparent between spur shoots which bore infected leaves the previous year and those which did not. Buds which had borne infected leaves open later than uninfected buds. The leaves produced on the shoots that were infected the previous season will remain dwarfed to half or less the length of normal leaves, and there are fewer leaves per shoot (Cohen 1967). The dead leaves may remain attached to spur shoots for a year or two.



Significant epidemics of larch needle blight in Idaho and Montana.

A History of Epidemics

Epidemics have been reported about every decade in northern Idaho, western Montana, and southern British Columbia. Weir (1913) indicated that during 1912 and 1913 severe larch needle disease occurred in Idaho and Montana. Schmitz (1923) reported severe defoliation in 1922 as a culmination of about five years of heavy infection in Idaho and Montana. Ehrlich (1942) reported severe infections in Idaho in 1941 and 1942 and Cohen (1967) reported that 1956 was a heavy infection year in Montana. Severe *H. laricis* infections were observed in aerial survey flights of northern Idaho and western Montana in 1964 and 1965 (USDA Forest).

A 1978 epidemic in northern Idaho was reported to have been primarily *Meria laricis* although high levels of damage from *H. laricis* also was observed that year (USDA Forest Service). Aerial survey in Idaho and Montana again detected severe infections in 1980, 1981, 1993 and 2002-2003 (USDA Forest Service).

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Related section in field guide.

Forest Insect & Disease Leaflet

2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Larch Needle Cast

Meria laricis Vuillemin

Susan K. Hagle
Plant Pathologist
Forest Health Protection
USDA Forest Service

- Western larch trees of all ages and sizes are infected
- This fungus has rarely been seen on alpine larch

Topics

Key Points

- Impact in a forest is rarely as significant in the long term as it appears during an outbreak.
- Select for resistance during precommercial thinning.
- Select resistant seed trees.
- Protect ornamentals and nursery stock with well-timed fungicide treatments.

Larch needle cast and blight team up

Meria laricis is favored by frequent rainfall from early leaf development continuing throughout the summer. In forests, *Meria* occurs commonly, though not always, in conjunction with *Hypodermella laricis* (a needle blight fungus). Both fungi are favored by spring rains. The two pathogens are easily distinguished by the appearance of infected needles and by their fruiting bodies.

Growth loss resulting from severe infection is probably the greatest effect. The combined effects of *Meria* and *Hypodermella* may have considerably greater impact than the effects of either fungus alone. The needle blight fungus defoliates the tree only once, shortly after bud break, and the tree refoliates. *Meria laricis*, however, is capable of almost continuous reinfection of foliage throughout the growing season, as long as periodic rainfall occurs. In years with wet spring weather followed by periodic rainfall throughout the summer, few needles may escape infection by one or the other pathogen.

Unlike *Hypodermella*, *Meria laricis* does not produce perennial infections. Needles shed the previous season or the few tufts of unshed, infected needles on branch tips provide inoculum from one year to the next.

Nursery impacts are most significant

Meria laricis is particularly troublesome in nursery settings. Losses in the form of direct mortality and, most commonly, culling due to reduced caliper, make *Meria* one of the most significant disease problems of western larch in nurseries.

The disease is usually detected in bareroot seedlings in their second growing season. Once present in a nursery, the disease usually persists.

Control Strategies

In nurseries, foliar fungicides are routinely applied to control *Meria*.

In forest settings, genetic resistance offers the best control.

In Nurseries and Ornamentals

Foliar fungicide sprays have been used successfully and routinely to control *Meria* needle cast.

- Rogueing larch from the area surrounding a nursery may reduce infection.
- Control is rarely warranted before the second year, and generally, only in bareroot stock.
- Spray schedules vary by location, weather and timing of bud break.
- Generally speaking, the first application should occur as the buds begin to expand and the green tips of leaves become visible in the early spring. Subsequent applications will follow to provide continuous protection (about every 2-3 weeks) until dry weather prevails or until the end of July.
- If overhead irrigation wets leaves throughout the growing season, protection will be required through the end of July.
- Chlorothalonil, generally under the trade name Bravo®, is commonly used to control needle diseases on ornamentals and in nurseries. **Always follow label instructions carefully when using chemicals.**
- In some locations, several years of consistent control of *Meria* may render a nursery free of the disease for a time. Fungicide treatment may be suspended until evidence of the needle spots reappear.

In Forest Settings

Silvicultural controls are recommended, emphasizing enhancement of natural resistance of some larch trees to infection by *Meria laricis*. Management of *M. laricis* and *H. laricis* should be considered together. There may be considerable variation in susceptibility to both fungi. Some larch in every stand have notably less infection by either or both fungi.

- Realize that longterm impacts in a forest are rarely as significant as defoliation by needle casts and blights appear during an outbreak.
- Thin to minimize lateral competition and maintain optimum growth of larch.
- Select for resistance during precommercial thinning. To some extent this will happen by default when the better-growing trees are selected as leave-trees.
- Select apparently resistant seed trees.

Continuous re-infection

***Meria laricis* is capable of almost continuous reinfection of foliage throughout the growing season.**

As periodic rainfall occurs, infection levels increase.

Life History

Sources of inoculum in the spring are infected leaves on the ground and tufts of infected needles on the terminal shoots of seedlings. Spores are carried by wind and splashing rain to the newly emerged leaves.

Spores are produced on simple fruiting structures called conidiophores which protrude in groups through stomatal openings (Figure 1). Conidiophores can be seen by using a hand lens and appear as rows of small white dots on the undersides of leaves.

While rain aids in the dispersal and germination of spores, it is apparently not a requirement for spore production or release (Peace 1962). Infection generally occurs at the tip or midportions of developing leaves, probably because young leaf tissue is more resistant to infection (Peace 1933).

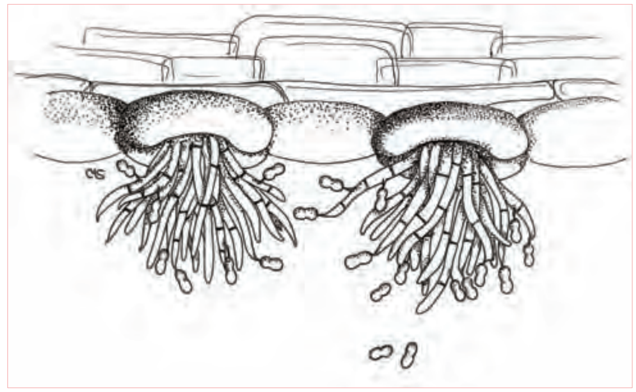
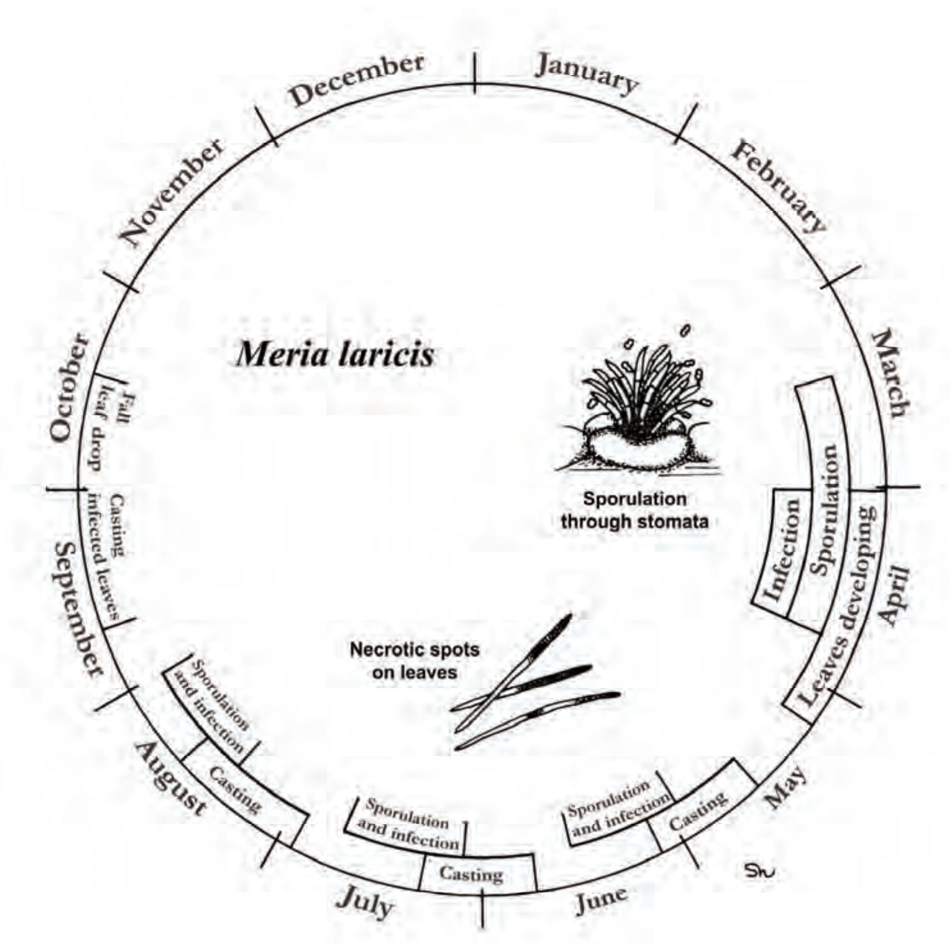


Figure 1. Meria laricis is a hyphomycete of the family Tuberculariaceae. This drawing illustrates clusters of conidiophores emerging through two stomata on the underside of a leaf. The peanut-shaped spores are released to be carried by wind or splashing rain.

Figure 2. Life cycle of Meria laricis



The cycle from infection, to leaf cast, to sporulation and reinfection may take only 2 to 4 weeks, depending on temperature and rainfall.

Meria laricis reproduces asexually in Europe and North America. It is not known to produce sexual sporulating structures, but may have once been capable of producing Rhabdocline-type sexual structures.

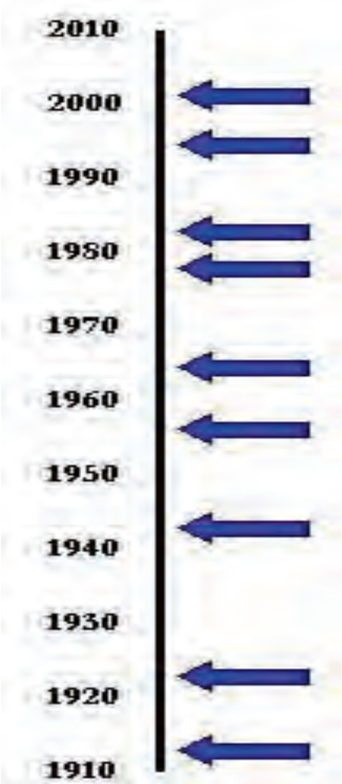
Based on analyses of the nucleotide sequences from the internal transcribed spacer region of _M. laricis_, this fungus appears to be closely related to other fungi which produce Rhabdocline fruiting structures (Gernandt and others 1989).

Life History (continued)

After infection, the fungus grows toward the base of the leaf. In early May, yellowing and withering of infected needle tips is noticeable. Leaves eventually turn brown and are cast. Early in the spring most symptoms on long shoots will be in leaves near the base of shoots because it takes some time for symptoms to develop (Peace 1933)

Spores are produced on newly cast leaves and reinfect previously uninfected leaves. The cycle from infection to sporulation (spore production) requires approximately two to four weeks. If favorable moisture and temperature conditions prevail throughout the summer, the inoculum load of *Meria* continues to increase and resulting damage escalates.

Most tree growth should be complete by August and the effects of infection at that point would be minimal.



Significant outbreaks of larch needle cast and needle blight in Idaho and Montana.

A History of Epidemics

Meria laricis was first reported on western larch in the United States in 1942 (Ehrlich 1942). It had been well-known in European larch and plantations of western larch in Europe. The disease was probably not a new arrival in western North America but had been previously overlooked due to its close occurrence with *Hypodermella laricis*, a more readily recognizable fungus.

Epidemics of *Hypodermella laricis*, usually with *Meria laricis*, in western larch in the U.S. have been reported about every 10 years. (See sidebar at left.)

In 1912 and 1913 a severe outbreak of larch needle disease occurred in Idaho and Montana. 1922 was, again, a culmination of about five years of heavy infection in Idaho and Montana. Severe infections were seen in Idaho in 1941 and 1942. In Montana, 1956 was a heavy infection year. A 1978 epidemic in northern Idaho was reported to have been primarily *Meria*. Aerial survey in Idaho and Montana also detected severe infections in 1980, 1981, 1993 and 2002-2003 (USDA Forest Service).

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No FIDL for this damage-agent

May 2005

Forest Health Protection and State Forestry Organizations

By John Guyon
US Forest Service

Management Guide for

Marssonina Leaf Spot

Marssonina populi **(Lib.) Magnus**

Topics

Marssonina leaf spot is the most common foliar problem on aspen in both urban and forested areas.

Populus spp. are hosts

- **Aspen and Cottonwood**

Key Points

- Reduced growth and poor appearance result from severe infections.
- Control is not practical in forest situations.
- Reduce inoculum by removing infected materials.
- Wet foliage increases disease.
- Foliar fungicide can protect new growth.

Identification

Small, brownish, circular spots are seen in early summer on leaf surfaces. Leaf spots expand and coalesce as the fungus proliferates on the leaf surface. A chlorotic halo may surround spots. From a distance the trees may have a bronze tint to them.

The blight causes the leaves to drop prematurely and in some cases may cause small branch and twig dieback which results in bushy trees.

Considerable clonal variation in susceptibility exists. Repeated defoliation may predispose trees to attacks by other pests.

Management

- Control is not practical in forest settings.
- In urban areas raking up and pruning infected twigs in the fall can reduce inoculum for the next year.
- Foliar fungicide application at budbreak in spring has been successful in controlling the disease.
- Thinning trees to allow more air movement among the leaves reduces infection.
- Avoid watering the lower branches and leaves of poplars.

Photo shows *marssonina* leaf spot disease with chlorotic halos surrounding infections.

Photo by Fred Baker

Life History

The fungus over winters on fallen leaves and twig branches. Spores produced on fallen leaves in spring and early summer are carried by wind and rain to infect emerging leaves and petioles. Rainfall favors sporulation and infection.

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No FIDL for this damage-agent

March 2004

By John Guyon
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Venturia Leaf and Shoot Blight

Venturia macularis (Fr) E. Muller & Arx *(=V. tremulae* Aderh.*)*--
Aspen Shoot Blight
Pollaccia radiosa (Lib.) Bald&Cif.
Venturia populina (Vuill.) Fabric.—Cottonwood and poplar shoot blight
Pollaccia elegans Servazzi

Topics

Venturia shoot blight can be found in most aspen forests, but it is rarely a significant cause of damage in a forested setting.

Host:

- trembling aspen
- white poplar and eastern cottonwood.
- *V. populina* is found on balsam and lombardy poplars, and a wide variety of cottonwood and poplar hybrids.

Key Points

- *Pollaccia* and *Venturia* are different life stages of the same fungus.
- Leaves and succulent shoots are killed not long after budbreak.
- Venturia shoot blight can be found in most aspen forests

Damage

Leaves and succulent shoots are killed not long after budbreak. Some Venturia shoot blight can be found in most aspen forests, but it is rarely a significant cause of damage in a forested setting. However, under the right conditions, up to 90 percent of entire aspen clones had terminal shoots killed during years with severe infections, and the disease has caused economic loses to hybrid poplar growers. This disease can often give aspen a "zigzag" appearance to saplings if the terminal leader is killed several years in a row forcing lateral branches to become the new leader. In some particularly susceptible aspen clones the young stems develop a bushy appearance due to repeated loss of the terminal. Gaining height in order to escape animal browsing is important for the success of an aspen clone, and if trees are kept shorter by shoot blight animal damage is exacerbated. Once stems are over 3 to 5 meters tall shoot blight is not usually damaging.

Life History

Initial infection in the spring occurs when conidia and ascospores from previously infected stems are splashed to newly emerging shoots. The fungus invades the leaves of the emerging shoots causing a brown or black leaf spot. Typically, the fungus grows through the leaf petiole and into the shoot the new shoot blackening the shoot causing the characteristic shepherd's crook. The prolific brown to green spores of the Pollaccia stage are produced in wet weather and can cause secondary infections through out the year if moist weather conditions prevail. Many of the blighted leaves are shed and the fungus overwinters in infected shoots that remain attached to the stems.

Identification

The curved shoot tip is the most distinctive diagnostic symptom, along with large irregular lesions packed with brown to olive green conidia.

Photo showing a good example of the distinctive "shepard's crook". Photo from Minnesota Department of Natural Resources Archives.

Management Considerations

Control is impractical in a forested setting. Homeowners and poplar nursery growers can reduce the impact of Venturia shoot blight on all hosts by:

1. Avoiding the most susceptible cultivars.
2. Raking and removing blighted leaves and pruning out blighted stems.
3. Fungicidal sprays applied shortly after budbreak, possibly repeated if wet weather continues.

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Foliage & Shoot

Insects

Foliage & Shoot

Insects

Aphids, Adelgids, & Midges

Related section in field guide.

No FIDL for this damage-agent

Feb 2006

By Steve Munson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Cooley Spruce Gall Aphid

Adelgid ***Adelges cooleyi*** **(Gill.)**

Cooley spruce gall adelgid is native to North America and is widespread over the northern and central Rocky Mountains.

Host:
- Spruce
- Douglas-fir

Topics

Key Points

- This species of adelgid requires two hosts to complete their life cycle; spruce and Douglas-fir.
- The galls it produces on spruce are formed by aphid - like insects.
- Excessive numbers of these insects occur on cones, which may affect seed production.

Damage

On Douglas-fir, nymphs suck the juice out of current needles causing needle discoloration, distortion and premature needle drop. Secondary damage may be caused by sooty mold that grows on honeydew excreted by the insect. Excessive numbers of these insects occur on cones, which may affect seed production. Yellow spots, distorted and bent needles result from feeding damage. Damaged needles may shed prematurely. Galls are not formed on Douglas-fir.

On spruce, nymphs form pinecone-shaped galls on tips of twigs and branches which usually kills the terminal growth. If only a partial gall forms on the terminal growth, it allows a portion of the upper needles to survive and the terminal continues to develop. Cooley spruce gall adelgids are commonly found on blue spruce, however they do little to no damage to the tree. The damage caused by this insect affects only aesthetics and does not threaten tree survival.

Old brown gall formed on the end of blue spruce. Photo by Eric R. Day

Life History

The complex lifecycle normally requires two hosts (spruce and Douglas-fir) to complete (Figure 1).

CYCLE ON SPRUCE: Wooly aphids overwinter as immature females underneath young branches. In the spring, females mature and lay a few hundred eggs near developing buds. The eggs hatch around bud break with the young nymphs migrating to new growth. The nymphs feed at the base of the expanding needles. Saliva introduced into the plant by feeding nymphs causes changes in plant development producing the pineapple shaped gall. The insects develop in chambers within the gall which gradually increases in size.

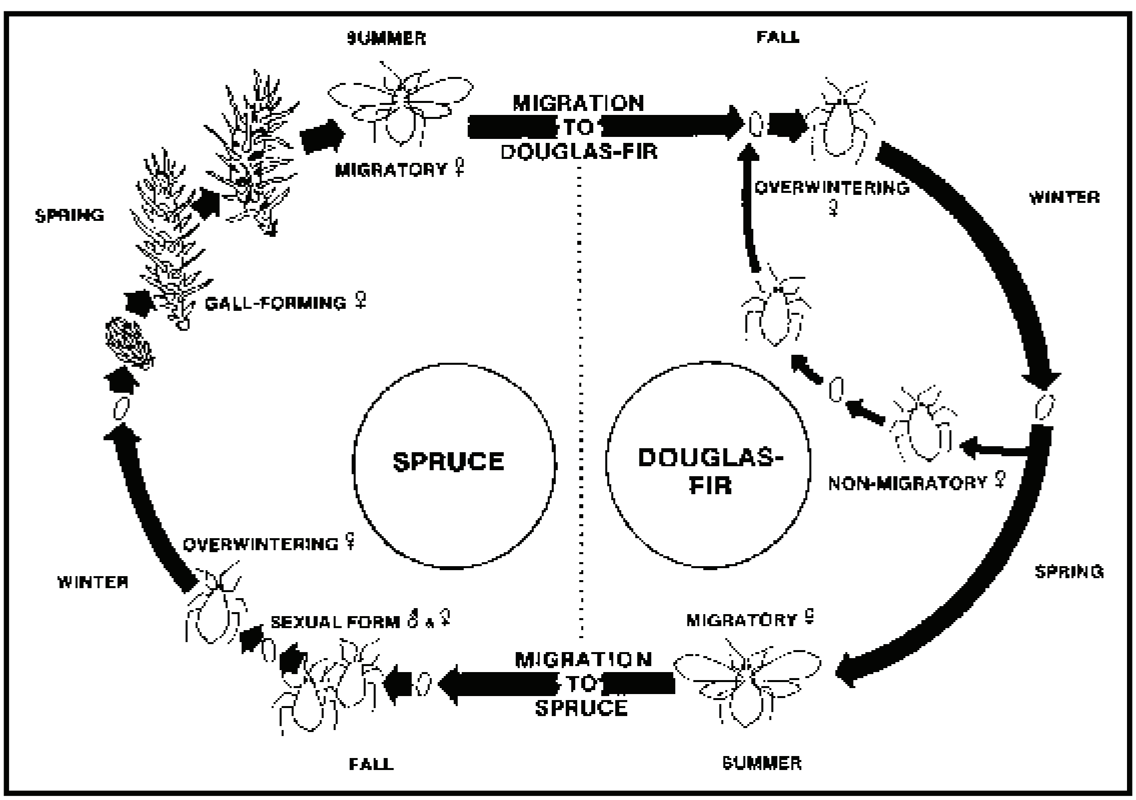
Life History

As the insects feed, the galls remain green with pink or purple shading (Figure 2). By late July, early August the galls dry out and the chambers open releasing the winged forms of the insect. Older galls are brown in color and may persist for years on affected spruce (Figure 3). Most of the winged forms then migrate to Douglas-fir trees.

CYCLE ON DOUGLAS-FIR: Migrating winged females from spruce lay eggs on needles producing several generations of woolly aphids.

Pini rot is often indicated by swollen knots on the stem which have a brown, punky interior. Photo by Whitney Shaw.

Figure 1. Life cycle of the Cooley spruce gall adelgid. Research indicates that the adelgids leaving spruce must develop on Douglas-fir before returning to spruce. Observations in Colorado suggest that spruce to spruce movement also may occur (Cranshaw, 2005)



Life History

These woolly tufts can be found on current and last years needles (Figure 4). On the lower surfaces of Douglas-fir needles look for white woolly tufts each containing a single adelgid. Late in the summer, some of the woolly aphids produce wings and migrate back to spruce to deposit eggs that overwinter. Other aphids are wingless and remain on the Douglas-fir producing other overwintering forms.

All foliar applications should be directed at the underside of spruce terminals where the overwintering aphids are concentrated.

Management

Administering treatments to control Cooley spruce gall populations are generally not necessary. The adelgid populations are highly cyclical, with population densities varying from one season to the next. However, to prevent aesthetic injuries that can detract from tree appearance there are registered insecticide treatments to control populations.

Control efforts must be initiated before the galls begin to form.

- Treatments can be applied in the fall, after the overwintering females have settled on plants or in the spring.
- Spring applications are most effective if applied before the insects have begun to swell with eggs which typically occurs in late April.

Foliar treatments

- Foliar treatments of carbaryl (Sevin) and permethrin have been most effective in Colorado State University trials.
- Although horticultural oils are also effective, they can cause temporary discoloration of spruce needles.
- Insecticidal soaps are only somewhat effective if applied to spruce, but are used widely to control populations of this insect on Douglas-fir. All foliar applications should be directed at the underside of spruce terminals where the overwintering aphids are concentrated.

On small spruce trees, prune current galls before adults emerge in late July. Removing old galls will not affect infestations because the insects have left the tree when the galls turn brown. Old (brown) galls are not used by any later stages of this insect. When establishing plantings, avoid placing Douglas-fir and spruce trees close together. Chemical control is not warranted in forest stands.

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Related section in field guide.

No FIDL for this damage-agent

July 2005

By Beverly Bulaon
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Douglas-fir Needle Midges

Contarinia pseudotsugae
C. constricta
C. cuniculator Condr

Topics

From a distance, damage looks like western spruce budworm defoliation.	**Host: Douglas-fir**

Key Points

- These three midges work together as a complex on Douglas-fir trees
- Maggots cause galls on current year's needles, causing them to fall off.
- Christmas tree plantations and entire crops can be ruined.

Damage

Maggots cause galls on current year's needles, causing them to fall off. Nearly 100 percent of needles can be destroyed. After years of consecutive defoliation, twig dieback can occur. From a distance, damage looks like western spruce budworm defoliation. Economic damage occurs in Christmas tree plantations and entire crops can be ruined.

These three midges work together as a complex on Douglas-fir trees, but *C. pseudotsugae* is the most abundant. Severe infestations occurred during 1952 and 1963 in northern Idaho and western Montana. Scattered infestations were found all over Montana in 1960, and there were outbreaks in the late 1960's in both states.

Life History

The life cycles of all three midges are fairly similar to that of *C. pseudotsugae*. The mature larvae (maggots) over winters in the soil under host trees. The larvae pupate in soil in late April and early May. Adult flies emerge and lay eggs on newly extending needles. Maggots bore into needles and remain first instars until early August. By late September most larvae are in the third and final instar. Larvae leave the galls from mid-October to December, drop to the ground, and spin cocoons in which to hibernate.

Identification

Needle midge damage on fir.

Look for gall on new needles. Galls of *C. pseudotsugae* are swollen on the lower surface and colored on both-surfaces with yellow, pink or purple. *Contarinia. constricta* galls first appear as a patch of yellow discoloration with a dark purplish spot visible on both surfaces of the needle. After about 6 weeks the gall becomes dilated and flattened. *Contarinia. cuniculator* galls affect mainly the upper needle surface. The upper side is dirty yellow with a glossy, waxy appearance. Frequently needles are bent at site of injury.

For more identification photos go the ***Field Guide*** *to Diseases and Insect Pest of Northern and Central Rocky Mountain Conifers.*

Management

Chemical controls have not been registered in the Northern Region. However, acceptable control was achieved with:

- endosulfan,
- dimethoate,
- lindane,
- liquid carbofuran
- Temikâ.

Endosulfan gave the best control when applied to foliage and soil just prior to female midge emergence but at median budburst.

During years of heavy midge populations:

- Christmas trees should be harvested at elevations above 3,000 feet.
- Midge-damaged trees should be left uncut to recover for future harvest.
- Sites for Douglas-fir plantations should be carefully selected to avoid a severe midge problem.
- Evidence indicates that synchronism of adult emergence with host development is an important factor in the successful establishment of *C. pseudotsugae*.
- Selecting planting stock with late bud burst might have some merit.

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Related section in field guide.

No FIDL for this damage-agent

April 2004

Forest Health Protection and State Forestry Organizations

By
Dwight Scarbrough
US Forest Service

Management Guide for

Spruce Aphid

Elatobium abietinum Wal

Topics

A significant pest of ornamental spruces, spruce aphid is thought to be a non-native insect, perhaps originating in Europe.

Hosts:

- **Sitka spruce**
- **Norway spruce**
- **Blue spruce**
- **Other spruce species**

Key Points

- Prolonged cool temperatures and spring frosts reduce populations.
- Too many aphids results in overcrowding and starvation of insects.
- If pesticide is used, apply in March and April.

Distribution and Damage in North America

Sitka spruce, Norway spruce, and blue spruce are preferred hosts; other spruce species may also be attacked. All ages of trees are susceptible, though damage is most severe on immature spruce. Spruce aphid has also been recorded on pine and Douglas-fir.

Spruce aphid is a destructive pest of ornamental spruce along the entire west coast of North America from Alaska to California and inland to Arizona, Utah, Nevada, and parts of western Canada. It infests stands of Sitka spruce in Oregon and Washington. It has also been reported in North Carolina.

This aphid feeds primarily on older and shaded needles in the lower crown. Needles turn yellow and are shed prematurely. Needle discoloration and needle drop varies according to attack density and weather conditions. This aphid is not known to cause tree mortality, but the damage is unsightly.

A very interesting life history in North America

Only the parthenogenic form of this aphid is known in North America, which means that they reproduce without mating. There are usually several generations per year. Populations reach a peak during late winter and early spring and then practically disappear during the summer.

Management

Weather is believed to strongly affect spruce aphid abundance and prolonged periods of cool temperatures or early spring frosts can result in lower populations.

Overcrowding and resultant starvation may be most effective in reducing populations.

Unfortunately, the high populations which occur during the winter and early spring are active too early for most insect predators to be effective in reducing aphid numbers. However, when conditions are favorable and they are active, ladybird beetles, lacewings, spiders, and other predatory insects as well as parasitic wasps and fungal diseases can also limit populations.

If chemical control is an option for management of this pest, the pesticide must be applied in March and April.

Recognizing spruce aphids

Foliage damage appears similar to some needle cast diseases. The presence of the insect is necessary to identify spruce aphid as the cause.

Spruce aphids are small (1/16 of an inch), soft-bodied, mostly wingless insects. They are light green when young and turn an olive-green when mature. Winged adults have two pairs of wings, with the front pair being much larger than the hind pair. Like other aphids the spruce aphid has sucking mouth parts which they use to suck the sap from foliage. They feed gregariously and secrete “honeydew” which attracts ants.

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Foliage & Shoot

Insects

Defoliators

Damage-agent is not in field guide.

No FIDL for this damage-agent

April 2005

Forest Health Protection and State Forestry Organizations

Management Guide for

Alder Flea Beetle

Macrohaltica ambiens (LeConte) (formerly *Altica* ambiens (LeConte))
(Coleoptera: Chrysomelidae)

By
Carol Bell Randall
US Forest Service

The alder flea beetle is a transcontinental species occurring in the West from California and New Mexico northward into Alaska.

Hosts:
Alder species;
willows and poplars-occasionally

Topics

Key Points

- **Beetle larvae and adults feed on alder leaves.**
- **Adults are about 1/5 inch long and dark, shiny cobalt blue color.**
- **Skeletonize leaves with numerous larvae are signs of attack.**

Damage

Beetle larvae feed in groups destroying the upper leaf surface. Adults chew holes through leaves.

When populations of this beetle are high, feeding damage turn patches of alder brown leading land owners/ managers to believe that the alder is dead or has been sprayed with an herbicide.

Defoliation can be complete, but seldom lasts more than one season. Defoliation does not cause economic loss. Lasting damage from alder flea beetle defoliation is rare.

Alder leaf showing damage from alder flea beetle larvae. Photo by: Ken Gibson

Life History

Adults aggregate to hibernate during the winter in debris beneath the tree and in other sheltered places. Adults are about 1/5 inch long, metallic greenish blue or cobalt blue in color. Adults will emerge in early spring to resume feeding.

Adults mate and lay clusters of yellow/ orange eggs on leaves shortly after emerging in the spring.

Larvae emerge from the eggs within a few days. They are 1/5 to ¼ of an inch in length when fully grown, brown/ black dorsally and yellowish ventrally with shiny black heads and short legs.

Larvae reach maturity in August, and pupate on the ground in the duff. New adults appear in a week to 10 days and feed voraciously on the foliage until the close of the season when they enter hibernation.

During the late summer/ early fall look for groups of metallic greenish blue or cobalt blue adults chewing holes through leaves.

Leaf damage from alder flea beetle. Photo by Rowena Hopkins of the Moncton Naturalist Club.

-Warning-

Remember, when using pesticides, always read and follow the label!

Management

Prevention

- Tactics geared toward maintaining plant vigor such as watering and fertilizing plants as needed to keep them healthy. Some have suggested that outbreaks of this insect are actually beneficial by reducing the amount of cover on a site and enabling regenerating tree species to receive direct sunlight.

Indirect Control

- Foster populations of natural enemies by minimizing use of insecticides in the area.

Chemical control

- Damage attributed to this insect has not risen to the level where insecticide use has been deemed necessary. Before using any pesticide, read the label and insure that use of the compound is registered for alder flea beetle control.

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Moncton Naturalist Club Photos

Cite as: Randall, C.B. 2005. Management guide for alder flea beetle. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Damage-agent is not in field guide.

No FIDL for this damage-agent

April 2004

By Dwight Scarbrough
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Spring & Fall Cankerworms

Paleacrita vernata (Peck) and *Alsophila pometeria* (Harris)

Cankerworms will completely consume all the leaves on elms and eat bark off new twigs. Repeated severe defoliation causes branch dieback and finally tree mortality.

Hosts:
Primarily Siberian and American Elms

Also a broad range of other hardwoods and understory plants.

Topics

Key Points

- Problems occur in shelterbelt elms.
- "BT" is a biological control that provides temporary control.
- Other tree species may be better for shelterbelts.

Life History

Larvae of these moths are known as "loopers" or "inchworms" and are chronic pests of Siberian elm shelterbelts in eastern Montana and North Dakota. Periodic outbreaks also occur in Utah along the Wasatch front.

Spring cankerworm overwinters as larvae in cells in the soil. Pupation occurs in late winter and adults emerge in early spring.

Female moths are wingless and crawl up tree trunks to lay egg clusters in bark crevices or under bark scales. Larvae emerge in early May and feed on leaves until mid-June, then enter soil.

Fall cankerworm overwinters as eggs in rows on twigs and small branches. Eggs hatch about the same time as the spring cankerworm and larvae of both cankerworms feed on leaves of Siberian elm during early May and June.

Fall cankerworm larvae drop to ground and pupate in cocoons in the soil. Adults emerge in November or December and the wingless females climb trees to lay eggs.

Recognizing spring and fall cankerworms

Look for larvae of both cankerworms on leaves from early May to end of June. Body colors on both species are varied and it is hard to identify them this way. Both, when full grown, are about 25 mm long.

The spring cankerworm's head is light and mottled with brown, and it has only two pairs of pro1egs, one on each of the eighth and anal segments.

The fall cankerworm's head varies from pale green to almost black. It has three pairs of prolegs, a small pair on the fifth, and larger ones on the sixth and anal segments.

Biological Control

The bacterium, *Bacillus thuringiensis*, is registered for aerial and ground applications.

The planting of Siberian elm for shelterbe1ts should probably be discouraged.

Spring cankerworm overwinters as larvae in cells in the soil, while fall cankerworm overwinters as eggs

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Related section in field guide.

No FIDL for this damage-agent

January 2006

By Leah Chapman

Forest Health Protection and State Forestry Organizations

Management Guide for

Defoliating weevils

Curculionidae: *Magdalis gentiles* LeConte
Scythropus elegans (Couper)

Topics

Adult feeding damage on needles can be mistaken for other defoliator damage such as that caused by pine sawflies.

Hosts: *Magdalis& Scythropus*

- **Lodgepole pine *Magdalis***
- **Ponderosa pine**

Alternative hosts:

- **Other pine**
- **Douglas-fir**

Key Points

- Adults are active from late June through August.
- Both Genera are attracted to fresh slash, but more often Magdalis may be found actually feeding on it.
- Thinning should be planned for mid-August or later, when beetles are less likely to fly to new sites.

Damage

Adult *Scythropus* feed by puncturing needles while *Magdalis* remove chunks from the needle sheath. The distal ends of the needles dry up and are broken off by wind or precipitation. Since damage usually occurs after most of the seasonal tree growth is completed, weevils are not usually considered an economic pest.
Adult feeding damage on needles can be mistaken for other defoliator damage such as that caused by pine sawflies.

Life History

Defoliating weevils likely over-winter as larvae in dead twigs or branches. Pupation occurs during spring in cells along larval mines. Adults are active from late June through August. In late August, eggs are laid on twigs. After eclosion, new larvae feed on cambium and wood tissue beneath the bark until falling temperatures cause them to over-winter.

Identification

Adult weevil Photo fromUSDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Adult weevils can be found on new needles from late June through August. *Magdalis* weevils are black, about 5mm in length and have long, prominently curved snouts like most Curculionidae. Weevils in the genus *Scythropus* lack their family's long snout and instead are broad-nosed. They are approximately the same size as *Magdalis*, but are scale-covered, making them appear metallic blue-green, gold, brass or bronze. Both genera are attracted to fresh slash, but more often than *Scythropus*, *Magdalis* may be found actually feeding on it.

Photo from USDA Forest Service Archives, USDA Forest Service, www.forestryimages. org

Damage from weevils in a logged area. Photo from USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Management

- There are no insecticides registered for control of defoliating weevils.
- The odor of fresh slash is an attractant; damage to young trees is most severe when thinning is done prior to late July.
- Thinning should be planned for mid-August or later, when beetles are less likely to fly to new sites.

Other Reading

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May 2004

Forest Health Protection and State Forestry Organizations

By Carol B. Randall
US Forest Service

Management Guide for

Douglas-fir Tussock Moth

Orgyia pseudotsugata McDonald

Topics

Key Points

- Locations of outbreaks are highly predictable
- Outbreaks are somewhat cyclical.
- Stand hazard can be reduced through silviculture.
- Chemical pesticides are temporarily effective.

Epidemics occur about every 8 to 10 years in conifer forests of Idaho.

Hosts

- Douglas-fir
- All true firs
- Spruce
- When favorite foliage is gone, they will eat most other conifers and many shrubs.

Periodic outbreaks in predictable locations

Mature, densely stocked stands of grand fir or Douglas-fir in certain locations in Idaho and Montana experience cyclical outbreaks of this insect; about every 8 to 10 years. Outbreaks occur on ridgetops and upper slopes with shallow volcanic ash soils in northern Idaho. In eastern Montana, outbreaks can occur in dry, Douglas-fir stands in the transition between forest and grassland.

Outbreaks last about 2 years in Montana, and average 3 years in northern Idaho.

Young larvae feed on new needles. Later instars can completely strip all needles from trees. Because of this, trees can be top killed or killed in 1 year. Entire stands of grand fir and Douglas- fir have been killed after 1 or 2 years of heavy defoliation. Continued defoliation also causes marked radial growth loss.

Management

A monitoring system using pheromone-baited sticky traps is used to watch for increasing populations. When outbreaks seem imminent, ground-based egg mass and pupal evaluation surveys are utilized to measure population levels and to help in making management decisions.
Management decisions involve; predicting damage, weighing effects of different management practices, estimating costs of various treatments, and translating socioeconomic impacts (Campbell and Stark 1980).

Life History

The female Douglas-fir tussock moth is wingless. Photo by Ladd Livingston

Tussock moth overwinters as eggs in a mass of female body hairs stuck together with a frothy, gelatinous substance. These egg masses are laid on top of cocoons which can be attached to foliated twigs, trunk, under large limbs, or other objects surrounding the tree.

Eggs begin hatching when buds burst on hosts. First instars feed on the tender new foliage. Larvae do not web needles together at any period, but they produce loose webbing from branch to branch while crawling.

Pupation occurs from late July to end of August inside a thin cocoon of silken webbing mixed with larval hairs. Moths emerge 10-18 days later.

The female moth does not have wings and crawls onto the top of her cocoon and produces a sex attractant pheromone to draw winged males for mating. After mating, she lays her egg mass on the cocoon.

Stands in areas of repeated outbreaks should be hazard rated to better predict their vulnerability to defoliation.

Hazard Rating for Douglas-fir Tussock Moth in northern Idaho

Some stands are more susceptible to outbreaks. Using these and other variables, stands can be risk rated for defoliation from aerial photographs.

This method has been demonstrated on the Palouse Ranger District, Idaho Panhandle National Forests.

Parameters	Trend
Physiographic Location	Defoliation is heavier on ridgetops and upper slopes
Depth of Volcanic Ash	Defoliation decreases as depth of volcanic ash increases
Site Occupancy	Defoliation increases as the ratio of total biomass at site productivity increases
Age of Host Trees	Little or no defoliation in stands with average host age less than 50 years
Proportion of Grand Fir in Stand	Rate of defoliation of grand fir increases as the proportion of grand fir the stand increases

Silvicultural Management

Preventing Tussock Moth Outbreaks on high-hazard sites in Idaho

- **Mature stands composed mostly of grand fir and Douglas-fir**: Harvest and establish seral species in stands .
- **Young pine or larch stands:** Thin one or more times to encourage their growth.
- **Multistoried stands with a diverse mixture of tree species, age classes, and sizes**: Improve growth of trees in the intermediate and lower stand levels by felling diseased and decadent trees in the overstory, followed by thinning to favor pines or larch.
- **Pole-sized, dense, even- aged stands composed predominantely of grand fir:** Use a multiple thinning approach. Remove intermediate, suppressed, and a few codominant trees during the first thinning. Followup treatments should be made at 3- to 5-year intervals to open up the stand gradually. Favor species other than grand fir or Douglas-fir as leave trees.
- **Mature stands composed of predominantly pines or larch with a distinct understory of grand fir or Douglas-fir seedlings or saplings:** Prescribed burning may destroy the unwanted understory which would develop into a high-hazard stand .

Silvicultural control offers the only long-term solution for high-hazard sites.

Chemical and biological pesticides can reduced the severity and longevity of an outbreak.

Reducing Douglas-fir Tussock Moth hazard in Montana forests

No hazard rating system has been developed for this state, but it seems the purer stands of Douglas-fir are more susceptible. High -hazard stands can be altered through silviculture. Brookes and others (1978) recommended the following practices.

⇒ **In mature and overmature stands**, regeneration cuts should be designed to establish seral species to develop new stands dominated by species other than Douglas-fir at maturity.

⇒ **In all stands with host species**; maintain vigorous trees.

Chemical Control

Past epidemics were aerially sprayed with chemical insecticides.

Carbaryl (Sevin-4-0i1®), Dimlan® (diflubenzuron), *Bacillus thuringiensis* (a bacterium), and a nucleopolyhedrosi s virus are registered for application; In addition, carbaryl is registered for ground sprays.

Natural Control

Mortality from starvation, weather, parasites, predators, and mainly virus, terminate epidemics.

- Lack of new foliage can cause high mortality in young larva populations and lack of any foliage causes older larvae to migrate which makes them vulnerable to predation and starvation.
- Frost damage to current year's foliage can starve high numbers of early instars.
- Excessive heat and associated dehydration cause mortality and may cause latent virus to become virulent.

Recognizing Douglas-fir Tussock Moth

Douglas-fir tussock moth is one of the easiest forest pests to identify because some obvious signs of its presence are apparent the entire year. Look for cocoons and egg masses from August until May. Look for hairy larvae from late May until August on foliage. First instars are gray with long hairs. Later instars develop four dense tussocks (brushes) of yellowish-brown hairs on their "backs". Mature larvae are up to 30 mm long, have two long, dark tufts or pencils (horns) of hair just back of the head, a similar but longer pencil on the posterior end, four tussocks on their backs, and the rest of the body is covered with short hairs radiating from red, button-like centers.

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May 2005

By Darren Blackford
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Forest Tent Caterpillar

Malacosoma disstria **Hubner**

The forest tent caterpillar (FTC) is the most widely distributed and destructive tent caterpillar in North America (Furniss and Carolyn, 1977).

Preferred Host
- Quaking Aspen

Minor Hosts
- Popular
- Willow
- Alnus
- Birch
- Cherry

Topics

Key Points

- Complete defoliation of aspen for three or more years may kill or reduce radial growth by 90 percent.
- Forest tent occur throughout Regions 1 and 4 where suitable hosts are found.
- Outbreaks typically last only two or three years but may cover extensive areas.

Damage

Defoliation results from larval feeding that begins about the time aspen buds begin to break. Young larvae of 2-3 mm length emerge as a colony from each egg band and feed initially on the opening buds, later consuming parts of or whole leaves. Defoliation progresses inward and downward from the outer tree crown and is usually complete by mid-June. If tree foliage is denuded before the completion of larval development, larvae migrate and feed on understory shrubs and other vegetation (Cerezke, 1991). Complete defoliation of aspen for three or more years may kill or reduce radial growth by 90 percent.

Life History

Forest tent caterpillar overwinters as larvae inside eggs in masses on twigs mostly in upper crowns. Larvae emerge when leaves begin to unfold and feed for 5 to 6 weeks, or until about the end of June. They do not spin tents, but form silken mats on trunks or branches on which they rest. Pupation takes place in July inside cocoons of pale yellow silk. Cocoons reside in folded leaves, bark crevices, or other sheltered sites. Moths emerge in late July from the cocoons and lay cylindrical egg masses.

Identification

Larvae can bee seen on leaves from mid-May to July. New larvae are black with long hairs. With each instar, markings on its dorsum characteristically marked with whitish or yellowish, keyhole-shaped spots and patches of very fine orange- or reddish-brown lines become more evident (Fig. 1).

Figure 1. Mature larva of the forest tent caterpillar.

Figure 2. Adult moth of the forest tent caterpillar displaying the dark lines along the forewings.

Fifth instars are about 50 mm long. The mature larva is dark brown with a bluish head and blue to blue-black sides. Look for lemon-yellow cocoons in July and egg masses from August to May. Adults are light yellow to yellow brown, with wingspread of 25 to 37 mm (Fig. 2). The forewings are crossed with two straight lines of slightly darker color, and the space between the lines is often darker so as to form a band. The egg masses are deposited as dark-brown, spiral rings completely encircling small twigs (Fig. 3). Eggs are cemented together and are coated with a frothy, glue-like substance which hardens and turns glossy dark brown.

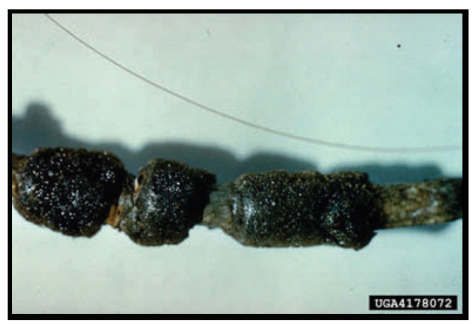

Figure 3. Egg mass deposited on a small twig.

Management

Forest tent caterpillars numbers are regulated by a variety of factors and their infestations do not usually last more than 4 or 5 years in a particular area.

Biological control: The collapse of large outbreaks of FTC can be attributed to depletion of food supplies, unfavorable weather conditions, and natural enemies such as predators, parasites, and pathogens.

- In the Northern Region, parasites and a nucleopolyhedrosis virus usually help terminate outbreaks.
- Below average temperatures from November to April and above average rainfall from May to July are unfavorable to population survival.
- Late spring frosts may kill young larvae before or after they hatch, or the frosts may damage new leaf growth, causing larval starvation.
- When there are high populations, the foliage food source may be depleted 2 to 3 weeks before larval development is complete, forcing larvae to migrate and resulting in high starvation mortality.
- In the adult stage, dispersing moths may be preyed upon by birds; the moths may also be wind-dispersed and perish in non-host areas or when attracted to urban lights. Birds are also effective predators of the larvae and should be encouraged. Up to 40 species of natural parasitic and predatory insects contribute to further losses during egg, larval, and pupal stages.
- One of the most important predators is the tachinid flesh fly (*Sarcophaga aldrichi* Parker), which may destroy over 80% of the larvae.

Cultural control: On small ornamental trees and shrubs in urban and rural landscapes, the egg bands (overwintering stage) can be removed by hand and destroyed between July and the following spring. After hatching, young colonies of larvae can be pruned off or squashed while they are resting in black clusters on the main stem, especially in the evening or on cool days. In June, when the caterpillars are migrating, a collar may be placed around the base of trees requiring protection.

Chemical control: The biological insecticide *Bacillus thuringiensis*, and various chemical insecticides, can be applied to host trees aerially in early spring. It is sprayed onto the foliage of host plants, which are later ingested by the caterpillar. The toxin produced by the bacterium destroys the digestive tract of larvae and usually causes death within a few days after ingestion. Optimum spraying benefits are obtained from treatment applied in the spring when larvae are 12 cm long. The need for insecticidal control measures should be based upon environmental risk assessments and surveys of population abundance (egg band or post-hatch larval surveys).

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March 2006

Forest Health Protection and State Forestry Organizations

By Lee Pederson and Steve Munson, US Forest Service

Topics

Management Guide for

Gypsy Moth

Lymantria dispar (Linnaeus) (Lepidoptera: Lymatriidae)

Gypsy moth is a polyphagous insect, the host range of the North American strain of gypsy moth consists of over 300 species of trees and shrubs compared to the Asian strain which has a host range that exceeds 500 species.

Perferred Hosts:
- *Quercus* and *Populus*

Riparian habitat hosts:
- *Salix*, *Alnus* and *Betula*

Other hosts:
- Lodgepole
- Ponderosa pines
- Western larch
- Spruce
- Douglas-fir

Key Points

- The Asian strain of the gypsy moth is native to Asia.
- Asian gypsy moth female's flight capability and larger host range makes it a serious threat to western forests.
- This insect consumes both old and new needles on conifers which are not able to refoliate.

Overview in the West

Eradication projects have been conducted for European gypsy moth populations throughout the western United States including Utah and Idaho. Early detection, delimitation trapping and the use of a biological insecticide applied when necessary have successfully eliminated introduced populations of this insect in the west. Sporadic introductions of the Asian gypsy moth (AGM) have occurred in the west primarily near west coast cities. However in 2004, an AGM introduction occurred in northern Idaho near Hauser Lake. Environmental consequences associated with the successful establishment of an Asian gypsy moth infestation are more threatening as the female moth is capable of flight. Dispersal distances up to 20 miles could result in an accelerated rate of infestation. AGM presents a more difficult challenge to eradicate because of its broader host range and flight capabilities compared to the North American strain established in the northeast and north central portions of the United States.

Adult female gypsy moth. USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org

History

The European gypsy moth was accidentally introduced into the United States near Boston, Massachusetts during the late 1860's. This introduced defoliator has now expanded its range to include all of the northeastern states, south to North Carolina with outlying infestations found as far west as Minnesota and Iowa. In some forested sites, forest composition has changed too less susceptible species due to periodic heavy defoliation of susceptible hosts.

History

Historical Archive Photo

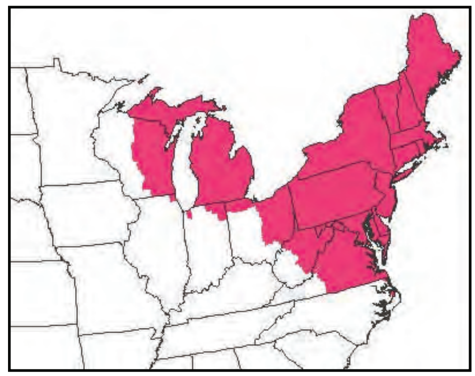
Photo shows use of ropes in climbing trees in treating gypsy moth egg clusters and pruning dead branches from trees when cleaning operations were considered necessary. 1930. USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Various chemical insecticides including lead arsenate, DDT, orthene, carbaryl, the insect growth regulator Dimilin®, biological insecticides such as *Bacillus thuringiensis* (Bt) and a natural virus, Gypchek have been used in suppression and eradication efforts.

The Asian strain of the gypsy moth is native to Asia. It was first identified in North America in late 1991 near the Port of Vancouver, British Columbia, Canada. Ships infested with egg masses from Pacific ports in eastern Russia introduced the pest while visiting west coast ports when larvae hatched from eggs and were blown ashore. These initial introductions were eradicated using multiple applications of Bt and pheromone traps. In the U.S. it has since been found in California, Washington, Oregon, and most recently in Idaho.

In addition to the female's flight capability the Asian gypsy moth has a larger host range than its European counterpart. Some North American western conifers are hosts for this insect and the insect is better adapted to colder climates. These traits make the Asian strain a more serious threat to our western forests if introduced populations of the insect become established.

Gypsy Moth Distribution—2005



Damage

Photo of gypsy moth defoliation. Mark Robinson, USDA Forest Service, www.forestryimages.org

Damage by gypsy moth occurs when the leaves or needles of hosts are consumed by developing caterpillars (Figure 1). During severe outbreaks, complete defoliation of susceptible trees or shrubs may result. Defoliated deciduous trees usually refoliate, but this depletes the trees' stored energy reserves, making them more susceptible to pathogens and other insects. Since this insect consumes both old and new needles on conifers and trees are not able to refoliate, severe defoliation may result in tree mortality. Because deciduous trees do refoliate, it generally takes 2-3 consecutive years of complete defoliation before branch and tree mortality occurs.

Caterpillar silk strands, droppings, destroyed leaves and dead moths are a nuisance in homes, yards and recreation areas. Caterpillar hairs can result in an allergic reaction in some people when exposed to larvae.

Figure 1. Late instars feeding on oak foliage. Photo by: Tim Tigner, Virginia Department of Forestry, www.forestryimages.org

Life Cycle

First instar larvae will drop on silken threads and disperse by the wind called "ballooning"

The gypsy moth life cycle has four stages: egg, larvae, pupa and adult moth. Eggs of the North American strain are laid on the bark of trees (Figure 2), female moths lay egg clusters in virtually any sheltered location including homes, vehicles, firewood, and on outdoor items. For the Asian strain egg masses can be deposited on the same substrates but egg laying behavior varies greatly throughout its native range.

In the Russian Far East, eggs are deposited on leaves, in Mongolia eggs are laid near the forest floor and in Japan the females select trees with light colored bark (primarily Betula) for egg deposition.

Figure 2. Egg mass on bark of tree. Photo by Daniela Lupastean, Faculty of Forestry, University of Suceava, Romania, www.forestryimages.org

Gypsy moth eggs hatch and larvae emerge in the spring after overwintering in protected egg masses consisting of 100-1000 individual eggs. In most cases larvae hatch in synchronization with bud break of preferred hosts. However, egg hatch is predominantly determined by temperature. After hatching first instar larvae spend from 3 –5 days on or near the egg mass, eventually the larvae climb vertically in response to sunlight. Depending on crowding and the suitability of the host, a percentage of the first instar larvae will drop on silken threads and disperse to a new location propelled by wind. This dispersal behavior is known as "ballooning:" Distances of dispersal usually average less than ½ mile (0.80 km), but can be as great as 12 miles (19.3 km) or more.

Once finding a suitable host, the larvae begin to feed. As larvae feed they go through a series of molts and increase in size with each consecutive molt. Instars are the larval stage between molts. Male larvae normally have five instars and females six before entering the pupal stage. Older larvae have five pairs of raised blue spots and six pairs of raised brick-red spots along their dorsal (back) side (Figure 3). If populations are sparse, larvae move up and down the tree depending on light intensity. Larvae in the later instars feed in the top of the tree at night and crawl down the truck to rest during the day. When populations are high, larvae feed continuously day and night until all the foliage is consumed.

McManus (1987) reports the time interval of individual instars can range between 4 to 10 days depending on temperature. The caterpillar stage can last from 8-12 weeks depending on temperature, food quality, and population levels. Caterpillars feed from early May to mid-July in the western U.S depending on elevation and the factors affecting growth mentioned previously. Late instar larvae can reach approximately 2 inches in length.

Figure 3. Photo of older larvae displaying the bright red spots along dorsal side. Photo by: Cooperative Extension University of California

Photo shows a gypsy moth trap in the late 40's. USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Life Cycle

A caterpillar may consume up to one square foot of foliage during its development. Once feeding is completed, the caterpillars are ready to pupate which can occur from late June to early August. Following pupation, which usually lasts from 10 to 14 days, adult moths emerge and mate.

Adult moths of the North American strain are slightly smaller (male wingspan about 1 inch, female wingspan up to 2 inches) compared to the Asian strain (male wingspan 1 ½ inches and female wingspan 3 ½ inches). Adult coloration is similar for both strains. Males are light tan to dark brown with blackish wavy bands across their forewings and arrowhead markings near the leading edge (Figure 4). Female moths are nearly white with faint, dark wavy bands on the forewings (Figure 4).

The North American strain generally deposits her eggs near her pupation site. Female moths of the Asian strain have flight capabilities up to 20 miles (32 km). Eggs are deposited in a single mass and then covered with dense layer of brown hair from the female's body. The cycle is completed when the fully developed embryos hatch in the spring.

Figure 4 male(left) and female (right) Asian gypsy moths - shown for comparison . USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org

Management

Figure 5. Photo shows today's pheromone delta traps being deployed in wooded area near high risk waterway USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org

The risk of introduced North American strain populations becoming established in the west increases as more people move from the generally infested areas in the east to the uninfested west. As trade increases with Asian countries, the risk of introducing the Asian strain to North America also increases.

Gypsy moth detection programs in the west rely on pheromone baited delta traps to locate introduced populations (Figure 5). If a single male moth is caught in the detection grid, the trapping grid is refined the following year. This delimitation trapping grid is used to locate developing populations. Occasionally egg mass and larval surveys are also conducted near a positive catch site if a suspected introduction has occurred.

Detection and delimiting programs are conducted jointly by State and Federal agencies placing pheromone traps in areas of risk. High-risk areas include cities, towns, National and State Parks, and campgrounds where susceptible hosts occur and people are likely to arrive from the generally infested areas. Most of the North American strain introductions occur in the west as the result of humans moving articles with egg masses from the generally infested area in the east.

Management

Spraying DDT in the 1930's. USDA Forest Service Archives, USDA Forest Service, www.forestryimages.org

Eradication programs are initiated in the west if multiple male moth catches of the North American strain occur within detection or delimitation trapping grids or other life stages of the insect is found. If a single Asian gypsy moth adult is captured, current APHIS (Animal, Health Plant Inspection Service) policy is multiple applications of Bt within a one mile radius of the positive catch site.

Historically, conventional pesticides such as DDT, carbaryl, and acephate were used in the northeastern states in gypsy moth suppression/eradication programs. Non-target impacts and human health concerns resulted in discontinuing these products as suppression/eradication strategies for gypsy moth. Suppression/eradication programs for gypsy moth typically involve an integrated pest management (IPM) approach.

Applying a barrier band used to capture migrating caterpillars. (Village of Hartland, 2001)

Integrated Pest Management

The following products or methods are often considered in developing an IPM program for gypsy moth in the west:

- Mass trapping with pheromone baited traps.
- Release of sterile male gypsy moths.
- Mating disruption with a registered synthetic version of the pheromone disparlure in products such as Disrupt®II, Luretape Gypsy Moth®, and Luretape Plus®.
- Diflubenzuron (Dimilin®), an insect growth regulator.
- Nucleopolyhedrosis virus (NPV), a natural disease agent in gypsy moth caterpillars. Gypchek® is a registered NPV product that is available for use.
- *Bacillus thuringiensis* kurstaki (Btk), a microbe that is a natural disease agent of caterpillars. Several registered Btk products are available for use.

Pesticide registrations change frequently; please contact County, State, or Federal pesticide coordinators for a list of registered insecticides.

Management

During severe outbreaks, complete defoliation of susceptible trees or shrubs may result.

Natural enemies play an important role in gypsy moth control during years of light infestations. Wasps, flies, ground beetles, spiders, and ants are common predators. Birds such as chickadees, bluejays, nuthatches, towhees, and robins serve as control agents. Several woodland mammals including mice, shrews, chipmunks, and squirrels are also predators. Over ten foreign biological control agents that includes parasites, predators, and disease organisms specific to gypsy moths, have been introduced for control purposes in North America.

Biocontol for gypsy moth - parastic wasp laying eggs on gyspy moth pupal case. Eggs will hatch into wasp larvae which will feed and kill host. USDA APHIS PPQ Archives, USDA APHIS PPQ, www.forestryimages.org

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No FIDL for this damage-agent

January 2006

By Lee Pederson
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Larch Budmoth

Zeiraphera improbana (Walker)
(Lepidoptera: Olethreutidae)

Topics

Epidemics have been recorded in western larch overstory in northwestern Montana and northern Idaho.

Host:

Western larch

Key Points

- This moth periodically causes severe defoliation to western larch at higher elevations.
- Moths fly in August, and each female will deposit up to 160 eggs over a four-day period.
- Larvae consume needles and frequently gouge out one side of new shoots.

Damage

Larvae consume needles and frequently gouge out one side of new shoots. Outbreaks usually last 1 to 2 years with little permanent damage. In 1985, over 225,000 acres of western larch overstory were defoliated during an outbreak on the Flathead, Kootenai, and Kaniksu National Forests.

Life History

Overwinter as single eggs or in clusters under flat lichens on stems or branches, bark scales, or cone scales. Emerging larvae coincide with bud break and feed singly in the needle clusters. By mid-June, needle clusters are tied together to form tubes that they line with silk. The last instars make shelters of dead needles and silk in mid-July. Several weeks later, they drop to the ground to pupate, making cocoons out of moss and dead larch needles. Moths fly in August, and each female will deposit up to 160 eggs over a four-day period under lichens on the tree surface or in tree niches.

Identification

Larch needle clusters tied with silk created by the budmoth larva. Photo by Scott Tunnock

Larvae may be found in needle clusters, needle tubes lined with silk, or webbed needles from May through July. The first four instars are yellowish-brown with dark brown heads. At fifth instar, they appear dusky-black with a nearly black head, and are about one-half inch in length. Larvae drop to the ground by August and pupate in the duff.

Photo above shows larva of the larch budmoth.

Management

There are no registered insecticides or silvicultural control strategies available. Removing overstory larch from high ridges may reduce stand susceptibility.

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January 2006

Forest Health Protection and State Forestry Organizations

Management Guide for

Larch Casebearer

Coleophora laricella **(Hubner)**
(Lepidoptera: Coleophoridae)

By Lee Pederson
US Forest Service

Topics

First reported in northern Idaho in 1957, the larch casebearer is the most important needle miner found in our Regions.

Host:

Western larch

Key Points

- The larvae can completely defoliate new foliage in early spring.
- Damage identification is similar to, and is often confused with larch needle cast or larch needle blight.
- Larch sawfly damage is similar from a distance, but chewed needles distinguish the damage.
- Look for distinctive "cases" to identify larch casebearer.

Damage

Larch casebearer larvae can completely defoliate new foliage in early spring, especially during its fourth instar. Defoliated trees can put out another flush of needles but summer larvae may consume them. Continued heavy defoliation causes appreciable radial growth loss, and after 5 years branch dieback begins, and trees gradually die.

In 1999, approximately 14,000 acres were defoliated across northern Idaho. Those infested acres declined to only a few hundred in 2000.

Life History

Larch casebearers overwinter as third instars inside cases attached to spurs (buds). Larvae start feeding by May as new needles appear. A larva fastens its case to a needle with silk and then mines the interior as far as it can reach without actually leaving the case. After going through the fourth instar, larvae pupate inside their cases in late May. Moths emerge from the end of May to early July and lay eggs singly on needles. Upon hatching, a larva bores through the eggshell directly into the needle. It mines the needle for about 2 months, and then lines a portion of it with silk. This case is chewed free from the rest of the needle. Both ends of the case are open and the larva feeds from one end of it from mid-August to late October. Larvae leave foliage before needle shed and secure cases to twigs for winter.

Identification

In the spring, tips of mined needles are straw-colored, have holes in them, and curl over or look wilted. Cases, made from hollowed needle segments and containing larvae, may be found on needles or twigs from the end of August through the following June. Cases are straw-colored and rectangular, becoming light gray and cylindrical-shaped during pupation. They are less than one-fourth of an inch long.

In June, when defoliated trees are disturbed, clouds of small, silvery moths will appear. Each female lays fifty to seventy eggs singly on needles from late May to early July. Hatching larvae bore into, and mine needles.

Photo above shows defoliation and needle color change due to feeding of larvae. Photo by Jerald E. Dewey

The distinctive “cases” that help identify the larch casebearer. Photo by Gyorgy Csoka

Management

Direct Control. –The application of insecticides over landscapes is usually not practical, as western larch grows with other species in scattered patterns of stands, groups, and individual trees. However, high value stands or groups of western larch can be treated by aerial application with Fyfanon® ULV (malathion), an insecticide currently registered for use in Montana and Idaho. In addition, Idaho has current registered use of malathion ULV. Chemical insecticide registrations for insect control change frequently. Contact County, State, or Federal pesticide coordinators for updates on current insecticide registrations and application methods.

Silvicultural alternatives. –No silvicultural control strategies are available for larch casebearer, although some research has been done on silvicultural treatment. One study showed larch casebearer populations to increase on saplings where the space between larches increased. Other data suggest that above 4,000 ft. casebearer populations cannot remain dense enough to affect the radial growth of infested larch. Sudden temperature change and late frosts are more common at these higher elevations, which effect larch casebearer development.

Natural control. –Weather, needle diseases, native predators and parasites all help to reduce larch casebearer populations, or keep them in check. In particular, two European parasitic wasps, *Agathis pumila* (Ratz.) a braconid, and *Chrysocharis laricinellae* (Ratz.), a eulophid, were introduced into western forests in the early 1960's, and have since become well established and very successful in reducing larch casebearer populations. Random samples indicate that either wasp can parasitize over 90% of the larch casebearer population in an infested area.

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Damage-agent is not in field guide.

No FIDL for this damage-agent

June 2006

By Lee Pederson
US Forest Service

Forest Health Protection and State Forestry Organizations

Larch Looper

Semiothisa spp.
(Lepidoptera: Geometridae)

Topics

Outbreaks are irregular in the Northern Region and have been known to occur in western Montana.	**Host:** **Western larch**

Key Points

- Infestations usually occur on higher ridges.
- Larvae partially eat needles or cut them off.
- Defoliation usually does not become noticeable until September.
- Promotion of density management and non-host species may reduce host susceptibility.

Damage

Infestations usually occur on higher ridges. Larvae partially eat needles or cut them off. Defoliation usually does not become noticeable until September. No top kill or tree mortality occurs.

In 1979, one outbreak was reported on the Colville National Forest in Washington. In British Columbia, Canada, outbreaks occurred in 1977 and 1990 around the west arm of Kootenay Lake, 50 miles north of the Idaho port of entry. Heavy defoliation by the larch looper lasts only 1 year and no tree mortality has been recorded.

Photo displays larch looper defoliation on side of mountain. Scott Tunnock, USDA Forest Service, www.forestryimages.org

Life History

Pupae overwinter in duff, with moths emerging in late spring to lay single eggs on needles that hatch in about 14 days. Larvae feed until September then drop to the ground to pupate. More extensive information regarding the life history of this moth in the Northern Region is unavailable.

Identification

Larvae are distinguished by the absence of mid-abdominal prolegs and a "looping" characteristic when crawling. Mature larvae or "inchworms" are either green or brown in coloration, with the green variety having distinct pale lateral stripes. The length of mature larvae ranges from 20-28 mm.

Usually by the time defoliation is detected, larvae have dropped to the ground to pupate under the duff near the soil. Pupae have brown bodies and greenish wing covers and are about 15 mm long. Photo shows both green and brown coloration, note the pale lateral stripes on the green larvae.

Management

Rodents, mainly shrews, apparently eat enough pupae to terminate infestations in 1 or 2 years. Parasitism and disease are also control elements that limit outbreak potential. Promotion of density management and non-host species may reduce host susceptibility. Currently, there are no insecticides registered for larch looper.

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Related section in field guide.

January 2006

Forest Health Protection and State Forestry Organizations

By Lee Pederson
US Forest Service

Management Guide for

Larch Sawfly

Pristiphora erichsonii **(Hartig)**
(Hymenoptera: Tenthredinidae)

Outbreaks can occur at irregular intervals in any western larch stands throughout the host range.	**Host: Western larch**

Topics

Key Points

- Larvae feed on needles of older twigs, resulting in needles with a "notched" appearance.
- Heavy populations can completely strip trees.
- Adult larch sawflies are actually non-stinging wasps that appear early to mid-summer.

Damage

Larvae feed on needles of older twigs, resulting in needles with a "notched" appearance. Heavy populations can completely strip trees. Epidemics seldom last more than 2 years, and permanent damage to trees is uncommon.

Defoliation is similar to that caused by the larch looper. Light damage may be confused with larch needle cast, larch casebearer, larch budmoth, or larch needle blight damages. Close examination will reveal distinct differences.

One of the largest outbreaks occurred in western Montana and northern Idaho in the mid- 1960's, and ended by 1967. Another outbreak caused considerable damage in northwestern Montana in 1977.

Life History

Pre-pupal larvae overwinter in cocoons in duff. Pupation occurs in the spring, and adults emerge from June into July. The female "saws" slits into the underside of current shoots and deposits a single egg in each slit. Larvae emerge in about 10 days and feed gregariously until late August. Mature larvae drop to the forest floor, crawl into the duff and spin tough, papery, brown cocoons for overwintering.

Identification

Adult larch sawflies are actually non-stinging wasps that appear early to mid-summer. They are about three-eighths inch long, black in color, with a characteristic orange band around the abdomen.

Look for colonies of larvae typically feeding on needles from late June through August. New larvae are cream-colored with brown heads. Mature larvae are gray-green along the back and whitish beneath with shiny, jet-black heads. They are about three-fourths inch long. Papery, capsule-shaped brown cocoons containing pre-pupa larvae can be found overwintering in duff.

Photo above shows mature larch sawfly larva feeding on larch needles. Photo by James Hanson.

Management

There are no insecticides registered or silvicultural methods developed for control of this insect on a forest landscape or stand setting in our Regions. The reduction of larch basal area in stands may make them less susceptible to outbreaks.

Natural control. –Factors contributing to larch sawfly mortality include parasites, predators, disease organisms, weather, flooding, and competition. Two introduced ichneuman wasps *Olesicampe benefactor* Hinz and the Bavarian strain of *Mesoleius tenthredinis* Morley have proven to be very effective in suppressing outbreak populations.

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March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Lodgepole Needleminer

Coleotechnites milleri Busck

By Beverly Bulaon
US Forest Service

Occasional outbreaks of this moth in the Northern Region. An out break occurred in Yellowstone National Park.

Host: Lodgepole pine

Topics

Key Points

- Larvae can damage every needle on lodgepole pines.
- Out breaks can last from 10 to 20 years.
- After damage the pine needles will turn reddish-brown.
- It may take up three or four years for complete defoliation.

Damage

This moth has never been an economic pest in Region 1. During epidemics, larvae can damage every needle on all lodgepole pines over large areas. Outbreaks can last from 10 to 20 years. After three or four years of complete defoliation, radial growth can be reduced by 90 percent and trees start to die. Damage has been observed on the Lewis and Clark National Forest, Montana.

Photo of stand trees with red needles from Louisiana State University archives.

Life History

This moth has a 2-year life cycle. It overwinters as larvae in old needles. Larvae extend mines in needles in the spring. In mid-July third instars migrate to new needles. Migration increases as larvae grow, and fourth instars mine until fall and then spend winter in needles. In the second spring they mine a few more needles before reaching the fifth or last instar stage. Pupation occurs in June in the last mined needle and lasts about 30 days. Moths can emerge from mid-July to end of August. Eggs are deposited in loosely bound groups usually within hollowed needles. Eggs hatch in September and new larvae bore into individual needles and feed until winter, then become dormant.

Identification

Needles that have been mined will be partially to entirely reddish-brown. Mined needles will be hollowed out with an entrance and exit holes, and contain frass. Larvae are solitary, and will be found one per needle.

Photo of lodgepole needleminer larvae. Photo by Connecticut Agricultural Exp Station.

Management

No registered insecticides or silvicultural methods of control are available. Aerial applications of malathion have been tested. Moths in late summer may be killed by violent storms, or storms can knock pupae and eggs in needles off trees. Natural controls such as parasites, diseases, or birds do not end epidemics.

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Related section in field guide.

No FIDL for this damage-agent

Nov 2005

Forest Health Protection and State Forestry Organizations

Management Guide for Other Needleminers

Ponderosa needleminer *(Coleotechnites moreonella* (Heinrich))
Pinyon needleminer *(Coleotechnites sp.)*
Spruce needleminer (*Endothenia albolineana* (Kearfott)
Hemlock needleminer (*Epinotia tsugana* (Freeman))

Topics

Ponderosa needleminer
Hosts: ponderosa pine
Distribution: In parts of Wyoming, throughout host range, locally heavy populations

Pinyon needleminer
Hosts: Singleleaf pinon, pinon pines
Distribution: Utah, Nevada, and Wyoming

Spruce needleminer
Hosts: Englemann spruce, Colorado blue spruce
Distribution: Throughout range

Hemlock needleminer
Hosts: mountain hemlock
Distribution: Utah

Key Points

- Other needlemining species have a 1-year lifecycle.
- Needleminers overwinter as pupae or larvae in the old needles.
- Mined needles may drop prematurely.

Damage

Needlemining causes damage to foliage and detracts from the tree's appearance.

During epidemics, larvae can destroy every needle on host trees over large areas. Outbreaks can last from 10 to 20 years, and after three or four complete defoliations radial growth can be reduced 90 percent and trees start to die. Trees weakened by needleminers may be attacked and killed by bark beetles. Damage is most conspicuous by June and early July.

Needle damage on white spruce. Photo by Steve Katovich.

Life History

Lodgepole needleminers have a 2-year lifecycle, ponderosa needleminers and other needlemining species have a 1-year lifecycle. Needleminers overwinter as pupae or larvae in the old needles. Needleminers that overwinter as larvae extend mines in needles in the spring and pupation occurs in June lasting about 30 days. Moths can emerge from mid-July to September. Eggs are deposited in loosely bound groups usually within hollowed out needles. Eggs hatch approximately in September. New larvae bore into individual needles and feed inside the pine needles, hollowing them out until winter. Each larva completes its development in a single needle. Mined needles may drop prematurely.

Identification

On needles, look for buff to reddish-brown discoloration, entrance and exit holes, hollow and mined areas. Photo to the right are signs of spruce needleminer damage: hollowed out, dead needles webbed to a spruce branch.

Photo by Linnea Gillman.

Spruce needleminer larvae. Photo from Connecticut Agricultural Exp. Station

Management Considerations

No silvicultural treatments are currently recommended for needleminers. Control may not be necessary because the larvae usually feed on old needles providing little nutrition to the tree. However, several years of heavy needleminer feeding does result in visible tree decline.

Highly valued trees can be protected against needleminers by spraying with an insecticide. Timing is always important in treating for insects and this problem is no exception. Treat when eggs hatch, about mid-September. Formulations of chlorpyrifos insecticides can be used for Lodgepole needleminer. Formulations of acephate are registered for Ponderosa needleminer. Be sure to check current product registration listings for individual states prior to use.

Moths in late summer can be killed by violent storms, or storms can knock pupae and eggs in the needles off trees. Natural controls such as parasites, diseases, or birds do not end epidemics.

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Related section in field guide.

Forest Insect & Disease Leaflet

January 2006

Forest Health Protection and State Forestry Organizations

Management Guide for

Pandora Moth

Coloradia pandora **(Blake)**

By Steve Munson
US Forest Service

Topics

One of the largest defoliating insects in North America. Found in the Western United States mainly in Utah, Wyoming, Colorado, Montana, Nevada, California, and Oregon.

Hosts:
- Ponderosa pine
- Jeffrey pine
- Lodgepole pine

Occasional hosts:
- Sugar
- Coulter
- pinyon pines

Key Points

- Defoliation occurs only every other year because of the insects 2-year lifecycle.
- Larvae feed on older foliage, leaving the tree with a tufted appearance
- Tree mortality can occur as the result of heavy repeated defoliation.

Damage

Defoliation occurs only every other year because of the insects 2-year lifecycle. Epidemics occur at intervals of 20 to 30 years and may last from 6-8 years.

Larvae feed on older foliage, leaving the tree with a tufted appearance (Figure 1). Infested trees have a reddish top with foliage only at branch tips. Tree mortality can occur as the result of heavy repeated defoliation. Reduced redial growth and loss of tree vigor occurs during each defoliation event. During the spring, needle growth of all sizes are consumed. However, terminal buds are not damaged thus new needles are formed.


Figure 1. Defoliation damage from the Pandora moth larvae within a pine stand.. Photo by Donald Owen.

Life History

Pandora moths have a 2-year lifecycle, spending the first winter as larvae in the tree canopy and the second as pupae in the litter or soil. Caterpillars prefer to pupate in pumice or decomposed granite soils. The adult moths emerge from pupal cases in June or July. Pupation typically lasts for about a year, but occasionally extends up to four years. Defoliation and adult moth flight occur in alternate years. Females generally do not fly until after mating. Females lay an average of 80 eggs distributed in several clusters, usually on the bark and needles of pines. Eggs are occasionally deposited on the ground litter or brush. Eggs hatch in August approximately 40-50 days after egg deposition. Young larvae feed in clusters on needles of the terminal shoots and overwinter at the base of the needles. Larvae overwinter primarily in the second instar and may begin feeding as early as April in warmer climates.

Identification

Figure 2. Larva of Pandora moth feeding on pine needles. Photo from Forest Service - Region 4 Archives.

Full grown caterpillars are large (2 ½-3" long) with a few stout, branched spines appearing on each segment. Mature caterpillars are gray with a white stripe down their back with orange-brown heads (Figure 2). Adult moths are gray, thick bodied with a wingspan of three to five inches. Forewings are brownish gray, hind wings are pinkish gray, with a black dot and wavy line on each wing (Figure 3). Female moths have narrow antennae whereas the males are feathery. Moth flights to nearby sources of light are sometimes the first indication of an increasing population of Pandora moth. Masses of greenish or brownish droppings can be found under infested overstory trees due to the enormous quantity of needles consumed by caterpillars. Pupae are stout, dark reddish or purplish-brown, 1 to 1 ½ inches long and found in the soil.

Figure 3. Female Pandora moth with distinctive narrow antennae. Photo from Forest Service - Region 4 Archives.

Some Native American tribes have collected and used Pandora moth larvae and pupae as food, which may have affected local populations of the insect.

Management

Natural Control- There are some natural control factors such as overwintering mortality, predators, parasites, high soil temperatures as larvae enter the soil for pupation and a polyhedrosis virus (wilt disease) affecting mature larvae. Rodents, ground squirrels and chipmunks are major predators of pupae. A few species of birds are predators of eggs (nuthatches and creepers) and larvae (Steller jays and vireos). Some birds are repelled by the spines on the larvae.

Chemical Control- Insecticide treatments are generally not required since natural control agents suppress outbreaks before extensive tree mortality occurs. Broad spectrum insecticides may be available in some states to suppress populations. *Bacillus thuriengensis* may be an effective insecticide treatment if applied to early instar larvae. Prescribed burning treatments have been used to kill pupae and larvae with variable success.

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Related section in field guide.

Forest Insect & Disease Leaflet

March 2004

By Laura Lazarus
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Butterfly

Neophasia menapia (Felder & Felder)

There has only been one outbreak in the Northern Region which began in 1969 and lasted until 1973.	**Primary Host:** Ponderosa pine	**Minor Hosts:** • Douglas-fir • Western white pine • Larch • Western hemlock

Topics

Key Points

- Under ordinary conditions larvae feed only on older needles
- Outbreaks occur at irregular intervals.
- These outbreaks of the pine butterfly result in severe defoliation and tree death.

Damage

Repeated defoliation can kill ponderosa pine, reduce radial growth up to 70 percent, or weaken trees enough to attract bark beetles. Under ordinary conditions larvae feed only on older needles, and not a big problem, but in epidemics, they consume new needles also. In normal years, pine butterfly feeding causes the twigs to be defoliated with the exception of the current year's growth. Trees then appear thin and only "tufts" of new needles remain.

Life History

The pine butterfly has one generation a year. It overwinters as eggs in single rows on a needle. Eggs hatch when new ponderosa pine shoots are about 2 inches long. Immature larvae feed in colonies on a single needle, usually on older needles, but later instars feed individually. Pupation occurs about August on needles, twigs, and ground vegetation. Peak butterfly flight occurs about mid-August and may occur until early October. The adults mate and deposit green eggs in rows on the current year's foliage within a few hours after emergence.

Pine butterfly larva.
Photo by Ladd Livingston

Pine butterfly at the pupal stage. Photo by Jed Dewey

Identification

Emerald green eggs can be found on needles from September to June. Look for immature pale green larvae with black heads, or full-grown larvae about 25 mm long with two white lateral stripes and green heads from June to August on needles. Pupae are also green with white stripes and are attached to needles, branches and stems, usually in August. White butterflies with black wing markings can be found flying around tree canopies from August to early October.

Pine butterfly displaying the black wing markings. Photo by Terry Spivey.

When ground observations of about 24 butterflies per tree are made, an outbreak can be expected next year.

Management Considerations

Direct Suppression

The bacterium, *Bacillus thuringiensis var. kurstaki*, is the only insecticide registered for aerial application to suppress the pine butterfly. This insecticide kills the larvae of moths and butterflies without causing direct adverse affects on other plants or animals.

Silvicultural Management

No correlation has been found between crown classes or diameters and resultant mortality from defoliation. Tree vigor, prior to defoliation, is important in a tree's recovery from defoliation. Damage might be reduced by applying prescriptions which favor stand species diversity and which would maintain vigorous growth in stands. This is a long-term action alternative and will do little to suppress the current outbreak. During epidemics, dead or weakened trees should be salvaged to reduce ecomonic loss and buildup of bark beetles.

Natural Control

Starvation, parasitoids, and especially predators usually terminate epidemics. *Theronia atalantae fulvescens* (Cresson), an ichneumonid wasp, is an important parasitoid of the pine butterfly.

Maintain Present Management

This alternative allows for infestations to continue until they decline naturally. Outbreaks usually persist two to five years before they are controlled by natural enemies and other factors.

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Related section in field guide.

March 2004

Forest Health Protection and State Forestry Organizations

By Dwight Scarbrough
US Forest Service

Management Guide for

Pine Looper

Nacophora mexicanaria (Grote)

Topics

Two separate infestations occurred in eastern Montana from 1969 to 1970 and 1971 to 1972.

Host: Ponderosa Pine

Key Points

- The pine looper is native to the western United States and British Columbia, Canada.
- Larvae of this moth are known as “loopers” or “inchworms”
- This insect has not been reported as being economically important.

Damage

Larvae feed on both old and new needles. Needles are often eaten down to the sheath. Trees of all sizes are attacked and mortality results if all the foliage is stripped. Defoliation by pine looper can result in tree mortality, especially of younger trees. Some mature trees may be killed by defoliation and others can be predisposed to secondary attack by pine engraver beetles (Ips).

Defoliation by pine looper can result in tree mortality, especially of younger trees.

Life History

Found throughout much of its host's range. Overwinters as pupae in the duff. Adult moths emerge from mid-June through early July. Eggs are laid in long clusters or masses on needles and irregular patches on branches. Larvae emerge in July and feed singly on needles until September, then drop to the ground to pupate in the duff.

Identification

Look for "inch worm" type larvae on needles from late June to September. The first two instars have smooth bodies and are light brown with yellow stripes along the sides. Instars III through V have varying shades of brown without stripes and have numerous tubercles the length of the body. They resemble pine twigs (see photo).

Pine looper larvae resemble a pine twig.

Mature larvae are up to 1-1/2 inches long. Dark brown pupae may be found in the duff from September to June. Adults, appearing in early summer, are mottled gray-brown with zigzag markings on wings and wingspan of up to 2 inches. Eggs are laid in clusters on the needles and stems in early July.

Adult Pine looper moth, note the zigzag markings on wing.

Management

No chemical or silvicultural methods of control have been developed for this moth. Aerial sprays would probably be effective.

Natural Controls

Parasites, predators, and diseases are common during outbreaks of the pine looper. Three parasites, *Coelichneumon pulcherior* (Heinrich), *Coelopisthia suborbicularis* (Provancher), and *Euphorocera edwardsii* (Williston) attack the larvae.

- A predatory bug, *Apateticus bracteatus* (Fitch) is also associated with looper outbreaks. Wild turkeys have often been observed consuming vast numbers of pupae during outbreaks.
- An unidentified bacterium is often the major cause of population collapses as it infects the larvae and causes death before pupation.
- A pathogenic fungus, *Paecilomyces farinosus* (Dicks. Ex Fries) has also been isolated from pupae, it is not known how effective it is as a natural control agent.

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April 2004

Forest Health Protection and State Forestry Organizations

By Beverly Bulaon
US Forest Service

Management Guide for

Pine Needle Sheathminer

Zelleria haimbachi Busck

Occasional epidemics of this moth occur in the Northern Region.

Hosts:
- **Lodgepole pine**
- **Ponderosa pine**

Topics

Identification

- Look for sheath-mining damage.
- Silken webbing around needle bases from June –August.
- Faded, damaged needles can easily be pulled out of sheaths.

Damage

Needles are attacked throughout their period of elongation by developing larvae. Larvae cut off needles within the sheath causing branch tips to thin out. During the mid-1960's and 1974, heavy defoliation was evident on the Flathead National Forest, Montana. Also in 1974, an outbreak was found north of Coeur d'Alene,Idaho. No economic damage has been recorded in Region 1.

Life History

This insect overwinters as first instars in needles. Larvae lengthen mines when temperatures are favorable during winter. Second instars emerge from mined needles when shoots open, and feed within new needle sheaths. Last instars bore holes in sheaths and only insert their heads and first few segments. Silken webbing is woven around needle bases. After 3 to 4 weeks of sheath-mining, or around mid-July, larvae begin to pupate. Pupation takes place in the mass of silken webbing around needle bases and moths emerge in August. Eggs are laid singly on needles and current foliage is preferred. Eggs hatch in about 10 days and larvae bore directly through the bottom of eggs into needles to spend winter.

Management

- ⇒ Larvae mining needle-sheaths can be killed with ground application of malathion.
- ⇒ No silvicultural controls have been developed.
- ⇒ Parasitism is an important regulator of sheath-miner populations.

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Cite as: Bulaon, B. 2004. Management guide for pine needle sheathminer. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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May 2004

By Carl Jorgensen
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Sawflies

Neodiprion nanulus contorae **Ross**
Neodprion edulicolus **Ross**
Neodprion **spp.**

The species of *Neodiprion* are similar in habits and appearance. Some attack young trees.

Hosts:

- Ponderosa pine
- Lodgepole pine
- Native and ornamental pines

Topics

Key Points

- Important pest in plantations.
- Attack trees of all ages.
- Sawflies may develop to outbreak locally or extensively.
- Outbreaks typically are of short duration and rarely kill trees.
- Natural enemies and weather main factors in controlling this insect.

Damage

Larvae can strip all old needles from trees. New foliage is not preferred. Mortality and top kill can occur on some hosts after consecutive years of defoliation. Pinyon sawfly causes most serious damage in small trees although trees of all sizes are defoliated. Some young trees are killed and others are rendered unfit for Christmas trees.

Life History

The life cycles of all *Neodiprion* spp. are similar and have one generation per year. The adult female uses a saw like ovipositor to cut slits in the pine needle where she lays her eggs in late summer and fall. The eggs over winter and hatch from mid to late spring. The small larvae feed gregariously on old foliage and the mature larvae feed individually during the summer. While most cocoons are formed in the duff and upper layer of the soil; some are found on foliage, bark and other surfaces. They pupate in late summer and the adults emerge in late summer and fall.

Identification

Look for larvae feeding in groups into July. Larvae resemble caterpillars but have six or more prolegs and one pair of eyespots on the head. There is wide variation in color, although most species' larvae are green or black. The adult females are about three-eighths inch long and yellow-brown with yellowish legs. The adult males are slightly smaller and darker.

Mature pine sawfly larvae.

Management

When only a few colonies of larvae are present on small trees, they can be picked easily by hand, shaken from the tree and destroyed, or washed-off with a high pressure hose. When larvae are present in an area or large numbers, registered insecticides can be used. Insecticides should be applied as soon as possible after hatching for best control on high-value trees. Typically, predators, parasitoids, and a nucleopolyhedrosis virus manage outbreak populations within two years, so management is often not necessary

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Cite as: Jorgensen, C. 2004. Management guide for pine sawflies. 3 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Damage-agent is not in field guide.

No FIDL for this damage-agent

January 2006

By Leah Chapman

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Tussock Moth

Lymantriidae: *Dasychira grisefacta* (Dyar)
formerly *Parorgyia grisefacta* (Dyar)

Topics

Pine tussock moth is a rarely seen, solitary defoliator.

Principal host:
Ponderosa pine

Potential hosts:
Douglas-fir, western hemlock, Englemann spruce, white spruce and to a lesser extent, subalpine fir, grand fir, western larch, western white pine and lodgepole pine.

Key Points

- Adults are active from late July through mid-August.
- Larvae prefer new growth but will consume old growth during outbreaks.

Damage

It normally prefers new growth, so younger stands are more likely to experience injury. With increased availability of young foliage, the likelihood of boosting moth populations to outbreak conditions also increases. Once populations have risen, old growth can be consumed as well as new. Although outbreaks are very uncommon in the Northern region, from 1965-1967, Eastern Montana's Custer National Forest was heavily infested.

Life History

Adults are active from late July through mid-August. Females lay eggs in clusters on pine needles. After hatching, larvae consume small amounts of the host tree foliage before hibernating under bark scales. The following spring, feeding is resumed and by mid-summer pupation occurs in cocoons secured to twigs.

Photo above show cocoons attached to twigs within pine needle foliage.

Below is closer look of the pine tussock moth cocoon.

Identification

Pine tussock moth larvae, in the last stage before pupation, are about 44 mm long. The head is dark brown and the body is rusty-brown with blackish sides. It has fore and aft black hair pencils that are typical of the genus along with ash-colored brushes of hairs above and numerous tufts of white plumed hair scattered over the body. Adults are grayish brown with light and dark bands across the forewings. The wingspan is 30-40 mm. Eggs are white spheres occuring in loose clusters.

Adult pine tussock moth

Control

Nucleopolyhedrosis virus (NPV) has been reported to cause a decline in population numbers during outbreak conditions

Cite as: Chapman, L. 2006. Management guide for pine tussock moth. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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April 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Variable Oakleaf Caterpillar

Heterocampa manteo **(Doubleday)**

By
Dwight Scarbrough
US Forest Service

Topics

In North Dakota, outbreaks occurred in 1971-73 and 1981.

Hosts:

- **All oak species, especially white oak**
- **Paper birch**
- **Beech**
- **American basswood**

Key Points

- Outbreaks are infrequent and cause little economic impact.
- "BT" is a biological control that provides temporary control.

Damage is mostly a matter of aesthetics

Trees of all sizes may be attacked. Defoliation ranges from "shot hole" type feeding to complete stripping of leaves. Because defoliation occurs late in the summer, saplings or larger trees can withstand two or three years of extreme defoliation before any mortality occurs.

The major impact during an outbreak is unsightly defoliation that degrades forest recreation sites. Usually, there is no major economic impact caused by this insect.

Life History

Overwinters as prepupae in cocoons under forest litter. In northern latitudes of it's range, pupation occurs the following spring and moths emerge in late June through July.

Females lay their eggs in clusters of 30 to 300 on the lower surface of host leaves. Larvae feed during July and August, then drop to the ground in early September to spin cocoons in the forest litter.

Recognizing Variable Oakleaf Caterpillar

Photo by Ron Billings, Texas Forest Service

Look for larvae on leaves during July and August. Full-grown larvae are yellowish-green, variously marked, and usually have a broad band down the back. They are about 37 mm long.

Photo by Scott Tunnock, USDA Forest Service

—CAUTION—

Variable oakleaf caterpillars produce formic acid when disturbed. Excessive handling may result in skin irritations for susceptible people.

Natural Controls

Insect parasites and predators destroy eggs, larvae, and pupae. Winter mortality also helps keep most infestations in check.

Biological Control

The bacterium, *Bacillus thuringiensis*, can be used for aerial and ground applications to protect high value trees.

No chemical nor silvicultural control methods have been developed to control this moth.

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May 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Blackheaded Budworm

Acleris gloverana (Walsingham)
(Lepidoptera: Tortricidae)

By Carol Bell Randall
US Forest Service

Topics

Defoliation of the western blackheaded budworm has often been accompanied or followed by high populations of other defoliators such as the hemlock sawfly and the spruce budworm.

Hosts

- Western hemlock
- Mountain hemlock
- True firs

Minor hosts:

- Spruce
- Douglas-fir

Key Points

- All ages are susceptible.
- Impacts from western blackheaded budworm defoliation start to appear after two years of moderate to severe defoliation.
- Western blackheaded budworm defoliation reduces the vigor of affected trees and may increase their susceptibility to attacks by secondary pest species.

Periodic outbreaks in predictable locations

The western black-headed budworm is an important defoliator of western hemlock. Western hemlock and true firs are the preferred hosts, but spruce and Douglas-fir can also be fed upon. When conditions favor a high population of the western blackheaded budworm the larvae can cause extensive defoliation. Trees of all ages may be killed, top-killed, or severely weakened.

The western blackheaded budworm is a native insect of western North America. The range of the western blackheaded budwormis from northern California and areas of the Rocky Mountains northward into the Yukon and Northwest Territories in Canada and southeastern Alaska. The eastern portion of its range may overlap with that of the eastern black-headed budworm, *Acleris variana* (Fernald), which extends to the Atlantic seaboard.

Damage

Western blackheaded budworm prefers to feed on the upper crowns of dominant and co-dominant trees. Healthy western hemlock appear to be able to withstand one year of severe defoliation without sustaining serious damage, often recovering within a year or two with minimal amounts of top kill or growth loss. Impacts from western blackheaded budworm defoliation start to appear after two years of moderate to severe defoliation. Western blackheaded budworm defoliation reduces the vigor of affected trees and may increase their susceptibility to attacks by secondary pest species.

The western blackheaded budworm may occur simultaneously with other defoliators. Under conditions of severe attack by multiple species of defoliators, trees may be completely defoliated in a single year and damage may be more severe.

Mortality- although this budworm is not know as a tree killer, mortality losses can occur when trees receive multiple years (>2) of moderate to severe defoliation.

Defoliation Impacts:

- Incremental growth loss- radial and height increment may be reduced by up to 50% for approximately 4 years following the collapse of an outbreak.
- Top-kill- especially in immature stands, results in the loss of previous height increments and can cause deformities in the stem (forks and crooks) as compensating laterals assume dominance. Stagnation of height growth in mature trees is another impact of defoliation.
- Mortality- although this budworm is not know as a tree killer, mortality losses can occur when trees receive multiple years (>2) of moderate to severe defoliation.

Life History

Eggs laid singly on the underside of needles, usually near branch tips in the upper crowns of susceptible host trees.

Western blackheaded budworm spends the winter as eggs laid singly on the underside of needles, usually near branch tips in the upper crowns of susceptible host trees.

Eggs hatch in the early spring and the small, pale yellow green larvae with black heads either mine needles or bore into opening buds where they usually remain until after the second molt. Mined buds are destroyed, one larva often boring into two or more buds. Needles of the opening buds are usually only partially eaten and as the larvae grow they clip some needles off at the base and web them together to construct loose shelters. The older larvae leave the buds and move into these shelters, leaving the shelters to feed.

As the larvae grow their bodies become green, and between the fourth and fifth instars the color of the head changes to brown. Feeding continues on the new foliage until it is depleted and then old foliage is consumed. They are wasteful feeders, leaving partially consumed needles that cause heavily infested trees to have a reddish brown appearance. A mature larva is about ½ inch long.

Pupation takes place within or near their webbed shelters from mid July to mid-August depending upon latitude. Pupae are green to brown and have a square cut abdomen. Pupation lasts from 10 days to two weeks.

Western blackheaded budworm populations usually build up for 2 – 3 years, remain at a high level for 2 or 3 years, and then decrease, often abruptly.

Identification

The yellow to green body without spots and the dark head capsule distinguish the western blackheaded budworm larva from other budworm species.

Adults are usually mottled gray with brown, gray, or white bands across the wings. Some have a yellow, orange, or white stripe down each wing. The moths have a wing span of ¾ of an inch. Moths may live up to a month or more and can lay as many as 150 eggs, but the average is about 80. Moths prefer to lay eggs in the tops of trees; during an outbreak eggs may be laid through-out the crown.

Western blackheaded budworm larvae feeding on fir needles. Photo by Edward Holsten.

Visible defoliation occurs from late June through July in the intermountain west and from mid July to mid August on the coast.

Signs of Attack

- Defoliation is often the first indication of western blackheaded budworm outbreaks. They are wasteful feeders not usually consuming entire needles. The dead, partially consumed needles turn red. Defoliation appears as a reddish haze in the summer; faint initially (first year) but becoming very bright during the summer (end of July) at the peak of the outbreak. Discoloration is usually heaviest in the upper crown.
- Look for black-headed, green-yellow bodied larvae feeding on new foliage; careful observation may reveal webbing on twigs. Adults may be seen in flight from late August to October, and eggs are present in the fall and winter.
- Old infestations may be identified by scattered dead topped trees, or in the case of severe repeated attacks, by groups of dead standing trees.
- Western blackheaded budworm populations often increase so rapidly that forests which are green and healthy one year may appear red the next. Defoliation becomes noticeable from late June to late July, depending upon latitude.

Hemlock sawfly, hemlock looper, and western spruce budworm populations may increase simultaneously with western blackheaded budworm populations. Walkthroughs of the affected area should be done to confirm the causal agent.

Monitoring

Population Monitoring and Predictive Sampling—Larval and egg sampling can detect building populations years prior to an outbreak. From egg sampling results during the early fall, defoliation predictions can be made for the following summer.

- **Larval Sampling:** To dislodge western blackheaded budworm larvae from sample trees, beat branches with a 8 foot pole held over a 6 x 9 foot ground sheet. Each plot sample consists of 3 trees. Annual sampling in this manner will detect increases in budworm populations prior to the occurrence of outbreaks.
- **Egg Sampling:** Sample a 45 cm branch tip per tree from each of the north and south aspects, from the mid-crown of 10 trees per sample location. The average number of healthy eggs per branch provides an estimate of next years defoliation levels as listed in Table 1. Visual assessments or the hot water method (as outlined for the western hemlock looper egg sampling) should be used to count the number of eggs per sample.

Table 1. Predicted defoliation levels for the western black-headed budworm based on the numbers of eggs per branch

Numbers of eggs per branch	Predicted Defoliation
1-5	**Trace** (evidence of feeding barely detectable close up)
6-25	**Light** (some branch and/or upper crown defoliation; barley visible from the air; and 25% average needle loss)
26-59	**Moderate** (pronounced discoloration and noticeably thin foliage; severe top defoliation; and 26-60% average needle loss)
60+	**Severe** (top and many branches completely defoliated; most trees more than 50% defoliated; and 61% average needle loss)

-Warning-

Remember, when using pesticides, always read and follow the label!

Please contact Forest Health Specialists before organizing a spray project for this insect.

Management Considerations:

Prevention-- Stand tending treatments such as spacing and fertilization will help maintain a healthy stand that is more resilient to budworm defoliation. Well spaced, even-aged mature stands should be less susceptible and suffer fewer impacts from western blackheaded budworm defoliations,

In certain areas where the probability of periodic outbreaks is high and where the pre-harvest stand composition is mostly preferred host species, reforestation prescriptions might include higher percentages of non-host species and irregular distribution of stand age classes.

Indirect Control—Western blackheaded budworm populations are normally held to low levels by several natural factors:

- Parasites- a recent study has confirmed the importance of egg and larval parasitism.
- Predators including insects and birds- small forest song birds are known to be effective natural enemies.
- Diseases- caused by fungi and viruses have been found in collapsing populations.
- Abnormal weather conditions- especially cold, wet summer periods.
- Starvation, caused by too many larvae and insufficient food, often is the most significant factor in terminating an outbreak.

Abundant preferred food supply and reduced occurrence of the natural control factors, alone or in combination, are suspected major reasons for the periodic population surges or outbreaks of the western black-headed budworm.

Phermones—Two attractant pheromones for the western blackheaded budworm have been identified: (E)-11, 13-Tetradecadienal and (Z)-11, 13- Tetradecadienal. To date no pheromone management or monitoring systems have been devised for this moth.

Pesticides—Only experimental aerial spray applications or operational trials have been made from 1956-1990 for control of damage by this occasional pest. Most recently trials using commercial formulations of the bacterial insecticide *Bacillus thuringiensis kurstaki* (Btk) suggest the possibility of strategic applications of this material, particularly within parts of sensitive coastal watersheds.

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Photo images: www.forestryimages.org/browse/subimages.cfm?SUB=87

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Related section in field guide.

No FIDL for this damage-agent

April 2005

By Carol B. Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Western False Hemlock Looper

Nepytia freemani (Munroe)
(Lepidoptera: Geometridae)

The western false hemlock looper is a native pest of immature Douglas-fir in the northwestern United States (south through Idaho to Utah), southern interior British Columbia, and southwestern Alberta.

Host:

Douglas-fir

Occasional hosts:

Western hemlock, spruce, alpine fir, larch, ponderosa pine

Topics

Key Points

- Larval populations periodically reach epidemic proportions.
- During outbreaks trees may be entirely defoliated in one season.
- Douglas-fir are seldom killed after only one year of severe defoliation.

Damage

Larvae are wasteful feeders; eating only parts of needles which they chew off at their base. Partially consumed needles dry out and change color, producing a reddish brown appearance of damaged trees.

Defoliation appears in June in the upper crowns, and by July or August entire trees may be defoliated.

During outbreaks trees may be entirely defoliated in one season. Douglas-fir are seldom killed after only one year of severe defoliation, but repeated attacks may result in top-kill or whole tree mortality.

Eggs are often laid on defoliated twigs and the resulting larvae may quickly consume new, adventitious foliage causing twig mortality.

In late summer the ground beneath heavily defoliated trees may be carpeted with partially eaten needles and frass.

Identification

Signs of Attack—Defoliation appears in June in the upper crown, and by July or August entire trees may be defoliated.

Look for slim, tan, black and yellow stripped larvae June - August. Extensive webbing is evident in heavily infested stands. Look for naked pupae in August. Grey colored moths with strong black wing markings emerge from August through October and fly at night.

Eggs are present in the fall and winter. By fall, the ground beneath heavily defoliated trees may be carpeted with partially eaten needles and insect frass.

Feeding by western false hemlock looper begins in new foliage of tree tops. Photo by BC Ministry of Forests.

Life History

Eggs are laid from August to October, singly or in groups of up to 13, although the average number of eggs is about 4 per group. Eggs are usually laid on the underside of host needles, but when defoliation is severe eggs may be found on bud scales, twigs, or in bark crevices. They hatch the following spring.

Young inch worm larvae begin to feed on new foliage in the upper crowns of trees during late May, progressing to the older foliage when new foliage is depleted.

Late instar larva of western false hemlock looper. Note square head and alternating dark and light stripes. Photo by BC Ministry of Forests

Larvae drop to lower branches on silken threads. Mature larvae are about 1 inch long, tan with a broad, reddish brown dorsal stripe boardered by narrow yellow stripes outlined with fine black lines. Each side is marked with a wide yellow stripe. The head appears almost square from above and has black dots.

Although the larvae are solitary feeders, they tend to congregate in loosely webbed enclosures to pupate. Pupae are light amber becoming dark red-brown, ½ to ¾ inch long.

Adult western false hemlock looper displaying the black wing markings. Photo by Scott Tunnock

Pupation occurs in late July or August and adults emerge from August to October. Adult moths are gray with strong black wing markings. Moths are nocturnal fliers. Females lay an average of 70 eggs.

Warning-
remember, when using pesticides, always read and follow the label!

Repeated attacks may result in top-kill or mortality.

Management

Prevention

Preventative treatments can be applied at the planning or prescriptive phase. In areas where the looper has occurred most frequently, management of stands to include a mix of tree species and ages will minimize damage.

Indirect Control

Outbreaks usually last for 1-3 years and collapse rapidly due to exhaustion of the food supply, weather factors, and rapidly building populations of natural enemies such as insect parasites or natural disease agents.

Pheromones

Components of the sex pheromone of the western false hemlock looper have been identified as optical isomers of 3,13-dimethylheptadadecane. To date this information has not been translated into management tools.

Pesticides

Insecticides may be used for direct control, particularly where prevention is impossible and when timber or aesthetic values are high. Advice and technical details concerning ground sprays for individual trees should be available from local pesticide control, horticultural or forestry officials. Please follow the label instructions carefully.

Aerial spray operations with synthetic organic insecticides and the bacterial agent *Bacillus thuringiensis kurstaki* (Btk) gave some protection, these experiences did not result in established spray protocols for this insect.

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Photo Credits:

Natural Resources Canada - Canadian Forest Service

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No FIDL for this damage-agent

April 2005

By Carol Bell Randall
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Hemlock Looper

Lambdina fiscellaria lugubrosa (Hulst)
(Lepidoptera: Geometridae)

The western hemlock looper is a defoliator whose larvae feed on the foliage of most conifers and some broadleaved species, but prefer western hemlock.

Hosts:

- Western hemlock
- Douglas-fir
- Western red cedar

Occasional hosts:
Subalpine fir, amabilis fir, grand fir, white spruce, sitka spruce, larch.

Topics

Key Points

- Larvae feed voraciously on both new and old foliage.
- Most hemlock can recover from less than 50% defoliation.
- Chewing off needles at their bases causing the stand to appear yellowish-red and then brown in color.

History of Outbreaks and Distribution

The western hemlock looper is a defoliator whose larvae feed on the foliage of most conifers and some broadleaved species, but prefer western hemlock (*Tsuga heterophylla*). Populations periodically increase sharply in coastal and interior forests, persist for 1 or 2 years, and then decline. These high populations often result in the death of large numbers of trees over limited but well defined areas. Although most outbreaks have occurred in mature and over-mature hemlock and hemlock-cedar stands, some infestations have occurred in vigorous hemlock stands 80-100 years old.

Outbreaks are generally brought under control by the action of parasites, predators, and diseases. Heavy rains during the moth flight period can reduce egg-laying and hasten the decline of an outbreak. In northern Idaho and western Montana outbreaks of this insect have been recorded in the 1930's, 1970's, and most recently in 2000-2003.

Relative to other defoliators, the wasteful feeding of this insect increases the amount of damage. Young larvae feed initially on new foliage, but they quickly move to old foliage. They return to the new foliage only when the old foliage is depleted. High populations can remove nearly all the new and old needles in a single season.

The western hemlock looper occurs from Oregon north through British Columbia and up into southeast Alaska. A related species, the hemlock looper (*Lambdina fiscellaria*) occurs in eastern North America from Georgia north to Nova Scotia and west to Wisconsin.

Adult western hemlock looper displaying the black wing markings. Photo by Jed Dewey

Damage

Western hemlock in the interior is intolerant to defoliation so mortality can occur following only one year of heavy defoliation and may continue for up to four years after the collapse of a western hemlock looper infestation. Coastal hemlock seems much more resilient.

Hemlock looper damage usually occurs in mature stands where severe defoliation can result in growth reductions, top-kill, and tree mortality.

Defoliation occurs most commonly on sites located in valley bottoms with a major western hemlock component, and is often in distinctive elevational bands.

Historically, this insect only reached epidemic levels in old growth, multi-canopy forests since it prefers to lay its eggs in mosses and lichens that hang from these older trees. Areas of second growth, single canopy forests were affected during recent outbreaks. Most hemlock can recover from less than 50% defoliation.

This looper is a wasteful feeder, often nipping only a small part of a needle before moving to another. As the needles dry out they change color and along with the exposed twigs, result in a reddish brown color characteristic of an infested stand. Often a mat of clipped needles collects under the tree. The wasteful feeding of this insect greatly increases the amount of damage relative to most other defoliators.

Older hemlocks, amabilis fir, and Sitka spruce are most vulnerable to damage. Young Douglas-fir appears to suffer more than older Douglas-fir.

Damage on spruce stand from hemlock looper. Photo by Manfred Meilke.

Life History

Classic “inch worm” looper larvae hatch from eggs in the late spring and begin feeding in the newly opened buds in the upper crown. Young larvae are marked with light gray and black bands. Feeding by early instars during May, June, and early July is light, and not particularly noticeable.

As larvae grow larger, from the middle of July to October, they become mottled gray to dark brown with an intricate pattern of darker markings. They feed voraciously on both new and old foliage and are more evenly distributed throughout the crown. Mature larvae are quite mobile and produce an abundance of silk webbing which is very evident in defoliated stands. The larvae are wasteful feeders, chewing off needles at their bases causing the stand to appear yellowish-red and then brown in color.

Defoliation starts in the upper crown, but as feeding progresses more and more of the crown is affected, increasing the risk of mortality. Late in summer, larvae are very mobile, crawling over tree trunks and shrubs, and dropping by silken threads from the trees to the ground.

Larvae then move to bark crevices, moss, lichen, or under debris to pupate. Pupae are mottled greenish-brown, ¾ inch long.

Buff colored moths emerge from pupae in 10-14 days. Moths have wings that are narrow at the base with a banded pattern, 2 bands on the forewing, 1 on the rear wings and a wing span of about 1 1/2 inches. Moths mate, and lay eggs on foliage, concentrating eggs in the upper crown of host trees.

By fall, the ground may be littered with parts of needles, insect frass, and later by thousands of dead moths.

Damage is similar to other defoliators, such as the western black-headed budworm, but the larvae are very distinctive.

Hemlock looper larvae feeding on grand fir. Photo from the Canadian Forest Service.

Identification

Signs of Attack—By the middle of July looper defoliation of new and old foliage is evident throughout the crown.

Look for mottled gray to dark brown larvae with an intricate pattern of darker markings feeding on old and new foliage.

Mature larvae produce an abundance of silk webbing which is very evident in defoliated stands. In areas of looper epidemics "these silken webs may become so abundant that the whole forest looks and feels like one big cobweb" (Keen, 1952).

Buff colored moths emerge from early September through October and "during an epidemic are so abundant as to give the impression of a snowstorm in the woods." (Keen, 1952). Eggs are present in the fall and winter.

By fall, the ground may be littered with parts of needles, insect frass, and later by thousands of dead moths.

Recent outbreak in the Prince George Forest Region can be seen along Highway 16 east between Purden Lake and McBride. Photo file from British Columbia Defoliator Management Guide.

Predictive Sampling Techniques

Egg sampling is done in the fall when defoliation has been noticed, or when an outbreak is anticipated, to predict levels of defoliation the following summer.

1. Samples of lichen found on the bole and branches of hemlock are taken from the lower crown of 5–10 trees per site, using pole pruners.

2. Eggs can be counted using a magnifying lamp or by using a hot water extraction method to determine the average number of healthy eggs per 100 grams of dry weight lichen. The procedure is as follows:

- spread lichen and allow to air dry (for 72 hours), or oven dry (at a low temperature) for 24 hours
- weigh each sample and record weight
- lace cut-up lichen sample into 100°C water for at least 30 seconds
- stir gently to dislodge eggs from lichen, then pour contents through 2-stacked strainers (0.297 mm or 20 mesh for top sieve)
- wash contents with strong jet of water to force eggs through top sieve (eggs will be retained in lower sieve)
- rinse eggs onto filter paper and dry
- count eggs using a magnifying lamp and categorize as noted below.

3. Healthy eggs must be distinguished from parasitized, infertile or old eggs as follows:

Condition	Color of eggs
healthy	bronze
parasitized	black
infertile	yellow
old	opaque

Predicted defoliation using the hot water method:

# healthy eggs per 100g dry wt lichen	Predicted defoliation
0-4	none
5-26	light
27-59	moderate
60+	severe

-Warning-

Remember, when using pesticides, always read and follow the label!

Management Considerations

Prevention— Well spaced, even-aged thrifty stands should be less susceptible and suffer fewer impacts from western hemlock looper defoliation. Promoting mixed species stands composed of less than 50% western hemlock, avoiding cedar hemlock mixes, and preferring non host species will also lessen susceptibility. Stand tending treatments such as spacing and fertilization will help maintain a healthy stand that is more resilient to western hemlock looper defoliation. Canadian researchers have developed system for assigning western hemlock looper hazard to stands. This system is summarized in Table 1. Stand tending practices which reduce hazard by altering stand composition, structure, density, or age should improve a stand's resilience to western hemlock looper attack.

Indirect Control-- Western hemlock looper populations are normally held to low levels by several natural factors:

- Parasites.
- Predators including insects and birds- small forest song birds are known to be effective natural enemies.
- Diseases- caused by fungi and viruses have been found in collapsing populations.
- Abnormal weather conditions- especially cold, wet summer periods. Heavy rains during the moth flight period can reduce egg-laying and hasten the decline of an outbreak.

Pheromone—Components of the sex pheromone have been identified and Canadian researchers are hoping to develop a pheromone-based, early warning system for building western hemlock looper populations. The system being developed would employ a series of permanent pheromone trapping stations. Data collection is still underway.

Pesticides—In British Columbia two formulations of the bacterial insecticide *Bacillus thuringiensis kurstaki* (Btk) were tested in 1993 and shown to effectively control the western hemlock looper. The western hemlock looper was included on the December 2003 FORAY7 96B pesticide label. Other chemical insecticides have also been labeled for use against western hemlock looper. Please check current labels to insure use is permitted for populations of western hemlock looper.

Table 1. Parameters influencing hazard for western hemlock looper in British Columbia.

Hazard			
Stand characteristics	**High**	**Moderate**	**Low**
Biogeoclimatic zone & subzone	Interior: ICH wk2; ICH wk3; ICH wk1; ICH mw3; Coast: CWH vm1; CWH dm1;	Interior: ICH mm; ICH mw2; ICH vk1; ICH vk;	Interior: ESSF mm1; ESSF wk2; ESSF wc2; Coast: CWH vw2;
Site	Lower elevation, cool wet poor site classes	Mid-slope, cold, wet medium site classes	Higher elevation, cool,wet good site classes
Species mix	>50% western hemlock, hemlock-western red cedar mixes	<50% western hemlock, cedar-hemlock mix, pure cedar, spruce -balsam mix	Non-hosts or pine, larch, and Douglas-fir stands
Stand density	Dense, overstocked	Spaced, gaps	Open grown
Stand structure	Layered or 2-story co-dominates	Single layer dominates	Even canopy
Maturity	Mature, > age class 6	Intermediate, age classes 3-6a	Immature/young <age class 3

[a] An increased incidence of spruce beetle (1994 –attacks of 8-12%) has been noticed in severely defoliated spruce-balsam stands on medium age sites.

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Natural Resources Canada - Canadian Forest Service
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Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

By Carl Jorgensen
US Forest Service

Management Guide for

Western Pine Budworm

Topics

Choristonerura lambertiana **(Busck)**

Occasional outbreaks of this moth occur in the west on several species of pine.

Hosts:

- **Lodgepole pine**
- **Ponderosa pine**
- **Limber pine**

Key Points

- Occasional outbreaks occur with little lasting damage.
- Control of this insect is probably not needed.

Life History

Larvae overwinter as first instars inside silken cells in bark crevices on the bole and branches of the host. In May or early June they migrate to new shoots and staminate cones to feed. Larger needles are not usually eaten. Pupation occurs within webbed needles by August. Moths typically emerge in late July and August and deposit eggs on the concave side of older needles, preferably in the upper crown. Eggs hatch within 7-10 days and the larvae seek overwintering sites.

Photo below is by Bernard J. Raimo, USDA Forest Service, Bugwood.org
Tortrix larvae on pine needle.

Identification

Look for larvae or pupae in webbed, chewed needle on current years shoots from June until August. Larger larvae are from 17-19 mm long and brown to rust color with ivory spots like the western spruce budworm. Pupae are smaller than the western spruce budworm and have yellowish-brown appendages and darker brown abdominal segments.

This insect is closely related to western spruce budworm and closely resembles it in all life stages.

Tortrix adult moth on lodgepole pine needle from the USDA Forest Service-Ogden Archive, Bugwood.org

Tortrix larvae on lodgepole pine branch from the USDA Forest Service-Ogden Archive, Bugwood.org

Management

If damage became economically or aesthetically intolerable, epidemics could be treated with aerial sprays. However, no insecticides have been registered or silvicultural methods developed for control. Outbreaks usually last 1-2 years and defoliated trees seem to recover without permanent damage. It was seen top-killing lodgepole pine in Idaho and Montana in the 1960's. This moth may not have to be managed in this Region.

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Cite as: Jorgensen, C. 2004. Management guide for western pine budworm. 2 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

May 2004

By Darren Blackford
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Spruce Budworm

Choristoneura occidentalis Freeman

Topics

The most chronic, destructive, defoliating insect of conifers in the Northern Rockies.

Hosts

- **Douglas-fir**
- **All true firs**
- Spruce
- Western larch
- During epidemics, pines and western hemlock may also be fed on.

Periodic Outbreaks with Severe Defoliation

Larvae mine buds and old needles prior to bud burst in May and June. They consume new foliage as the buds flush. Radial growth is decreased after several years of heavy defoliation. After 3 to 5 years, branch dieback, top kill, and tree mortality can occur. Cones and seeds of Douglas-fir, larch, true firs, and spruce are also destroyed. Terminal and lateral new larch shoots can be severed.

The western spruce budworm is a native insect that has co-evolved with Douglas-fir, spruce and true fir forests. Budworm populations are somewhat cyclic across many of our forests, especially west of the Divide. These Forests, with the exception of the Bitterroot and Lolo National Forests, usually have long periods between outbreaks where no budworm defoliation is detected. On many of our forests east of the Continental Divide, such as the Helena National Forest, the population is chronic, occurring over large areas with relatively short periods between outbreaks. As forests have become denser with proportionally more Douglas -fir, budworm outbreaks may have become more frequent and severe.

Key Points

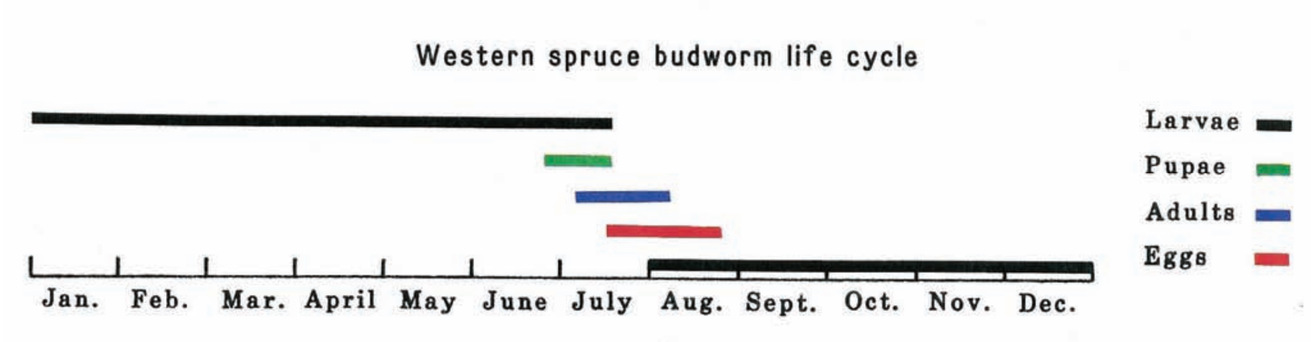
- Multi-storied stands of Douglas-fir or true firs are most damaged.
- Shade tolerant trees are defoliated heaviest in mixed stands.
- Heaviest defoliation and tree killing are seen in Douglas-fir stands on south-facing slopes.
- Manage for resistant species.
- Select for phenotypically resistant trees during harvest.

Management

Encourage pines and larch because outbreaks usually occur in Douglas-fir, grand fir, and subalpine fir forests.

Avoid multi-layered stand conditions in which Douglas-fir or true firs are in overstory as well as understory.

Accept some defoliation as a normal stand-development process.



Life History and Behavior

Good budworm habitat consists of dense, multiple layers of climax host species.

Eggs hatch in late summer and first instars migrate to over-wintering sites. The larvae molt to the second instar and overwinter in silken shelters under bark scales. Larvae emerge in spring, April to June, and mine buds and old needles until bud flush. As the buds flush, larvae web new needles together to feed in a protective shelter through the sixth instar. They pupate in these silken shelters and emerge as adults by August. Eggs are laid in a mass containing up to 130 eggs, on the underside of a needle.

Insect dispersal occurs during the adult and larval stages of development. Horizontal dispersal, from tree to tree and from one stand to another, occurs mainly during the second larval instar and adult life stages (Carlson et aI. 1988). Frontal systems and associated winds can carry populations from one drainage to another. This may account for sudden population increases in areas previously un infested. Vertical distribution is more prevalent in the older, larval stages which are not as buoyant on wind currents, but also occurs throughout all larval stages. Through management, we can negatively influence this stage of budworm development, mainly through interrupting dispersal by reducing the number of canopy layers through harvesting.

Budworm habitat quality is determined by stand structure, composition, and density. Good budworm habitat consists of dense, multiple layers of climax host species. The climate of these stands may influence the probability of an outbreak, but stand conditions will determine the duration and intensity. The upper story provides a good food source and refuge from predation and parasitism. The lower canopy layers intercept budworm spinning from the upper layers and provide sanctuary from the predators on the forest floor. Dense, even-structured stands will limit the diversity of bird predators (Langelier et at. 1986) and may reduce the efficacy of i~ parasites.

Temperature fluctuations and precipitation patterns can greatly affect budworm behavior and population development (Kemp et al. 1983). Climatic influences are an integral part of the hazard rating system developed for budworm.

History

Present conditions exhibit more synchrony of infestations that are more widely dispersed across our forests than we have seen In the past. The most popular hypothesis is that the greater extent and immensity of budworm outbreaks in this century is related to human-caused forest changes. Selective harvesting of ponderosa pine and Douglas-fir in the past, and fire suppression after 1900 led to 20th century forests with higher proportions and densities of budworm host trees than existed in pre-settlement forests (Swetnam & Lynch 1993).

Outbreaks were reported as early as 1922 in the Northern Region. Outbreaks have not become more frequent across most forests but have increased in duration and intensity (Anderson et al. 1987). Although temporal patterns of budworm may not have significantly changed, the composition and structure of forests have, and subsequently have effected the spatial dynamics of budworm outbreaks.

Periodic outbreaks of western spruce budworm have always been part of western forest dynamics.

Current Conditions

The most extensive defoliation reported in the Northern Rockies occurred in 1958 and affected more than 4.9 million acres. The least defoliation recorded since the beginning of aerial surveys in 1948 was in 1993 where only 45,000 acres were reported defoliated. This was a significant decline from 1992 and was probably due to the unusually wet and cool summer of 1993. Weather has a direct effect upon larval development and dispersal and adult dispersal.

During the mid-1990s, we expect the population to recover slowly across the Region. However, in areas where budworm was thriving in 1993, defoliation will probably continue to increase in both intensity and area affected. Most of our Douglas-fir and true fir stands across the region are susceptible to budworm. Although certain forests such as the Kootenai and Clearwater appear to have longer periods of time between outbreaks than many of our east-side forests.

More than 4.9 million acres were defoliated by western spruce budworm in 1958.

Future

If we continue to restrict fire from most of our Douglas-fir, true fir forest types, we will continue to intensify the outbreaks across the region. Silvicultural practices and management objectives are changing which might either contribute to, or reduce the potential of future outbreaks.

The most effective approach from a budworm management perspective is to evaluate larger land areas and prioritize treatment of stands based upon hazard and risk rating when possible.

Budworm can disperse over long distances. Although treating a stand may protect individual trees within the stand, the effects of budworm from surrounding stands will in turn effect the protected stand.

Habitat Types

Western spruce budworm defoliation occurs in 46 habitat types described for Montana (Fellin et al. 1983); across much of Montana and part of Idaho.

They fall in these habitat type series—

- **Douglas-fir**
- **spruce**
- **grand fir**
- **western red cedar**
- **western hemlock**
- **lower elevations of the subalpine fir series.**

Hazard Rating

When conducting large scale area analyses, hazard rating for insects and diseases should be an integral part of the process. This can help set priorities for treatment based on stand susceptibility to insects and diseases. Hazard rating for budworm integrates site and stand conditions known to influence budworm. The model we recommend for the Northern Region is the Generalized Indexing Model developed by Carlson and Wulf (1985).

Hazard Rating for Western Spruce Budworm
Carlson and Wulf (1985)

Character	Descriptive Variable	Index Value Range
Species Composition	% host crown cover and % climax host crown cover	0-2.4 0.6-2.4
Stand Density	Total % crown cover	0.8-1.6
Crown Class Structure	Coefficient of variation of host tree heights	0.9-1.7
Stand Vigor	Basal area stocking/average maximum basal area and incidence of stress-inducing pests	0.9-1.6
Stand Maturity	Basal area weighted mean host tree age	0.3-1.3
Site Climate	Habitat type group	0-1.5
Regional Climate	Geographic location	0-1.2
Surrounding Hosts Type Continuity	% host type in surrounding 1,000 acres and adjacent to the stand	0.6-1.7

Risk rating can be used in combination with hazard rating to project the probability of a budworm outbreak and the level of damage that will result.

Risk Rating

Risk rating refers to stand vulnerability, or how much damage will result from an insect outbreak. A risk rating system for budworm is based upon cumulative years of budworm defoliation taken from aerial survey information. Risk rating can be used in combination with hazard rating to project the probability of a budworm outbreak and the level of damage that will result. We are in the process of developing an indexing system to rate susceptibility and vulnerability to budworm for a larger land unit such as drainage.

This should complement our current ecosystem management philosophy. Its also very practical because budworms disperse across many stands during an outbreak therefore the impact on the landscape should be considered and not just on individual stands.

Permanent Plots

By 1995, we will have 360 permanent plots located throughout the region in areas at risk to budworm. Plots were established in low, moderate and high defoliation areas. Stands were also selected to represent diverse conditions across stand and site conditions. After the initial measurements, stand information is collected 2-3 years following an outbreak or at least once every 5 years. Defoliation and population measurements are made annually. Impact data on individual trees and stands are measured from plots, including effects on succession. The data will also serve as a measure of impacts on wildlife habitat, recreation and visual qualities.

FVS-Linked Budworm Damage Model

Permanent plot data is also being used to validate a budworm damage model for application in Northern Region. The budworm damage model is linked to the FVS model and can be used to adjust tree growth and mortality based on budworm defoliation rates.

We are also in the process of improving and streamlining the budworm population dynamics model. The budworm population dynamics-FVS model can simulate budworm-stand interactions over long time periods. The model can be used to make 1ong-term projections of population dynamics and defoliation which can then be used to help determine outcomes of different management alternatives.

For more information or assistance in using any of these models, contact an FPM specialist.

Silvicultural Alternatives

The silviculturist has a variety of management options to prevent or reduce budworm impacts. These options include both even- and uneven-aged regeneration systems, and intermediate treatments on stands not ready for harvest. Maintaining a healthy forest offers the greatest potential for preventing or reducing the severity of budworm outbreaks. Providing diverse habitat for insectivorous birds, mammals, and other insects is also important for preventing budworm outbreaks.

Cultural manipulation of stands offers the greatest hope for preventing outbreaks or reducing impacts.

Silvicultural Alternatives

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historcal1y long fire intervals.

Understory layers provide food, shelter, and a moderated climate which promote budworm population growth

This can be accomplished by proper snag management, leaving adequate woody residues on the site, and enhancing the edge effect. Natural predators and parasites are not as effective during outbreaks as they are when populations are at lower levels. However, their presence at low population levels may prevent an outbreak from occurring.

Even-aged management systems mimic stand replacement fires and are an applicable system in areas of historcal1y long fire intervals. Multiple use applications of even-age systems are suited to provide increased water yields, diversity of habitat (particularly browse habitat) required by game and non-game wildlife (Gibbs 1978). Clearcutting and seed tree systems promote development of seral plant communities. Climax species invariably become part of the overstory and as the stand develops, increased amounts of suppressed, climax species develop in the understory. Imermediate treatments may be necessary to modify stand density, tree spacing, and favor seral species.

Shelterwood cuts should be used with care but can be used in areas where the probability of budworm infestation is slight. Dependent on the site, residual overstory, and number of entries made to remove the overstory, the climax species are more or less favored. Removal of the overstory should be made within 10 years following initial entry.

Developing two or three-stored stands with one or two levels of regeneration beneath a near1y closed canopy will promote and support budworm infestations. Understory regeneration will be climax species. Should a budworm infestation develop in the overstory, vertically dispersing larvae will be intercepted by the understory. These understory layers provide food, shelter, and a moderated climate which promote budworm population growth (Schmidt et al. 1983). In addition to the development of budworm populations, the genetic quality of the seral species will be lost by the second or third cut. Thus, the future management could be relegated to climax species and chronic budworm infestations. When other management objectives lead to creating multi-storied stands, consideration should be given to maintaining healthy stands through intermediate cuttings and fire, and by creating conditions that are favorable to natural enemies of budworm.

Manipulating stand density and tree spacing, if properly timed and applied, can increase growth on other host and non-host trees. The foliage food value, with regard to budworm, appears to be better in foliage from stressed trees. Therefore, reducing stress within stands should reduce the food quality. Increasing tree spacing will reduce interception of larvae by the understory and increase their vulnerability to predators, parasites, and erratic weather conditions. Favoring non-host trees and host trees showing less damage as the residual trees, will have an impact on the outbreak by the simple removal of the food source.

Uneven-age management can occur in stands of irregular or uneven-age structure, on fragile sites, steep slopes, high water tables, very dry sites, or sites that would be adversely affected by complete removal of forest canopy. The multiple use applications of uneven-age silviculture are best suited to travel influence zones, water influence zones, watershed protection, scenic areas, wildlife habitat requiring high forest cover and vertical diversity in vegetation (Gibbs, 1978).

How can uneven-age management be recommended in budworm situations and not multi-storied management? In properly applied uneven-age management, the fast-growing, quality trees are left to grow to maximum size: they produce seed and their progeny, because of their fast growth, are always an integral part of the stand (Gibbs 1978). In an uneven-age stand, each crop tree has adequate room to grow so the vigor of the regeneration is insured. Harvest entries occur at more frequent intervals in an uneven-age stand and regulation of the understory to promote seral species development and occur at that time. In multi-storied stands, harvest entries occur at 80- to 100-plus-year intervals by which time suppression is already occurring in the understory. Promoting seral tree development is not likely unless intermediate treatments to accomplish this objective are scheduled.

Intermediate treatments are effective in preventing or reducing damage from budworm outbreaks. Generally, they are applied to stands not ready for harvest. (See sidebar.)

Intermediate Treatment Objectives
(Schmidt, 1983)

⇒ Maintain tree vigor to enhance survival and recovery

⇒ Alter the stand physical and biological parameters to reduce budworm habitat

⇒ Capitalize on natural resistance of individual trees and species

Chemical and Biological Pesticides

The most recent operational spray program for budworm on national forest land in the northern Rocky Mountains took place in 1979. In the near future, we do not expect to implement any large spray programs aimed at budworm because of both economic and environmental constraints.

Several chemical insecticides are registered for use on budworm: they include acephate, carbaryl, malathion, methomyl, naled. The naturally occurring bacterium, *Bacillus thuringiensis*, is also registered for budworm control. Acephate implants can be used on individual trees to protect cone crops.

Pesticides provide only temporary protection against budworm. Protection usually only lasts 2-3 years before populations resurge.

Natural Control
General recommendations for improving natural enemy habitat

Natural control agents, or natural enemies of budworm, play a significant role in lengthening the period of forest stability between pest outbreaks. Birds and ants play an especially important role in stabilizing budworm populations across the region (Carlson et aI. 1984).
Several wasp and fly parasites also have critical roles in the population dynamics of budworm, and some important budworm pathogens have also been identified.
Maximizing the survival of natural enemies by habitat conservation and enhancement can reduce the impact of budworm on all resources.

⇒ **Diversify the managed forests by utilizing irregularly shaped cutting techniques.**
⇒ **Plant a variety of tree species where possible, conserve streamside or pond habitat which will improve bird nesting success.**
⇒ **Leave dead woody materials to increase carpenter ant habitat (Torgersen et al. 1990). Both carpenter and mound building ants are important predators of spruce budworm.**

Effects of Budworm on Resources

Mortality is usually concentrated in the smaller, suppressed pole and sapling size trees.

Timber—

The amount of defoliation is often highly variable among stands and even among trees in a stand. Although defoliation can significantly affect tree growth and survival, foliage recovery can be dramatic and within a few years tree crowns can appear healthy. However, volume of live crown and wood volume may be substantially reduced. Budworm feeding can cause growth loss in the form of topkill, deformities, mortality and reduction in seed production. Most of these effects are concentrated to specific trees based upon individual tree characteristics; and localized areas, usually based on individual stand dynamics such as species composition and structure. Mortality is usually concentrated in the smaller, suppressed pole and sapling size trees. With both Douglas-fir and grand fir, the stimulation of adventitious and epicormic branching during an outbreak or a chromic period of budworm feeding, may significantly contribute to tree recovery.

Budworm reduces seed and cone production directly by feeding on seeds and cones. topkilling, and indirectly through the effects of defoliation. During periods of even light defoliation, significant losses in cone production can occur. One study conducted in Montana, demonstrated that 9-71 % of cones were infested during a period of light budworm defoliation.

Stands and Succession—

Insects and diseases, as well as fire, have a natural role and function in forest dynamics. Under endemic conditions, insects and diseases are nature's tools to keep a forest healthy. They work quietly to keep stands thinned. Even periodic outbreaks of insects serve a useful purpose. They weed out genetically inferior stock in a stand providing more growing room for resistant trees.

In unmanaged, mixed-species stands, if fire and insects such as budworm were allowed to play out their natural roles, there would be a shift away from true firs to include more resistant species such as Douglas-fir, larch and pines essentially resetting succession. Over the short term, there would be losses in terms of recovery of volume per unit area, but probably minimal impacts on other resources directly resulting from budworm.

In pure Douglas-fir stands, which comprise much of our east-side budworm habitat, natural cycles of budworm would weed out individual large trees and suppressed smaller, slower growing trees, resulting in a push toward climax.

In managed stands, depending upon objectives, we have the opportunity to create resistant stands composed of primarily resistant trees. In mixed conifer stands, openings could be created to encourage invasion by seral species. In pure Douglas-fir stands, stand maintenance and improvement could be obtained through intermediate thinnings across size classes, management of understory, and by leaving individual trees that show resistance to budworm damage.

In Douglas-fir stands... natural cycles of budworm weed out individual large trees and suppressed smaller, slower growing trees, resulting in a push toward climax.

Wildlife—

Depending upon the duration and intensity of an infestation, budworm has the potential to adversely impact big game habitat. In areas that have chronic budworm infestations, both hiding and thermal cover could be affected. However, top killing and tree mortality will open up the stand and forage production will increase. This might affect hiding cover but probably not thermal cover over the long term except in isolated instances where an area is defoliated repeatedly. In areas where budworm occurs less frequently and/or the duration of outbreaks is short, neither thermal or hiding cover are probably affected.

Budworm larvae and pupae provide a valuable food resource for many species of birds and small mammals. Carpenter ant populations, which benefit from increases in budworm populations, are a primary source of food for animals such as grizzly bears and the pileated woodpecker during certain times of the year.

Budworm larvae and pupae provide a valuable food resource for many species of birds and small mammals.

Aquatic Ecosystems—

Even during budworm outbreaks, little or no mortality usually occurs in larger diameter size trees and less than 100 percent defoliation usually results. The greatest amount of defoliation occurs in the upper portion of tree crowns and should not significantly effect canopy closure and therefore neither stream temperature or flow. Low levels of tree mortality in riparian areas due to budworm may actually improve fish habitat by adding, organic debris to streams. Budworm larvae and adults may also fall into streams during dispersal, enhancing the food supply of some fish species.

Visual quality and recreation are the two resources budworm has the greatest potential to affect.

Visual Quality and Recreation—

Visual quality and recreation are the two resources budworm has the greatest potential to affect. People have an image of what a forest should look like and to most people that means needles on trees. During a budworm outbreak, between 75-100 percent of foliage can be consumed especially if the outbreak has been occurring over many years. Forests appear reddish-brown in color, and the perceived texture changes drastically as well. An impacted area may take up to a decade to significantly recover in both color and especially texture. Color and texture changes affect the quality in the fore-, middle and background of a person's visual area. Top-kill and mortality affect viewing at all three distances. but have the greatest impact in the fore-ground. Recreation and recreation economics can be greatly affected in outbreak areas where top-kill and tree mortality occurs.

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Foliage & Shoot

Insects

Scales

Related section in field guide.

March 2004

By Lee Pederson and
Brytten Steed
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Black Pineleaf Scale

Nuculaspis californica (Coleman)

Topics

Sustained heavy feeding for several years progressively weakens and can kill trees.

Hosts:
- Ponderosa pine
- Western White Pine

Scale Insects infest stressed trees

Trees under stress from soil moisture deficit, soil compaction, spray drift, root damage, salt, smog, and dust tend to be especially susceptible to scales. Dust may have a deleterious effect on the natural enemies of the scale, or upon reduced photosynthesis (which may favor scale survival), or both.

Scale insects are capable of killing trees after several years of infestation. Persistent infestations cause sparse, short foliage on twig tips. Needles turn blotchy, yellowish-green and may drop off.

Black pineleaf scale covers about the same range as the pine needle scale and can be associated with it. During the late seventies it killed many mixed-sized ponderosa pines, near the Clearwater River west of Orofino, Idaho.

Key Points

- Stressed trees are susceptible to scale insects
- Dust is particularly damaging, especially to natural controls of scales.
- Pesticide application in June reduces populations by killing crawlers.

Management

Preventing or minimizing infestation is the most efficient means to manage scale insects. Chemical control may also be effective.

Prevent or minimize

- Keep trees vigorous— trees under stress are the most likely victims of scales.
- Maintain biological controls—The wasp parasitoid, *Prospaltella* sp., normally keeps scale populations at low densities. Dust may have a deleterious effect on *Prospaltella.*

Chemical control

- Spraying is effective and should be directed against the crawlers near the end of June. There are several insecticides registered for scale control such as carbaryl and acephate. Always follow label instructions when using pesticides.

Life History

Black pineleaf scale overwinters as nymphs under black scale covering. In mid-June males emerge and mate with immature females. Eggs are laid under scales and the new crawlers settle on the same needle or nearby spring needle. Nymphs suck needle juices until fall. There is one generation per year.

Identification

Sites on needles infested by the scale tend to become spotted or blotched with yellow patches. Scale coverings are gray to black and the scale of the mature female is about 2 mm long, broadly oval in outline, broadly conical in profile, and has a central ye11owish- brown nipple. The insect and eggs under the scale are yellow.

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Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Needle Scale

Chionaspis pinifoliae (Fitch)

Revised by
R. Ladd Livingston
State of Idaho

Topics

Primary hosts:

- Lodgepole pine
- Ponderosa pine
- Many ornamental pines

Minor hosts:
Englemann spruce and Douglas-fir.

This insect is a chronic pest throughout the northern Rocky Mountains.

Key Points

- Look for white scales on needles any time of year.
- Avoid planting pines where they will be predisposed to scale.
- Ornamentals can be sprayed with foliar pesticide to kill scales.

Scale insects weaken, sometimes kill trees

Nymphs suck the juice out of needles and turn them yellowish-brown. Ornamentals become unattractive when covered with white, waxy adults and their secretions. Heavy populations cause needle fall, reduce growth, and can kill trees after a few years. Weakened pines are often attacked by *Ips* and wood borers.

Severe infestations have occurred in Glacier National Park in the early 1960's, on the Helena National Forest in 1975, and Flathead Indian Reservation from 1977 to 1978.

Life History

Pine needle scale overwinters as eggs underneath white scale. Eggs hatch from late May to late June. Newly hatched nymphs crawl over the needles for several days, select a needle, and insert their stylets (mouth parts). Females stay on this needle for the rest of their life cycle. Males remain until they become winged adults. Nymphs molt twice and form white scales in August. Females lay eggs under themselves in late August and die about 1 month after oviposition.

Management

Prevent or minimize infestation

- Do not plant pines or other hosts along dusty roads or in areas of heavy air pollution.
- Natural mortality factors gradually reduce populations.

Chemical control

- The insecticide Diazinon ® is registered for spraying ornamentals. Always follow label instructions when applying pesticides.

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Related section in field guide.

No FIDL for this damage-agent

October 2005

Forest Health Protection and State Forestry Organizations

By Brytten Steed
US Forest Service

Management Guide for

Pinyon Needle Scale

(*Matsucoccus acalyptus* Herbert)

This native sap-sucking insect was first described in southern Idaho but has been found throughout the Southwest including California, Idaho, Nevada, Utah, Arizona and New Mexico.

Hosts:

- on single-leaf pinyon
- common pinyon
- bristlecone pine
- sugar pine

Topics

Key Points

- Pinyon needle scale infestations seldom kill trees but are a concern on ornamental trees.
- Tree mortality more often results from a combination of scale feeding, drought, and pinyon ips.
- Control scale with horticultural oils,insecticide treatments and thinning option.

Damage

These insects feed on the sap of needles older than one year. Individual needles are often killed, and successive years of defoliation can damage or weaken trees. Repeated attacks often reduce new growth and cause needle stunting.

Pinyon needle scale infestations seldom kill trees. Tree mortality more often results from a combination of scale feeding, drought, and pinyon ips (*Ips confusus*) that subsequently attack severely stressed trees. However, repeated feeding may result in death of smaller trees. Scale infestations are more of concern on ornamental trees where the damage could affect shade or aesthetic values.

Life History

Pinyon needle scale has a one-year life cycle. Males overwinter on the ground as pupae while females overwinter as second-stage larvae on the previous year's needles. In late April winged males emerge from their ground cocoons to mate with females as the females back out of their immobile waxy covers. Large numbers of flying males can be seen swarming around scale-infested trees. Mated females then crawl to oviposition sites and lay an oval cluster of yellow eggs that are loosely held together by thin cottony webbing. Preferred oviposition sites include the root collar, crotches of large branches, along the underside of large branches, and in fissures of rough bark.

Winged males mating with emerging females. Photo by Bob Cain.

Life History

Generally outbreaks subside after a few years with most trees recovering from an infestation.

In late May or early June, small red eyespots become visible in the eggs. Within another 7-10 days the yellow crawlers emerge and make their way to the ends of branches to settle on the needles formed the previous year. Within the next 24 hours the crawlers will usually align themselves with their heads toward the base of the needle, insert their small feeding tubes into the soft needle tissue, become immobile, cover their bodies with wax, and turn black.

Cluster of yellow eggs at the base of tree. Photo by Bob Cain.

Scales remain in place on the needle through the nymph stage. When the young scale outgrows its waxy outer shell, the shell ruptures smoothly along the middle of the back with a larger shell developing. Female scales never move until the next spring when the adults emerge and mate. Male scales emerge from their immobile protective cover in October or November as mobile crawlers with legs. In this form the males crawl to the ground, spin a loose cottony web under sticks or pebbles, and transform into the prepupal stage. After 3-4 days the prepupae molt within their cocoons, spending the winter in the pupal stage. In some instances, male prepupal and pupal stages may be delayed until early spring.

Life history information was gathered from Grand Canyon, Arizona and Mesa Verde, Colorado. Life cycles may vary in other portions of its native range.

Identification

Pinyon needle scales are most often seen in the protected larval state and appear as small, black, bean-shaped, motionless objects on the needles of infested trees (McCambridge 1974).

Pinyon needle scale in larval state. Photo by Britton Steed.

Management Considerations

Few alternatives for managing pinyon needle scale outbreaks in forested landscapes exist. Generally outbreaks subside after a few years with most trees recovering from an infestation.

Oils
Pinyon needle scale is more readily controlled with horticultural oils than are some other armored scales such as oystershell scale (Cooper & Cranshaw 2004). Oils applied during the dormant season (dormant oils) are recommended for pinyon needle scale. Also, summer oils that can be applied during the growing season can be effective treatments. Summer oil applications can kill young, settled scales in addition to the crawler and egg stages. Do not apply horticultural oils when new growth emerges or if plants are under stress from drought.

Chemical
Sometimes the most effective control for pinyon needle scale is “crawler stage” insecticide applications. The insecticide treatments are timed to coincide with the vulnerable crawler stage of the insect. Many yard and garden sprays are labeled for this purpose, including insecticidal soaps, Sevin (cabaryl), Orthene and related products.

- Apply insecticide treatments shortly after egg hatch when the “yellow” crawler stage is visible on the bark or found by shaking a branch over a piece of white paper.
- Survey for the crawler stage from May through June. If egg laying and crawler activity continues over a period of several weeks, a second application may be required.
- If an insecticidal soap is used, several applications may be required because of the short efficacy associated with this product. To protect natural enemies, only apply insecticide treatments when the crawler stage is present. Scale infestations may be localized on the tree, therefore only spot treatments using an insecticide may be required.
- Pesticide treatments, however, are not recommended for use in pine nut production areas for safety reasons (McCambridge 1974).

Silvicultural treatments (thinning, sanitation, etc.) may improve tree vigor in dense stands but are not considered effective in controlling scale populations or reducing stand susceptibility to pinyon needle scale. This is particularly true when scale outbreaks are related to drought-stress. If thinning treatments are undertaken, silvicultural treatments should not be applied during drought years or in areas with very active pinyon ips activity.

Thinning applications for pinyon needle scale. Photo by James Steed.

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Root Diseases

Related section in field guide.

February 2004

(Scientific names updated April 2015.)

By Sue K. Hagle
US Forest Service

Forest Health Protection and State Forestry Organizations

Root Disease Management: Overview

Topics

Key Points

- Manage for least susceptible species.
- Avoid partial harvests that leave susceptible species as crop trees
- Precommercial thinning may improve growth and survival of pines and larch
- Untreated root disease patches often develop into long-term brush fields.

Consider Root Diseases in your management plan

Mortality from root diseases is common in northern Rocky Mountain forests.

Root diseases are the most damaging group of tree diseases. They are most common in Douglas-fir, grand fir and subalpine fir in Montana and Idaho. In Utah forests, Engelmann spruce, lodgepole pine and piñon pine are more likely to be damaged.

Economic losses from insects and diseases are a function of land management objectives. In areas where maintenance of big game habitat is of high priority, openings created by root diseases may provide extensive browse and, therefore, be beneficial. However, in developed recreation areas, root diseases may reduce site desirability by killing trees and making them hazardous to people and property. In commercial forest stands, root diseases affect yields by killing trees and causing decay. Forest land may also be rendered nonproductive when disease centers regenerate with susceptible tree species that are subsequently killed before they reach merchantability. Procedures proposed for dealing with root diseases in developed sites and recreation areas are similar to those for hazard tree reduction in general.

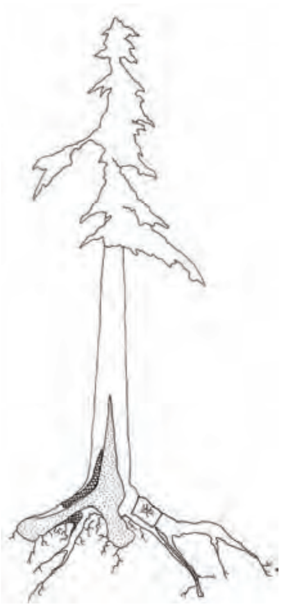
Forest management practices affect root disease spread and intensification. Some practices, like repeated partial harvests and sanitation-salvage cutting, can result in severe losses, even the loss of the site for timber production. On the other hand, treatments that establish and maintain disease-tolerant, site-suited tree species can reduce losses. See Table 1 on the following page.

There is no cure, but prevention can be very effective

Root disease prevention is especially important. Once established, root pathogens persist for decades in the roots of stumps and dead trees, and kill trees that are planted or that seed in naturally. Site rehabilitation may be impractical. Thus, it is most desirable to avoid treatments that unduly intensify pathogen buildup in tree and stump root systems.

Probably the most common cause of root disease proliferation is regenerating infected sites with disease-susceptible species (Table 2).

Partial harvests such as commercial thinning which leave susceptible trees on site can also intensify root disease. See “Thinning” on page 2.



An individual tree may be attacked by several root pathogens and beetles at once.

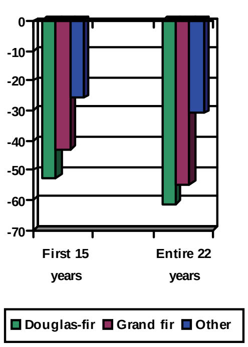
Table 1. Common Root Diseases in the Northern Rockies

Location	Forest type	Pathogens	Notes
Western Montana, North Idaho	Douglas-fir, grand fir, subalpine fir	*Armillaria ostoyae, Heterobasidion* spp., *Phellinus weirii*	Highly significant losses in these forest types. Important consideration in management plans.
Eastern Montana	Douglas-fir, subalpine fir	*Armillaria ostoyae, Heterobasidion spp., Phaeolus schweinitzii*	Scattered heavily impacted stands. Not generally distributed.
South Idaho	Douglas-fir, subalpine fir	*Armillaria ostoyae, Phaeolus schweinitzii*	Minor impact overall, Significant decay or defect from butt rot on some sites.
Southern Idaho, Utah, Nevada	Engelmann spruce, lodgepole pine, piñon pine	*Onnia tomentosa, Leptographium wageneri*	Locally important on some sites. *L. wageneri* especially damaging on piñon pine.

Thinning may be a poor option in mature forests

Disease intensification in commercially thinned or other partially-harvested stands appears to be due to the rapid colonization of the stumps and roots after infected trees are cut. Infested stumps then serve as effective food bases for the pathogens enabling them to infect and kill other nearby trees.

Only a fraction of the root disease infected trees can be detected by above-ground symptoms at any given time. So, it is virtually impossible to remove all root disease afflicted trees from a stand. Whenever possible, disease -tolerant species should be favored if root disease affected stands are thinned. Douglas-fir and grand fir often die within a few years after thinning, having produced little or not additional growth. See the chart at left comparing 22-year results of thinning Douglas-fir and grand fir stands.



Permanent plots on the Panhandle National Forest. Percent change in number of leave-trees following commercial thinning. The "other" species were western larch, western hemlock, ponderosa pine and western white pine.

Precommercial thinning can help

Root disease mortality is often evident by 10-15 years of age in a stand. Depending on the pathogen and stand composition, damage may continue to worsen for a century. Species selection during precommercial thinning can provide a much better outcome than ignoring the problem. Leaving apparently healthy, rapidly growing, susceptible species, can be a powerful temptation. In most stands of Douglas-fir or true firs, mortality rates will not peak until trees are 40 or 60 years of age, but by that time much will have been invested in trees that may have little potential to yield an economic harvest. However, precommercially thinned stands of pines, larch, and cedar are generally highly productive.

Root pathogens are fungi

Several root pathogens are damaging to stands in the northern and central Rocky Mountains. Three; *Armillaria ostoyae, Phellinus weirii*, and *Heterobasidion occidentale,* are associated with most tree mortality.

Root diseases are caused by fungi that spread from the roots of diseased trees to those of healthy ones. Spread may be through root grafts, root contact, or short distance growth of the fungus through the soil. Tree- to-tree spread results in enlarging "pockets" or "centers" of dead and dying trees. The radius of a center increases at an average rate of about 1-2 feet per year in fully stocked stands of susceptible species. Still, the area occupied by root disease in a stand can double every 10 years.

It is common for two or more root pathogens to be active at the same location, and the effects of both must be considered. For example, *A. ostoyae* involves and kills trees weakened by *P. schweinitzii*. Root- systems of these dead trees then serve as food bases allowing *A. ostoyae* to kill regeneration that occupies the openings.

Most root pathogens reproduce via mushrooms or conks.

Managing for disease-tolerant species is usually the most effective and cost efficient means of overcoming root disease.

Annosus root disease may increase significantly from one generation to another of susceptible hosts.

Table 2. Conifer species susceptibility to common root pathogens

Pathogen	Least Susceptible	Moderately Susceptible	Highly Susceptible
Armillaria ostoyae	Larch, pines, cedar	Spruces, hemlocks	Douglas-fir True firs
Heterobasidion occidentale (fir-type)	Larch, pines	True firs, hemlocks, cedar	Douglas-fir, Subalpine fir
Heterobasidion irregulare (pine-type)	All other species	Western white pine	Ponderosa pine
Phellinus sulphurascens	Larch, pines	Cedar, hemlock, subalpine fir	Douglas-fir, grand fir
Phaeolus schweinitzii	All other species	Ponderosa pine	Douglas-fir
Leptographium wageneri	All other species	Lodgepole pine, Douglas-fir	Piñon pine, ponderosa pine
Onnia tomentosa	All other species	Douglas-fir	Spruces, lodgepole pine

Bark beetles may be an indication of root disease.

Root pathogens and bark beetles often work together

Bark beetles are able to detect trees which are damaged by root disease long before they are visibly weakened. Larger declining trees are often attacked and killed by bark beetles. Beetles may significantly shorten the lives of root disease-afflicted trees.

Douglas-fir beetles, fir engraver beetles and western balsam bark beetles may utilize root disease weakened trees to maintain endemic population levels.

Thinning for beetle control could exacerbate root disease problems.

Other Reading

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Forest Health Protection and State Forestry Organizations

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US Forest Service Region Four
Ogden (801) 476-9720
Boise (208) 373-4227

Related section in field guide.

See explanatory note regarding naming conventions for this fungus.

February 2007

Forest Health Protection and State Forestry Organizations

By Susan K. Hagle
US Forest Service

Mangement Guide for

Annosus Root Disease (Fir-Type)

Heterobasidion occidentale (fir-type annosus)

Topics

Hosts:

- **True firs**
- **Douglas-fir**
- **Engelmann spruce**
- **western redcedar**
- **western hemlock**

In northern Rocky Mountain forests, mortality is common in Douglas-fir, grand fir and subalpine fir. Butt rot commonly develops with infection in spruce, true firs, western redcedar and western hemlock.

In the central Rockies, butt rot is common in true firs and spruce but mortality is rare

Key Points

- **One of two important species of *Heterobasidion* in North America**
- **Serious disease of true firs, Douglas-fir and cedar**
- **Spore-initiated infections directly or through wounds on roots**
- **Usually found with *Armillaria* or *Phellinus weirii***

Introduction

Annosus root disease is the most common and damaging fungus disease of conifer forests in the northern hemisphere. In northern Idaho and western Montana, Annosus root disease is economically important in true firs and Douglas-fir. Further south in Idaho, Wyoming, Utah, and Nevada, it is frequently found decaying roots and butts of mature trees, and sometimes killing small trees, but the overall impact is thought be minor.

Annosus root disease is caused by several species which, until recently, have been grouped under the names *Fomes annosus* or *Heterobasidion annosum*. They are differentiated most readily based host preference. In the northern and central Rocky Mountains, Douglas-fir, grand fir, and subalpine are commonly killed by the fir-disease type. Other tree species, particularly spruces, western redcedar and western hemlock develop extensive butt rot and occasionally die from infections of fir-annosus. Ponderosa pine is the only significant host for pine-annosus in this area.

Trees of all ages can die from this disease and volume losses from butt rot are substantial in some species. Establishment of new infections through root or basal stem wounds appears to be the most common means of spread of fir-annosus.

Overview of Fir-Annosus Root Disease Management

1. **Favor resistant species.** Especially pines and western larch.
2. **Thin early and avoid partial harvests.** Precommercially thin.
3. **Avoid basal stem and root damage.** Use care when logging.
4. **Use caution when thinning western redcedar.** Cedar decline may become a problem if cedar residuals are to be managed.

About Types of Annosus

Similar but Genetically-Distinct Types of Annosus

Heterobasidion annosum in western North America consists of two inter-sterile (non-interbreeding) groups. These two types, 'fir' and 'pine', have very different host specificities.

The hosts for the fir type include true firs, Douglas-fir, Engelmann spruce, western red cedar, and western hemlock. (See Table 1 for details.)

Ponderosa pine is the main host for the pine type.

Taxonomy: Awaiting a name

The basidiomycete fungus *Heterobasidion annosum* (Fr.) Bref. has been known for many years to consist of at least two distinct types, based on host preferences. Molecular and genetic studies of European isolates have demonstrated that the former *H. annosum* consists of at least three distinct species. The pine pathogen retains the name *H. annosum*. The species formerly referred to as "s" type in Europe was recently named *Heterobasidion parviporum* Niemela & Korhonen. This species is found primarily on *Picea abies* (Norway spruce). *Heterobasidion abietinum* Niemela & Korhonen, is the new name suggested for the pathogen of European true firs (*Abies)*.

The fir pathogen of this complex in western North America has yet to be named, and is currently referred to as the "North American S group" (Korhonen and others 1998). For this publication, it will be referred to as 'fir-annosus'.

Incidence in northern Rocky Mountains

Grand fir and Douglas-fir

In northern Idaho and western Montana, fir-annosus is broadly distributed and very common in forest types that include grand fir and Douglas-fir. *Armillaria ostoyae* root disease generally co-occurs with fir-annosus, making it impossible to distinguish the individual impacts of the two diseases.

Stands without prior harvests as well as harvested stands with sufficient host composition, have abundant symptoms and signs of annosus root disease. First-entry grand fir stumps, in particular, produce abundant annosus conks, indicating pre-existing root infections in a high proportion of trees. Northern Idaho, from St. Maries to the Salmon River, appears to have an especially heavy incidence of fir-annosus. Most the annosus-related Douglas-fir mortality is reported from this geographic area as well.

Bark beetles, especially fir engraver in grand fir, frequently attack trees with fir-annosus root disease. Mortality rates of root disease-afflicted trees are probably significantly increased by bark beetle attacks.

Subalpine fir

Fir-annosus is implicated in a widespread decline of subalpine fir in the northern Rocky Mountains. Mature trees are especially damaged, with rapid death following long periods of growth decline. Western balsam bark beetle (*Dryocoetes confusus*), fir engraver beetles, and *Armillaria ostoyae* also are involved in the decline.

Other tree species

Extensive root decay and very gradual death of western redcedar is common on drier and partially-harvested cedar sites (Hagle, unpublished data). Fir-annosus, *Armillaria ostoyae*, and *Phellinus weirii* appear to be about equally responsible for the damage. Butt rot in western redcedar, Engelmann spruce and western hemlock are also very common, particularly in mature trees.

Central Rocky Mountains

1. **Annosus root and butt decay are common in older trees, with little apparent mortality.**
2. **Conks are common in decayed stumps and dead wood.**
3. **Small trees are occasionally killed.**
4. **Good data are lacking on the extent or impact of the disease.**

Table 1. Conifer species susceptibility to fir-annosum root disease in the northern and central Rocky Mountains.

Location	Least Susceptible	Susceptible but tolerant	Highly Susceptible
Northern Rockies (Montana and Idaho north of the Salmon River)	**Larch, ponderosa, lodgepole, and whitebark pines**	**Spruces, hemlocks, western redcedar, western white pine;** butt rot and extensive root decay may develop but mortality rates are low.	**True firs, Douglas-fir**; butt rot is common in grand fir and mortality is common in trees of all sizes.
Central Rockies (southern Idaho, Utah, Nevada, western Wyoming)	**Pines**	**True firs, Engelmann spruce;** Butt rot and root decay, some small pockets of mortality.	**Unknown** Extent and severity of annosum remains unknown in many areas.

Life History

Basidiospore-initiated infections

Trees can become infected in numerous ways but it appears the most common occurrence is spore-initiated infections in live trees (Figure 1). Airborne basidiospores land on, or are rain-washed to, a freshly wounded root or lower stem. Here the spores germinate and hyphae penetrate the wood to establish either latent or active infections. Latent infections may remain viable for decades before resuming growth (Garbellotto and others 1999) while active infections begin expanding immediately. The infection expands preferentially toward the root collar. The pathogen grows nearly unhindered in root and butt heartwood of true firs. In true firs and western redcedar, particularly, annosus often produces large cavities in roots and lower stems of trees showing little or no outward symptoms of disease.

Minimal secondary spread

There is relatively little spread of the disease from tree to tree via root contacts compared to other important root diseases such as *Armillaria* root disease and laminated root rot. Most individuals, or genets, are confined to a single tree. Occasionally groups of several trees are infected by the same genet but this appears to be uncommon.

Despite minimal tree-to-tree spread, very high rates of infection are typical of true fir, western hemlock and western redcedar stands in the interior West. The abundance of spores capable of taking advantage of wounds and high frequency of root and stem wounding in these species apparently provide ample opportunity for successful establishment of new infections.

Abundant spore production in dead trees and stumps

When infected trees die, the fungus may continue to live for many decades in the moist, underground portions of the tree.

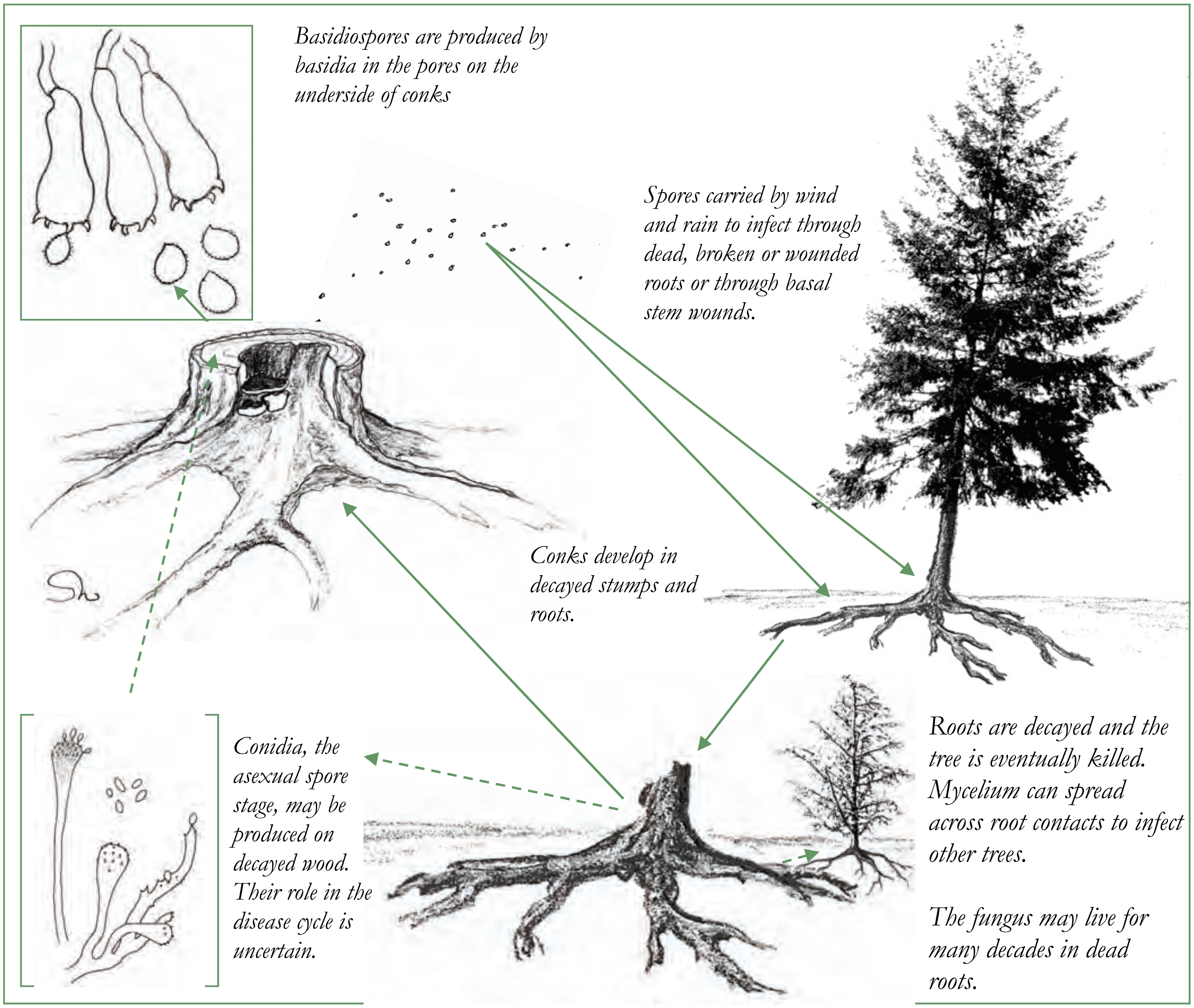
Genet

A genet is an individual derived from compatible spore pairing; a diploid mycelium.

Spore-initiated infections through tree roots or basal stem wounds may account for most of this disease.

Mortality due to Armillaria root disease often obscures the effects of fir-annosus when the two occur together in stands.

Figure 1. Life History of fir-annosus



Sporophore production on roots and in hollow stumps continues for many years after the host has died.

Although mycelia in stumps and dead trees infrequently spread to nearby living trees, they produce conks that are important sources of spores that spread the disease.

Sporophore production continues for many years after the tree has died and airborne basidiospores can nearly always be found in abundance in coniferous forests. These spores are able to infect freshly cut stump surfaces as well as basal and root wounds in live trees.

Asexual spores

Fir-annosus conidiospores are commonly seen in culture and on incubated specimens of infected wood but are not often found in nature. They do not appear to produce a mycelium that is vigorous enough to infect live tissue nor to compete with other fungi for dead wood substrates. Garbelloto and others (1999) suggested that they may play a sperm-like role in producing the heterokaryotic mycelia typically found in stumps. For now, their function remains a mystery.

Spore production by fir-annosum

Annosus sexual sporophores, commonly called “conks”, are often found inside decayed, hollowed stumps (Figure 2). Less often, they are found on the outside of roots of dead trees, just below the duff. Small, incompletely formed, sporophores called "button conks" occasionally appear on roots of small trees killed by annosus root disease.

Annosus conks usually are perennial, sometimes annual. They may be effused-reflexed (shelf-like) or resupinate (crust-like). The older layers are tough and woody but the newest pore layer is softer and white to cream-colored. The pore layer (hymenium) wraps over the outer edge of an effused-reflex conk producing a “sterile margin” of cream-colored tissue. This contrasts with the dark brown or gray upper surface of the conk (Figure 4) making them easy to spot in dark stump hollows. The pores of the hymenium are small, typically 0.3-0.6 mm diameter.

Figure 2 *Annosum* sporophores (conks) often are produced in abundance in decayed stumps. This grand fir stump had 14 conks lining the perimeter of the hollow, including those in Figure 4 at right. [Photo by S. Hagle]

They are mostly round or oval but can be elongate near the margins. Basidia line the interior of the pores producing basidiospores on short sterigmata (Figure 3). The spores are forcibly ejected from the basidia, effectively launching them into the air. In conifer forests, basidiospores of annosus may be found in the air whenever the temperature is above freezing and the humidity is not too low. Basidiospores are washed into soil and along roots by rain and may remain viable for a year. Annosus is incapable of living freely in soil or duff so the spores must germinate on a suitable substrate. Clearly, few spores survive.

The basidiospores are typically dikaryotic, that is, they bear two nuclei, and these nuclei are haploid. Upon germination, basidiospores produce a homokaryotic mycelium which must mate before producing the sexual sporophores. Mating is a simple matter among fungi. Compatible mycelia that meet, can fuse and exchange nuclei. There is another reason for mating of two homokaryotic mycelia; heterokaryotic mycelia are more vigorous than homokaryons (Korkonen and Piri 1994), making them more effective pathogens.

Annosus also produces an asexual spore stage in the form of conidia. They are borne on top of club-shaped conidiophores (Figure 5). Both homokaryotic and heterokaryotic mycelia produce conidia so these spores can be either. The conidia-producing stage bears it’s own name, *Spiniger meineckellus* (A.J. Olson) Stalpers.

This spore stage is readily produced in culture and on incubated specimens of infected wood. However, it is not generally observed outside of the laboratory. The role of these spores in the disease cycle is not known. They do not appear to be capable of producing infections in living hosts.

Figure 3. Sexual spores of annosus

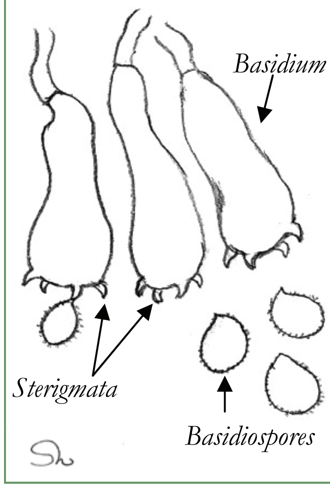
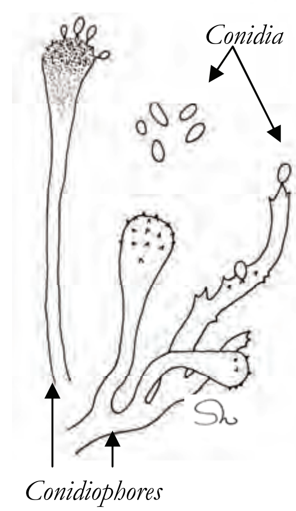


Figure 4. Effused-reflexed annosus conks growing inside a stump. [Photo by S. Hagle]

Figure 5. Asexual spores of *annosus; Spininger meinekellus*



Ecology of fir-annosus root rot

High rates of fir-annosum infection are typical of mature true fir, western hemlock, and western redcedar stands in the interior West.

Fir-annosus infection in the northern Rockies:

- **High rates of infection are typical of mature grand fir, subalpine fir, and western redcedar.**
- **Despite high infection rates, mortality rates usually are low except where *Armillaria ostoyae* is present as well.**
- **Butt rot is very common in grand fir and western redcedar.**
- **Most infections in live trees probably originate from basidiospores but the mechanism of infection is poorly understood.**
- **Root-to-root spread between trees is minimal.**

Annosus root disease is the most common and damaging fungus disease of conifer forests in the northern hemisphere. It has been studied extensively in Europe, especially Sweden, Finland, Great Britain, and France, as well as in North America. Only recently, technology has provided the means to separate the species that have been known under the name *Heterobasidion annosum*. Therefore, most of the literature refers to the species complex as *H. annosum*. The following summary applies to the ecology of fir-annosus.

Modes of spread

Annosus root disease can spread in several ways. "Primary spread" is due to airborne spores produced by a fruiting body or "conk" (Hodges 1969, Hsiang et al. 1989). When spores land on a newly cut stump or fresh basal and root wounds they may germinate and colonize the wood, if conditions are favorable. "Secondary spread" results from growth of the mycelium along host roots. From a diseased tree annosus can spread to a neighboring tree by ectomycelium growing across root contacts, or internally by endomycelium expanding through root grafts.

Fine roots can be infected by mycelium from woody inoculum or by germinating spores. Dead roots are less likely to be avenues of infection because annosus is a poor competitor with saprophytic fungi that inhabit dead roots (Stenlid and Redfern 1998). Annosus is not known to have insect vectors (Hunt and Cobb 1982)

Primary spread

Fir-annosus, at least in western North America, appears to rely more on spore-initiated infection directly in live hosts, than on stump-to-tree or root-to-root spread (Otrosina and Cobb 1989, Garbelloto and others 1993). Several studies have reported fir-annosus genets to be numerous and of limited size Lockman 1993, Garbelloto and others 1997, 1999. Garbelloto and others (1999) studied genet distribution in white fir stands in California. They found that genets of fir-annosus tended to be small, often infecting a single tree or even a single root. Multiple homokaryotic infections are commonly seen in live trees, indicating there are abundant opportunities for basidiospore infections to establish.

Wounds on the basal stem and on roots appear to be likely entry points for basidiospore infections, but there is considerable uncertainty regarding the modes of establishment of fir- annosus in live trees and other substrates. Small root wounds from insect and rodent feeding, and superficial wounds resulting from surface fires and rock abrasion may provide entry courts. Garbelloto and others (1999) postulated that a period of latent infection may occur based on isolations of pathogen from asymptomatic sapwood and roots. Wounding or a period of drought stress may trigger growth of the fungus from latent infections.

Origins of stump infections

Filip and others (1992) found that infection of fresh stump surfaces probably plays an insignificant role in initiating infections in stands in eastern Oregon. High rates (89%) of stump infection in true fir stumps were measured following clearcut harvesting but most were thought to have originated from mycelia already present in the trees before harvest. This observation is consistent with that of Garbelloto and others (1999) who also concluded that most trees already had root infections before tree harvest activity occurred. Additionally, neither harvest season nor stump size appear to influence frequency of stump infection. (Filip and others 1992).

Lockman (1993), studying fir-annosus in northern Idaho, found a possible increase in diversity of annousm from clearcut compared to uncut stands, using vegetative compatibility testing. Basidiospore infection of stumps could account for such an increase. She also found that at least 70% of the genets were limited to a single tree or stump, leading her to conclude that most infections are spore-initiated and had not spread to other trees or stumps.

Mycelium spread from stumps is uncommon

Despite high rates of infection in fir stumps (89%), Filip and others (2000) reported finding very low rates of infection of trees regenerated near stumps. Less than 0.5% of young fir trees growing near stumps died of annosus infection in the ensuing 15-19 years. If primary spread had occurred, it had caused little mortality.

Lockman (1993) found only 19% *H. annosum* infection in stumps of clearcut-harvested stands in northern Idaho. The stumps were mostly Douglas-fir and grand fir that had been harvested several decades earlier. Subsequent, naturally regenerated, 10-30 year-old Douglas-fir and grand fir trees had a 1.7% rate of infection. This was lower than the 2.6% infection in paired stands on never-harvested sites. Douglas-fir and grand fir were about equally infected. Like Filip and others (2000) Lockman commonly found both fir-annosus and *Armillaria ostoyae* in symptomatic roots.

Similarly, Slaughter and others (1991), found no significant mortality in trees surrounding infected fir stumps in California up to 6 years after harvest. This lack of spread of annosus from stumps may be partly due to loss of viable mycelia in stumps within a short time. Morrison and Johnson (1978) reported a steep decline in stump infection rates of coastal Douglas-fir and western hemlock. Initially 82% of Douglas-fir stumps and 62% of western hemlock stumps were infected, but within five years those rates dropped to 5% and 7.5%, respectively.

Small genets in live trees have consistently been found to be unrelated to stump infections (Filip and others 1992, Lockman 1993, Sullivan and others 2001, Garbelloto and others 1999). In the latter study, infected trees generally were not near stumps and isolates from stumps were heterokaryotic, while infections in live trees were homokaryotic. It is, therefore, unlikely that the live-tree infections originated from stumps.

Role of stumps:

- **Most fir-annosus in stumps was present in the roots of the tree prior to cutting.**
- **Neither harvest season nor stump size appear to influence frequency of stump infection**
- **This fungus rarely transfers from infected stumps to kill young trees.**
- **Stumps and dead trees are sites for mycelium mating and sporophore production.**

***H. annosum* is a poor competitor with saprophytic fungi that inhabit dead wood.**

Airborne basidiospores are abundant most times of the year, and individual spores may survive a year or more in bark crevices.

These factors allow annosus basidiospores to take advantage of most of the wounds that occur throughout the life of a tree.

Fir-Annosus Rate of Spread

Longitudinally in roots:

Average — 23-58cm (9-23 in.) per year

True fir in California *(Garbelloto and others 1997)*

Site Factor

Acidic soils inhibit ectotrophic mycelium development— growth is slower without ectotrophic growth

The fact that live-tree infections were homokaryotic probably indicates that they were basidiospore-originated. Lockman (1993) reported finding the same genet in a tree and nearby stump only once in 53 isolates.

Mycelium mating and sporulation in stumps and dead trees

The significance of stumps and dead trees appears to be that they provide a substrate for mating of homokaryotic mycelia. The homokaryons originate either from basidiospore infection of the live tree (before it was cut or otherwise killed) or spore infection of stump surfaces. The resulting heterokayons produce sporophores (conks) in the stumps or dead trees. This process plays a significant role in increasing spore-loading on a site. In order for the fungus to take advantage of wounds as they occur in live trees, an abundance of spores must be present continuously. Therefore, even without direct spread of mycelium, stumps and dead trees probably play a important role in increase of the disease in stands.

Basidiospores are wind transported and capable of establishing mycelium in live and dead host tissues. Stump surfaces are only infected when they are fresh (Morrison and Redfern 1994, Morrison and others 1986), before competing saprophytic fungi have become established. *Heterobasidion annosum* is a poor competitor.

Secondary spread

There is no evidence that *H. annosum* can achieve the tremendous sizes and ages that result from secondary spread in *Armillaria ostoyae* genets. The largest published *H. annosum* genet was about 50 m. (Korhonen and Stenlid 1998) Assuming an average radial growth of the fungus to be 20cm per year, the age would be not much more than 100 years.

Tree-to-tree transmission

Secondary spread between live trees also appears to be minimal. Lockman (1993) found genets to be mostly confined to single trees. At least 70% of genets in stands included in her northern Idaho study were limited to a single tree or stump. She concluded that most infections are spore-initiated. However, in at least one case, the genet had clearly spread to several adjacent trees producing a mortality cluster in a stand otherwise apparently unaffected by the disease. Four mature grand fir and Douglas-fir trees were symptomatic or dead and a single genet of *H. annosum* was isolated from them. These trees were growing close together and thus tree-to-tree transmission was suspected. In both cases the trees bearing isolates of the same genet were less than 7 m (23 ft) apart.

Garbelloto and others (1999) also found that nearly all genets (86%) occupied only one tree in white fir stands in California. Multiple-tree genets colonized up to 11 trees, and extended up to 10 m diameter. Despite the low frequency of secondary spread, the few genets that had spread to multiple trees accounted for 33% of the infected basal area. All inter-tree spread was via root contacts or grafts by endotrophic mycelium. (Ectotrophic mycelium was not observed.)

Although wounding appears necessary for infection by spores, penetration of intact bark by mycelium is common in the case of spread from root contacts.

Mortality is clustered in stands

Garbelloto and others (1999) noted that, although the trees were not infected by the same genet, mortality tended to be clustered in stands. Clusters of mortality typically had several genotypes of fir-annosus. Similar clustering of mortality is often observed in the northern and central Rockies. Several factors may be involved in producing this mortality pattern. Study of fir-annosus is often confounded by the close-association of Armillaria root disease and laminated root rot. These diseases occur on the same sites with fir-annosus and, commonly, in the same tree. The relative ease of diagnosis of Armillaria root disease also probably results in under-diagnosis of annosus root disease.

Armillaria ostoyae root disease, in particular, could be the cause of clustered mortality without regard to annosus genet distribution. Additionally, fir engraver and the western balsam bark beetle are known to frequent trees with annosus root disease (Hertert and others 1975, Lane 1976, Ferrell and Parmeter 1989). These beetles commonly cause clustered mortality as bark beetle pheromones aggregate attacking beetles.

Clustered mortality is characteristic of fir-annosus infected stands even though studies indicate that most trees are independently infected by basidiospores rather than by mycelium spreading from adjacent trees or stumps.

Biological Control

Many naturally-occurring saprophytic fungi invade conifer stumps shortly after tree harvest or thinning. These organisms have the potential to limit the development of root disease fungi. Among the most common fungi seen fruiting on stumps in the northern rockies are *Fomitopsis pinicola* (Swartz:Fr.)Karst., *Trichaptum abietinum* (Dicks.:Fr.) Ryv., and *Gloeophyllum sepiarium* (Fr.) Karst. and *Antrodia heteromorpha* (Fr.) Donk. In addition, several are routinely isolated from dead roots of trees, in particular *Perenniporia subacida* (Pk.) Donk, *F. pinicola*, *Resinicium bicolor* (Alb.& Schw. ex Fr.) Parm. and *T. abietinum*. These fungi are probably natural controls for this and other root diseases by competing for woody substrates.

Another fungus that is occasionally seen fruiting in the northern Rockies, *Phlebiopsis gigantea* (Fr.) Jül, has been developed as a biological control for European species of *Heterobasidion*. Spores of this decay fungus are commercially available as Rotstop ® for inoculation of fresh stump surfaces (Nicolotti and Gonthier 2005). The current state of our knowledge of fir-annosus suggests that this or other direct methods to prevent stump infections are not warranted because 1) most stump infections arise from pre-existing root lesions rather than stump surfaces and 2) fungus does not appear to spread aggressively from stumps. However, the spore-producing role of stump-inhabiting mycelia could be important in maintaining the disease.

Figure 6. Saprophytic fungi such as *Antrodia heteromorpha* (shown on a Douglas-fir stump above and below) quickly establish on stumps and dead trees and effectively exclude root pathogens from the resource. They probably play an important role in limiting the buildup of root diseases on harvested sites. (Photos by S. Hagle)

Management of fir-type annosus

MANAGING FIR-ANNOSUS

Resistant species
Conversion to disease resistant species is usually the most practical method to control damage.

Thin early
Density may promote mycelial spread tree-to-tree and may increase effects of drought stress including more rapid extension of annosus root lesions and attack by bark beetles.

Avoid partial harvests
Partial commercial harvests that leave a large composition of susceptible species may produce the undesirable outcome of losing most of the remaining trees within a few years.

Avoid wounding
Wounds may establish new infections and stimulate growth of existing lesions.

Use particular care with cedar
Western redcedar often goes into a long-term decline after thinning, due to rot diseases.

Silvicultural Management

Altering species composition to increase the proportion of root disease resistant species, avoiding tree wounding during thinning, and reducing tree density at an early age to minimize drought effects are recommended measures to manage fir-annosus impacts. Also an important consideration for management is the fact that other root pathogens and bark beetles usually co-occur with fir-annosus.

Alter stand composition—manage for resistant species

Pines and western larch are not significantly damaged by fir-annosus. They provide the most practical means to minimize root disease impacts. True firs and Douglas-fir are the species most likely to be killed by fir-annosus, while growth loss and slow decline is typical of annosus-infected western redcedar. Regeneration harvest, planting, and stand-tending to maintain pines and larch are efficient means of managing fir-annosus and other fir root diseases.

Thin early

Density may affect tree-to-tree spread of fir-annosus root disease, perhaps more than the other root pathogens. Early thinning may also help alleviate some of the effects of drought. If, in fact, latent infections do establish in fir, and if these infections are stimulated by factors such as drought, preventing over-crowding may forestall the lethal effects of annosus. Thinning is also thought to reduce the impacts of fir engraver beetles, possibly also by reducing the impacts of drought. Care should be taken to avoid over-thinning western redcedar which also seems to stress the trees and possibly cause increased infection by annosus and expansion of existing infections.

Avoid partial harvests that leave susceptible residuals

This is recommended for all of the major fir root diseases. Although this method may not increase mortality rates, it is unlikely to decrease them and often renders the residual stand less manageable because the continuing mortality in the residual susceptible trees leaves little commercial value to finance site preparation and artificial regeneration. Natural regeneration is generally heavy to susceptible species and therefore unlikely to improve the overall condition.

Avoid wounding trees

Wounds may also be significant in fir-annosus development in susceptible stands. In addition to mechanical wounds, it is likely that infection also occurs directly though root bark or through minor wounds caused by insect and rodent feeding. In any case, prevention of wounding is always a good practice management practice.

About those stumps...

Harvest of grand fir stands, in particular, often reveals high rates of pre-existing butt rot from annosus. Even at the time of the first harvest entry the rates of butt rot often are very high, indicating that a history of harvest is not necessary to incite high infection rates. However, studies in eastern Oregon indicated that incidence of annosus root disease in true firs increased with each stand entry. Wounding associated with logging may account for most of this increase. Evidence appears strong that stump-infesting mycelia do not commonly expand to infect live trees. At this time, it appears efforts to directly control infection in fir stumps are unlikely to produce much improvement.

Special considerations for cedar

Western redcedar can be considerably damaged by fir-annosus although it is considered a moderately resistant species. In fact, on some sites cedar has a high rate of root decay and butt rot caused by fir-annosus, especially in residual cedar after a partial harvest. Several other root pathogens are involved and although mortality rates are low, growth decline and loss of crown vigor is often dramatic (Hagle, unpublished data).

Koenigs (1969) reported severe root infection of western redcedar by 20 years after thinning in Priest River Experimental Forest in northern Idaho. *Armillaria* (probably *ostoyae), Corticium galactinum*, *Phellinus weirii* and *H. annosum* (probably fir-annosus) were found in decayed roots. Roughly 90% of the basal area had been removed from 80-yr old stands leaving only western redcedar. The released cedar were young, understory trees; 20 years after thinning they averaged 4.4 to 5.5. inches dbh. Both thinned and unthinned stands had high rates of root infection (94% and 67%, respectively) but the rate of basal cankering was much higher in thinned stands (75% compared to 27%). These cedar also exhibited chlorosis, basal resinosus and growth decline 20 years after thinning (Koenigs 1969).

Recent excavations on the Clearwater National Forest in north Idaho revealed that at least 80% of the lateral roots of western redcedar (trees at least 5 inches dbh) were infected by fir-annosus, *Armillaria ostoyae* or *Phellinus weirii* whether stands had been disturbed by harvest or not. However, extent of root and basal stem girdle was significantly greater on sites with evidence of harvest activity several years prior (average 63% compared to 21%). Also, the cause of root decay and basal stem girdle was more often *Armillaria ostoyae* or fir-annosus on harvested sites, and more often *Phellinus weirii* on unharvested sites.

The amount of root girdle near the root collar correlates with decline symptoms (Figure 7) in the crowns of mature cedar. Although mortality rates are low, decline rates indicate substantial cumulative effect of these infections.

Although research on this continues, it is clear that annosus and other root diseases cause significant damage in cedar stands and that severe thinning that leaves residual western redcedar promotes development of long-term, root-disease caused, decline.

Figure 7. Crown thinning, chlorosis and poor growth are typical symptoms of cedar decline.

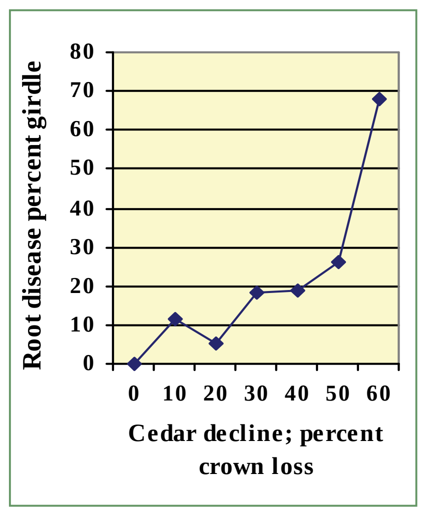


Figure 8. Relationship between root collar girdling by basal cankers caused by root disease and visible crown loss in western redcedar at least 5 inches dbh.

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Explanatory note:

Scientific names for the two species of fungi that cause annosum root disease in North America are now firmly established. *Heterobasidion occidentale* (Otrosina & Garbel.) causes annosum root disease (fir-type) and *Heterobasidion irregulare* (Garbel. & Otrosina) causes annosum root disease (pine-type). The sections for annosus root disease in this management guide were written while these names were still somewhat tenuous or not yet proposed, and therefore the name of *H. annosum* was still being used for both. In addition, there is discussion presented in regards to the possible delineation between the two fungi, and the biology of two inter-sterility groups (S-type and P-type) of the fungus *H. annosum*.

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Related section in field guide.

See explanatory note regarding naming conventions for this fungus.

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Forest Health Protection and State Forestry Organizations

By Blakey Lockman

Management Guide for

Annosus Root Disease (Pine-Type)

Heterobasidium irregulare (Fr.) Bref.. (= *Fomes annosus* (Fr.) Cke.)

P-type Host:

Primarily Ponderosa pine

S-type Hosts:

- Douglas-fir
- Engelmann spruce
- western redcedar
- western hemlock

In northern and central Rocky Mountain forests, butt rot develops with infection in spruce, true firs, and western hemlock. Mortality is common in pines and Douglas-fir.

Topics

Key Points

- P-type annosus is a threat to ponderosa pine, S type is not.
- Fresh stump surfaces can lead to new infections and increase inoculum.
- Chemical stump protectants are the only practical method available for P type annosus control in managed forests.

Introduction

Annosus root disease is a white root and butt rot of many conifer species throughout the western United States and many other temperate forest ecosystems (Hodges 1969). It is caused by the fungus *Heterobasidion annosum* (Fr.)Bref.. Annosus root disease occurs in both old growth and regeneration, and has long been recognized in many forest types in the northern and central Rockies.

In Intermountain forests, butt rot is associated with infection in spruce, true firs, and western hemlock and outright tree mortality is more common in pines and Douglas-fir (Hagle 1985, Byler and Hagle 1985). Bark beetles often attack infected trees (Byler 1989, Ferrell and Parmeter 1989, Hadfield et al. 1986).

Overview of Annosus Root Disease Management in Pines

1. **Assess the need. In many areas, pine-type annosus appears not to be present or not to cause significant damage. In areas with the threat of p-type annosus, preventing spread and intensification of the disease at the time of harvest or commercial thinning is the only practical measure.**
2. **Chemical. Protect fresh stump surfaces that are 14 inches diameter or greater from surface infection by spores.**

About Types of Annosum

Similar but Genetically-Distinct Types of Annosus

Heterobasidion annosum in western North America consists of two intersterility groups or biological species. These two types, 's' and 'p', have very different host specificities.

Ponderosa pine is the main host for the p-type.

The hosts for the s-type include true firs, Douglas-fir, Engelmann spruce, western red cedar, and western hemlock.

This host specificity is not apparent in stump infections; both groups have been isolated from "non-host" stumps without causing disease in neighboring "host" trees (Lockman 1993, Otrosina et al. 1992, Kliejunas 1986).

Click here for a discussion of S-Type annosus root disease management.

Life history

Annosus root disease can spread in several ways. *H. annosum* in a diseased tree can infect a healthy neighboring tree by ectomycelium growing across root contacts, if the neighboring tree is a susceptible species. *H. annosum* can also spread by airborne spores (Hodges 1969, Hsiang et al. 1989). When spores land on a newly cut stump or fresh basal wound they may germinate and colonize the wood if conditions are favorable.

Spore infections are usually limited to the tops of freshly cut stumps in pine species (Otrosina and Cobb 1989), while freshly cut stumps and fresh basal wounds are susceptible to infection in other species (Schmitt et al. 1984). The newly infected stump or tree may then initiate a new disease center by root-to-root contact.

A newly infected stump may initiate a new disease center by root-to-root contact.

Stump Diameter and Infection

In a Forest Health Protection (FHP) survey in California, only ponderosa pine stumps greater than 14" in diameter were found to be infected with *H. annosum* (DeNitto 1988). Another FHP survey in California looked at the lower limit of stump diameter on which *H. annosum* was an effective pathogen in eastside pine tupe stands. In this survey, 75 of 83 disease centers had stumps >18" as an apparent source of infection (DeNitto 1985). Although various studies show infection occurring in stumps as small as 6.0", field observations and mortality surveys in California indicate that only stumps greater than 16.0" routinely cause disease in neighboring trees (Kliejunas 1989).

A survey done in southern Idaho indicated stump size did not affect infection center initiation in ponderosa pine. The average diameter of stumps initiating annosus root disease centers was 22.3" and ranged from 11" to 31". Smaller stumps were not observed in the survey, likely due to stump deterioration and/or the lack of smaller trees at the time of cutting (Marshall and Hoffman 1983).

In western Montana, the size of ponderosa pine stumps infected after a commercial thinning averaged 14.5", and ranged from 9.0" to 32.0" (Hagle unpublished). It remains to be seen what size of stumps lead to disease and mortality in surrounding trees.

Incidence of P-type annosus

P-type annosus root disease is quite common on the Flathead Indian Reservation in western Montana, and is becoming common on several national forests in western Montana. A survey was completed in Region One on the Lolo NF in 2002 and the Bitterroot NF in 2003 to determine the incidence of p-type *Heterobasidion annosum* (Meyer comp. 2003). Surveyed stands were in the ponderosa pine forest type, with mature harvesting 20+ years ago and 30+ acres in size. Stumps in ten percent or more of these stands were surveyed to determine the incidence of *H. annosum* fruiting bodies.

Twenty-five percent of the surveyed stands on the Lolo NF contained *H. annosum* fruiting bodies (n=48), with an average infected stump diameter of 25.5". Over 70% of the surveyed stands on the Bitterroot NF contained *H. annosum* fruiting bodies (n=42), with an average infected stump diameter of 31.1".

S-type annosus root disease is quite common throughout true fir types in western Montana and north Idaho. Less is known about the incidence of s– and p-type in eastern Montana.

Annosus Stump Survey Results

National Forest	Positive *H. annosum*	Ave. Stump Dia. (in.)
Lolo	12 (25%) (n=48 stands)	25.5 (n=11)
Bitter root	30 (71%) (n=42 stands)	31.1 (n=35)

Annosus root disease in pine appears to be-coming more common in western Mon-tana.

Management of P-type Annosus

Silvicultural Management

P-type annosus is routinely found acting as the only root disease agent in ponderosa pine stands. The sites where annosus root disease has been recognized as a problem are sites where ponderosa pine is the most suitable and desired tree species, so species conversion is not a viable management option.

The trend today in managing ponderosa pine is to use multiple entries to maintain old growth or to intensively manage second growth ponderosa pine. Presently, there are few known areas in northern and central Rockies with extensive mortality from p-type *H. annosum*, but with repeated entries into ponderosa pine stands, it appears to be only a matter of time before the fungus colonizes sufficient stumps and causes disease in residual trees. Once annosus root disease becomes established in a stand, there is no economically feasible procedure for directly suppressing the disease. Preventing introduction of the disease is the most efficient and economical method of reducing the impact from *H. annosum*.

When damage from *H. annosum* is already extensive, stump treatments will not be effective. At this point in stand development, favoring less affected species during stand entries is recommended.

Preventing the introduction of annosus root dis-ease is the best method for re-ducing the im-pact from *H. an nosum* in pine stands.

Preventing Stump Infection

Control of p-type *H. annosum* has traditionally been accomplished by protecting freshly cut stump surfaces from infection. Chemicals such as borate compounds have a history of success (DeNitto 1993, Kliejunas 1989). The need for

Preventing stump infections:

- **Highly recommended in western Montana, especially on the Lolo and Bitter root National Forests**
- **Use currently registered product**
- **Treat within 48 hours of cutting**
- **Treat ponderosa pine stumps 14” and greater in diameter**

Preventing Stump Infection (continued)

stump protection in the Northern Region has not been definitively demonstrated, but is highly recommended when managing ponderosa pine. Stump treatments in Region One are presently recommended in ponderosa pine stumps 14” and greater in diameter in ponderosa pine stands in western Montana.

Although there is no environmental reason preventing its occurrence in eastern Montana, P-type annosus root disease has not been identified in eastern Montana, and as such, stump treatments are presently not recommended.

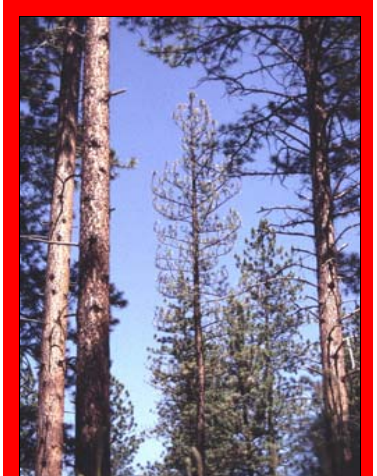
Biocontrol using competing wood decay fungi

Biocontrol agents, such as *Phlebiopsis gigantea* (Fr.) Jul., have been used with success as stump treatments in other parts of the United States and in Europe, but have not been tested in the Northern Region. Biocontrol agents as stump treatments in the Northern Region warrant more investigation.

Symptoms of Infected pine trees include:

- **Chlorotic foliage**
- **Reduced needle retention**
- **Reduced growth**
- **Branch mortality**

Branches may take on a “lion tail” appearance



Recognizing Annosum Root Disease

Trees with annosus root rot may display typical root disease symptoms. Infected trees may have faded, chlorotic crowns, reduced needle retention, reduced growth, stress-induced cone crops, resin-soaked and discolored wood, and decay in the roots and butts.

Incipient decay appears as yellow-brown to red-brown stain. Advanced decay is characterized by a white stringy or spongy mass, which may contain small black flecks running parallel to the grain.

H. annosum fruiting bodies (i.e. sporophores or conks) can sometimes be found inside decayed hollowed stumps, just under the duff layer at the base of infected pines, and also as small "button conks" on the outside of infected roots and root collars on all susceptible species. Annosum fruiting bodies are perennial, woody to leathery, with dark brown upper surface and white to cream-colored lower surface with very small pores. "Button conks" are small, corky mounds of sterile tissue, and are generally cream-colored.

Culturing and/or incubating the decayed wood and observing the imperfect stage of the fungus, *Spiniger meineckellus* (A.J. Olson) Stalpers, may be necessary for positive identification of the decay.

H. annosum **can produce small “button conks” on the outside of infected roots and root collars**

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Explanatory note:

Scientific names for the two species of fungi that cause annosum root disease in North America are now firmly established. *Heterobasidion occidentale* (Otrosina & Garbel.) causes annosum root disease (fir-type) and *Heterobasidion irregulare* (Garbel. & Otrosina) causes annosum root disease (pine-type). The sections for annosus root disease in this management guide were written while these names were still somewhat tenuous or not yet proposed, and therefore the name of *H. annosum* was still being used for both. In addition, there is discussion presented in regards to the possible delineation between the two fungi, and the biology of two inter-sterility groups (S-type and P-type) of the fungus *H. annosum*.

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February 2008

By Susan K. Hagle
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Armillaria Root Disease

Armillaria ostoyae (Romagnesi) Herink

Topics

Hosts: Primarily Douglas-fir and true firs

All conifers may be damaged.

***Armillaria* species are the most damaging and broadly distributed forest tree pathogens in the world.**

***A. ostoyae* is the most pervasive killer of Douglas-fir and grand fir in the northern Rockies.**

A Disease of the Site

Armillaria root disease should be considered a "disease of the site". That is, established mycelia of this fungus are essentially permanent, so the best course to minimize losses is to manage tree species that will survive on infested sites. In large areas of northern Idaho and western Montana, this includes most of the potentially best timber-producing sites.

Elsewhere in the northern and central Rockies, *Armillaria* is often less damaging and more easily tolerated. *Armillaria ostoyae* is a native pathogen with a broad host range but is most common and damaging on Douglas-fir, grand fir and subalpine fir. Mortality rates are highest on warm, moist habitats but large disease patches develop on dry sites and cold, high-elevation sites as well.

The Four Modes of Armillaria Root Disease

Most patterns of *Armillaria* root disease can be identified as one of four types. Management options vary according to the mode of disease development.

I. Distinct, generally large, root disease patches with single or few host species.
II. Multiple clones merge forming essentially continuous coverage of sites. Grouped as well as dispersed mortality occurs throughout the stand. A mosaic of brushy openings, patches of dying trees, and apparently unaffected trees may cover large areas.
III. Primary spread of infection from stumps of the previous generation results in clusters of mortality of seedling and sapling trees, but secondary spread does not occur. By 20-30 years of age, root disease mortality has nearly ceased.
IV. Root lesions of limited extent, often accompanied by butt rot probably resulting from primary inoculum from dead trees and stumps of a previous generation on the site. Little mortality results until advancing age or environmental stresses trigger extension of root lesions. Small groups of mortality result from limited secondary spread of the disease. Impact is generally low.

Key Points

- Know which type of Armillaria root disease you are managing.
- Manage for pines, larch, and cedar.
- Precommercial thinning may improve growth and survival of pines and larch.
- Avoid harvests that leave susceptible species (usually Douglas-fir or true firs) as crop trees.

Management overview

See '*About the Four Modes of Armillaria Root Disease*' on page 9.

Figure 1. A 60-foot wide strip was destumped to control spread of Armillaria root disease at the advancing edge of the disease patch. [Photo by Robert James]

Armillaria mycelia can not be practically eradicated from a site but damage can be kept at tolerable levels with appropriate management. Selecting the management options best suited for each situation depends first on understanding the mode of *Armillaria* root disease. Other options may also be considered, depending on the mode of Armillaria root disease to be managed. Tables 1 and 2 will help identify the mode of *Armillaria* root disease in your forest.

Root Disease Resistant Species

The most widely used and successful approach to controlling *Armillaria* root disease damage is through the use of disease tolerant or resistant species that are from a local seed source and are well adapted to the site (Table 2). Pines, western larch, spruces, western redcedar and hemlocks are more resistant to *Armillaria* root disease than are true firs and Douglas-fir over most of western North America. There are notable exceptions to this rule, depending upon the mode of *Armillaria* root disease encountered and the location. Precommercial thinning, commercial thinning, and site regeneration offer opportunities to change species composition.

Inoculum reduction

Stumps can be removed by pushing out with a dozer (fig. 1), or pulling up using a grapple. Root-raking removes root fragments from the soil. Push-over or pop-up logging, involves uprooting trees as part of the harvest operation. Roth and others (2000) reported that destumping by push-out logging was only effective in reducing mortality of the subsequent regenerated stand if accompanied by hand-picking of root fragments.

Table 1. Diseases caused by *Armillaria*. (Exceptions are seen in all locations.)

Location	Forest conditions	Damage	Management approach
Eastern Montana	Douglas-fir stands	**Mode I**: Discrete root disease centers, often large and aggressive, but not common.	Mark the locations of centers before harvest; use resistant species; remove inoculum in or around perimeter of center.
Western Montana, Northern Idaho	Broad range of habitat types with Douglas-fir and true fir components	**Mode II**: Present in most stands. Diffuse mortality and large and small root disease centers.	Highly significant losses usually requiring species conversion. Important consideration in management plans. Favor resistant species.
Northern Idaho	Lodgepole pine	**Mode I**: Rare, discrete root disease centers, can be large.	Aggressive disease seen in lodgepole pine and associated subalpine fir. Currently unmanaged.
Southern Idaho	Douglas-fir, subalpine fir	**Mode IV**: Small groups and individual trees killed.	Minor impact overall, Significant decay or defect from butt rot on some sites.
Southern Utah	Ponderosa pine, mature true firs, spruce	**Mode III**: Primary pathogen killing a few trees at a time	Usually minor impact. Favor resistant species in disease pockets.
Remainder of Utah	Douglas-fir, grand fir, pines, spruce, subalpine fir	**Mode IV**: Broadly distributed; mostly weak pathogen or saprophyte.	Causes little direct mortality so it is rarely directly managed.
Nevada	Douglas-fir, grand fir pines, spruce, subalpine fir, incense cedar	**Mode IV**: Broadly distributed; mostly weak pathogen or saprophyte.	Causes little direct mortality. Root disease pockets closely associated with endemic bark beetle populations. Rarely directly managed.

These procedures can significantly reduce the food base available to the fungus and delay infection of susceptible crop trees. On the other hand, direct inoculum removal is temporary in effect (the fungus often re-infests), expensive and may damage soil (Quesnel and Curran 2000) and other site amenities. It has been used to good effect in high value plantations such as orchards and in ornamental plantings.

Avoiding Hazardous sites.

Where root disease is limited to discrete patches that occupy relatively small areas, these patches may be excluded from timber management. Where root pathogens are more generally distributed, avoid managing highly susceptible species on the most hazardous sites. Moist grand fir, cedar and hemlock habitat types are hazardous sites in northern Idaho and western Montana. Douglas-fir and true firs may be especially poor risks on most of these sites.

Chemical Control

Chemical soil fumigants that destroy *Armillaria* in root fragments are useful in orchards and vineyards. Stumps are removed to remove most of the large inoculum before fumigation. Chemicals can be protectants, eradicants or curatives.

Table 2. Common disease expression by host and location.

Tree species	Location	Susceptibility	Typical disease
Douglas-fir	Eastern Montana	Highly susceptible at all ages	**Mode I.** Relatively rare; distinct root disease patches
Douglas-fir	Idaho north of Salmon River and Montana west of the continental divide	Highly susceptible at all ages	**Mode II.** Diffuse and concentrated mortality involving entire stands and drainages. Often severe by age 40. Most stands affected.
Subalpine fir	Idaho north of Salmon River and Montana west of the continental divide	Between Douglas-fir and grand fir in susceptibility	**Mode II.** Mortality often diffuse; also commonly large distinct disease patches.
Grand fir	Idaho north of Salmon River and Montana west of the continental divide	Highly susceptible at all ages, though somewhat less so than Douglas-fir	**Mode II.** Diffuse and concentrated mortality over large areas. Large trees often develop butt rot while root disease progresses slowly.
Pines, western larch	Idaho, Montana, Utah and Nevada	Highly resistant (with rare exceptions)	**Mode III.** Mortality common in saplings, but rarely significant in mature trees.
Western redcedar	Idaho and Montana	Moderately resistant	**Modes III and IV.** Some mortality in saplings. Residuals of partial harvests often develop severe infections but are very slow to die.
Engelmann spruce	Idaho, Montana, Utah and Nevada	Moderately resistant	**Modes III, and IV.** Mortality common in saplings. Old trees may have butt rot.
Engelmann spruce	Southern Utah	Moderately resistant	**Mode IV.** Mature stands on cool sites at high elevations may develop patches.
Grand fir	Southern Utah	Moderately resistant	**Mode IV.** Mature stands on cool sites at high elevations may develop small patches.
Douglas-fir	Northwestern Montana (Eureka area)	Moderately resistant	**Mode IV.** Butt rot often develops in mature trees but mortality is uncommon.
Incense cedar	Nevada	Moderately resistant	**Mode IV.** Rare in young trees. Older trees may develop butt rot.

Pay attention to seed zones

Severe root disease is often seen in planting stock that is off-site, regardless of the expected disease resistance of the species.

Maintain tree vigor

Tree vigor plays a role in *Armillaria* resistance on sites or species where the fungus is not an aggressive pathogen. In these situations, the fungus may be secondary to predisposing events such as insect attack, fire or logging injury, or severe drought.

Where the pathogen is aggressive, tree vigor is probably not an important factor. For example, in young coastal Douglas-fir where *Armillaria* root disease is often quite damaging, tree vigor, as the growth efficiency of trees, was not a factor in determining later infection and mortality. On permanent plots monitored for at least 10 years, Rosso and Hansen (1998) found that the biggest and fastest growing trees were as likely to die from *Armillaria* as the smallest and poorest trees.

Ecology of Armillaria in forest ecosystems

Armillaria ostoyae **is commonly found infecting the same trees and even the same roots with other root pathogens.**

Genet

A genet is an individual derived from compatible spore pairing; a diploid mycelium.

A single **genet** can produce multiple **clones** (ramets) by fragmentation.

Fragmentation may result from loss of substrate, or replacement by competing fungi in portions of an area occupied by a genet. Isolation of portions of the genet results in multiple clones that are genetically identical.

Persistent and expanding mycelial clones

New clones result from basidiospore-infection of available substrates. Survival rates of newly established mycelia are probably exceedingly low. This is evident in the relative stability of clones on sites, which are often estimated to be in excess of 1000 years of age (Shaw and Roth 1976, Smith and others 1992, Ferguson and others 2003). An individual derived from a single mating of haploid spores (forming a diploid mycelium) is called a 'genet'.

New genets originate from a single mating between two haploid spores. The resulting mycelium spreads by vegetative growth of mycelium and rhizomorphs.

Most recognizable mortality patches are probably a single genet (Dettman & van der Kamp 2001a). Genets vary greatly in size, probably depending on site conditions and history. Dettman and van der Kamp found most genets in southern interior British Columbia to be less than 2 hectares in size (2001b) and those in the central interior ranged from less than one to more than 15 hectares (2001a). Several remarkably large, and potentially very old clones have been found. Those described by Ferguson and others (2003) in the Blue Mountains of Oregon ranged from 20 to 965 hectares. This included the largest genet reported to date. It covers 2,200 acres (965 hectares) and spans 3.5 miles (5.6 km). See the '*Armillaria ostoyae* clones' sidebar on page 7.

Established mycelia expand outwardly, provided there is suitable substrate. (Read 'Anatomy of a disease patch' on page 7.)*Armillaria* species are capable of forming specialized structures called rhizomorphs, which grow root-like through soil. However, *Armillaria ostoyae* produces few rhizomorphs (Cruickshank and others 1997), relying, instead, on growth of mycelium along and within tree roots to facilitate spread. Expansion rates have been estimated to be 0.7 to 1.3 m/yr (2.3-4.3 ft./yr) in Douglas-fir plantations in southern interior British Columbia (Peet and others 1996).

A similar spread rate (1 m/yr) was reported for a young, naturally regenerated ponderosa pine stand in Washington (Shaw and Roth 1976).

In mature (110-yr old) Douglas-fir in central interior British Columbia van der Kamp (1993) estimated the average spread rate of *A. ostoyae* to be 0.22 m/yr (0.7 ft/yr), about a third that observed in young stands.

Saprophytic and parasitic existence

Armillaria ostoyae can survive as a saprophyte on dead organic matter such as old stumps and roots for several decades.
Even small debris on a site may harbor significant amounts of the fungus. Komroy and others (2005) isolated *Armillaria ostoyae* from as much as a third of small (<2 cm) woody fragments in the upper layers of soil. They also isolated *A. ostoyae* from a number of deciduous tree and shrub species including aspen, honeysuckle and blueberry. Though not considered a primary parasite of these species, the fungus is clearly capable of utilizing a wide variety of substrates to maintain itself on a site.

Hyphae of *A. ostoyae* penetrate wood, causing a 'white rot" type of decay in which both cellulose and lignin are degraded. The mycelium spreads from these woody substrates to the roots of live trees either through direct root contact with infected wood, or by rhizomorphs.

Once established on a root of a live tree, the fungus invades and kills the cambium of the root and the decays the dead root tissues. The mycelium may eventually travel up the root to colonize the root collar, and girdle the tree.

Growth declines

Decay and girdling are usually slow processes that can be delayed for extended periods while the fungus remains latent in non-expanding lesions. Growth decline of infected trees has been detected for 30 years or more before death in mature Douglas-fir (Bloomberg and Morrison 1989). The longer the period of decline before death, the greater the cumulative growth loss. Smaller trees typically have shorter detectable periods of decline before death than larger trees (Bloomberg and Morrison 1989).

In young trees, terminal growth decline is often observed for only one or two years before death. Much also depends on the relative aggressiveness of the pathogen and whether bark beetles attack the weakened tree.

Butt rot may develop

Under some conditions, the fungus establishes infection in the heartwood of the roots and in the lower stem (butt) of the tree. Generally the taproot falls victim at an early age and the pathogen travels from the decayed taproot directly into the butt heartwood. The fungus can produce a large cavity of decay in the heartwood of the stem, usually extending less than three feet above the ground. Grand fir, cedars, hemlocks and spruces commonly develop this mode of disease which can persist for many decades without killing the tree.

Spores abundant but rarely successful

Honey-colored mushrooms may be produced at the base of infected trees during late summer or early autumn. The role of spores from these mushrooms in disease development is not well understood.

At times the fungus seems to invest tremendous energy in the production of these sporophores. Hundreds of pounds of mushrooms can be collected from a site at one time. Each mushroom is capable of producing hundreds of thousands of spores. And yet, no evidence of direct infection of living trees by basidiospores exists. No inoculations of live hosts using basidiospores have succeeded.

Most likely, *Armillaria* spores establish on woody debris initially. The survival rate of even those spores that manage to land on a suitable substrate are probably exceedingly low. Thus, the great abundance of basidiospores may be necessary to ensure the occasional success.

Rhizomorphs

Armillaria root disease has been called "*shoestring root rot*" because of the appearance of rhizomorphs. These root-like structures are used to seek out new substrates.*

Rhizomorphs are highly differentiated aggregations of hyphae surrounded by a dark cortex of protective cells. They grow from a tip that resembles the meristem of a root.

Rhizomorphs facilitate movement of the fungus through soil and under bark. They grow from inoculum, usually roots or stumps of killed trees, to suitable substrates.

Armillaria ostoyae produces relatively few rhizomorphs compared to many other species of *Armillaria*. They have a dichotomous branching pattern (Morrison 1989).

Probably because of inoculum potential, rhizomorph-originated infections are less successful than are infections spread from root contact with inoculum (Robinson and Morrison 2001).

*There is evidence rhizomorphs also provide water, nutrients and oxygen to the mycelium.

Figure 2. Fire probably has little direct effect on Armillaria inoculum in roots that are more than an a few inches below the ground surface.
(Photo from USFS files)

Fire

Fire has been a historically important factor in shaping forest composition and structure in northern and central Rocky Mountains. Based on the considerable age achieved by *Armillaria* clones, it is reasonable to conclude that they typically survive forest fires. There is little direct evidence of the effects of fire on established *Armillaria* mycelia but abundant anecdotal evidence suggests that the fungus is capable of surviving and thriving in subsequent regenerated stands. This is to be expected because most of the inoculum resides deep in root systems.

Filip and Yang-Erve (1997) tested survival of *Armillaria ostoyae* in buried wood on sites broadcast burned in fall and spring. In general, burning had no effect on inoculum survival although a reduction of viability was observed in inocula buried nearest the surface in the fall-burning treatment. The burn treatments were not accomplished according to plan, so it remains unclear whether slash burning affects shallow inocula.

Primary vs. secondary spread

Figure 3. Primary spread of infection from stump or snag roots to trees following fire or harvest.
(Photo by John Schwandt)

Primary spread (Figure 3)

In inland western forests, root disease of stands established after harvest or severe fires generally results from infections spreading from primary inoculum (stumps or buried woody material from the previous stand). Inoculum potential slowly declines as the roots of stumps and snags deteriorate. Although the disease can be severe in the first few years after stand establishment, mortality of resistant species, such as pines and larch, generally declines after two or three decades, often with little lasting impact on stands.

Secondary spread (Figure 4)

Also in inland western forests, root disease of Douglas-fir, grand fir and, probably, western redcedar results from both primary and secondary spread of the fungus. Secondary inoculum is produced on roots of *Armillaria* -killed trees. The fungus is capable of maintaining very large mycelia for at least several centuries by means of secondary inoculum.

The ability of trees to wall off root infections and, eventually slough those infections, limits secondary spread of *Armillaria.*

Figure 4. Secondary spread from tree to tree may continue throughout the life of the stand. (Photo by Susan Hagle)

Secondary disease spread varies by location

Primary and secondary spread of disease is common in Douglas-fir stands in inland forests; however in coastal forests of the pacific northwest from Oregon to British Columbia, Douglas-fir acts more like inland ponderosa pine. The disease may be severe in young stands for a decade or two after harvest but subsides thereafter. Secondary spread of the disease does not play a significant role.

Similarly, while ponderosa pine is relatively resistant to secondary spread in most inland western forests, in some natural pine stands in central Washington both primary and secondary disease spread is common (Shaw and Roth 1976). On these sites, Douglas-fir is considered to be relatively resistant to root disease.

Armillaria often becomes the primary pathogen in regeneration after a fire or harvest, even though laminated or _annosus_ root diseases were dominant in the pre-harvest stand.

Waves of mortality and regeneration in root disease patches

Wave patterns of mortality and regeneration are most clearly observable on sites that have no cutting history and large infection patches. At the margins of the disease patch, the slow advance of the fungus into the non-diseased portion of the stand produces the initial wave of mortality (See 'Anatomy of a root disease patch' below). This is followed by a wave of regeneration in the canopy opening, then slow mortality of seedlings and saplings. When the survivors of this cohort of regeneration reaches roughly pole size, the food base will be sufficient to fuel a second wave of mortality in what is now the older portion of the disease patch.

The result is a stand with zones representing the temporal sequence of root disease development in the stand. These zones form concentric rings from the center to the perimeter of the disease-affected area .

The primary difference between the wave pattern in root disease infected stands on sites with no cutting history and that on sites that have been cut is that the harvest sets the timing of the wave by stimulating the regeneration that will reach pole size at about the same time.

Primary spread from stumps results in new infections in these young trees. As in the uncut stand, the young trees die a few at a time until the survivors are large enough to provide a substantial food base for the fungus. At this point, secondary spread will accelerate the rate of mortality. As trees die, they are replaced by abundant regeneration. Mortality then slows until sufficiently large root systems have been produced to fuel another wave of mortality. Recognizable root disease patches eventually re-emerge in cutover stands as groups of trees are killed and openings are regenerated.

Anatomy of a root disease patch

Trees from the original stand die at the margins of the disease patch (A).

A zone of open canopy, heavy fuel-loading and new regeneration can been seen just inside the patch margin, where recent mortality has expanded the patch area (yellow).

[Photo by James Byler]

In the older portions of the patch (shaded), some trees reach sufficient size to produce secondary inoculum. This leads to clusters of mortality (B) in older portions of the patch.

Armillaria clones are the largest organisms known to man.

Big

The original "humongous fungus" is 38 acres (15 hectares), 1500 to 10,000 years old, weighs about 100 tons. It is *A. gallica*. Found living in the upper peninsula of Michigan and was widely covered in the press; even on a TV talk show (David Letterman). (Smith and others 1992)

Bigger

1,500 acres (600 hectares), *A. ostoyae,* Southeast Washington (Shaw and Roth 1976)

Biggest

2,400 acres (965 hectares) and estimated to be at least 2,400 years old, *A. ostoyae*, in the Blue Mountains of eastern Oregon. It stretches 3.5 miles (5.6 km) wide and covers an area larger than 1,600 football fields. (Ferguson and others 2003)

Inoculum Potential

Energy is required for *Armillaria* to overcome a tree's defenses. When the fungus is able to establish on a large root mass, it has a large food base to provide energy, which means it has a large inoculum potential.

Low inoculum potential of rhizomorphs may render them less effective in establishing infections than mycelium growing directly from a more substantial food base.

The main differences in host resistance appear to be determined by the frequency and longevity with which lesions are restricted by secondary periderms.

Secondary periderms may have several layers of phellem. The tree root may have several successive necrophylactic periderms that have been produced as each previous periderm was breached.

Most lesions are halted in the bark or cambium of roots. If prevented from expanding long enough, periderm-surrounded infections will eventually be sloughed (as the root grows) and the root will heal.

Mechanisms of Resistance to Armillaria root disease

Armillaria ostoyae occurs throughout Europe and north America and is primarily a pathogen of conifers. It is also known to attack and kill some hardwoods growing in association with conifers including birch (Morrison and others 1985) and aspen (Pankuch and others 2003). Although all native forest conifers in the Rocky Mountains are considered susceptible, differences are readily observed. The effectiveness of resistance mechanisms of conifers vary by host and pathogen species and by the age of trees.

Bear in mind that there is a world of difference between a pathogen simply being capable of infecting a host, and that pathogen causing sufficient disease in that host to present a management challenge.

Primary Defense— Chemical

Root bark of conifers contains phenolic compounds that are inhibitory to *Armillaria ostoyae*. Larch has much higher concentrations of phenols in the root bark, compared to Douglas-fir or grand fir (Entry and others 1992). Ponderosa pine and western white pine were intermediate. These chemical defenses probably prevent most infections. These authors also suggest that the relatively higher sugar content in Douglas-fir and grand fir bark contributes to the success of the pathogen.

Resin production in response to infection of the cambium presents at least a temporary physical barrier as well as biochemical. Time and energy are required to digest resins in order for hyphae to penetrate resin-soaked tissues.

Secondary Defense—Physical Barriers

As a secondary defense, a tree under attack will attempt to "compartmentalize" a wound or infection (Tippet and Shigo 1981). This is a relatively rapid, generic, response of the tree to wounding or pathogenic infection. In effect, the cells near the infection site, that were present at the time of infection, are fortified. The cell walls become lignified and suberized. The cells also are made toxic to invading hyphae through the deposition of secondary metabolites (phenolic compounds, mostly). Within months, trees will produce an organized periderm to wall off the infection.

Referred to as necrophylactic periderms, they consist of single or multiple phellem layers which wall off infected tissue. These periderms delay extension of the infection but they may be eventually breached by hyphae. The main differences in host resistance appear to be determined by the frequency and longevity with which infections are restricted by secondary periderms.

Two important studies compared a relatively resistant species (western larch) to a highly susceptible species (Douglas-fir) at three ages (Robinson and Morrison 2001, Robinson and others 2004). At 6-11 years of age both tree species were readily infected, girdled and killed by *Armillaria ostoyae*.

Resistance was more effective in 18-19 year-olds of both species but differences between larch and Douglas-fir were evident. Necrophylactic periderm formation had delayed the advance of nearly half of the infections in larch and only a fourth of those in Douglas-fir (Robinson and Morrison 2001).

At 25-27 years of age, the necrophylactic periderms formed by larch roots were far more impervious to breaching (55% intact) than those in Douglas-fir (none intact) (Robinson and others 2004).

Larch periderms also were more often replaced if breaching did occur. These studies suggest that resistance develops in larch somewhere between 8 and 15 years of age but much later in Douglas-fir, probably closer to 35 years.

Most of the lesions on older trees are contained in the bark or outer portions of the root near infected cambium (Robinson and Morrison 2001). If prevented from expanding long enough, these infections will eventually be sloughed and the root healed. If the pathogen manages to girdle the root cambium, the distal portions of roots are killed and decayed by the pathogen (Shaw 1980). At some point the inoculum potential developed by the fungus on these killed roots may become sufficient to allow it to breach the periderm. The host is often seen to lay down repeated periderms following each breaching. Larger roots, nearer the root collar, react more aggressively and are more successful at containing infections.

Timing is everything

Young trees have small root systems that provide little inoculum potential when overcome by the pathogen (figure 5). Therefore, the early susceptibility of larch and pines probably contributes little to secondary spread of *Armillaria* root disease. The converse is also true; as older, larger trees are killed the mass of each root system contributes significantly to the inoculum potential of the pathogen. As inoculum potential increases, secondary spread of the disease also increases. Therefore, the delayed resistance of Douglas-fir probably contributes greatly to the increases in inoculum potential and to the secondary spread observed in Douglas-fir forests. This may hold for true firs as well.

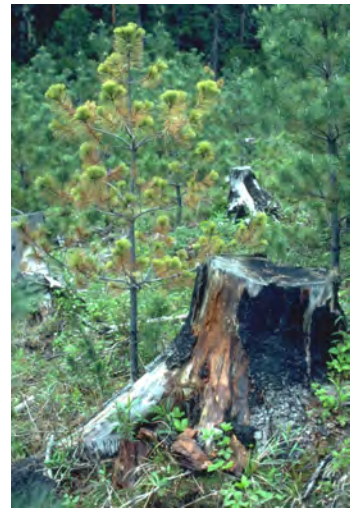


Figure 5. Although susceptible at a young age, the surviving western white pine will become resistant before they are large enough to contribute significantly to inoculum potential on this site. With little potential for secondary spread, Armillaria root disease will decline. [Photo by James Byler]

About the Four Modes of Armillaria root disease

MODE I — DISTINCT ROOT DISEASE PATCHES

The etiology (pattern of development) of *Armillaria* root disease mode I is best understood. This disease mode is typified by more or less round patches of root disease-killed trees (figure 6). They are ringed with newly dead and dying trees and usually have advanced regeneration in their centers, where young trees have taken advantage of the disease-caused opening.

These disease patches increase in radius at a rate of about 0.2–1.3 m (0.7-4 feet) per year. As susceptible trees at the margin are encountered, the pathogen infects, girdles and kills these trees and then uses the root system to spread to adjacent live trees. In the interior of the disease patch, susceptible trees regenerate and grow in the opening. They are in turn killed as their roots encounter inoculum in the decaying roots of the previous generation.

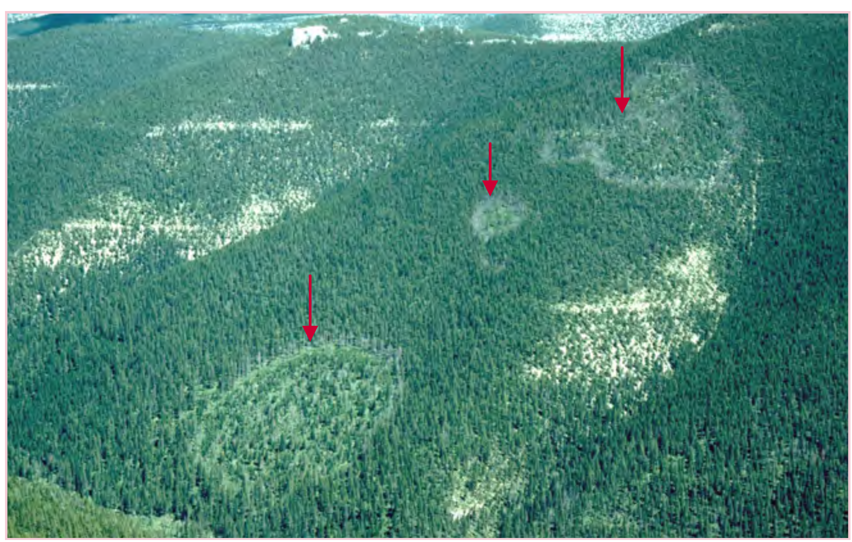


Figure 6. These three root disease patches in a Douglas-fir forest in eastern Montana form distinct fairy-ring patterns when observed from a distance. Discrete patches with clearly defined edges are typical of Mode I Armillaria root disease. [Photo by Ralph Williams]

Managing Mode I

Resistant species
If there are resistant tree species that are suited and economically feasible to grow on the infected site, this is usually the most effective and efficient means of reducing damage.

Avoid infected sites
This may be an option for this type because the infected area may be fairly limited and distinct. The fungus is likely to continue to expand at the margins of the disease patch if susceptible trees are present.

Reduce inoculum
Stump removal, especially around the perimeter of the disease patch may contain the fungus. Removal within the disease patch can be expected to reduce but not eliminate the disease.

66% of acres in northern Idaho and western Montana have significant root disease impacts.

Most is due to Mode II *Armillaria* alone or in combination with Annosus root disease or laminated root rot.

Root disease patches in eastern Montana

Root disease patches east of the Continental divide in Montana appear to fit this etiology very well. *Armillaria* is nearly always the only disease of consequence in these patches. They are typically seen in Douglas-fir stands of uniform age, and density. The disease patches are strikingly uniform in shape (round or oval) and profile. The profile (figures 6 & 7) shows the largest advanced regeneration in the center of the patch. The size and age of regenerated trees declines toward the margins of the patch where an increasing number of still-standing dead trees are seen. In the margins, recently dead, red trees are mingled with thin-crowned dying trees and those showing little or no apparent decline.

Figure 7. Mode I *Armillaria* root disease patches have a distinct margin. The interior of the patch has successively older regeneration nearer the center of the patch. [Photo by Ralph Williams]

These patches probably represent single successful genets established hundreds or thousands of years ago. They survive on one generation of trees after another as wildfires sweep through on long intervals to restart stands on the site. Douglas-fir generally occurs as single-species stands in this situation.

Disease patches on dry sites

Dry site types, such as those with Douglas-fir habitat types (Dry Biozone in British Columbia) generally have a lower incidence and smaller extent *Armillaria* genets than do moist sites (Byler and others 1992, Morrison and others 2000). They commonly form distinct patches in a forest typifying Mode I root disease.

Lodgepole pine and subalpine fir in northern Idaho

Large, apparently single-genet *Armillaria* disease patches are uncommonly seen in lodgepole pine stands and mixtures of lodgepole pine and subalpine fir in northern Idaho. Here, as in the Douglas-fir stands of eastern Montana, the fungus aggressively eats away at the margins of the disease patch while infecting the trees that regenerate in the older, central portions of the disease patch.

MODE II — PATCH AND DIFFUSE MORTALTIY

Mode II *Armillaria* root disease is by far the most common mode in Idaho and western Montana. The disease probably has a similar etiology to Mode I but there may be many more clones, perhaps larger individuals and, sometimes, more variety of both host and root pathogen species involved. The profile of a diseased stand is much more complicated than that of Mode I, but the development of the disease may not be. As in Mode I disease, primary spread from killed trees and stumps following disturbance such as stand-replacement fires and regeneration harvests establish the pathogen in the subsequent generation of trees on the site.

Secondary spread from roots of infected trees to adjacent trees results in mortality beyond the reach of infected stump roots and maintains the fungus long after the stumps have rotted away.

A wave-like pattern of mortality is evident but made more difficult to observe as patch boundaries merge.

Mode II *Armillaria* is most typical of root disease in Idaho and western Montana. Douglas-fir is typically the most-damaged host with grand fir, white fir and subalpine fir also very susceptible. As individual clones of *Armillaria* merge they produce extensive disease patches (figure 8). Studies of naturally occurring *Armillaria* colonies have shown minimal overlap of individual clones of the species indicating that they are capable of excluding other individuals of the same species (Smith and others 1992, Ferguson and others 2003).

Figure 8. Dispersed and concentrated groups of mortality and irregular clusters of regeneration mark this hillside on the Nez Perce forest in Idaho with a long history of Mode II Armillaria root disease. The boundaries of patches are indistinct with continuous root disease symptoms extending for several miles in all directions in this forest type. [photo by Susan Hagle]

Dettman and van der Kamp (2001) studied the distribution of *Armillaria ostoyae* in moist forests (Interior Cedar-Hemlock) of southern interior British Columbia (presumably similar to that across the border in northern Idaho). They found 88% of the forested area to be infested, with genets less than 2 hectares (5 acres) in size. The genets were uniformly pathogenic and probably mostly very old and stable.

Root infection is common, even in young trees. Morrison and others (2000) estimated that about 38% of 13-24 year old trees were infected on moist sites in southern interior British Columbia (comparable to grand fir habitat types in Idaho and Montana). Thirty two percent were infected on wet (cedar and hemlock habitat types) if there were dead trees present. Even where no dead trees were present, 25% on moist and 15% on wet types were infected. As stands age, these infection rates increase steadily. By comparison, only 10% of trees on dry sites were found to be infected even with mortality present. On dry sites, in southern interior British Columbia, Idaho and Montana, *Armillaria* root disease tends to fit the Mode I pattern. Genets are fewer leaving most of the forest uninfected (Byler and others 1992, Morrison and others 2000).

Managing Mode II

Resistant species

For Mode II *Armillaria* root disease, conversion to disease resistant species is usually the only practical method to control damage.

Increasing proportions of less-susceptible species to 60% may greatly reduce damage to susceptible trees by interfering with root transfer of the fungus on site.

Species diversity can be enhanced with *Armillaria ostoyae* resistant hardwoods such as birch or mountain maple.

The presence of many overlapping clones, and nearly continuous distribution over large areas limits the application of inoculum reduction and hazardous site avoidance.

Partial harvests that leave a large composition of susceptible species may produce the undesirable outcome of loosing most of the remaining trees within a few years.

How fast do they die?

Douglas-fir 17 to 23 years of age took an average of one to three years to die after basal resinosus was detected.

(Morrison and Pellow 1974)

(Photo by Susan Hagle)

Sources of data for graph:

- Byler, Marsden and Hagle 2006, Root disease-caused tree mortality in northern Idaho stands: 22 year monitoring results and implications. (In preparation)
- Hagle, Marsden and Welborn, 2006. Indicators and patterns of conifer mortality caused by root disease. (In preparation).
- Hagle, 2005. Root disease and associated bark beetle mortality estimation for intermountain west risk map. Summary of results from 758 permanent plots in northern Idaho and western Montana, monitored 8-18 years. In-house report.
- Morrison and others 1988
- Morrison and Pellow 1994

In mixed conifer forests of the Blue Mountains in northeast Oregon, Ferguson and others(2003) measured genets ranging from 20 to 965 hectares (49-2,385 acres) in size. They estimated the age of genets to range from 1,900 to 8,650 years. Although similar in most ways to *Armillaria* root disease in northern Idaho, in these stands true fir species appear to be more susceptible to the disease than Douglas-fir.

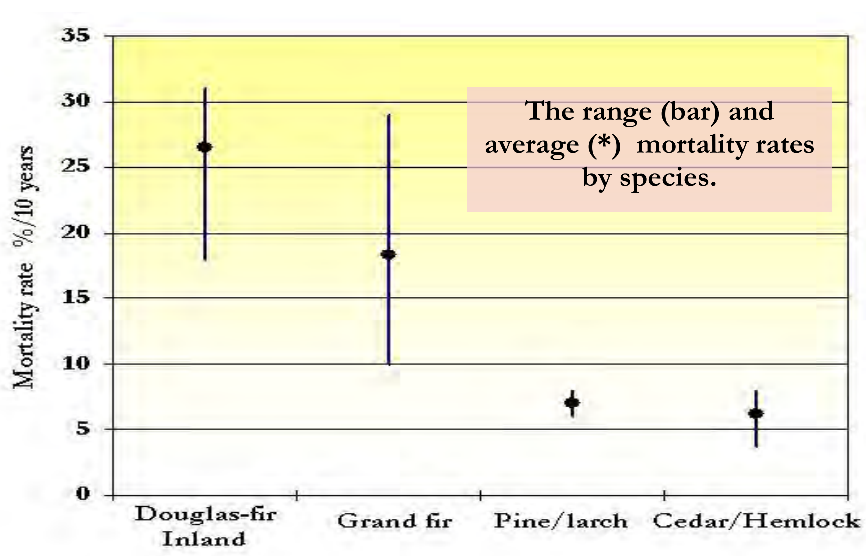
Expected mortality rates in Mode II disease

Mortality rates vary by stand age, species composition and site quality. In the northern Rocky Mountains, Douglas-fir and grand fir mortality rates are considerably higher than those of pines, western larch, western redcedar and western hemlock (figure 9). From nine studies that have employed permanent plots to monitor root disease mortality of forest trees, results are remarkably consistent. The primary causes of mortality on plots in the northern Rockies were usually a combination of *Armillaria ostoyae* and *Phellinus weirii* (fir type). Elsewhere, it was almost entirely *Armillaria ostoyae*.

In unthinned stands, mortality rates of ponderosa and lodgepole pines, western redcedar and western hemlock averaged 1.5% to 10% per decade. Likewise, mortality rates for coastal Douglas-fir were less than five percent per decade. Young western larch averaged 18% mortality in one study (Morrison and others 1988). The rate of mortality of larch declined throughout the 14-yr monitoring period. Grand fir was variable, ranging from 10 to 30% per decade. Douglas-fir mortality averages ranged from nearly 20% to a little more than 30% per decade in the various studies. Little is known about mortality rates of subalpine fir but they appear to fall between those of Douglas-fir and grand fir.

In general mortality rates of pines, coastal Douglas-fir and western larch declined with age and thinning. The opposite was the case for inland Douglas-fir and grand fir. Mortality rates ranged from 13%/decade in 5-19 yr old Douglas-fir (Morrison and others 1988) to 30%/decade at 100 yrs of age (Byler and others, in preparation).

Figure 9. Root disease mortality rates of trees at least 20 yrs old.



Site Predictors of Mode II Armillaria root disease

Site factors such as moisture and temperature show promise as indicators of disease-proneness.

Disease incidence

Incidence of *Armillaria* root disease is highest on hemlock, grand fir and cedar habitat types. On the Lolo National Forest, Byler and others (1990) reported a high of 80-88% of stands with root disease (mountain and western hemlock habitat types) to a low of only 13% (ponderosa pine habitat type). Half of the stands on grand fir habitat types had root disease. A third or fewer were afflicted on other habitat types (figure 10). Species composition interacts significantly with habitat type to influence root disease prevalence. In this case, many stands on cedar habitat types were dominated by western redcedar and grand fir with few live Douglas-fir remaining whereas Douglas-fir was a primary component on grand fir, Douglas-fir and western hemlock habitat types. Species composition alone was not a good predictor of root disease because of the strong influence of habitat type.

Surveys of Douglas-fir stands on moist cedar-hemlock in southern interior British Columbia found root disease on 88% of hectares (Dettman and van der Kamp 2001b). An assessment of the Coeur d'Alene Basin National Forest (figure 11) uncovered root disease in 98% of stands with Douglas-fir and grand fir cover types, across all habitat types, but the highest severity classes were most common on grand fir and cedar/hemlock habitat type groups (Hagle and others 1994).

Disease severity is highest on grand fir and moist subalpine fir habitat types with Douglas-fir, grand fir or subalpine fir forest types. The most severe condition, root disease patches in which few trees survive, have been reported to occupy 5.1% of the Coeur d'Alene Forest (Williams and Marsden 1982). This agrees well with a later assessment of root disease on the Coeur d'Alene Basin Forest in which 5.8% of stands had severe root disease, defined as having 75% or greater loss of canopy to root disease (Hagle and others 1994). Approximately one third of the Coeur d'Alene Basin Forest has Douglas or grand fir cover type. Williams and Marsden (1982) reported finding most of the disease patches on grand fir or western hemlock habitat types. Hagle and others found severe disease most common on grand fir, western hemlock or moist subalpine fir habitat types. Mortality rates of Douglas-fir and grand fir are highest at a relatively younger age on highly productive sites such as western redcedar and western and mountain hemlock habitat types (Hagle and others, in preparation).

Visually estimated root disease severity (Hagle 1992) is a measure of cumulative root disease impact in a stand. Recent analysis of permanent plot data from north Idaho found the root disease severity assigned at the time of plot establishment was the best predictor of mortality in the subsequent 20 years. Figure 12 illustrates this relationship (Hagle and others, in preparation).

Figure 10. Percent of plots with root disease by habitat type series Lolo National Forest (Source: Byler and others 1990)

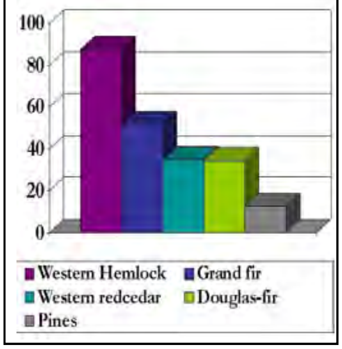
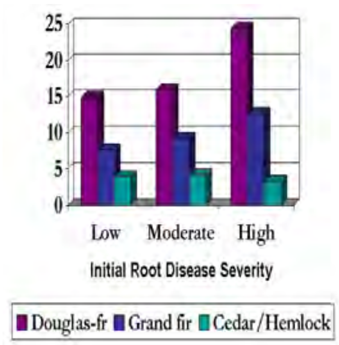


Figure 11. Mortality rates by habitat type series and initial plot root disease severity. (Percent of trees/10 years)



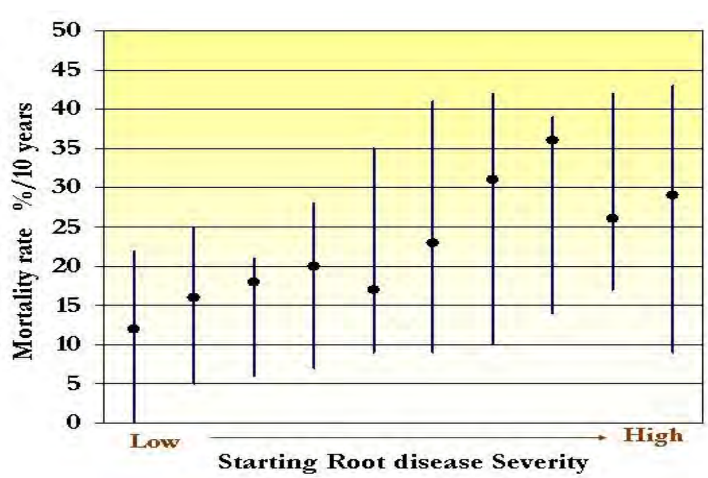


Figure 12. Mortality rates (all tree species) from permanent plots in Idaho and Montana.

Comparing commercially thinned and unthinned stands

Figure 13. Root disease mortality; trees Mature Douglas-fir and grand fir
Percent change; stems/10yrs

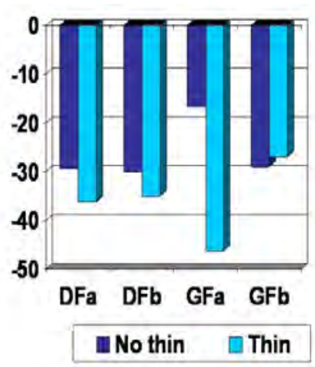
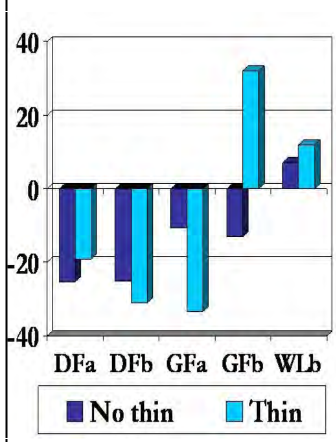


Figure 14. Root disease mortality; volume

Mature Douglas-fir, grand fir and western larch
Percent change; volume/10yr



Data sources:
(a) Hagle and others (in preparation) 213 permanent plots monitored 20 years.
(b) Byler and others (in preparation) 12 permanent plots monitored 22 years.
Both studies located on the Idaho Panhandle National Forest in northern Idaho.

Thinning in Modes I and II Armillaria root disease

Commercial thinning

It is fairly safe to say that *Armillaria*-afflicted stands will not respond favorably to commercial thinning if susceptible species are left. Mortality rates vary greatly by location and through time. By the time stands reach commercial size many have high mortality rates. If mortality rates in a stand are already high, increases in mortality after thinning tend to be small or none. However, where mortality rates were initially moderate or low, increases can be dramatic following thinning.

Most reports are from retrospective studies comparing thinned stands to uncut stands. For example, comparing selectively harvested stands to uncut stands, Morrison and others (2001) observed a trend in infection and mortality rates, subsequent to harvest, that was associated with site quality. Rates were low on dry sites, moderate on wet sites, and high on moist sites. All site types had slightly higher mortality rates if stands were selectively harvested compared with the uncut stands. Differences were statistically significant in two out of four comparisons.

Byler and others demonstrated differences in response between Douglas-fir and grand fir where laminated root rot and *Armillaria* root disease were both primary causes of mortality (unpublished report). The permanent plots, in northern Idaho, were monitored for 22 years after commercial sanitation thinning (with unthinned controls). Mortality rates (percent of trees) for Douglas-fir remained fairly consistent between the two time intervals regardless of whether stands were thinned or not, and regardless of the time following thinning (Figure 13). Grand fir, however, had a low initial rate of mortality after thinning. This rate nearly doubled between 15 and 22 years after harvest, compared to the first 15 years. Also, in the Byler study, Douglas-fir timber volume decreased at both 15 and 22-year remeasurements post-treatment (figure 14). However, grand fir volume increased in the first 15 years following thinning then declined rapidly. Grand fir appeared to respond positively to sanitation thinning for at least the short term, leading the authors to suggest that grand fir may be an acceptable leave tree choice when a regeneration harvest is to follow within 10-15 years.

Hagle and others (unpublished) found the grand fir decline to begin sooner, between 8 and 10 years after thinning with a net loss of 67% in 20 years in the thinned stands compared to 22% loss in the unthinned stands (figures 13 & 14). Douglas-fir mortality rates were slightly higher if measured as proportion of stems, or not significantly different, if measured as proportion of volume following thinning. In both Byler and Hagle studies, the largest and most vigorous-appearing trees were retained during the thinning. Thinning did not improve survival of remaining Douglas-fir or grand fir.

Morrison and others (2001) found that, on moist sites, as much as 90% of live, codominant trees in undisturbed stands had *Armillaria* root lesions. Root systems remain alive for a time after the tree is severed, during this time they can prevent colonization by saprophytic fungi but the *Armillaria* lesions are able to expand (Shaw 1980). During this time the stumps may become extensively colonized by pathogenic fungi. This increase in inoculum potential allows the pathogen to spread from roots of stumps to residual trees and post-harvest regenerated trees.

Precommercial thinning in modes I and II

Even small stumps, from precommercial thinning have been found to be colonized by *Armillaria* spp. Cruickshank and others (1997) reported finding up to 77% *Armillaria* infection in precommercial thinning stumps in British Columbia. Infection rates were highest on interior cedar/ hemlock sites, where rates ranged from 28 to 77% and averaged 51%. Inland Douglas-fir sites averaged about one third. Lowest rates were in the coastal forests (average 12-22%).

About half of the individual stump root infections lead directly to infection of Douglas-fir crop trees; again the rates were a little higher in the interior cedar/ hemlock type. These sites develop Mode II disease so these early infections have the potential to lead to considerable long term impacts. Resulting mortality has not, as yet, been monitored.

Although little can be said, as yet, about mortality rates of Douglas-fir, grand fir or subalpine fir after thinning, we have fairly reliable data suggesting that resistant species improve growth and survival following precommercial thinning.

In stands or portions of stands with low root pathogen incidence, precommercial thinning may provide satisfactory results. The increase in growth of the residual stand may offset subsequent mortality enough to justify the thinning investment. However, careful examination of the candidate stand is in order because even a moderate rate of infection may not be obvious in young stands. Young trees die and loose their foliage quickly. Close inspection of small openings in young stands may reveal more mortality than is otherwise apparent. Precommercial thinning, especially in sapling-size trees may not greatly increase the long-term losses but the money spend thinning may prove to be poorly spent if few of the residual trees reach maturity.

If less susceptible species are favored in thinning and the resultant stand has an improved species composition, thinning can be an excellent investment.

Western larch and lodgepole pine are particularly sensitive to lateral competition (crowding). Thinning may be required to maintain these species even where root disease mortality rates are expected to be fairly high among competing Douglas-fir and grand fir. Large root pathogen biomass may be maintained by dying Douglas-fir and grand fir. Armillaria attacks on larch and pines may be more frequent under these conditions, with subsequently higher rates of mortality and lower rates of growth in these species as well.

Also a factor, is the delay between crown closure and the highest rates of root disease mortality. It may take decades after crown closure before sufficient root disease mortality has occurred to open the canopy. In many cases, the easing of crowding occurs too late to benefit intolerant species; larch and lodgepole pine, in particular.

The infection rates detected in young, unthinned stands that have few above-ground symptoms suggests that new infections resulting from thinning may not greatly alter the impact on stands. As stated earlier, Morrison and others (2000) found 32-38% of saplings to have root infections on moist and wet sites in interior British Columbia. Mortality rates were low in these stands at this age but could be expected to increase as the infections spread across the tree root systems.

Figure 15. Precommercial thinning and weeding, removed mostly Douglas-fir and grand fir while retaining mostly western larch. These released larch can be expected to become increasingly resistant to Armillaria root disease.

To the extent that thinning increases growth, it probably also increases infection rates as the larger root systems contact more inoculum. In trees of resistant species with good growth, this increase in contact with inoculum is presumably offset by the ability of the tree to contain and eventually shed infections. This is demonstrated through lower mortality rates of resistant species following thinning (Filip and others 1989). However, species with inferior resistance, such as Douglas-fir and grand fir have higher mortality rates among the faster-growing trees.

Precommercial thinning in mixed-species stands is discussed in more detail under Mode III—Disease of young trees.

Brush removal improves conifer growth and may increase Armillaria root disease

Brushing can increase mortality rates

There is mounting evidence that increased growth following brush cutting may lead to several fold increases in crop tree mortality rates.

Removal of hardwood shrubs and trees (by cutting) to release young conifers is a common practice in the intermountain west, especially on private timber land. Early seral hardwood shrubs and trees often grow rapidly in the first decades after disturbance. In many cases, hardwood trees and shrubs endure long-term where root disease prevents conifer canopy closure or produces openings by killing trees.

Several recent studies in the interior cedar-Hemlock and Interior Douglas-fir forest types of southern interior British Columbia have revealed significant increases in *Armillaria ostoyae* activity following cutting of competing hardwood trees. Paper birch, in particular were removed by various means to release young Douglas-fir (Baleshta and others 2005, Simard and others 2005) and lodgepole pine (Simard and others 2005). Although the birch thinning significantly improved residual tree growth, Douglas-fir and lodgepole pine mortality due to *Armillaria* root disease also increased with increasing hardwood thinning intensity. In general, a 1.5 to several times increase in Douglas-fir mortality rates were measured following hardwood thinning compared to unthinned stands. The increased mortality of lodgepole pine was temporary, lasting only 3 years after thinning (Simard and others 2005).

Increased growth of crop tree roots probably accounts for at least some of the mortality increase. Larger root systems contact inoculum more readily. Also, although birch is considered tolerant to *Armillaria*, severed root systems may have been utilized by the fungus to increase inoculum potential.

MODE III — DISEASE OF YOUNG TREES

Armillaria root disease commonly develops in young pines, and western larch regenerated on harvested sites. Young spruces, cedars and hemlocks are sometimes killed as well. Primary spread of the pathogen occurs from large stumps of the previous generation. Young trees are infected and killed as their roots contact infected stumps.

Two or three decades later, as the inoculum dies out or recedes into the interior of the old stumps, the mortality rate of young trees declines. Secondary spread is minimal, probably due to increasing resistance of the young pines, larch, spruces, hemlock and redcedar to *Armillaria*. Therefore, these species should be favored over inland Douglas-fir and grand fir in silvicultural treatments.

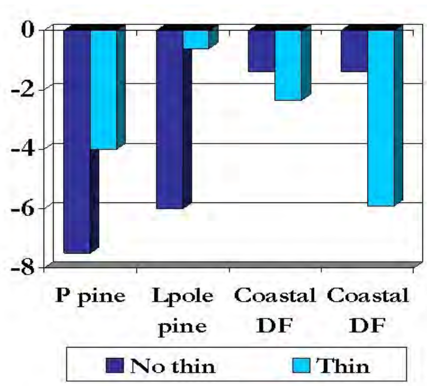
In young stands with extensive root disease mortality, thinning should be delayed, but lightly affected stands can be thinned. Mortality due to mode III Armillaria root disease declines after about 15 to 20 years and is minimal after 25-30 years of age. There is usually little lasting effect from this early mortality. The small canopy openings are usually insignificant in a mature stand.

In contrast to inland Douglas-fir which nearly always exhibits mode I or mode II disease, coastal Douglas-fir generally follows the mode III pattern. Little damage is seen after the first two or three decades after stand establishment.

Precommercial thinning in Mode III Armillaria root disease

Among tree species exhibiting mode III disease, response to precommercial thinning varies significantly. Therefore, species composition is an important factor in realizing benefits from precommercial thinning in *Armillaria ostoyae*- affected stands.

Figure 15. Mortality after precommercial thinning
Percent change; stems/10yrs



Thinning is generally intended to improve growth of crop trees by reducing inter-tree competition and, in some cases, to alter species composition. Douglas-fir stands in Western Cascades realized no significant differences in growth or mortality Filip and Goheen (1995) following precommercial thinning. In contrast, precommercial thinning may have been an effective method of increasing both growth and survival of ponderosa pine stands with *Armillaria* root disease (Filip and others 1989).

In another study in the Cascades (Rosso and Hansen 1998) *Armillaria* root disease in Douglas-fir was described as more consistent with Mode II behavior in that mortality continues well beyond the first two to three decades. Here, a positive increase in growth was measured following precommercial thinning but incidence of *Armillaria* root disease was also higher in thinned stands compared to unthinned controls. The most significant finding in this study was that tree vigor was not a factor in root disease. Vigorous and non-vigorous Douglas-fir were equally likely to be killed by *Armillaria* root disease.

Managing Mode III

Tolerate losses Damage from primary inoculum is short-term and usually not significant in at the final harvest.

Reduce inoculum Stump removal can significantly reduce primary inoculum on sites and prevent most damage from this inoculum source. The economics of stump removal depends on anticipated damage from primary inoculum and potential damage to the site.

Match planting stock to the site
Resistance does not hold up if the planting stock is not appropriate for the site. Check seed zones and potential vegetation or habitat types.

Precommercially thin
Thin favoring resistant species, and to maintain growth of resistant trees.

Disease Types I or II in Douglas-fir and true firs may occur on the same site with type III in other tree species if a variety of tree species are present.

Managing Mode IV

Maintain tree vigor
Initial infection is probably not preventable because the fungus can establish small lesions and maintain quiescent infections for prolonged periods on healthy trees. Therefore the goal of preventing the development of severe root disease is accomplished by scheduling harvest to avoid tree senescence; proper timing of thinning to help trees resist drought affects; and prevention of bark beetle and defoliator outbreaks.

Precommercial thinning in dense lodgepole pine stands in Alberta, British Columbia, did not change mortality rates during 11 years after thinning compared to unthinned controls, but did improve growth (Blenis 2000). Post-thinning mortality rates were generally less than 0.5%/year but ranged as high as 1.5%/yr on a few plots. From this it is reasonable to conclude that precommercial thinning is probably of benefit to species that normally develop Mode III *Armillaria* root disease.

MODE IV — WEAK OR SECONDARY ROOT AND BUTT DECAY

Armillaria root disease is typically manifest in aging or stressed trees. Root lesions probably establish from primary spread early in the process of stand establishment following harvest or fire. Lesions progress little, perhaps even become quiescent for some time. Lesions may begin to expand as trees become less efficient through aging or as a result of stressful conditions such as drought, fire or logging injuries, fir engraver strip attacks, budworm defoliation, etc. Some infections spread enough to contribute to tree mortality. Killed roots may provide sufficient inoculum to support secondary spread of the fungus to adjacent live trees. Small groups of mortality may result. The overall stand impact is minor.

Armillaria root disease and forest succession

"Douglas-fir is a short-lived species on the better white pine sites; root-rotting fungi often cause heavy mortality beginning in the sixth or seventh decade of life." Watt, 1960

The status of Douglas-fir, at least in the white pine type, has undoubtedly changed greatly in the past 80-100 years. Early in the 20th century, Douglas-fir was not generally a major stand component; certainly not like it is now. For example, based on 400 permanent plots established in the white pine type in northern Idaho and western Montana between 1909 and 1927 , Davis (1942) described the average mature stand as having only 15% larch and Douglas-fir (combined) . He reported 22% grand fir, 49% white pine and 14% western redcedar in the stands.

Armillaria root disease was recognized as an important factor in limiting Douglas-fir in these forests as far back as at least the 1940's. Analysis of results from the above plots led Haig and others to conclude,

> *"Douglas-fir fails to keep up sufficiently rapid height growth to maintain its position in the dominant canopy and is not sufficiently tolerant to thrive in an intermediate position. Its susceptibility to attack by fungi, particularly the root rot fungus (Armillaria mellea), removes individuals from the stand at a comparatively early age. – according to consistent records from permanent sample plots on the better white pine sites this weeding-out process may begin as early as 40 years."* [Haig and others 1941]

Watt, 1960 also observed the temporary nature of Douglas-fir importance in stands but noted the relatively longer tenure of grand fir. Based also on permanent plot results, Watt stated,

> *"At 75 years (oldest age class), grand fir was still hanging in and increasing its proportion of the stands. "*

Larch in these stands grew well in young age classes on the better sites but, in the absence of thinning, declined in the sixth or seventh decades because of lateral competition.

A recent study in forests of northern Idaho and Montana further examined effects of root disease on forest succession (Hagle and others 2000). Composition and structure changes were analyzed for 25,670 acres of western redcedar habitat type over a 40-year period. from 1935 to 1975. This was a good time to look at forest change in the Northern Rockies. Early seral tree species (pines and western larch) were still abundant in 1935 although white pine blister rust (*Cronartium ribicola*) had recently invaded many white pine forests, and fire control was just beginning to be effective.

Stands that were well-stocked, pole size (6-14 inch average diameter at breast height) Douglas-fir on western redcedar site types (habitat types) averaged 42 years of age in 1935. They were actually mostly mixed species stands with Douglas-fir making up the majority of the stand volume. Regional yield tables would project these to be larger diameter, well-stocked Douglas-fir stands 40 years later, when they would average about age 82. However, only 9% of these stands met this expectation.

Most of the sample stands were dominated by cedar in 1975, most of the Douglas-fir had already died out. Many other stands had become low density grand fir or Douglas-fir stands with severe root disease. They had less than 20,000 board foot volume per acre; very low stocking for 80 year old stands on these productive sites.

In most of these stands, *Armillaria* root disease is still active in what Douglas-fir remains on the site, and has become increasingly active in the grand fir component. The Douglas-fir wasn't harvested; there was no evidence of tree cutting in the sample. This represents a natural course of succession on cedar habitat types where root diseases are an important feature of most sites.

Root disease was the primary driver of succession in 83% of these acres. Douglas-fir beetle was also active on 14% of acres. Between the two, they directed succession on 86% of acres. Only those stands with no detectable root disease activity followed the expected successional pathway by retaining Douglas-fir forest type while growing to large tree and well-stocked stand structures.

The pervasive influence of root disease in northern Rocky Mountain forests is easily overlooked because change happens slowly. It is also less obvious, in many cases, because the mortality and brushy openings are so consistently present as to appear unremarkable to the untrained eye.

Succession mediated by root disease on a western redcedar site

Time period: 43 years

A mixed stand of 45-yr old Douglas-fir and grand fir had understory of grand fir and western redcedar in 1962. The owner of this forest projected culmination of the stands and expected harvest of mature Douglas-fir at age 90 (in 2007). Today, the Douglas-fir can be seen on the forest floor under a 40-60 year-old stand of western redcedar and grand fir.

[Photos by Susan Hagle]

Identity Crisis Averted

Originally recognized for it's common and edible mushroom, *Armillaria* species have been known since the early 1700's (Watling et al 1991). *Armillaria mellea* was, until relatively recently, the name assigned several of these pathogens of trees throughout much of the northern hemisphere.

Mating reaction studies in Finland starting in the early 1970's contributed to unraveling the *Armillari*a species confusion which has lead to better understanding of *Armillaria* species ecologies (Wargo and Shaw 1985). By the late 1970's, the species *Armillaria mellea* was recognized as an amalgam of at least 10 distinct "biological species". Among these, *Armillaria ostoyae* emerged as the primary conifer pathogen in western North American forests (Morrison and others 1985, McDonald and others 1987).

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Related section in field guide.

2009

Forest Health Protection and State Forestry Organizations

Brennan A. Ferguson
Ferguson Forest Pathology Consulting, Inc.; Missoula, MT

Management Guide for

Black Stain Root Disease

Leptographium wageneri (Kendr.) Wingf.

Topics

Hosts:

Douglas-fir
Ponderosa pine
Pinyon pine

Occasionally, other pine species.

This disease is common and damaging in and west of the Cascade range of Oregon, Washington and northeast California, and in parts of eastern Oregon.

It rarely causes significant damage in inland or Rocky Mountain forests.

Key Points

- A wilt disease
- Vectored by insects, and then spreads root-to-root
- Rarely damaging in the northern Rockies.
- May be serious in off-site plantations
- Avoid attracting the insect vectors

Introduction

Black stain root disease (BSRD) is a wilt-like disease of conifers caused by the native, insect-vectored, fungal pathogen *Leptographium wageneri* (Kendr.) Wingf. (Harrington and Cobb 1983). It is considered one of the five most-damaging root diseases in Western forests (Hadfield et al. 1986). Black stain root disease is widespread across much of the range of its hosts, but incidence and severity, and thus the importance to forest management, vary greatly.

Incidence and severity of BSRD in Douglas-fir and ponderosa pine is greatest west of the Cascade Range in Oregon, Washington, and northern California. In southwest Oregon BSRD was detected in 18.6% of 500, 10- to 30-year-old Douglas-fir plantations, compared to 1.2% of same with Armillaria root disease and 7.0% with laminated root rot (Hessburg et al. 2001). In a subset of eighty of the 500 plantations that underwent intensive BSRD surveys the percentage of crop trees affected was: <0.1% in 93% of stands; 0.1-2% in 3% of stands; 2.1-5% in 3% of stands; and >5% in 1% of the stands (Hessburg et al. 2001). In the most heavily impacted Douglas-fir plantations in southwest Oregon and northwest California, stocking levels were found to be reduced by as much as 50% (DeNitto 1982, Goheen et al. 1983, Goheen et al. 1984, Goheen et al. 1985).

Overview of Black Stain Root Disease Management

1. **Favor mixed species.** Plant mixtures that include resistant species and favor resistant species during precommercial thinning.
2. **Minimize soil disturbance.** Avoid tractor-logging which may compact soil and attract the insect vectors.
3. **Avoid tree injury or remove injured trees of host species.** Injured trees attract vectors. Minimize injuries during skidding, falling, road building, and brushing operations, especially near young trees.

Pathogen nomenclature, taxonomy, and population genetics

There are three varieties of *L. wageneri*. They, and the hosts they primarily affect, are:

- ***L. wageneri* var. *pseudotsugae*** - Douglas-fir (Harrington and Cobb 1987);
- ***L. wageneri* var. *ponderosum*** - ponderosa, Jeffrey, and lodgepole pines (Harrington and Cobb 1986);
- ***L. wageneri* var. *wageneri*** - singleleaf pinyon and pinyon pines (Harrington and Cobb 1986).

Figure 1. Cross-section of infected Douglas-fir root showing typical staining pattern. (Photo courtesy of E. Hansen, Oregon State University)

Hansen and Goheen (1988) reported that 30-40 cm diameter Douglas-fir continued to die on long-term study plots across western Washington and Oregon. Losses in ponderosa pine can be locally severe as well (Byler et al. 1979, Owen 2000).

As an insect-vectored pathogen, and with the vectors generally attracted to weakened trees such as those infected by other root pathogens, *L. wageneri* often occurs in complexes with other root disease fungi (Filip and Goheen 1982, Goheen and Filip 1980, Morrison and Hunt 1988). It has been found colonizing the same roots of Douglas-fir as *Armillaria ostoyae* (Byler et al. 1983, Goheen and Hansen 1978, Morrison and Hunt 1988), *Phellinus weirii* (Filip and Goheen 1982, Goheen and Filip 1980, Morrison and Hunt 1988, Witcosky 1989), and *Heterobasidion annosum* (Kelsey et al. 1998b).

In Idaho and Montana it is rare for BSRD to be found acting as a primary pathogen of Douglas-fir or pines, and the disease is not perceived as a concern in forest management. Where it has been observed it is in conjunction with other root pathogens considered to be the primary agent of mortality (Byler et al. 1983), or in off-site ponderosa pine plantations. Other wood-staining, root-infecting fungi in the genus *Leptographium* can also be found in Idaho and Montana (Wingfield et al. 1994).

Host infection

Leptographium wageneri cannot decay wood or penetrate non-wounded host roots. Smith (1969), using an isolate collected ponderosa pine, found the fungus had no ability to break down cellulose. Hessburg (1984) concluded that *L. wageneri* cannot penetrate to the xylem on its own and requires an existing opening to initiate an infection. *Leptographium wageneri* spreads tree-to-tree at root contacts and grafts like other root disease fungi, but can also grow through the soil for a few centimeters (Goheen 1976, Hessburg and Hansen 1986a, Landis and Helburg 1976). Hessburg and Hansen (2000) demonstrated that minute wounds and natural openings in seedling root systems, where a direct path to the xylem was exposed, serve as infection points for *L. wageneri* hyphae growing in soil.

Pathological anatomy

The pathological anatomy of BSRD has been studied in pinyon pine (Wagener and Mielke 1961), ponderosa pine (Smith 1967), and Douglas-fir (Hessburg and Hansen 1987). Wagener and Mielke (1961) were the first to note that pathogen growth followed the annual rings (Figure 1), a unique pattern compared to the wedge-shaped staining commonly seen with blue stain fungi. Smith (1967) reported that mature host tracheids were the sole habitat for the fungus in infected ponderosa pine, and that hyphal movement between tracheids was via bordered-pit pairs.

Hessburg and Hansen (1987) found the pigmented hyphae of *L. wageneri* exclusively in the sapwood xylem tracheids of Douglas-fir, moving between tracheids via bordered-pit pairs (Figures 2-3).

The most noticeable host response to *L. wageneri* var. *pseudotsugae* infection is partial to complete plugging of tracheids by gums; this and plugging of tracheids by pathogen hyphae were proposed as the primary cause of water blockage and subsequent wilting (Hessburg and Hansen 1987). Non-pathogen-colonized tracheids adjacent to colonized tissue become plugged as well, and stain columns sometimes consist of 20% hyphae-clogged tracheids and 80% gum-clogged tracheids. Colonization of tissue by the amber-colored hyphae results in columns of black-stained tissue extending along infected roots and rootlets of all sizes, and for short distances up the stem from the root collar (Hessburg and Hansen, 1987) (Figure 4). Once a stain column extends up to the root collar it can descend down a non-infected root. Resinosus is often present on the exterior of infected roots or outside stain columns above the root collar. Earlywood is typically colonized prior to latewood within the same growth ring, so that in cross-sectional view the stain columns appear as concentric rings in the earlywood of successive growth rings (Figure 1).

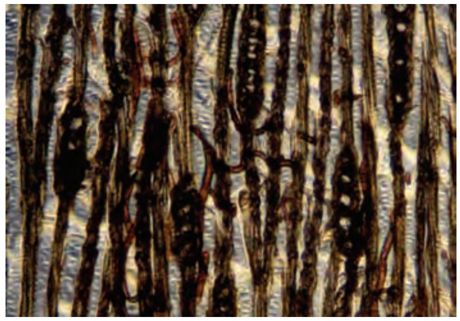

Figure 2. Tangential view of amber-colored *L. wageneri* hyphae within Douglas-fir tracheids.

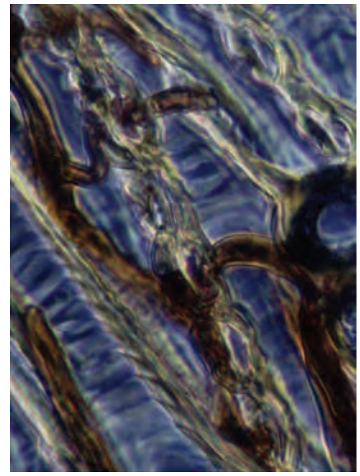

Figure 3. *L. wageneri* hyphae passing through pit pairs of Douglas-fir tracheids.

The most noticeable host response is partial to complete plugging of tracheids by gums.. the primary cause of water blockage and subsequent wilting (Hessburg and Hansen 1987)

Pathogenesis (disease development)

The wilt-inducing nature of BSRD is seen in host responses to advancing colonization. Hessburg (1984) reported a critical water shortage occurred in Douglas-fir seedlings 30 to 40 days after inoculation with *L. wageneri*. Lawson (1988) found colonization of Douglas-fir by *L. wageneri* corresponded to reduced water uptake and transpiration, and that an increase in colonization correlated with a 50% reduction in water transport to needles compared to non-infected controls. Douglas-fir forms pathological heartwood in reaction to colonization by *L. wageneri*, and like normal heartwood, pathological heartwood does not function in water transport. In 20-year-old Douglas-fir, the mean basal, cross-sectional area of normal heartwood in non-infected trees was 23%; the basal, normal-plus-pathological-heartwood in non-symptomatic, diseased trees was 44%; and the basal, normal-plus-pathological-heartwood in symptomatic, diseased trees was 77% (Lawson 1988) (Figure 5). At breast height the percentages of heartwood in these same trees were 18%, 32%, and 64%, respectively.

Figure 4. Staining caused by L. wageneri var. *pseudotsugae* in Douglas-fir. (Photo courtesy of E. Hansen, Oregon State University)

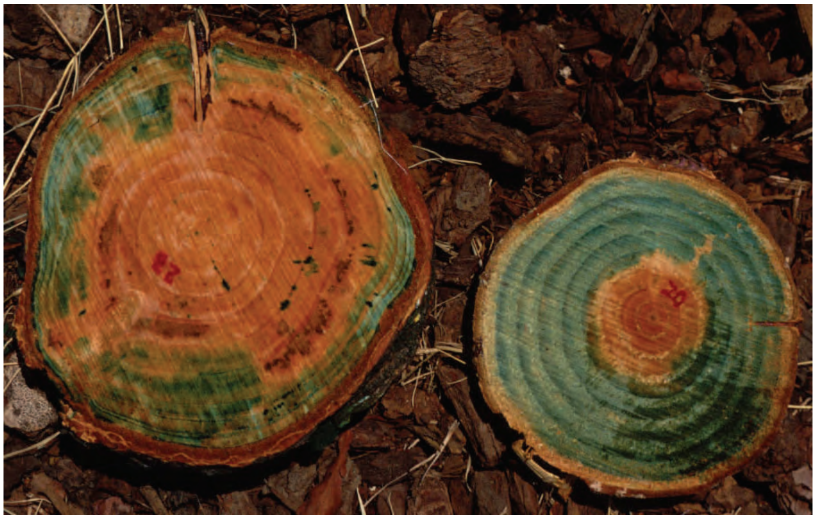

Figure 5. Dye-uptake (green) in BSRD-infected (left) and non-infected (right) basal cross-sections of Douglas-fir (See Lawson 1988). Pathological heartwood in infected cross-section has extended to encompass *L. wageneri* stain columns. (Photo by T.T. Lawson; courtesy of E. Hansen, Oregon State University)

Impacts on water transport are similar in ponderosa pine. Infection by *L. wageneri* had a profound effect on hydraulic conductivity in ponderosa pine roots examined by Joseph et al. (1998). Nearly 100% of the xylem in apparently non-infected, healthy roots was capable of conducting water, compared to just 12% in roots infected with *L. wageneri*. The specific conductivity of infected roots was 5% that of healthy roots, while the conductivity of functional xylem in diseased roots was only one third that of functional xylem in healthy roots.

Symptoms

Figure 6. Symptomatic crowns of Douglas-fir in a black stain root disease infection center.

Black stain root disease in Douglas-fir causes progressive crown symptoms similar to other root diseases (Figure 6). Leader, branch, and needle length is reduced, followed by loss of older needles and a resultant thinning crown, and finally development of off-color, or chlorotic, foliage (Cobb and Platt 1967, Goheen and Hansen 1978, Witcosky and Hansen 1985). Distress cone crops and basal resinosus on infected trees is common but not consistent. The typical black to dark-brown staining has usually reached the root collar by the time chlorosis is evident (Goheen and Hansen 1978).

The interval between appearance of above-ground symptoms until death lengthens with age in *L. wageneri*-infected Douglas-fir. Six- to eight-year-old Douglas-fir with BSRD in coastal British Columbia did not usually exhibit chlorosis or growth reduction prior to death (Morrison and Hunt 1988), while severe leader reduction in young Douglas-fir plantations in southwest Oregon preceded death in most cases by three and four years (Witcosky 1981). Terminal-growth reduction occurred one to four years prior to death in 15- to 25-year-old Douglas-fir in coastal British Columbia (Morrison and Hunt 1988), while measurable height reduction occurred for five or more years without mortality in 20-year-old Douglas-fir plantations in northern California (Lawson 1988).

Damage from BSRD in Douglas-fir stands appears as small infection centers consisting of combinations of dead, symptomatic, and non-infected trees, although infection centers up to 4 ha and involving hundreds of trees can occur (Goheen and Hansen 1978).

Infection centers in ponderosa pine in California can exceed 10 ha (Cobb et al. 1982).

The rate of expansion in BSRD mortality centers has been variously estimated. Hansen and Goheen (1988) monitored 27 infection centers in Douglas-fir across Oregon and Washington for 10 years and calculated an average rate of expansion of 0.7 m/year. Hessburg and Hansen (1986b) measured a growth rate of 2.2 m/year for *L. wageneri* in 20-year-old Douglas-fir, with a maximum rate of 3.6 m/year. In pine, the average rate of spread has been measured at 1.0 m/year, but varied widely from 0 to 7.0 m/year (Cobb et al. 1982); spread was significantly and positively related to host density. Expansion of BSRD centers in *P. monophylla* has been reported as 2 m/year (Wagener and Mielke, 1961). The average rate-of-expansion in 30 BSRD mortality centers in *P. edulis* was estimated at 1.1 m/year (Kearns and Jacobi 2005).

Rate of root to root spread

In Douglas-fir:
0.7 to 3.6 meters/year

In ponderosa pine:
0 to 7.0 meters/year

In pinyon pine:
average 1.1 meters/year

Pathogen survival

As a non-wood-decay fungus that likely depends on cell contents for nutrition (Hessburg 1984), *L. wageneri*'s ability to survive after the death of a host is relatively limited compared to root diseases caused by the wood decaying fungi, *Armillaria ostoyae*, *Phellinus weirii*, and *Heterobasidion annosum*, all fungi that can survive for decades after host death by utilizing the woody biomass of roots and stumps.

Wagener and Mielke (1961) reported that "the fungus does not appear to maintain its viability for long after the affected host or host part dies", but noted it had been isolated one time from a pinyon pine dead for ten years. Kearns and Jacobi (2005) found the pathogen could be isolated regularly from roots of pinyon dead five years, occasionally from trees dead eight years, and once from a tree estimated dead for 16 years. Goheen (1976) attempted to isolate *L. wageneri* from infected ponderosa pine roots which had been excavated and reburied for six or nine months, and from roots of ponderosa pine which had been dead from 1 to 10 years; only one of 400 isolation attempts, from a tree dead three years, yielded the fungus. Adams and Cobb (1986) tested survival of *L. wageneri* var. *pseudotsugae* by planting Douglas-fir seedlings around *L. wageneri*-infected and non-infected stumps of Douglas-fir in both clearcuts and selection cuts. Subsequent infections of seedlings indicated the fungus remained viable for at least two years following harvest of the infected overstory.

Insect Vectors

Root and root collar-feeding bark beetles and weevils are the most commonly reported vectors of *L. wageneri.*

Bark beetle genera
Hylastes and *Hylurgops*

Weevil genera
Pissodes and *Steremnius*

Insect vectors

The pathogen-vector relationship of BSRD is well-defined for *L. wageneri* var. *pseudotsugae* and Douglas-fir. It is less clear for *L. wageneri* var. *ponderosum* and *L. wageneri* var. *wageneri* and their hosts, but very likely involves root- and root collar-feeding bark beetles and weevils in the genera *Hylastes*, *Hylurgops*, and *Pissodes*.

Insect vectors of blackstain root

Figure 7. Adult *Hylastes nigrinus*; average length 4-5 mm.

Figure 8. Adult *Pissodes fasciatus*; average length 5-8 mm.

Figure 9. Adult *Steremnius carinatus*; average length 7-10 mm.

Three beetles vector *L. wageneri* var. *pseudotsugae* (Harrington et al. 1985, Witcosky et al. 1986a). One is a root-feeding bark beetle, *Hylastes nigrinus*, and two are weevils, *Pissodes fasciatus* and *Steremnius carinatus* (Figures 7-9). All are consistently associated with *L. wageneri*-infected Douglas-fir in all stages of decline (Witcosky and Hansen 1985). Prior to being recognized as a vector of *L. wageneri* var. *pseudotsugae* the weevil *S. carinatus* was best known as a regeneration pest (Condrashoff 1968). An important distinction between *S. carinatus* and the other two vectors is that *S. carinatus* is flightless; it is therefore considered a likely factor in within-stand spread.

Leptographium wageneri var. *pseudotsugae* can sporulate adjacent to or within feeding galleries and pupal chambers of insects on infected roots (Witcosky 1981). The spores (Figure 10) stick to the exterior of adult vectors and are carried to new feeding sites. Infections can be initiated after the vectors transmit the spores to seedlings (Harrington et al. 1985), or to the roots of a living tree or recently cut stump that is grafted to a live tree (Witcosky et al. 1986a). The proportion of emerging beetles carrying spores is estimated at under 5% for all three vectors (Witcosky et al. 1986a).

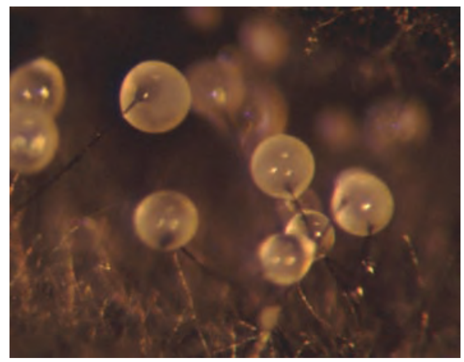

Figure 10. Conidiophores of *L. wageneri* (in vitro) bearing spores in a sticky matrix.

Relation of soil disturbance to disease incidence

Soil compaction can result in increased soil bulk density, reduced porosity, reduced aeration, and changes in drainage (Adams and Froehlich 1981). These soil conditions are likely to result in microsites with year-round or seasonal hypoxic growth conditions, and Douglas-fir roots are known to synthesize ethanol, a common byproduct of stressed trees, under hypoxic or anoxic conditions (Joseph and Kelsey 1997, Kelsey 1996, Kelsey et al. 1998a). A large proportion of this ethanol then diffuses into the soil water (Joseph and Kelsey 1997). Witcosky et al. (1987) demonstrated that *H. nigrinus* and *S. carinatus* are attracted to *L. wageneri*-infected roots of Douglas-fir, as well as ethanol and alpha-pinene, and speculated that periodic anaerobic conditions produced host metabolites, such as ethanol, which attracted the insects.

Incidence of BSRD infection centers in Douglas-fir plantations is closely correlated with soil disturbance (Goheen and Hansen 1978, Hansen 1978, Hessburg et al. 2001). Eighty percent of 202 BSRD infection centers across western Washington and Oregon occurred on disturbed areas such as stream drainages, road edges, clearcut margins, and thinned plantations (Goheen and Hansen 1978).

Hansen (1978) found significantly more BSRD infection centers along roads compared to 25 m or more within the stand. Incidence and damage from BSRD increased in association with a stand history of tractor versus cable yarding (Goheen et al. 1983, Goheen et al. 1984). Hessburg et al. (2001) also found BSRD more frequently adjacent to roads and major skid trails than within plantations and away from skid trails.

Effects of soil compaction may cause tree roots to release ethanol, an attractant to root-feeding beetles.

The beetles may transmit blackstain root disease while feeding.

Relation of precommercial thinning to disease incidence

Black stain root disease has been repeatedly correlated with prior precommercial thinning in Douglas-fir plantations (DeNitto 1985, Goheen and Hansen 1978, Harrington 1983). Precommercial thinning results in an often heavy, homogenous distribution of slash and small stumps across a site. The thinning slash and stumps then release volatiles, including alpha-pinene (a conifer monoterpene attractive to the vectors of black stain root disease) and ethanol, as they dry.

Harrington et al. (1985) examined a precommercial-thinning study in 27-year-old Douglas-fir in northwest California 12 years after treatment. Eighteen of 23 thinned plots had mortality from BSRD, while no BSRD was found on the six non-thinned control plots. It was speculated that the high incidence of disease on thinned plots resulted from increased vector response following thinning, but a baseline disease survey was not available for comparison. DeNitto (1985) surveyed BSRD on thirty, 12- to 27-year-old Douglas-fir plantations, half thinned and half non-thinned, on the Six Rivers National Forest in northern California. Mortality from BSRD was found on nine of 15 thinned plantations three to nine years after precommercial thinning, compared to two of 15 non-thinned plantations.

Witcosky et al. (1986b) used non-baited flight and pitfall traps to monitor the two-year response of *H. nigrinus*, *P. fasciatus*, and *S. carinatus* to precommercial thinnings of Douglas-fir in southwest Oregon. Treatments were applied in September, January, and May of the year prior to trapping. All three vectors responded in higher numbers to thinned plots, regardless of the time of thinning, compared to control plots. Fewer *H. nigrinus* and *P. fasciatus* were caught in the May-thinned plots relative to the September and January thinnings, but no significant difference was seen in the response of *S. carinatus* based on treatment. The conclusion was reached that precommercial thinning done at any time of the year prior to insect flight increased the stand's attractiveness to all BSRD vectors, and that timing of thinning could influence the response of *H. nigrinus* and *P. fasciatus*.

Following the insect-trapping portion of the study (above), Witcosky et al. (1986b) then excavated roots of both stumps and crop trees in the precommercially-thinned plots.

Precommercial thinning

Can increase the incidence of blackstain root disease in areas where the disease is common.

Risk can be reduced by timing thinning so that slash is less attractive to the beetles the following year.

Stumps may be colonized by *L. wageneri* up to seven months after precommercial thinning.

A significantly higher number of *H. nigrinus* individuals and egg galleries were found on roots from the September and January thinnings than from the May thinning. Also, more residual crop trees on thinned plots had insect wounding compared to the non-thinned plots. The mean attack intensity of *H. nigrinus* on stumps from the June-July precommercial thinning was 2.9, compared to 14.6 for stumps from the September and January thinnings, while the attack intensity on residual crop trees was 0.02 in June-July versus 0.14 for September and January. Stumps from the May thinning best supported growth of *L. wageneri* in inoculation trials, and appeared to be suitable for colonization up to seven months following thinning (Witcosky 1985).

Hessburg et al. (2001) surveyed 500 Douglas-fir stands in southwest Oregon and found that precommercially thinned stands were significantly more likely to have BSRD whether prior harvest had been done by either tractor logging or cable yarding. Stands that were at least partially tractor logged, however, were somewhat more likely to have BSRD than stands that had undergone only cable yarding.

Disease management

MANAGEMENT IN BRIEF

- **Use mixed-species planting on high-risk sites,**
- **Favor species resistant to BSRD when thinning in infection centers,**
- **Perform precommercial thinning between late June and early August,**
- **Minimize soil disturbance and tree injury,**
- **Avoid road-side tree damage during road building, maintenance, and brushing,**
- **Offsite plantations are especially susceptible to BSRD. Ensure planting stock is appropriate for the site.**

Management recommendations for BSRD in Douglas-fir arose from Witcosky et al.'s (1986b) work on the effect of seasonal timing of precommercial thinning on vector response. Hansen et al. (1986) expanded upon these findings by recommending: 1) favoring trees other than Douglas-fir when thinning in existing infection centers; 2) reducing the potential for new centers by minimizing disturbance and tree injury; and 3) limiting chances for successful vectoring. Specific actions on high-risk sites, or those within approximately 1.6 km of active infection centers, include: 1) no tractor logging, 2) using mixed-species plantings on high-risk microsites, 3) avoiding road building or other actions that result in tree injuries in plantations, and 4) performing precommercial thinning between late June and early August.

Hessburg et al. (1995) and Hessburg et al. (2001) present preventive and corrective management measures for BSRD. Preventive measures include: 1) use of high-lead and skyline logging in place of tractor logging, 2) use of skid trail layout and dry-season yarding to reduce soil compaction if tractor logging is necessary, 3) removal of high-risk host species along each side of newly constructed roads, 4) avoiding the creation of high-moisture microsites, 5) avoiding use of rotary-blade brushing and branching along roads, and 6) performing precommercial thinning between the end of June and the end of August. Corrective measures included planting a mix of species in new plantations proximal to existing infection centers, favoring non-hosts during thinning in infected stands, and avoiding thinning in active infection centers.

Management of BSRD is critical on ponderosa pine sites with a known history of the disease (Owen 2000).

PROMOTE TREE SPECIES DIVERSITY AND CONTROL TREE DENSITY

Recommendations include avoiding development of a pure pine type by promoting mixed-species stands, keeping overly dense stands from developing, and limiting management activities such as precommercial thinning to seasons that are less likely to promote disease development.

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Forest Health Protection and State Forestry Organizations

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Related section in field guide.

2009

Forest Health Protection and State Forestry Organizations

Susan K. Hagle
USDA Forest Service

Management Guide for

Laminated Root Rot

Phellinus sulphurascens (Pilat)
[formerly *Phellinus weirii* (Murr.) Gilb. Douglas-fir form]

Hosts: Primarily Douglas-fir and grand fir

All conifers may be infected

Two distinct biological species of this fungus occur in western North America; one primarily on Douglas-fir and true firs (discussed here), and the other, on western redcedar (see Chapter 13.5; Cedar Laminated Butt Rot).

Topics

A serious disease in northern Idaho and western Montana.

This fungus kills trees in expanding patches in forests. These patches can be from a few trees to many acres in size. Trees of all ages are killed as their roots are destroyed by the fungus. Many also die through wind-throw following decay of support roots. The fungus spreads underground through tree root systems and survives for many decades in dead roots and stumps.

Laminated root rot should be considered a "disease of the site". That is, established mycelia of this fungus are essentially permanent, so the best course is to minimize losses by managing tree species that can be expected to have better survival on infested sites.

Laminated root rot is estimated to infest at least 739,000 acres in Idaho and Montana. Mortality centers occupy over 15,000 acres of federal, state and private forestland on and near the Idaho Panhandle, Clearwater, Lolo, Kootenai and northwestern Bitterroot National Forests in Idaho and Montana. It is rarely seen south of the Salmon River in Idaho. Douglas-fir and grand fir forests on warm, moist site types are most damaged.

Key Points

- Manage for pines, larch, and cedar.
- Precommercial thinning may improve growth and survival of pines and larch
- Thinning for bark beetle control may result in increased mortality if laminated root rot is present.

Overview of Laminated Root Rot Management

1. **Favor resistant species.** Especially pines and western larch.
2. **Thin early and avoid partial harvests.** Precommercially thin favoring root disease resistant species.
3. **Avoid commercial thinning that will leave susceptible crop trees.** Mortality rates of susceptible leave-trees are likely to remain high, or increase following thinning.

Laminated root rot in Western North America
by
Thies and Sturrock, 1995

This useful publication provides excellent photographs and summarizes the relevant information for the identification and management of this disease.

Phellinus sulphurascens

- **Pathogen of conifers in the northern hemisphere.**
- **Annual sporophore**
- **Douglas-fir and grand fir are the most important hosts.**
- **Does not mate with *Phellinus weirii*.**
- **Monomitic hyphal system suggests genus name *Inonotus*.**

Nomenclature of *Phellinus sulphurascens*

The name *Phellinus sulphurascens* was officially assigned to the Douglas-fir/ true fir form of *Phellinus weirii* by Larsen and others in 1994. But at least as far back as 1954 the two distinct forms of *Phellinus weirii*, one found primarily on Douglas-fir and the other in western redcedar, were recognized (Buckland 1954). The name change will reduce the confusion that has resulted from using the same name for two dissimilar fungus species, with different hosts, and vastly different disease management methods.

Larsen and Lombard initially proposed separation of the cedar form from the Douglas-fir form into two distinct species in 1989. They found significant differences in cultural characteristics, length of setal hyphae, basidiospore germinating characteristics and host specificity. Cedar and Douglas -fir forms are distinctly intersterile groups in culture (Angwin and Hansen 1988). Despite finding nearly complete genetic isolation of Douglas-fir and cedar forms Angwin (1989) recommended considering them to be intersterility groups rather than distinct species. Intersterility observed in cultures was confirmed by Bae and others (1994) in naturally-occurring populations.

Banik and others (1993) found Douglas-fir isolates to be distinct from the cedar form in ELISA (seriological) tests. They also demonstrated that the Douglas-fir form is serologically related to Siberian isolates of *P. sulphurascens*. It is more closely related to the Asian *P. sulphurascens* than to cedar form isolates of *P. weirii*. They concluded that the Douglas-fir form is probably conspecific with *P. sulphurascens*. Based on results from monocaryon matings, Larsen and others (1994) also concluded that the correct name for the Douglas-fir form is *Phellinus sulphurascens* Pilat. They also described the hyphal system of both Douglas-fir and cedar forms as being monomitic. A monomitic hyphal system is the principle criterion that separates the genus *Inonotus* from *Phellinus*. Therefore the correct generic placement of both *P. weirii* and *P. sulphurascens* is *Inonotus*.

Beginning in 2007 Sturrock and associates adopted the use of *Phellinus sulphurascens* to refer to the Douglas-fir form (Sturrock and others 2007, Lim and others 2008). This is the binomial I will use in the present document.

Ecology of laminated root rot in forest ecosystems

Life Cycle

Phellinus sulphurascens begins life, like most fungi, as a spore. The mostly annual, crust-like sporophores typically form on the moist underside of downed logs. The sporophore matures in late summer or fall. The simple, single -celled spores are produced en masse within pores of the sporophore. They are wind or water-dispersed; rarely landing on a substrate that is suitable for their survival.

Moisture is required for germination. The mycelium that is subsequently produced must establish on suitable wood and repel competitors or perish. Most perish.

Persistent and expanding mycelial clones

New myclia from germinating spores probably join with, and exchange nuclei (conjugate) with other mycelia to become heterokaryotic. These mycelia may have ecological advantages over those grown from a single spore Angwin and Hansen (1993). Even so, life is precarious for the new heterokaryote and few will live to establish as a clone.

There is little genetic variation within established clones, indicating that they start from single basidiospores and do not mate with or combine genetic material with new spores or colonies (Bae and others 1994). Vegetative incompatability among clones effectively prevents initiation of new infections in areas occupied by established clones (Bae and others 1994). This means that established clones effectively block invasion by new clones of *P. sulphurascens*. It appears that once a clone is established on a site, it may survive for centuries by utilizing both living hosts and dead substrates. Generation after generation of trees serve as hosts for the same clone on a site.

Because clones within infection centers are genetically distinct from one another, the approximate extent and age of clones associated with some infection centers have been determined. For example, a clone in a mountain hemlock forest in Oregon was estimated by Dickman and Cook (1989) to be at least 460 years old.

Saprophytic and parasitic existence

Phellinus sulphurascens has been reported to live saprophytically in the roots and lower stem of fallen trees or in individual cut stumps for as long as 50 years (Hansen 1976, 1979a). Hyphae penetrate the wood, causing a ‘white rot” type of decay in which both cellulose and lignin are degraded. Dead wood utilized by *P. sulphurascens* also may be from tree and woody-shrub species that were resistant when they are alive.

The mycelium spreads from woody substrates to the roots of live trees through direct root contact with infected wood. Infection intensity may increase with each generation (Tkacz and Hansen 1982). In northern Rocky Mountain forests, Douglas-fir and grand fir are particularly susceptible to infection. Once established on a root of a live tree, the fungus invades and kills the cambium of the root and the decays the dead root tissues. The mycelium may eventually travel up the root to colonize the root collar, and girdle the tree.

Aggregated and dispersed infections in stands

Laminated root rot occurs in complex patterns in forest stands, with many or most of the infected trees bearing no above-ground symptoms of infection. Distinct infection centers are easily detected as aggregations of dead and diseased trees. Much of the infection in a stand will be within and adjacent to these infection centers.

Laminated root rot* is commonly found in the same trees and even the same roots with other root diseases such as *Armillaria, Annosus, and Tomentosus root diseases.

Mycelium—
Plural: Mycelia
The vegetative (non-fruiting) part of a fungus consisting of a mass of branching, thread-like hyphae.

Monomitic—
a fungus that has only one kind of hyphae, generative hyphae.

Heterokaryotic—
cells having two distinct nuclei. Generally produced by conjugation of two different mycelia.

Homokaryotic—
cells having one nucleus. Homokaryotic mycelia generally result from germination of sexually produced spores, such as those from sporophores.

Expansion Rates

Bloomberg (1990) monitored the rate of expansion of 62 laminated root rot centers, for 27 years, in three coastal Douglas-fir plantations in British Columbia, Canada.

The overall average rate of expansion was unimpressive: 1-8 cm/yr. **Roughly 0.5 to 4 inches per year.**

This was because most of the perimeter of an infection center had no change at all in most years.

However, where expansion did occur, the average rates were impressive: ranging from 54 to 63 cm/yr. **Roughly 27 to 31 inches per year.**

Infected trees also are found dispersed throughout stands in locations having no apparent relationship to infection centers (Thies and Nelson 1997, Thies and Sturrock 1995). Thies and Nelson (1997) reported that infection rates at considerable distance from infection centers were as high as they were at the edges of infection centers, near confirmed inoculum sources.

> "In most stands, the pattern of [*P. sulphurascens*] infection was diffuse rather then distinctly aggregated, and in no case did openings accurately portray the distribution of the disease." Thies and Nelson 1997

Trees that were expected to be infected based on proximity to known inoculum sources (within 5 m) and having symptomatic crowns (poor growth, thin crowns, chlorosis) were, in fact, no more likely to be infected than trees that grew far from known inoculum sources and had healthy-appearing crowns (31% of the former compared to 29% of the latter). The dispersed infections may eventually become the focus of new infection centers (Thies and Nelson 1997).

Fire

Fire has historically been an important factor in shaping forest composition and structure in the northern Rocky Mountains. Based on the considerable age achieved by *Phellinus sulphurascens* clones, it is reasonable to conclude that they typically survive forest fires. They may be fragmented by partial destruction of the mycelium or by exhaustion of substrate in spots, but regeneration and growth of suitable hosts has the effect of allowing re-expansion of clones.

The most significant effect of fire may be the opportunity it provides for less-susceptible tree species to establish. Pines and larch are sometimes able to survive fires that kill Douglas-fir and grand fir, and to take advantage of fire-produced openings to regenerate. Historically, fires probably played an important role in reducing laminated root rot by favoring disease-resistant tree species.

Forest structure and composition effects of laminated root rot

As previously discussed, *P. sulphurascens* infections are both dispersed and aggregated in stands. However, most mortality occurs where infections are aggregated, also known as "infection centers". As overstory trees are killed in infection centers, openings in the forest canopy result. This produces a characteristically patchy forest structure. Canopy openings provide opportunities for conifer regeneration, and growth of woody shrubs and forbs. These openings increase structural diversity, and sometimes species diversity, in a forest. (Holah and others 1993, Holah and others 1997). After timber harvest, some vegetation differences between former gaps and previously intact forest persist (Ingersoll and others 1996).

Timber harvest

Following harvest, *Phellinus sulphurascens* readily infects the subsequent regeneration of susceptible trees. Although rapid and nearly complete mortality of Douglas-fir regeneration, due to laminated root rot, has been reported (Ingersoll and others 1996), this is not usually the case.

In fact, *Armillaria ostoyae* is often the more aggressive pathogen in the first two decades after timber harvest (Bloomberg 1990, Thies and Sturrock 1995). In northern Idaho and western Montana, stands regenerated after a harvest are usually 25-40 years old by the time laminated root rot begins causing more mortality than Armillaria root disease.

Temporal patterns of mortality and re-growth: wave pattern

Patches of laminated root rot exhibit slow expansion into surrounding forest; a rate of about one foot per year (Thies and Sturrock 1995). In addition to expansion at the perimeter of patches, trees within the disease patch regenerate, grow and die in a pattern described by Dickman and Cook (1989) as waves of infection.

The initial mortality wave occurs as the pathogen moves outward along the margins of the disease patch into the non-diseased portion of the stand. The resulting canopy opening is eventually filled with tree seedlings. When this new cohort of trees contacts inoculum from infected roots from the previous stand, they in turn are killed; the second wave of mortality.

Subsequent waves follow as new cohorts of trees regenerate, reach enough biomass to fuel a pulse of fungal growth, and die to once again open the canopy. The result is a stand with zones representing the temporal sequence of root disease development in the stand. These zones form concentric rings from the center of the disease-affected area to the perimeter.

Mortality wave patterns on harvested sites

The primary difference between the wave pattern in root disease infected stands on sites with no cutting history and that on sites that have been cut is that the harvest sets the timing of the first wave by stimulating the regeneration that will reach pole size at about the same time.

Primary spread from stumps results in new infections in these young trees. As in the uncut stand, the young trees die a few at a time until the survivors are large enough to provide a substantial food base for the fungus. At this point, secondary spread will accelerate the rate of mortality. As trees die, they are replaced by abundant regeneration. Mortality then slows until sufficiently large root systems have been produced to fuel another wave of mortality. Recognizable root disease patches eventually re-emerge in cutover stands as groups of trees are killed and openings are regenerated.

Dispense with the vigor myth

Contrary to popular belief, superior vigor does not confer improved resistance of Douglas-fir to laminated root rot. Hansen and Goheen (2000) refer to this as “the widespread but false belief that pathogens in natural ecosystems only kill weakened trees”. In reality, faster growing trees have an equal or somewhat higher probability of dying from laminated root rot compared to slower growing trees (Miller and others 2006) This is probably just a matter of their larger root systems contacting more inoculum.

The wave phenomenon was described by Dickman and Cook (1989) as “outwardly-spreading rings within rings.”

WAVE PATTERN

As a result of the temporal pattern of tree death and subsequent regeneration, ranks of trees of similar ages are observed in concentric circles.

Recognizing this pattern in stands will aid in identifying the extent of an infection center.

THE VIGOR MYTH:

The widespread but false belief that pathogens in natural ecosystems only kill weakened trees (Hansen and Goheen 2000).

On sites where a mature stand with laminated root rot has been harvested, Armillaria root disease often becomes the primary pathogen in young conifers that regenerate following harvest.

It may take several decades for laminated root rot to again become the most prevalent disease.

INFECTION DETECTION

Ectotrophic mycelium

Thies and Nelson (1997) found that the presence of ectotrophic mycelium identified 82 percent of the infected trees in a mature stand.

Wallis and Bloomberg (1981) found that only half of the infected Douglas-fir trees 25 to 60 years of age have above-ground symptoms.

Impact of laminated root rot on forest productivity

Infection rates

Although nearly all conifers are occasionally infected, Douglas-fir, mountain hemlock, grand fir and white fir are most susceptible (Hansen and Goheen 2000). In the northern Rockies, Douglas-fir and grand fir are the most common hosts.

The disease is best known and probably most damaging in coastal Douglas-fir forests of Oregon, Washington and British Columbia. Surveys indicate that 8.6% of the Douglas-fir forest area in western Oregon is occupied by laminated root rot centers in which half of the Douglas-fir have been killed (Hansen and Goheen 2000). The disease is present in 80% of second-growth Douglas-fir stands on Vancouver Island, British Columbia (Bloomberg and Reynolds 1985).

A recent analysis in Idaho and Montana, estimated that 739,000 acres are infested with this disease. Of these, 156,000 acres have mortality rates of at least 25% of the basal area every 15 years. Large canopy gaps, with over 75 percent canopy loss caused by laminated root rot occupy 15,400 acres of the most productive forest land types in these two states.

Growth decline

Decay and girdling can be slow processes and considerable infection can develop in root systems before trees begin showing obvious crown symptoms. The first symptom to develop is usually growth decline. The cumulative growth depends on the age of trees. Bloomberg and Wallis (1979) detected reduced radial increment in infected trees lasting 30 years or more before death in mature Douglas-fir. Smaller trees typically had shorter detectable periods of decline before death. The longer the period of decline before death, the greater is the cumulative growth loss. Diameter growth is more affected by laminated root rot than height growth in coastal Douglas-fir (Harrington and Thies 2007). As expected, trees with the highest rates of root decay exhibit the largest declines in growth.

Mortality

In coastal forests, grand fir is the most susceptible species, followed by Douglas-fir (Table 1). Nelson and Sturrock (1993) measured grand fir mortality rates averaging about 31% in 17-20 years for trees planted around infected stumps in coastal Oregon and British Columbia. Rates for coastal Douglas-fir averaged about 26%. Western hemlock and ponderosa pine had moderate mortality rates of 12% and 11%, repectively. Other pines and western redcedar mortality rates lowest, around 5%.

Similar rates of mortality were measured in inland forests on randomly-placed plots. In this case, Douglas-fir had the higher mortality rate compared to grand fir. A net loss in basal area of 35% for Douglas-fir and 20% for grand fir was measured. The plots, in northern Idaho, monitored trees that were at least 5 inches dbh, at the start of the study, over a 20-year period (Hagle, in preparation).

Perhaps the relative rates of mortality can be inferred from a survey reported by Filip and Schmitt (1979). They selected locations with at least 15% mortality and *Phellinus* as the primary cause. They found 20% of the Douglas-fir dead and 23% of grand fir. This may suggest similar mortality rates for these two species; but the relatively longer needle retention of dead grand fir could give a false impression of a higher mortality rate.

Table 1. Relative susceptibility to *Phellinus sulphurascens* in the northern Rockies .

Species	**Susceptibility**	**Reported mortality rates (infested sites)**	**On northern Rocky Mountain sites**
Douglas fir	High	35% /20 yrs ID[1] 20% E. OR/WA[2] 26% /17-20 yrs Coastal[3]	This is the most damaged species in the Rocky Mountain and west coast portions of the range of laminated root rot in North America. Both coastal and inland varieties of Douglas-fir are highly susceptible.
Grand fir	High	20% /20 yrs ID 23% E. OR/WA 31%/17-20 yrs Coastal	Grand fir is very susceptible to infection but dies somewhat more slowly than Douglas-fir.
Subalpine fir	High	43% /20 yrs ID	Subalpine fir can be very susceptible when growing in association with grand fir on the warm/ moist end of the range of subalpine fir. Cold and dry habitats appear to inhibit development of the disease.
Mountain Hemlock	High	32% E. OR/WA	We know little about root diseases in this species in the northern Rocky Mountains but it is considered highly susceptible on the eastern slopes of the Cascades.
Western larch	Moderate	6%/20 yrs ID 27% E. OR/WA	Damage is uncommon, usually occurring in older, unthrifty, trees growing with Douglas-fir or grand fir.
Western hemlock	Moderate	4% /20 yrs ID 12%/17-20 yrs Coastal	We rarely see significant damage in this species in inland stands.
Western redcedar	Low	>1%/20 yrs ID 5%/17-20 yrs Coastal	Western redcedar is reported as either immune or highly tolerant.
Ponderosa pine	Low	>1%/20 yrs ID 11%/17-20 yrs Coastal	Damage is rare in this species; has been observed in individuals growing with Douglas-fir and grand fir.
Lodgepole pine	Low	>1%/20 yrs ID 9% E. OR/WA 5%/17-20 yrs Coastal	Damage is rare, usually occurring in older, unthrifty, trees growing with Douglas-fir and grand fir.
Western white pine	Low	>1%/20 yrs ID 5%/17-20 yrs Coastal	Damage is rare but has been observed in older trees.
Engelmann spruce	Low	Insufficient data	Damage is rare; usually occurring in trees grown with Douglas-fir and grand fir.

1 Percent of trees killed in 20 years with *Phellinus* as an identified cause; on permanent plots that had known *Phellinus* inoculum within 30 feet (Unpublished data, Hagle 2008.) Plots are in northern Idaho.

2 Percent of trees that were dead at the time of the survey; stands were east of the Cascade range in Oregon and Washington (Filip and Schmitt 1979.) Plots were selected on the basis of having at least 15% mortality with *Phellinus* as the primary cause.

3 Percent of trees killed in 17-20 yrs in plots with known *Phellinus* infection; coastal forests of Oregon and British Columbia (Nelson & Sturrock 1993.)

Sites that are prone to laminated root rot in Idaho and Montana

Laminated root rot

Is found mostly on western hemlock or grand fir potential vegetation types.

Laminated root rot causes problems on a narrower range of habitat types than do *Armillaria* or *Annosus* root diseases. Cool, moist types typified by western hemlock potential vegetation type (PVT) and warm moist habitats with grand fir PVT make up the majority of the infested sites. Likewise, a high proportion of these PVTs may be infested by this pathogen within it's range. Byler and others (1990) found sites on the Lolo NF in western Montana on western hemlock PVT to have far higher probability of laminated root rot than other sites. They found the pathogen on seven of eight stands (87%) sampled in this PVT group compared to the second highest, 17% of 106 samples, in grand fir PVTs. In contrast, they detected laminated root rot on only 4% of the sample in Douglas-fir habitat types and 11% in western redcedar habitat types.

Western hemlock and grand fir PVTs had the highest constancy and highest severity of laminated root rot in 312 randomly placed permanent plots in the Coeur d'Alene Basin of northern Idaho (Figure 1). Of 73 plots in western hemlock PVT group, 62% had confirmed laminated root rot. Of 88 plots with grand fir PVTs 54% had the disease (Hagle, unpublished.) Overall, 48% of the 312 plots had laminated root rot. In contrast Douglas-fir PVT plots had a lower than average probability of infection, only 26%. None of the 13 western redcedar PVT plots showed infection, but they all had redcedar forest composition, a resistant tree species. Only four plots with subalpine fir PVTs were sampled and none had evidence of *P. surphurascens* infection. The pathogen has been observed on subalpine fir habitats, as well as on this host, but not often.

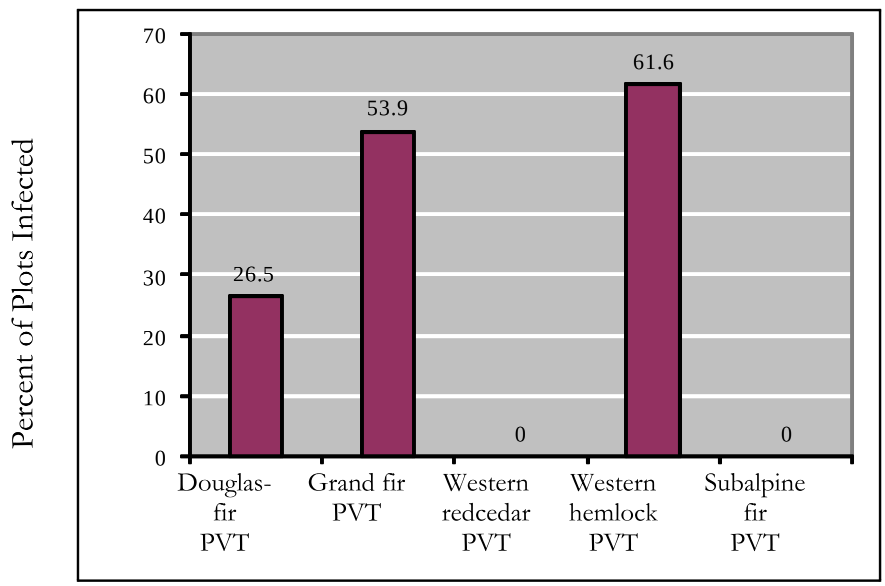

Figure 1. Percent of 312 plots with confirmed laminated root rot within five sampled habitat type groups. [Coeur d'Alene Basin, Hagle 2008 unpublished.]

Western Montana

Frequency of *Phellinus sulphurascens* by habitat types on the Lolo National Forest: [Byler and others 1990]

Western hemlock PVT— 87%

Grand fir PVT— 17%

Western redcedar PVT— 11%

Douglas-fir PVT— 4%

Assessing Laminated Root Rot

Disease intensity on infested sites

Root Disease Severity Rating

Root disease severity is a measure of the cumulative impact of root disease in a stand or on a site. It is visually rated based on relative effect of root disease on forest canopy density (*see sidebar*). At the most severe end of the scale, no trees of the original overstory remain alive. At the low end of the scale, little evidence of the disease will be seen and little or no canopy loss will have occurred. Laminated root rot is more likely to cause severe loss of forest cover than are the other major root diseases in northern Idaho and west-central Montana.

Loss of forest cover, or canopy is reflected in the site root disease severity (Hagle 1993). Disease severity can be assessed using aerial photography or on the ground. It is a rapid and efficient method to assess the relative impact of the disease on a site and to predict future impacts (Hagle and others 1992, Hagle 1993, Hagle 2000).

In 312 permanent plots in northern Idaho, monitored for 18 to 24 years, root disease severity assigned at the beginning of the monitoring period was the best predictor of tree mortality over the entire period. Severity was a highly significant indicator (P= >.0001) for subsequent Douglas-fir mortality, in particular.

At the highest levels of disease severity, stands commonly have only a few surviving trees by 80 to 100 years of age. Large openings in the tree canopy permit growth of shrubs, forbs, and conifer regeneration. Douglas-fir and grand fir regeneration in these openings seldom reaches maturity. However, if disease-resistant species, western hemlock and western redcedar in particular, establish in the openings, they are likely to survive and eventually return the forest canopy to full closure.

Figure 2 illustrates the relatively greater severity of root disease impact with laminated root rot compared to other root diseases on permanent plots in northern Idaho. The proportion of plots falling in the highest disease severity levels was nearly double compared to all plots. A similar trend was found in permanent plots on the Kootenai NF in Montana. *Phellinus sulphurascens* was seldom the only root pathogen detected on a plot, with *Armillaria ostoyae* or *Heterobasidion annosum* commonly also present.

ROOT DISEASE SEVERITY CLASSES

0 —No evidence of root disease.

Low—Ranges from minor evidence up to 20 percent canopy reduction.

Moderate—Between 20 and 75 percent loss of canopy.

High— at least 75 percent loss of canopy.

[Guidelines for rating root disease severity: see Hagle 1993 or on the web Hagle 2009.]

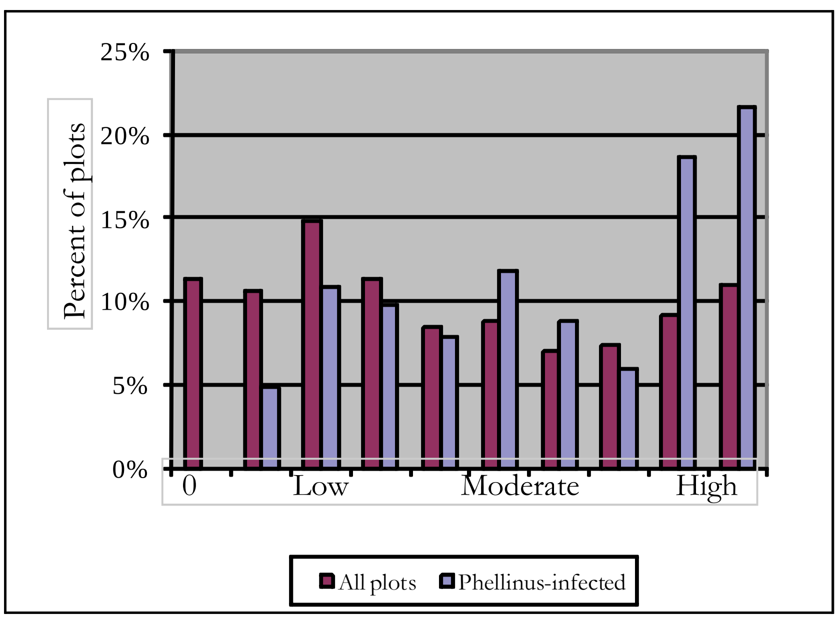

Figure 2. Distribution of root disease severities among 213 plots (all plots) compared to 102 plots with *confirmed Phellinus sulphurascens* (*Phellinus-infected.*) Coeur d'Alene Basin, Idaho Panhandle NF

The characteristic brown stain in the sapwood of recently cut stumps is used to identify many of the

Mechanisms of spread

Thies and Westlind (2005) recently concluded that there is "*a need to examine more closely the epidemiology of laminated root rot.*

...the infection process is more complex and needs to be better understood."

Root to root spread has long been the accepted model for laminated root rot and fits most field observations of the disease. However several recent discoveries seem inconsistent with this mechanism of spread.

Thies and Westlind cite:
1. scattered infected trees,
2. the appearance of laminated root rot in replacement stands where it had not been present before harvest, and,
3. nearly a third of plots that had laminated root rot before harvest, having no disease-killed trees in the replacement stand.

However, the presence of *P. sulphurascens* was significantly associated with more severe root disease.

Surveying stands for location and size of infection centers

Most of the laminated root disease in a replacement stand will be where it occurred in the previous stand. Before stand harvest, openings or gaps caused by root disease are easily observed. These infection centers can be mapped by walking parallel transects and marking the beginning and end of each infection center using GPS (or a sketch map). This method is especially appropriate in coastal forests where the disease is more often concentrated in discrete infection centers. See Thies and Sturrock (1995) for more information.

Stump survey

After harvest, cut stump surfaces can be examined for symptoms of laminated root rot. A portion of the stumps with infected roots will have decay or stain visible at the stump surface. The locations and number of visibly infested stumps are a good indicator of the biomass of the root pathogen on the site (Thies and Westlind 2006). Such information can be used to direct planting of disease resistant trees or other efforts to reduce damage in the replacement stand.

Considerations for managing laminated root rot

Some important characteristics of laminated root rot to considered for management of the disease include:

1) Laminated root rot is a 'disease of the site' because the pathogen, *Phellinus sulphurascens.* persists on a site from one generation of trees to the next.
2) The fungus is both an efficient parasite and saprophyte, meaning that both live and dead wood is utilized by the fungus.
3) The fungus biomass on a site is limited by the biomass of host tissue. So if there is an abundance of large host trees, the fungus can achieve very large biomass on a site sufficient for survival for many decades, perhaps hundreds of years after the host has died. However, if host biomass declines, so will the fungus biomass.
4) The effective host range (species on which the fungus can build biomass) is limited.
5) The pathogen is probably naturally limited by competing fungi, especially saprophytic species that are capable of growing rapidly in dead wood.
6) The pathogen is rarely successful in establishing new infection centers so infestations are fairly stable.
7) Scattered infections, unassociated with disease centers, on roots of apparently healthy trees, are common. This probably accounts for the disease appearing in locations in replacement stands which were judged to be disease-free in the previous stand.
8) Laminated root rot is rarely the only root disease present in stands in Idaho and Montana.

Managing laminated root rot

Management objectives will guide the choice of methods to be used, but it is also important to consider the presence of root disease when developing the objectives for a stand or group of stands. Established root pathogens can be as limiting as other features that determine site capability such as latitude and altitude, soils, moisture regimes, and exposure. Realistic management objectives will take into account the laminated root rot considerations outlined in the previous section.

Methods for managing laminated root rot fall into two categories, silvicultural control of damage and direct inoculum removal. Silvicultural methods for managing root diseases are nearly always more successful and cost-effective than are chemical fumigation or physical removal of inoculum. However, for high-value trees there is some indication that chemical fumigation can rid live trees of infections. Inoculum removal by de-stumping infested sites also may have some applicability.

BOTTOM LINE

- **Root disease is permanent**
- **You may be able to reduce the mass of the fungus but you won't eliminate it.**

Usually, you will need to change tree composition to more resistant species.

Silvicultural control methods

Regeneration Systems

Armillaria and annosus root diseases are commonly found on sites that have laminated root rot. Fortunately, silvicultural control methods used to manage laminated root rot should be equally effective against these other major root pathogens of Douglas-fir and true firs.

Even-aged silvicultural systems, are aimed at producing a replacement stand that is better suited to resist or tolerate laminated root rot. Whether clearcut or seedtree methods are used, the target replacement stand should be comprised of less than one-third Douglas-fir and grand fir (combined). Pines (western white, ponderosa and lodgepole), western larch, Engelmann spruce and western redcedar are good choices for disease-resistance. Mixed-species stands are nearly always more resilient than single-species stands.

Shelterwood or uneven-aged systems should be avoided because they usually result in too much Douglas-fir, grand fir or subalpine fir regeneration. Disease intensification in partially-harvested stands appears to be due to the rapid colonization of the stumps and roots after infected trees are cut. Infested stumps then serve as effective food bases for the pathogens enabling them to infect and kill other nearby trees.

Western redcedar, normally considered a root disease-tolerant species, may develop a progressive decline after a partial harvest. If western redcedar is an important component of the residual stand, it would be prudent to avoid removing more than about one third of the overstory canopy to minimize risk of *Armillaria* root disease losses in the residual cedar. This does not apply to western redcedar that regenerates after the harvest.

Western larch (above) and ponderosa pine (below) seed-trees are used to regenerate root disease infested sites.

Photo above shows uneven-aged stands often provide ideal habitat for root pathogens as Douglas-fir and grand fir regenerate in partial shade.

Utilization of stumps by *P. sulphurascens* is about the same whether the stand is clearcut or partially harvested. What makes the difference in subsequent impact is the composition of the stand on the site following harvest. Therefore, when possible, resistant or disease-tolerant species should be favored when harvesting in root-disease afflicted stands. Douglas-fir and grand fir often die within a few years after thinning, having produced little or no additional growth. Douglas-fir and grand fir left as shelterwood or seed or crop trees, are likely to exhibit rates of mortality around 30 to 40 percent per decade following a partial harvest (figure 3).

Commercial thinning

Impacts of root diseases following commercial thinning, like other partial harvests, mostly depends on the composition of the residual stand. As discussed with respect to shelterwood and uneven-aged systems, higher rates of mortality in residual Douglas-fir and grand fir can be expected (figure 3). To minimize the effects of mortality and, perhaps, slow the spread of the disease, reduce Douglas-fir and grand fir to less than one third of the basal area. Even so, you can expect high rates of mortality in residual Douglas-fir and grand fir.

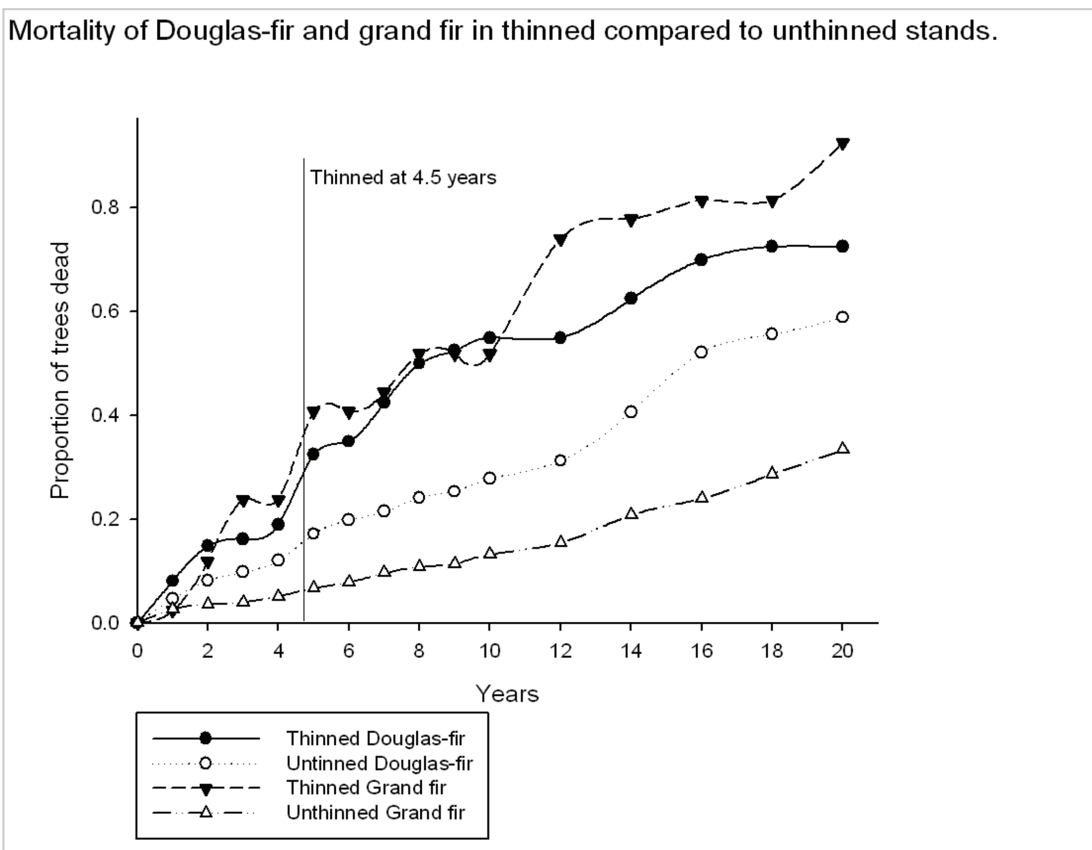

Figure 3. The rates of mortality in commercially thinned (filled symbols) compared to unthinned (hollow symbols) Douglas-fir and grand fir stands. The already-high rate of mortality of Douglas-fir was increased somewhat by thinning. Grand fir mortality was much higher in the thinned stands compared to those left unthinned. The stands have a combination of laminated, *Armillaria* and annosus root diseases .

Removals for bark beetle control

Douglas-fir beetle (*Dendroctonus pseudotsugae*), fir engraver beetle (*Scolytus ventralis*) and western balsam bark beetle (*Dryocoetes confusus*) are all associated to some extent with root disease-weakened trees. In most cases, they can utilize weakened trees to maintain endemic populations. Epidemic populations are not so closely tied to weakened trees and may attack many healthy trees.

Removal of attacked trees

Root pathogens almost certainly utilize the roots of bark beetle-killed trees in much the same way they use stumps of harvested trees. Efforts to control bark beetles by removing beetle-infested material from the woods may be of benefit in controlling the beetle populations and would be unlikely to increase root disease impacts. The roots of killed trees would be utilized by the fungus whether the stem was removed or not.

Bark beetle prevention thinning

Thinning to reduce stand density and thereby reducing the attractiveness of a stand to bark beetles is, in effect, a commercial thinning. If the species composition of the residual stand can be shifted by thinning to leave mostly disease resistant species, it will benefit both beetle and root disease management.

If most of the after-thinning stand will be Douglas-fir and true firs, laminated root rot and other root diseases can be expected to increase. The increase in mortality is fairly rapid, more than doubling rate of mortality in 10 years, to kill over half the Douglas-fir and grand fir in a stand in the first decade after thinning. After a decade or so of poor growth, and high mortality rates, the residual stand volume often is so low as to render a regeneration harvest no longer economically feasible.

Precommercial thinning can be used to push the stand species composition toward disease resistant or tolerant species, especially western larch and pines. If possible, a reduction of the combined composition of Douglas-fir and grand fir to less than one third will minimize laminated root rot impact. By maturity such stands are likely to have even less Douglas-fir and grand fir and root pathogen biomass should be fairly low.

Laminated root rot can be problematic in western larch. Observation suggests that most of the problem occurs in poor growing trees. Periods of crowding or severe dwarf mistletoe infection may compromise the natural resistance of western larch to root infections. Precommercial thinning can enhance resistance of western larch by maintaining the tree's ability to produce phenols and necrophylactic periderm to limit the spread of *P. sulphurascens* infections. Larch dwarf mistletoe infection levels can also be reduced by selective removal of obviously infected trees during precommercial thinning. For other strategies to reduce dwarf mistletoe infection, see Hoffman (2004).

If the disease severity is moderate or higher, precommercial thinning leaving Douglas-fir crop trees may be uneconomical because of poor subsequent survival.

Tree Resistance

Necrophylactic periderms in roots produced in response to injury or infection. Trees may produce several successive necrophylactic periderms as each previous periderm is breached.

Most lesions are halted by defense chemicals (phenolic compounds) in the bark or cambium of roots. If prevented from expanding long enough, periderm-surrounded infections will eventually be sloughed (as the root grows) and the root will heal.

Photo shows fire is an important natural control for root disease by favoring the survival and regeneration of pines and western larch.

Saprophytic fungi such as *Antrodia heteromorpha* (shown on a Douglas-fir stump above and below) quickly establish on stumps and dead trees and effectively exclude root pathogens from the resource. They probably play an important role in limiting the buildup of root diseases on harvested or burned sites.

Mortality rates of Douglas-fir remain about the same whether stands are precommercially thinned or not and growth response of this species is both minimal and temporary.

Management by fire

Fire can be very effective in creating large mosaics typical of the natural fire patterns on habitats where laminated root rot is prevalent. The outcome with respect to laminated root rot will depend on the species that are regenerated. Burning does not harm *Phellinus sulphurascens* nor the other major root pathogens because they reside well below ground.

The roots of trees killed or damaged by fire will be utilized by root pathogens to increase biomass and spread to the residual trees and regeneration. So, like a regeneration harvest, expect higher mortality rates among residuals and adjacent to the burn-treated area. Be prepared for a short flush of bark beetle mortality in fire-damaged trees.

Fertilization

Improvements in Douglas-fir growth may (Miller and others 2004) or may not (Nelson and others 1994) be realized through nitrogen and potassium fertilization. However, laminated root rot mortality is unaffected by fertilization (Thies and Westlind 2005, Miller and others 2006). Fertilization of Douglas-fir with nitrogen alone may increase the probability of *Armillaria* root disease-cause death (Moore and others 2004). Faster growing trees are likely to contact more inoculum which may increase mortality rates relative to slower growing trees (Miller and others 2006)

Managing laminated root rot: Biological control

Antagonistic fungi have been used successfully as biological pesticides in forest nurseries and in other agricultural settings. A common mold-type fungus, *Trichoderma viride* Pers., is an aggressive fungal antagonist in culture (Nelson 1964). When inoculated in holes drilled into *Phellinus*-infested stumps, *T. viride* was successful in killing *Phellinus* near the inoculated sites (Nelson and Thies 1985, 1986). Unfortunately, *Trichoderma* had limited ability to penetrate the woody substrate, which limited the its ability to interact directly with the root pathogen.

Many other naturally-occurring saprophytic fungi invade conifer roots shortly after tree death or harvest. These organisms have the potential to limit the development of root disease fungi. Among the most common fungi seen fruiting on stumps and snags in the northern rockies are *Fomitopsis pinicola* (Swartz:Fr.) Karst., *Trichaptum abietinum* (Dicks.:Fr.) Ryv., *Gloeophyllum sepiarium* (Fr.) Karst., and *Antrodia heteromorpha* (Fr.) Donk. In addition, several are routinely isolated from dead roots of trees, in particular *Perenniporia subacida* (Pk.) Donk, *F. pinicola*, *Resinicium bicolor* (Alb.& Schw. ex Fr.) Parm. and *T. abietinum*. These fungi probably naturally control laminated root rot and other root diseases to some extent by competing for woody substrates.

Managing laminated root rot: Direct Inoculum Removal

The amount of inoculum in the soil significantly influences the transmission and subsequent disease severity in the regenerated stand (Miller and others 2006). Methods and results of reducing the biomass of pathogen inoculum has been studied extensively in western coastal Douglas-fir forests where site values are high and alternative tree species have much lower timber value and productivity (Thies and Sturrock 1995).

Root removal

Stump and root removal can be accomplished either by digging out the stump and roots after the harvest or by push-falling trees and then raking the roots from the soil. An excavator is used for digging out stumps and roots and can also be used for push-falling trees. After push-falling, the trees are shaken to remove soil from the root wad. Roots still need to be raked from the stump site after push-falling. As many of the large roots as possible are removed from the soil. Once deposited above ground the roots become too dry to support the pathogen.

Either method is expensive and would likely only be used on high-value sites where Douglas-fir or grand fir were the preferred species. In the interest of operator safety, slopes should be less that 30 percent (Thies and Sturrock 1995).

Sanitizing the infested area

Destumping infection centers has reduced laminated root rot mortality by over half in the first two decades after site regeneration (with Douglas-fir) in coastal forests (Morrison and others 1988, Thies and others 1994). Perhaps a third of the treated area had no laminated root rot. Infected stumps are identified by the presence of stain or decay at the stump surface. All infected stumps are removed along with as much of the root system as possible.

Isolating the infested area

Lateral expansion of root disease centers may be halted or slowed by removing root systems in a buffer surrounding an infection center. Although the infection center itself is still unsuitable for growing Douglas-fir and grand fir, it is somewhat contained in this way. Bear in mind that some infections will be present in non-symptomatic trees outside the obvious infection center and may become new expanding centers.

We have little experience with physical removal of inoculum in inland forests (see sidebar). These approaches probably have limited application in Idaho and Montana where at least two other aggressive root pathogens are also likely to be present both within and outside of obvious infection centers.

Chemical control

Most of the early research efforts were aimed at fumigating around or in stumps to kill inoculum. A recent study has also shown efficacy in killing infections in living trees.

ISOLATING THE INFESTED AREA

Stumps were removed to restrict spread of the root pathogen at the margin of the infection center (at left in the above photo). All stumps were removed and wind-rowed in a 200-foot buffer (see photo below). This control effort was implemented on industrial forest land in Montana to control Armillaria root disease. Although it was not entirely successful, it did restrict expansion of the disease along most of the treated edge.

In most cases, infections are dispersed throughout the forest area, limiting the use of this control method.

Non-target effects of chloropicrin stump treatment

- No significant release of chloropicrin from treated stumps into surrounding soil at one year following treatment (Ingham and Thies 1995) and at 5 years following treatment (Massicotte and others 1998).
- Little or no effect on vegetation three years following fumigation (Luoma and Thies 1997)
- No affect on mycorrhizae on Douglas-fir seedlings 4 to 5 years after stump treatment (Massicotte and others 1998).
- Rare and minor effects on soil fungi, bacteria and amoeba populations near treated stumps in the first year following treatment ((Ingham and Thies 1995).
- No effect on soil arthropods and nematodes the first year after treatment (Ingham and Thies 1995).

Stump treatments to reduce inoculum

Emphasis for chemical control has been eradication or reduction of inoculum in dead tissues of stumps. We know that *P. sulphurascens* infections are often abundant in apparently healthy portions of a forest, not associated with recognizable disease centers (Thies and Nelson 1997). However, nearly all mortality occurs within active disease centers. Therefore it is tempting to try eliminating the fungus from disease centers thereby returning the site to Douglas-fir productivity. De-stumping is often not practical because of steep terrain, large stumps, soil disturbance and the difficulty of removing the decayed roots that break away from stumps.

Chemical fumigation of stumps to kill the pathogen has been somewhat more successful in eliminating most of the inoculum (Thies and Nelson 1987, Fraser and others 1995). Holes are drilled into the tops of stumps, the fumigant is poured in, and the holes are plugged. The authors reported reduction of infected root tissue to just 22% (by weight) of what they estimated to have been infected before treatment. Despite this success in reducing inoculum, just 16 years after replanting with Douglas-fir, there was no reduction in the amount of laminated root rot near treated stumps compared to non-treated stumps.

Perhaps the most important discovery here is the realization that very little inoculum is needed to sustain a disease center from one generation of host trees to the next.

Curatives for live trees

More recently, Harrington and Thies (2007) have reported success of MITC, chloropicrin, and Vorlex as curatives for infected roots in live trees. Nearly all fumigant treatments reduced root infection and, in some cases eliminated infection. Live Douglas -fir tolerated most of the tested fumigant treatments, although there was some cambium damage. The authors suggested that altering the time of treatment to the dormant season may reduce tissue damage. These results are encouraging because they suggest a potential to treat high-value trees growing in residential or administrative locations. Further research is needed to refine the application procedures.

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Related section in field guide.

No FIDL for this damage-agent

January 2006

(Scientific name updated April 2015.)

By John Guyon
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Tomentosus Root Disease

Onnia tomentosa (Fr.) Karst.

Hosts:
Primarily
- **Engelmann spruce**
- **Blue Spruce**
- **Lodgepole pine**
- **Western Larch**

Tomentosus root disease has caused over 20% volume loss in some spruce stands in southern Utah

Topics

Key Points

- Infected sites and stands can not be "cured"
- Manage for resistant species on infested sites
- Tomentosus disease pockets may harbor spruce beetle populations

Introduction

Onnia tomentosa infections of tree roots may result in mortality, premature windfall, growth reduction, and butt cull. Tomentosus root disease is common in Canada and the northern United States, but also found in pockets throughout most of the Intermountain Region and the Rocky Mountains, and in the eastern United States.

Onnia tomentosa is primarily a pathogen of spruce forests, (*Picea engelmanni* and *P. pungens*) but it also infects western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziezii*), western hemlock (*Tsuga heterophylla*), western larch (*Larix occidentalis*), ponderosa pine (*Pinus ponderosa*), as well as grand and subalpine fir (*Abies grandis* and *A. lasiocarpa*) are all susceptible in at least part of their range. Lodgepole pine (*Pinus contorta*) is an important host in some parts of North America. The disease is often called "stand opening disease" in spruce stands, and red root and butt rot in other hosts.

Tomentosus Root Disease Management

1. **Prevention. Regenerate infected sites with resistant species.**
2. **Inoculum reduction. Results are mixed, but removal of infected stumps and as many of the roots as possible may reduce damage in subsequent stands.**
3. **Intermediate Harvests. Precommercial and commercial thinning should favor resistant species. Selective removal of symptomatic trees, leaving susceptible residual stands, will not effectively control the disease.**

Trees infected by tomentosus root disease are often reservoirs for endemic level populations of spruce beetles and spruce engraver beetles.

Tree-to-tree spread of the disease and windthrow of infected trees results in expanding openings in the stand. These openings and windthrow are often the easiest ways to determine if tomentosus root disease is present.

TOMENTOSUS SPOROCARPS

Sporocarps are annual; produced during the fall or late summer after periods of high rainfall. They are small (about 1 to 4-inch diameter), firm yellow-brown with a pale buff pore layer underneath. They usually have a central stalk up to 1.5 inches tall and can be found on the ground surrounding infected spruce.

Damage

Attack by *Onnia tomentosa* on tree roots may result in mortality, premature windfall, growth reduction, and butt cull. In southern Utah, survey estimated volume loss at over 20% in larger trees (Guyon 1997). Similar levels of infection and mortality have been reported in other areas. Surveys in 70 to 111-year-old white and black spruce stands in Saskatchewan revealed volume losses averaging 28 percent due to root rot-caused mortality and cull (Whitney 1973).

Canadian researchers have found that site factors influence disease incidence and that the most important site factor is soil moisture regime as influenced by slope position and soil texture (Bernier and Lewis 1999).
In southern Utah, *I. tomentosus* appears to be largely confined to a narrow elevational band in stands containing both blue and Engelmann spruces.

Trees infected by tomentosus root disease are often reservoirs for endemic level populations of spruce beetles (*Dendroctonus rufipennis*) and spruce engraver beetles (*Ips pilifrons*). If populations of spruce beetles build up, they can cause landscape-scale outbreaks and mortality.

Life History

Disease centers are initiated either by basidiospores, which can infect wounded roots, or by mycelium from diseased roots left from the previous stand. The fungus may survive in buried roots for over 30 years following the death of the host. In the arid Intermountain west, the production of sporocarps (fruiting bodies) is rare. When found, the fruiting bodies are one of the few ways to positively identify tomentosus root disease on standing live trees without root excavation or boring.

The main spread within a stand is by root contacts between healthy and diseased roots. This rate of spread averaged about 20 cm/year in Canadian studies (Hunt and Peet 1997). Following initial infection, the fungus typically moves up the center of the root, eventually spreading into other major roots.

Within a year of infection, a chocolate to red-brown discoloration, often with a reddish pink margin, develops in the wood of infected roots. This symptom has shown up first in the lower portion of the roots in spruce surveyed in Utah. The decay, a white pocket rot, is discernable about 18 months after infection.

Decay of main supporting lateral roots greatly reduces windfirmness and may lead to windthrow of green trees.

A brown stain in the center of a root develops in advance of tomentosus decay.

Tree-to-tree spread of the disease and wind-throw of infected trees results in expanding openings in the stand. These wind-thrown trees are often the easiest ways to determine if tomentosus root disease is present. The exposed roots of wind-thrown trees can then be easily checked for typical discoloration and decay.

Diagnosis of tomentosus root disease is easiest in wind-thrown trees. Exposed roots can be checked for typical discoloration and decay.

Management

Root rot caused by *Onnia tomentosa* can be called a "disease of the site," since the pathogen survives for extended periods of time in woody material and can infect susceptible regeneration on the site. Therefore, harvesting infected stands and regenerating with susceptible species perpetuates the disease. Poor planting practices that result in dead or deformed roots have led to infection by *O. tomentosa*.

Management recommendations in the literature are limited to the following: clear-cutting heavily infected stands, converting to hardwoods or less susceptible conifers, and utilizing proper planting techniques to avoid deformed roots. Some attempts have been made at selective harvesting of root disease pockets plus a buffer strip, but with mixed results. Stumping and push-felling of infected trees has been tried in some areas, but the results are not yet conclusive. Cutting only symptomatic trees will salvage potential mortality but will not reduce spread of the disease to the remaining trees.

Aspen and most hardwoods are not infected by *O. tomentosa* If areas with root disease are regenerated with hardwoods, the fungus is deprived of suitable host material as the spruce roots decay.

Tree symptoms

Often difficult to discern, but can include:

- Reduced internode length
- Short needles
- Abnormal curling of branches
- Chlorotic foliage may not appear until 40 percent of the roots are dead
- Basal resinous
- Predisposition to windthrow

Harvesting infected stands followed by regeneration with susceptible species will perpetuate the disease.

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Rusts - Stem & Branch

SEED & CONE INSECTS

January 2006

By Sandra Kegley
US Forest Service

Seed and Cone Insects: Overview

Only a few of the more important seed and cone insects are discussed in this section.	**Hosts:** **Pines and firs.**

Topics

Key Points

- The main groups are beetles, moths, true bugs, wasps, and flies.
- There are hundreds of species of seed and cone insects feeding on most if not all of our forest trees.

Overview

Seed and cone insects can severely limit cone and seed production in both seed orchards and wild stands. There are hundreds of species of seed and cone insects feeding on most if not all of our forest trees. These insects usually feed within cones and can destroy cones before seeds develop. Some attack only seeds. The main groups are beetles, moths, true bugs, wasps, and flies. Their life cycles are complicated, and damage can be difficult to identify. The western spruce budworm, an important defoliator, can also consume cones and seeds of Douglas-fir and western larch.

Monitoring

Pheromones have been identified for certain insects and have been used to determine the timing of insecticide treatments. Pheromones may have application in mating disruption or trap out strategies in seed orchards in the future.

Management

The management of seed and cone insects is difficult because they are often concealed and protected inside cones. Insecticides have been the main management tool and are usually only practical in seed orchards or plantations. Residual sprays can be applied to developing cones but timing is critical to ensure insects come in contact with the insecticide. Systemic insecticides can be injected into trees' vascular systems or placed in the soil to be absorbed by the roots and transferred to the cones.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

January 2006

By Sandy Kegley
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Coneworm

Diorvctria abietivorella **(Grote)**

Topics

This moth is a chronic pest in western white pine seed orchards in northern Idaho and Douglas-fir stands in Montana.

Hosts:

- **Douglas-fir**
- **True firs**
- **All pines**
- **Spruces**
- **Western hemlock**
- **Mountain hemlock**

Key Points

- Detection seen as conspicuous clumps of frass stuck together with silk webbing on the outside of cones.
- Insecticides have proven effective in managing coneworm populations in western white pine seed orchards.

Damage

Larvae mine and riddle cones—feeding on cone tissue and seeds. They are very mobile and will emerge from feeding on one cone to continue feeding on another. Larvae can also bore into graft unions of Douglas-fir, western white pine, and ponderosa pine and have been found infesting western white pine blister rust canker margins. Frass and webbing are obvious on the outside of cones and bark where coneworms have been feeding.

Life History

Life history is variable and not well known. Larvae develop from June through September in the new growing cones. Some larvae pupate in cocoons on the ground during July, August and September and adults emerge shortly after to lay eggs, which overwinter. Other larvae overwinter as prepupae in cocoons in the ground, or in cones, pupate in the spring and emerge as adults during May and June. Eggs are laid on twigs and cone bracts.

Coneworm frass on outside of larch cone. Photo from FHP photo library.

Photo above: Coneworm adult moth. Photo from FHP photo library.

Identification

Infested and normal western white pine cone. Note discoloration and frass on infested cone. Photo by Sandra Kegley

Coneworm presence in cones or in graft unions can be detected by conspicuous clumps of frass stuck together with silk webbing on the outside of cones or bark. Damaged cones may also have circular exit holes and can be discolored. Mature larvae are about 18 mm long with a deep amber brown, shiny head. The body is amber brown to reddish-purple with faint dorsal lines and broader subdorsal stripes. Adults are gray and white with dark gray crossbands on the forewings. Hind wings are pale gray. Wingspan is about 25 mm.

Coneworm larva inside western white pine cone. Photo by Sandra Kegley

Management

Chemical contols

Insecticides have proven effective in managing coneworm populations in western white pine seed orchards. Two applications of fenvalerate*, a synthetic pyrethroid, applied in May and again in June, significantly increased seed yield (Haverty et al. 1986).

Monitoring

Pheromones have been identified but appear to be unstable in the field. Recently, research identified a new pheromone formulation which has shown promise and may be available for use in the near future. Pheromones can be used in traps to monitor populations and determine timing for insecticide treatments. They might also be used in mating disruption and trap out strategies in seed orchards.

*Chemical insecticide registrations for insect control change frequently. Contact County, State, or Federal pesticide coordinators for updates on current insecticide registrations and application methods.

Other Reading

Haverty, M.I.; Shea, P.J.; and Stipe, L.E. 1986. Single and multiple applications of fenvalerate to protect western white pine cones from *Dioryctria abietivorella* (Lepidopters: Pyralidae). Journal of Economic Entomol. 79(1): 158-161.

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<u>Cite as</u>: Kegley, S. 2006. Management guide for coneworm. 3 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Damage-agent is not in field guide.

No FIDL for this damage-agent

March 2004

By Nancy Sturdevant
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Douglas-fir Cone Midge

Contarinia oregonensis Foote

Douglas-fir cone gall midge is considered the most significant pest of Douglas-fir seed orchards (Schowalter et al., 1985) and can destroy up to 70 percent of the seed crop.	**Host:** Douglas-fir

Topics

Key Points

- This pest is persistent in Douglas-fir seed orchards in the Northern region.
- Larvae overwinter in ground litter and pupate in early spring.
- Simple sanitation may prove useful in reducing populations by removing infested-aborted cones from the orchard floor.

Damage

Larval or maggot feeding causes a gall in the vicinity of the seed. This can kill the seed or fuse it to the cone scale and it can't be shed or extracted. All seeds in heavily infested cones can be destroyed. This pest is persistent in Douglas-fir seed orchards throughout the Northern Region.

Life History

Larvae overwinter in ground litter and pupate in early spring. There is one generation a year, but diapause for one or more years is common. Adults lay eggs in female conlets during the brief period they are open for pollination in the spring. Larvae feed in the seeds until fall and when cones become wet, they drop to the ground to overwinter.

Identification

Look for galled seeds in cones. Maggots in galls are orange in color and about 2mm long. Adult males have bright orange abdomens, beaded-antennae that are approximately as long as the body, and they are 2.3 to 2.8 mm in length.

Adult Cone Midge
Photo by Dave Overhulser

Management

- Simple sanitation may prove useful in reducing populations by removing infested-aborted cones from the orchard floor.
- A pheromone trapping system to determine the need and timing for treatment of cone crops with insecticides was described by Willhite et al. 2004.
- Insecticides such as esfenvalerate are currently available for control of many cone and seed insects. The timing of spraying is critical because cone midge adults are only active for a short period of time. Spraying should precede or coincide with peak emergence of the adults. Please check with current labeling guidelines to insure the insecticide is still labeled for use against the cone midge.

Other Reading

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Damage-agent is not in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

By Nancy Sturdevant
US Forest Service

Management Guide for

Douglas-fir Seed Chalcid

Megastigmus spermotrophus Wachtl

Topics

This insect can kill between 2 and 47 percent of the cone crop annually.	**Host:** Douglas-fir

Key Points

- This insect can chronically infest the cones of Douglas-fir but does not usually cause significant losses of the seed crop.
- However, this insect can infest up to 47% of extractable seed especially during low cone crop years.
- Seed orchard managers may want to identify infestations likely to result in high seed losses.

Damage

The larvae feed inside the seeds. Heaviest damage usually occurs when the cone crop is light because then the percentage of seeds attacked is greatest.

Life History

Female wasps lay eggs in seeds in immature cones that are 2 to 3 weeks old. Susceptible cones are from 1 to 3 inches long. Younger or older cones are usually not attacked. Eggs are laid directly into developing seeds, normally 1 egg per seed. Larvae overwinter inside seeds on the forest floor. They pupate in early spring within seeds and emerge during May into June.

Identification

There is no external evidence of damage. Dissection or x-rays of extracted seed is required to detect damage. Look for maggot-like larvae inside the seeds. They are approximately 2 mm long and creamy white.

Management

- Insecticides such as esfenvalerate are currently available for control of many cone and seed insects. Please check with current labeling guidelines to insure the insecticide is still labeled for use against the seed chalcid.
- Also, the manager can adopt an Integrated Pest Management system to incorporate monitoring and treating the Douglas-fir chalcid. Publication R6-FPM-UP-008-94 describes monitoring with sticky traps and information to help orchard managers decide whether or not to treat.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

Febuary 2006

By Sandra Kegley
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Pine Cone Beetle

Conophthorus ponderosae Hopkins

Topics

This is one of the most destructive insects attacking western white pine cones in seed orchards in northern Idaho.

Hosts:

- western white pine
- ponderosa pine
- lodgepole pine
- limber pine
- whitebark pine

Key Points

- Larvae feed on seeds and cone tissue, pulverizing cone contents to a fine powder.
- Cone beetles can destroy 90% or more of western white pine cone crops .
- Cleaning up and removing aborted, infested cones reduces populations.

Damage

Adult beetles girdle cone axes causing stunted cones and cone death. Larvae feed on seeds and cone tissue pulverizing cone contents to a fine powder. Damaged western white pine cones abort and fall to the ground before winter. Damaged lodgepole and ponderosa pine cones remain attached to the stem (Furniss 1997). Damage by cone beetles can be extensive. Cone beetles can destroy 90% or more of western white pine cone crops (Shea et al. 1983, Williamson et al 1966), and 50-80% of limber pine cones (Keen 1958).

Life History

Adult beetles overwinter inside cones. In spring, adults emerge and enter second year conelets through scales at their base. Female beetles initiate the attack and bore around the cone axis, girdling the cone. They then bore distally along or inside the cone axis and lay eggs along a straight gallery. Eggs hatch in 5 to 10 days and larvae go through two instars before pupating in mid- to late summer. They change to new adults in late summer and stay in the cones to overwinter.

Normal and cone beetle damaged western white pine cones.

Identification

Attacked cones often have distinct pitch tubes at the site of beetles' entrance holes. Look for adult beetles or powdery frass and cone contents inside stunted cones. Adults are 3 to 4 mm long, shiny black, and cylindrical. They are in the same family as bark beetles and look similar.

Pitch tube caused by attacking cone beetle in ponderosa pine

Cone beetle inside western white pine cone.

Monitoring

Pheromone traps can be used to monitor cone beetle populations and help in the timing of insecticide treatments.

The semiochemicals pityol and alpha-pinene have been shown to be most attractive to North Idaho cone beetles in baited traps in western white pine (Rappaport et al. 2000).

Management Considerations

- In seed orchards, cleaning up and removing aborted, infested cones reduces populations.
- Single and multiple applications of the insecticide, permethrin, applied to second year conelets in a western white pine seed orchard significantly reduced loss of cones to cone beetles (Shea et al. 1983).
- Prescribed burning, and the use of a propane flamer greatly reduced populations of red pine cone beetles (*C. resinosae*) (Miller 1978) and white pine cone beetles (*C. coniperda*) (Sery and Katovich 1996) in the Midwest and may have application in western white pine where infested cones fall to the ground.

Other Reading

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Related section in field guide.

No FIDL for this damage-agent

Febuary 2006

Forest Health Protection and State Forestry Organizations

Management Guide for

Western Conifer Seed Bug

***Leptoglossus occidentalis* Heidemann**

By Sandy Kegley

This insect can have huge seed production impacts in western white pine seed orchards.	Hosts:
	• Pines • Douglas-fir • Grand fir

Topics

Key Points

- Seed bugs can reduce the amount of viable seed by 80%.
- Type of damage to the seed depends on the time and length of the feeding period.
- Monitoring, use of synthetic pyrethroid, and natural controls should be used to control large seed bug infestations.

Damage

The insect feeds by using its long mouthparts to pierce through cone scales into developing seeds. The insect's saliva softens or dissolves seed contents which are then imbibed. Type of damage to the seed depends on the time and length of the feeding period. When feeding occurs before the seedcoat hardens, the contents of the seed are completely removed and the seedcoat collapses. After seedcoats harden, the damaged seeds do not collapse even though all or parts of the contents are removed. Cones will develop normally but produce no viable seed (Hedlin et al. 1981). Partially filled and empty seeds can be detected on radiographs of extracted seed. Seed bugs can reduce the amount of viable seed by 80% (Connelly and Schowalter 1991). They can also cause abortion of first year conelets and feed on developing male flowers, reducing pollen production.

Life History

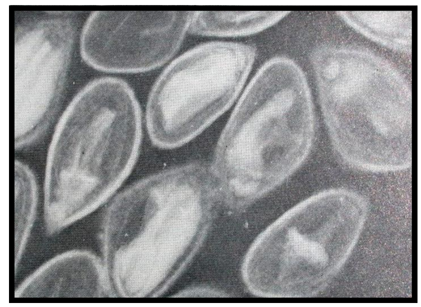
Adults overwinter in dead trees, bird or rodent nests, or people's houses. They become active in the spring and lay barrel-shaped eggs in rows on the needles of host trees from May to July. Eggs hatch into nymphs which feed on seed in developing cones. They pass through 5 nymphal instars and reach maturity by late August. New adults continue to feed on the ripening cone crop or first year conelets until the onset of cold weather. There is one generation per year (Koerber 1963).

Seed bug barrel-shaped eggs laid in rows on needles of host tree from May to July.

Identification

Photos show adult seed bug

Adults are active and quite conspicuous from spring through fall. They are large—about an inch long with long legs and antennae. The hind tibia is flattened and expanded. Their body is reddish brown to dark gray-brown in color with a thin zigzag white line across its forewing. They have orange and black markings on the upper abdomen that are evident when in flight. Nymphs have brightly colored orange markings. Both adults and nymphs are somewhat gregarious and tend to congregate on branch tips and cones on the sunny sides of trees. Nymphs will hide on the underside of cones or foliage when disturbed. Adults readily fly when disturbed. In flight, adults produce a buzzing noise. Both adults and nymphs emit an unpleasant odor when disturbed or squished. Adults can be quite a nuisance when they enter buildings in the fall in search of overwintering sites.



Radiograph of seeds damaged by seed bugs.

Chemical insecticide registrations for insect control change frequently. Contact County, State, or Federal pesticide coordinators for updates on current insecticide registrations and application methods.

Management

General management options include:

Monitoring:
Monitoring seed bug populations in seed orchards can be been done by visually examining cones on trees.

Chemicals:
When numerous seed bugs are found, insecticides may be applied to protect seed. The synthetic pyrethroid, permethrin*, has been used successfully to control seed bugs in North Idaho western white pine seed orchards. Seed bug activity may be detected by radiographs, biochemical marker based techniques (Lait et al. 2000, Bates et al. 2002) or staining techniques (Cambell and Shea 1990).

Natural controls:
Parasites of seed bug eggs have been identified and could potentially be used in an integrated pest management program in the future (Bates 2004).

Other Reading

Bates, S. 2004. Parasitoids of *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae) in British Columbia. Journal of the Entomol. Society of British Columbia. http://www.findarticles.com/p/articles/mi_qa4139/is_200412/ai_n13510931

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Cite as: Kegley, S. 2006. Management guide for western conifer seed bug. 3 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Stem Damages & Cankers

<u>Stem Damages</u>

Diseases

Related section in field guide.

No FIDL for this damage-agent

March 2004

Forest Health Protection and State Forestry Organizations

Abiotic Diseases: Overview

By
Marcus Jackson
US Forest Service

Topics

Abiotic damages

Abiotic tree diseases are caused by non-living agents that do not multiply and spread from tree to tree.	**Hosts:** **All species**

Damage

Whereas most insects and biotic diseases affect a particular tree species, or group of tree species, abiotic diseases will often affect various tree, shrub, and herbaceous species sharing the same or adjacent space.

However, different species and trees of different ages and vigor often vary in their susceptibility to damage.

Identification

Identification of abiotic diseases often requires learning the history of the site, comparing injury between trees and other plants of the same and different species, looking for patterns across a site, and ruling out damage from other agents such as insects and diseases. Factors causing these diseases may operate for only a brief period (frost), for most of the growing season (prolonged summer drought), or accumulate over a series of years (pollution).

Related Guides:

-Drought

-Chemical

-Floods

-Spring freeze

-Winter injury

Cite as: Jackson, M. 2004. Abiotic diseases: Overview. 1 p. *In*: Forest insect and disease management guide for the northern and central Rocky Mountains. USDA Forest Service, Northern and Intermountain Regions, State and Private Forestry, Forest Health Protection; Boise, ID, and Missoula, MT. In cooperation with the Idaho Department of Lands and the Montana Department of Natural Resources and Conservation. (Non-standard pagination.)

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Related section in field guide.

Forest Insect & Disease Leaflet

May 2005

Forest Health Protection and State Forestry Organizations

Management Guide for

Atropellis Canker

Atropellis piniphila (Weir)Lohman and Cash)
Atropellis pinicola(Zeller and Goodding)

By Blakey Lockman
US Forest Service

Topics

This canker is sporadic over much of the Northwest, but is rather common in northern Idaho and western Montana.

Primary Host:

A.piniphila
- Lodgepole pine

A.pinicola
- Western white pine

Occasional host:
- Ponderosa pine for both

Damage

Key Points

- Cankers kill the cambium resulting in a distortion of growth.
- Disease may reduce the volume in infected trees by as much as 50%.
- The wood behind cankers is often stained a blue-black color.

The fungus causes cankers that kill the cambium resulting in a distortion of growth. On lodgepole pine, cankers often develop on the bole. On western white pine, cankers usually are found on small branches, and bole cankers are uncommon. The wood behind cankers is often stained a blue-black color.

Damage is most severe in densely stocked stands on low quality sites. The fungus does not grow quickly and is not an aggressive girdling agent. Single cankers may occasionally kill small trees. Mortality is uncommon in vigorous trees, and usually only occurs when multiple cankers happen to combine and eventually encircle the stem. If the incidence of infection is high in young trees, the disease may cause stands to stagnate, especially if the stand is overly dense and the trees are slow growing. The disease may reduce the volume in infected trees by as much as 50%. The pulp value of affected wood is greatly reduced. The high resin content and the stain may cause chips to be rejected.

Branch canker on lodgepole pine.
Photo by Johns Sxhwandt

Life History

Infection usually occurs through undamaged bark near branch nodes or whorls. Rarely, the fungus will infect through pruning wounds on western white pine. Fruiting bodies often form within 2-3 years on small suppressed trees, but it may take 15- 20 years on large open-grown trees. Once spore production has started, it will continue throughout the life of the canker.

Spores are produced in early summer through early fall during wet weather, and are forcibly ejected into the air and may travel up to 300 feet. On dry sunny sites, spore production on dead trees will cease after a few weeks. If cankers on dead trees remain moist or shaded, spore production may continue for 1-2 years.

Identification

Stem cankers are the most common symptom in lodgepole pine.

Sunken cankers are formed several years after infection and cause stem deformity. Dead branches or "flags" are obvious symptoms on western white pine (these may be mistaken for blister rust "flags"). Copious amounts of resin are produced in cankered areas. Stem cankers are the most common symptom in lodgepole pine and can be identified by the elongated areas of heavy resin production. If the bark in the cankered area is removed, the blue-black stain is visible. In a cross-section, the stain appears as a wedge, tapering toward the pith. Tiny (1/32" -1/16" diameter), black, cup-shaped fruiting bodies are usually present on older cankers. Bark in the cankered areas clings tightly to the underlying wood.

Heavy resin production on lodgepole pine. Photo from US Forest Service Archives.

Management Considerations

Stocking level is closely associated with both disease incidence and growth loss.

A study of young lodgepole pine in British Columbia, Canada showed that the most significant reduction in disease incidence occurred when stands were thinned to 800 -1,000 trees per acre.

Ideally, stands should be thinned before the trees are 15-years-old, because that is the age at which trees become susceptible to infection. If stands are thinned at a later age, attempts should be made to remove infected trees. However, it is very likely that many infected trees will be left because small and incipient infections are hard to detect.

Removal of infected residuals within 300 feet of the young stand will greatly reduce the risk of new infections. Because the fungus can remain active on dead trees in moist and shaded areas, infected trees that are cut should be removed from the site, burned, or scattered in bright sunlight, which will cause the fungus to become inactive.

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April 2004

Forest Health Protection and State Forestry Organizations

By John Guyon
US Forest Service

Management Guide for

Cytospora Canker of Quaking Aspen

***Cytospora chrysosperma* (Pers.) F. (asexual stage)**
***Valsa sordida* Nits. (sexual stage)**

Topics

Populus spp. are hosts

- Aspen and Cottonwood

Cytospora canker is caused by an opportunistic pathogenic fungus, quick to attack trees weakened by heat, drought, winter damage or other pathogens, but will not cause serious damage on healthy trees. It is present in all aspen stands.

Key Points

- Weakened trees are subject to attack.
- Cytospora is present at some level in virtually all aspen stands.
- The fungus is spread by wind and rain.
- Reduce infection by preventing wounding.

Identification

The disease kills bark and causes lesions and cankers on trunks, large limbs, small branches, and twigs. Diseased inner bark rapidly turns dark brown and the sapwood is stained light brown. The dead bark remains attached to the tree for 2 or 3 years and falls off in large pieces.

Quaking aspen with *Cytospora* stem canker.

Damage

Little direct mortality is associated with Cytospora canker on pole size or larger trees, but it may hasten death of trees injured or weakened by other agents. Cytospora canker is one of the primary killers and "natural thinning agents" of seedling and sapling size trees.

Management

- **Prevent wounds during stand entries.**

Life History

Cytospora spore tendrils on an aspen stem.

This fungus is a normal inhabitant of the surface of aspen bark, and readily invades injured tissues. Canker development depends largely on the effectiveness of host defenses. On small injured branches or in periods extreme stress, canker development can proceed unimpeded resulting in a diffuse annual canker.

In healthy trees, host defenses inhibit canker expansion resulting in perennial canker that expands slowly over several years.

Black fruiting bodies that look like tiny pimples appear on the outer bark several weeks after infection. Spores emerge from these pimples in long, coiled, orange to dark red masses called spore tendrils. During rains these spores are disseminated over the bark.

A second spore stage develops on infected bark the following year, and produces spores that are carried by air or water to other host trees.

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Stem Damages

Insects

Related section in field guide.

No FIDL for this damage-agent

January 2006

By Sandra Kegley
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Sequoia Pitch Moth

Synanthedon (Vespamima) *sequoiae* (Hy. Edwards)

This moth is distributed throughout its host range from British Columbia to California and in Montana and Idaho.

Hosts:

- **Lodgepole pine**
- **Ponderosa pine**
- **Jeffrey pine**
- **Pinyon pine**

Occasional host:

- **Douglas-fir**

Topics

Key Points

- Attack sites are often at the base of trees, at the junction of bole and limbs, or in wounds.
- It can be a significant pest of ornamentals.
- Damage is usually heavier on dry, sunny slopes and where pines are planted off site.

Damage

Larvae bore under bark in phloem and outer layers of wood causing large masses of pitch to form around their entrance holes. Repeated attacks can girdle and kill young, small-diameter pines or cause the tops or branches of larger trees to break. Attack sites are often at the base of trees, at the junction of bole and limbs, or in wounds. It can be a significant pest of ornamentals. Pitch masses can contribute to fire hazard.

Pitch mass associated with a hip canker on lodgepole pine

Life History

Larvae spend two winters in their galleries. They pupate around late June the second year within the pitch mass. Pupae push their way partially out of the mass so emerging moths won't come in contact with the pitch. Moths appear from late June through July and lay eggs in bark crevices, junctions of limbs and bole, and in wounds caused by pruning or other mechanical means. New larvae bore into the phloem to feed until freezing temperatures, spend the winter in the phloem and resume feeding in the spring. They will spend another year in the galleries before pupating.

Pitch masses often occur at the base of trees.

Identification

Pitch masses containing larvae are soft, whitish, and have some reddish boring dust mixed in. Old masses turn hard and yellowish. Brown pupal skins might be sticking out of masses in late June through July. Mature larvae are yellowish-white and about 25-30 mm long. Adults are clearwing moths with black and yellow markings much like a yellow jacket wasp but they cannot sting.

Pupal case sticking out of pitch mass.

Photo above: Adult sequoia pitch moth resembles a yellow jacket moth but cannot sting. Photo left: Larva inside pitch mass.

Pheromone traps are available to help determine when adults are active (DeAngelis).

Management

- Damage is usually heavier on dry, sunny slopes and where pines are planted off site.
- Avoid damage to residual trees during thinning and logging operations, especially around bases.
- Pruning ornamental trees should be avoided when moths are active in the spring and summer.
- The best time to prune to avoid attacks on pines is between October and February (Overhulser 2002).
- Larvae or pupae in pitch masses can be individually killed by spearing them with pointed wires or opening the masses and destroying them.

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Forest Nursery Diseases

January 2006

By Robert James
US Forest Service

Forest Health Protection and State Forestry Organizations

Management Guide for

Forest Nursery Diseases

Hosts: All conifer species produced in nurseries	Environmental conditions within nurseries are ideal for proliferation of disease-causing pathogens

Topics

Key Points

- Caused by many fungi
- Prevention is the most effective control
- Consistent monitoring allows a timely response
- Sanitation is critical
- Timing of irrigation and fertilization are important factors

Introduction

Diseases are important limiting factors in the production of forest seedlings within nurseries. Environmental conditions within nurseries are often ideal for the proliferation of disease-causing pathogens. Seedlings are usually grown in extensive monocultural systems either outdoors within fields (bare root) or within greenhouses (container). High moisture and nutrients supplied to nursery seedlings often promote proliferation of important pathogens.

The organisms inducing nursery diseases are unlike those that cause diseases of trees within forests. They are similar or the same as those pathogens that cause diseases of agricultural crops. Pathogens associated with nursery-grown seedlings are usually not problems once seedlings are planted in forest areas. Management procedures to reduce impact of diseases within forest nurseries are similar to those used to control agricultural pests. Therefore, many of the chemical and non-chemical control methods used in forest nurseries have been adopted from agricultural system that have similar pathogens.

Pathogens causing disease in forest nurseries are also common pests of agricultural crops.

Overview of Forest Nursery Disease Control

1. **Cultural.** Disease prevention is the main objective of cultural management of nursery diseases. Reduce inoculum in growing areas and avoid conditions which promote disease spread. Sanitary practices including greenhouse, containers, and seed.
2. **Biological.** Some commercially-available biocontrol materials have shown some promising results.
3. **Chemical.** Use as a last resort. Fungicides often are specific to a particular group of fungi, as are the application methods so a proper diagnosis is very important.

Table 1. Major Diseases in Inland Pacific Northwest Nurseries

Pathogen Name	Types of Disease
Fusarium spp. (Fig. 5)	Seed Rot, Damping-off, Root Disease, Stem Blight
Phytophthora spp.	Root Disease
Pythium spp. (Fig. 3)	Root Disease
Botrytis cinerea (Fig. 4)	Foliar Blight, Storage Mold
Cylindrocarpon destructans	Root Decay
Sirococcus conigenus (Fig. 1)	Tip Blight
Sphaeropsis sapinea	Tip Blight
Meria laricis (Fig. 2)	Needle Cast
Phoma eupyrena	Tip Blight, Foliar Blight

Figure 1. Tip dieback of bare root ponderosa pine seedling caused by *Sirococcus conigenus*.

Successful management of nursery diseases often involves reducing pathogen inoculum in seedling production areas.

Nursery Disease Management

Diseases in forest nurseries are best prevented because pathogens can spread very quickly and cause extensive damage in relatively short time periods within nurseries. Once disease symptoms appear, pathogen infection has usually been extensive and therapeutic treatments are often not effective. Therefore, successful management of nursery diseases often involves reducing inoculum of potential pathogens in seedling production areas. Another major approach is to promote conditions which are non-conducive for pathogen infection and spread. Treating with chemical pesticides is often the least desirable and often last-implemented management approach, although sometimes this is the only way to prevent extensive losses.

Figure 2. Extensive epidemic of *Meria* needle cast on 2-0 bare root western larch seedlings.

Cultural control

Continual monitoring of the seedling crop is important so that the first indications of disease can be determined and so that control efforts can be initiated promptly to reduce chances for pathogen spread.

Sanitation is an important aspect of managing diseases in forest nurseries. Many of the most important pathogens can reside saprophytically on many types of organic matter that may be present within seedling-growing areas. Removal of organic matter within greenhouses that may harbor pathogens is very important in reducing disease losses. Greenhouse interiors and reused styrofoam or plastic containers should be sterilized between crops to preclude carryover of pathogens onto new seedling crops. Seedlings with disease symptoms should be periodically removed from both bare root and container stock to reduce chances for secondary spread of pathogens.

It is very important that pathogen-free seed be used to produce seedlings within nurseries. Some seedlots may require chemical treatments if high levels of pathogens are present; all seedlots should be routinely treated with running-water rinses to help reduce pathogen surface contamination of seedcoats.

Controlling timing and amount of irrigation is very important in reducing losses from some diseases such as those caused by *Cylindrocarpon*, *Pythium* (Figure 3), and *Phytophthora* spp. It is especially important that container-grown seedlings are not over-irrigated; persistently high levels of water in containers promote anaerobic development of pathogens which often results in extensive root decay. Irrigation should be applied only in the morning to allow foliage to dry quickly during the day to help control Botrytis blight.

Air circulation within greenhouse is important so that seedling foliage can rapidly dry after irrigation to help reduce losses from *Botrytis* and *Fusarium* spp., both of which may attack above-ground tissues (Figures 4 and 5).

Figure 4. Botrytis blight on container-grown Engelmann spruce seedlings. The pathogen is usually prolific at the base of seedlings where high moisture conditions persist.

Another way to reduce disease losses is by restricting fertilizer during certain parts of the growth cycle. For example, nitrogen should not be applied to young, succulent seedlings when they are particularly susceptible to damping-off.

Diseases of bare root seedlings can be reduced by bare fallowing fields for one or more years between seedling crops.

Figure 3. Root disease of bare root Douglas-fir seedlings caused by *Pythium* spp.

Sanitation is important for managing diseases in forest nurseries.

Figure 5. *Fusarium* root disease on container-grown Douglas-fir seedlings within a greenhouse.

If cover or green manure crops are grown between seedling crops, fields must either be subsequently fallowed or fumigated prior to sowing new seedling crops because most pathogen populations increase on organic matter produced by cover crops. Rotating different seedling species among fields also helps reduce pathogen buildup within soils.

When seedlings are lifted from either production fields or containers, they must be carefully examined for indications of disease. All seedlings with disease symptoms should be culled during the packing process.

Biological Control

Biological control formulations provide an environmentally–friendly alternative to chemical pesticides for control of some nursery pathogens.

Some commercially- available biocontrol formulations (biofungicides) developed for other agricultural crops show promise in forest nurseries. These are made up of either fungi or bacteria that are antagonistic towards pathogens. Biocontrol formulations are usually applied early in the growing cycle. They are either incorporated into soil-less growing media, which is made up of mixtures of peat moss with other organic or non-organic materials, or they can be applied directly adjacent to seed during sowing. Some biocontrol agents are applied to directly to seed prior to sowing.

Some ectomycorrhizae are also antagonistic toward pathogens. Commercially-available mycorrhizal preparations are available and can be applied several times during the seedling growing cycle.

Chemical pesticides

Chemical pesticides should only be used if other ways to control diseases are ineffective.

Chemical pesticides are usually applied as a last resort. In order to use the right chemicals, it is important to properly diagnose pathogens prior to treatments. Certain chemicals are only effective against certain groups of pathogens. For example, metalaxyl only controls oomycete pathogens (*Pythium*, *Phytophthora*) and is not effective against other pathogens such as *Fusarium*. Chemicals should be applied according to label instructions for timing and dosage rates.

It is best to rotate pesticides in order to reduce chances for pathogens to develop resistance. Selected pesticides should have different modes of action to limit chances for genetic mutations of pathogens.

Most pesticides are not effective therapeutically; they help prevent pathogen infection and colonization rather than kill pathogens that are already colonizing hosts. Pesticide applications just prior to lifting may be important to preclude fungal development during cold storage.

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