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Forest Disease Ecology and Management in Oregon

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Contents

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Introduction

CHAPTER 1

This manual is intended for forest land owners and managers who want to understand and prevent unnecessary forest damage from insects. This manual covers only insects that infest living trees, not those that infest dead wood.

The manual is organized into chapters based on the part of the tree that is affected by insects: foliage, shoots and twigs, trunks and large branches, and roots.

Some insect groups appear in several chapters because they affect more than one part of the tree. For example, some aphids affect foliage as well as twigs and branches.

The following example illustrates how a woodland owner or manager would use this manual:

1. Observe the tree damage; for example, a dead terminal branch on a Sitka spruce.
2. Determine what part or parts of the tree are affected; in our example, only terminal branches are dead, not lateral branches.
3. Identify the tree species, keeping in mind that more than one species may be affected. In our example, only spruce is affected; hemlocks and firs are healthy.
4. Look in the tables under tree species and part damaged. In this case, look up Sitka spruce under "shoot- and twig-feeding insects," Table 2 (pages 18–19).
5. Identify the possible insect group. In our case, four insects are listed that infest Sitka spruce: aphids, beetles, moths, and weevils.
6. Refer to the appropriate chapter for specific identification and management options. In our example, the damage resembles that caused by white pine weevil described in Chapter 3.
7. If you cannot identify the insect, send samples to your OSU Extension agent or Oregon Department of Forestry forester.

This manual is a companion to *Forest Disease Ecology and Management in Oregon*, Manual 9. See page 42 for other related publications.

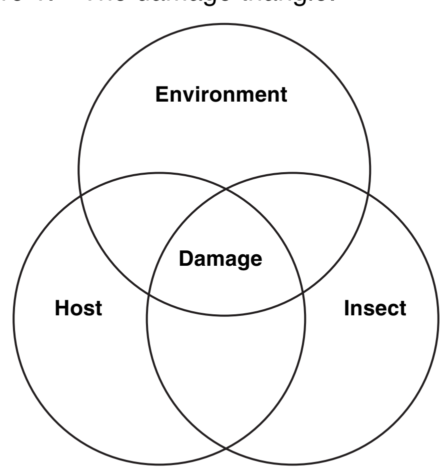
Forest health

Good forest health is a condition that implies a resiliency to natural disturbances such as insect damage, tree diseases, fires, and wind. It also implies that forest managers can achieve management objectives without impairing this resiliency.

Disease, fire, and wind may be related to insect-caused damage in many ways. For example, insect-caused mortality may increase the likelihood of fire, or wind damage may increase a tree's susceptibility to some insect pests. Thus, insect-caused disturbances or damage often involve more than the simple interaction of insects and their host trees.

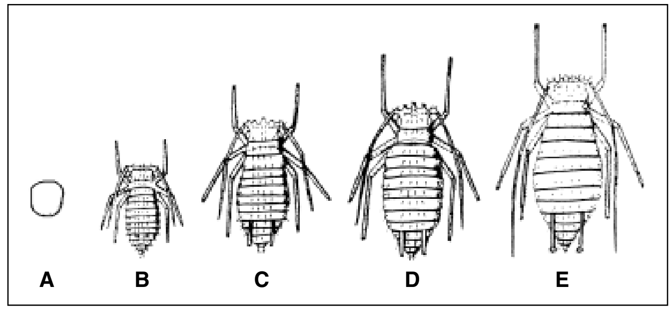
Insect damage is the product of three interacting factors: the host (tree), the insect, and the environment (Figure 1). If any one of these factors is missing or unfavorable, damage will not occur. For

Figure 1.—The damage triangle.



example, assume a tree species is susceptible, and spruce budworm larvae are feeding on the foliage. However, the spring weather is too cold for the larvae to develop, and birds eat them. In this case, the environment for insect development is not optimum—the weather is too cold—so defoliation does not occur even though the host and budworm are present.

Figure 2.—Incomplete or simple metamorphosis.



Insect life cycles

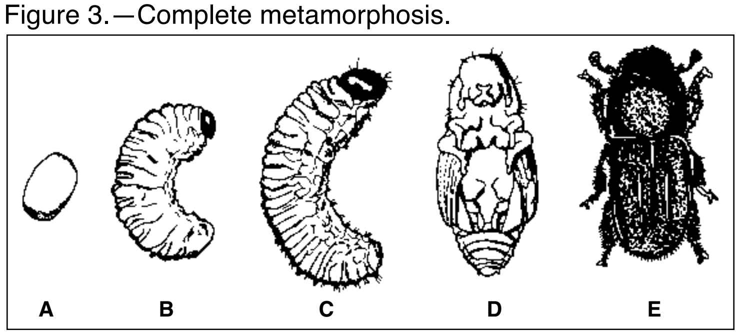
There are more than 900,000 identified species of insects in the world, more than any other kind of animal. Insects are arthropods, a group of organisms that also includes crustaceans, spiders, and mites. Although spiders and mites are related to insects, most of the arthropod damage to forest trees in Oregon is caused by insects. This guide focuses on insects and discusses other arthropods only briefly.

Insects go through distinct stages of development, from eggs to adults, called *metamorphosis*. Metamorphosis may take a few weeks to several years. Knowing what kind of metamorphosis an insect goes through will help in identification, since often only one life stage of the insect is present on damaged tree parts.

In *incomplete* or *simple* metamorphosis, insects change from eggs to nymphs to adults (Figure 2). The nymphs resemble the adults. Aphids are examples of insects with incomplete metamorphosis.

In *complete* metamorphosis, insects change from eggs to larvae to pupae to adults (Figure 3). In this case, the larvae are completely different from the adults in appearance and habits. Budworms and bark beetles are examples of insects with complete metamorphosis.

Figure 3.—Complete metamorphosis.



Not only do insects change form during the growing season, but populations also increase or decrease from year to year or even decade to decade. These cycles often are somewhat predictable over the course of 20 or more years. For example, tussock moth populations seem to peak for 1 or 2 years every 10 years. Budworm populations peak for 10 years every 20 years.

Climate, food, and natural enemies are major factors affecting insect populations. It is important to understand insect population dynamics and the factors that affect them in order to know when and how to control undesirably high populations of certain damaging insects.

Biotic and abiotic factors affecting insects

Biotic factors are the living parts of an insect's environment. Food supply is an important biotic factor that limits insect populations. Some insects feed on several tree species, while others rely on only one species of host tree. Defoliating insects usually have an abundant food supply, but specific kinds of foliage sometimes are limited. For example, some defoliators such as the spruce budworm feed on only newly developing foliage. Other defoliators such as the pandora moth feed on only older foliage. Some bark beetles require old or dying trees. If these trees are in short supply, beetle populations remain low.

Many *abiotic* (nonliving) factors also regulate insect populations. For example, temperatures that are too high or too low kill insects. Extremely low temperatures (below -20˚F) can kill bark beetles. Most insects cannot live above 120˚F. Temperatures also affect insect development. Therefore, increased altitude or latitude can prolong the time required for insect development.

Moisture and drought can have profound, although indirect, effects on insect populations. Water stress alters trees and their environment, making trees more susceptible to insect attack. Under these conditions, certain insects grow faster and have higher survival rates. On the other hand, some insects are vulnerable to desiccation (drying out) especially during molts (skin shedding). Drought can be induced either by lack of precipitation or by heavy competition among trees in an overstocked stand. Too much water resulting from flooding or raised water tables also can stress trees and make them more susceptible to insect attack.

Wind, snow, and ice affect insects directly and indirectly. Wind currents carry insects farther than they normally fly. Indirectly, wind, often in combination with snow and ice loading, can result in windthrown or broken trees. The broken trees and tops are ideal breeding material for certain bark beetles.

Lightning and fire influence forest insects by affecting their hosts. Both can severely weaken or kill trees, making them more susceptible to bark beetle and wood borer attack. Trunk wounds created by lightning or fire often are invaded by microorganisms. The increased resin flows and volatile odors accompanying wounds also attract bark beetles. On the other hand, either natural or prescribed fire can benefit a forest by killing insects that live in the duff and by thinning overstocked stands.

Tree wounds caused by humans, animals, or other trees or objects can weaken trees and increase their susceptibility to bark beetles and wood-boring insects. As wounds to trunks, branches, or roots get bigger and older, they are more likely to experience decay caused by fungi and other microorganisms. The decayed wood then is susceptible to wood-boring insects. If the wound is large enough, a tree may be weakened sufficiently to be attacked and killed by bark beetles.

Slash created from live branches, tops, and stumps makes excellent breeding material for many forest insects. Twig and branch insects dwell in the smaller material; bark beetles and wood borers live in the larger wood pieces, especially those more than 3 inches in diameter. The pitch volatiles released when cutting slash are very attractive to many insects that attack and breed in the inner bark and sapwood. If enough slash is present and insect populations become large, standing green trees can be attacked and killed by bark beetles such as pine engravers.

Disease can predispose trees to insect attack. Root diseases in particular can weaken trees and make them more susceptible to bark beetle attack. Douglas-fir beetles are especially likely to infest Douglas-firs that already are affected by laminated root rot. Fir engraver beetles commonly infest white or grand fir that is affected by laminated root rot, Armillaria root disease, or annosus root disease. White pine blister rust can weaken white pine so that it is more susceptible to mountain pine beetle. Dwarf mistletoes also can predispose trees to bark beetles.

Natural enemies of insects can have profound effects on insect populations. Natural enemies include other insects, spiders, microorganisms, birds, and mammals. For example, parasites such as wasps or flies lay their eggs on larvae or pupae of their host insects. The eggs hatch, and the developing parasite larvae feed on the host and kill it. Arthropod predators include spiders, ants, and true bugs that hunt down, snare, or ambush other insects. Birds and small mammals are the major vertebrate predators of forest insects. Pathogens are disease-causing organisms such as fungi, viruses, or bacteria that infect and kill their insect hosts.

Introduced or non-native insects can affect insect populations. Introduced insects have a beneficial effect when they become parasites or predators of damaging insects. Intentional introductions are used to control a target insect pest such as the larch casebearer.

On the other hand, introduced insects can affect host trees so dramatically that the trees are killed or are weakened enough to be more attractive to other insects. For example, in the eastern United States, the gypsy moth predisposes oak to bark beetles. Introduced insects may cause particularly severe damage because they may lack natural enemies to keep their populations in check.

Important insect groups

There are several main groups or orders of insects, but only three cause severe damage to living trees in Oregon: aphids and scales (Homoptera), butterflies and moths (Lepidoptera), and beetles (Coleoptera). Two other orders may cause moderate damage: midges (Diptera) and sawflies (Hymenoptera).

These important forest insects can be grouped by the part of the tree they affect. These groups include foliage-feeding insects, shoot- and twig-feeding insects, trunk- and large-branch-feeding insects, and root-feeding insects.

Use pesticides safely!

- Wear protective clothing and safety devices as recommended on the label. Bathe or shower after each use.
- Read the pesticide label—even if you've used the pesticide before. Follow closely the instructions on the label (and any other directions you have).
- Be cautious when you apply pesticides. Know your legal responsibility as a pesticide applicator. You may be liable for injury or damage resulting from pesticide use.

Foliage-feeding insects

CHAPTER 2

The important foliage-feeding insects of Oregon include aphids, budworms, caterpillars, flea beetles, loopers, midges, miners, sawflies, scales, and webworms (Table 1, pages 6–7).

Aphids

Aphids are small, soft-bodied insects that may have several generations annually. Most are parthenogenic; i.e., they reproduce asexually. They overwinter mainly as eggs, and some species require two species of hosts. Aphids have piercing mouth parts through which they suck plant sap from foliage, twigs, and even roots. They produce a sweet, sticky substance called honeydew that attracts ants and is a good medium for sooty mold. Adelgids are similar to aphids, and both sometimes are referred to loosely as aphids.

The most important foliage-feeding aphids in Oregon are found on Sitka spruce and Douglas-fir (Table 1). The most common aphids are the spruce aphid on spruce and the Cooley spruce gall aphid on spruce and Douglas-fir.

The **spruce aphid** (*Elatobium abietinum*) affects Sitka and most ornamental spruces in Oregon. This insect probably was introduced to North America from Europe. On the coast, spruce aphids are on trees all year and have several generations each year. Mild winter temperatures, typical of the coast, may favor destructive aphid outbreaks.

Aphid populations increase dramatically in late February and early March. Aphids suck the sap from spruce needles, causing yellow patches at the feeding site. The heaviest damage is in the lower or mid crown of the tree. By May, damaged needles turn completely brown and drop.

Figure 4.—Cooley spruce aphid galls.

The **Cooley spruce gall adelgid** *(Adelges cooleyi)* causes a gall on spruce twigs (Figure 4) and a yellowing and twisting of Douglas-fir needles, which is noticeable in spring. Neither kind of damage is of much economic importance in forest trees. On nursery seedlings and ornamental trees, however, the aphids tend to stunt and deform new growth.

The galls form on spruce, but on Douglas-fir, the presence of aphids is marked by cottony tufts on the needles. When both hosts are present, there are six stages in addition to eggs and crawlers. If one host is absent, there are only three stages. The entire life cycle requires 2 years.

Budworms

Budworms get their name from the larvae that feed on developing buds and new foliage. The most important budworms in Oregon affect true firs, Douglas-fir, western hemlock, Engelmann spruce, and some pines (Table 1).

(continued on page 8)

Table 1.—Foliage-feeding insects of Oregon trees.*

Tree species	Aphids	Budworms	Caterpillars	Loopers	Midges	Miners	Sawflies	Scale	Webworms
Conifers									
Cedar									
Alaska-			x						
Incense-			x						
Port-Orford-			x						
Western red			x	x				x	
Fir									
Douglas-	**X**	**X**	**X**	**X**	**X**	x	x	**X**	**X**
Grand/White	x	**X**	**X**	**X**		**X**	x		**X**
Noble	x								
Pacific silver	x	**X**		x		x	x		
Shasta red						x			
Subalpine	x	**X**	**X**	x					
Hemlock									
Mountain		x				x	x		
Western		**X**	x	**X**		x	**X**	**X**	x
Juniper			x			x	x	x	x
Larch	x	x	x	x		**X**	**X**		
Pine									
Jeffrey	x		**X**			**X**	**X**	**X**	
Knobcone						x		**X**	
Limber		**X**				x			
Lodgepole	x	**X**	**X**	x		**X**	**X**	**X**	**X**
Ponderosa	x	**X**	**X**	x	x	**X**	**X**	**X**	**X**
Sugar	x	**X**	**X**			**X**	**X**	**X**	
Western white	x		x				**X**		
Whitebark	x								
Redwood	x								
Spruce									
Brewer	x								
Engelmann	x	**X**	**X**	x		**X**	x		
Sitka	**X**	x	x	**X**		x	x		**X**
Yew									

*Insect groups marked in bold are discussed in text.

Table 1.—Foliage-feeding insects of Oregon trees (continued).

Tree species	Aphids	Beetles	Budworms	Caterpillars	Loopers	Miners	Sawflies	Scales	Webworms
Hardwoods									
Alder	x	**X**		**X**	x	x	**X**	x	**X**
Ash									**X**
Aspen			**X**	**X**	x	x			
Birch	x			**X**	x		x		
Buckthorn									
Cherry				**X**			x		**X**
Chinkapin				**X**					
Cottonwood		x		**X**		x	x		
Dogwood									
Madrone				**X**		x			**X**
Maple	x								
Myrtlewood						x			
Oak	x				**X**				
Tanoak				**X**					
Willow	x			**X**	x	x	x	x	x

Adult moths lay eggs on foliage in late summer. Eggs either overwinter or hatch in the fall into larvae that hibernate in bud scales or in hibernacula (an individual light silken web) on bark. Beginning in the spring, the larvae feed on buds and newly emerging foliage and go through several stages or instars before pupating in the summer. The pupae hatch into adult moths (Figure 5).

The **western spruce budworm** *(Choristoneura occidentalis)* is one of the most destructive foliage-feeding insects in Oregon. Millions of acres of susceptible Douglas-fir, spruce, and true firs (except noble and red fir) have been defoliated. When budworm populations are high, all new foliage can be stripped from host trees.

Outbreaks typically last 10 years in eastern Oregon. Three to 5 years of defoliation can reduce tree growth, cause top-kill, and kill some trees, especially seedlings and saplings. Mature trees also can die, especially when subsequently attacked by bark beetles. Cone crops on host trees can be destroyed during outbreaks. Western spruce budworm outbreaks can occur on the western slopes of the Cascade Mountains, but defoliation usually lasts for only a few years.

In May and June, when foliage growth starts, budworms frequently "web" together adjacent shoots, giving trees a twisted or stunted appearance. Attacked tips eventually turn red, making an infested stand look scorched. Older larvae often feed on older foliage during outbreaks. The upper crown often looks bare after several years of feeding. Ants and birds are significant predators of budworm larvae.

Other budworm species occur in Oregon but are not nearly as destructive as the

Figure 5.—Adult budworm moth.

western spruce budworm. The **western blackheaded budworm** *(Acleris gloverana)* also can cause significant defoliation of hemlock, Douglas-fir, true firs, and spruce in western Oregon. The **modoc budworm** *(Choristoneura viridis)* primarily defoliates white fir in southern Oregon. The **sugar pine tortrix** *(Choristoneura lambertiana)* feeds on several pines in Oregon. The **large aspen tortrix** *(Choristoneura conflictana)* can cause 1 or 2 years of defoliation of aspen stands.

Caterpillars

Caterpillars are multilegged, often brightly colored, and occasionally covered with hairs. They are the larval stage of adult moths or butterflies. The most important caterpillars in Oregon affect Douglas-fir, true firs, pines, spruce, and several species of hardwoods (Table 1). The most destructive caterpillars in Oregon are larvae of the Douglas-fir tussock moth, the western tent caterpillar, the pine butterfly, and the pandora moth. An introduced caterpillar is the gypsy moth.

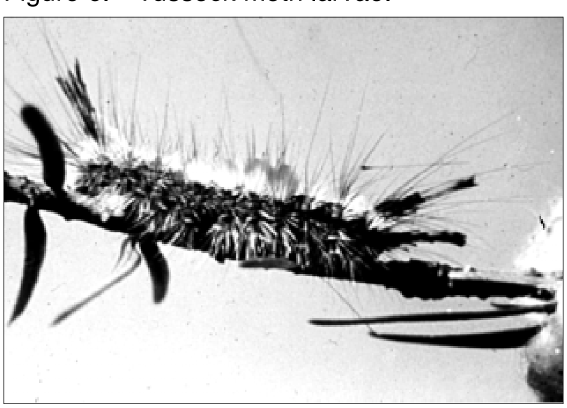
Among the most destructive caterpillars, especially in eastern Oregon, are the larvae of the **Douglas-fir tussock moth** *(Orgyia pseudotsugata,* Figure 6). Outbreaks in Douglas-fir and true fir develop suddenly over thousands of acres and collapse after 1 or 2 years of intense defoliation. Engelmann spruce and ornamental spruces also are defoliated. Tussock moth defoliation can cause tree growth loss, top-kill, and mortality, but some fully defoliated trees can recover.

After eggs hatch in late May or early June, young larvae congregate at the tops of trees and drop on silken threads. These silken threads act like parachutes and allow the larvae to be carried by the wind to adjacent trees. The residual silk at the tree top forms a small tent that is one of the first signs of a tussock moth infestation.

Initially, larvae feed on the current year's foliage, causing it to shrivel and brown. Unlike young budworms, however, tussock moth larvae feed on all ages of foliage.

By mid-July to August, the maturing larvae develop tufts of hairs or tussocks. Pupae form in late July and August and hatch into adult moths in mid-August. The female moth is flightless. Eggs are laid in clusters in August and September. The eggs overwinter and hatch in May.

Figure 6.—Tussock moth larvae.



The **rusty tussock moth** *(Orgyia antiqua)* is a widespread insect that feeds on hardwood and conifer foliage. In western Oregon, it causes localized defoliation in red alder stands. The caterpillars resemble the Douglas-fir tussock moth but have four distinctive golden brushes of hair on their backs.

The **western tent caterpillar** *(Malacosoma californicum)* is the most common insect pest of hardwoods in Oregon. During outbreaks, which can last 2 or 3 years and cover thousands of acres, trees are partially or completely defoliated. Unsightly trees and thousands of caterpillars often cause public alarm, but tree mortality is rare. In eastern Oregon, outbreaks can kill some branches on bitterbrush, an important browse for deer.

In April and May, caterpillars construct and enlarge white, silken tents while consuming adjacent foliage. Tree limbs with tents often are completely defoliated. Pupae form in midsummer and hatch into adult moths. Eggs usually are covered with a yellow to brown frothy substance produced by the female. The eggs overwinter and hatch into caterpillars in the spring at budbreak.

The **pine butterfly** *(Neophasia menapia)* is a pest of ponderosa pine, particularly old-growth, in Oregon. Defoliated stands can die, especially if trees already are stressed by bark beetles. During outbreaks, the larvae also may feed on associated conifer species. Outbreaks last only a few years. Very large numbers of butterflies often are seen before significant defoliation occurs.

The larvae feed in clusters when young, but as they mature they begin to feed singly. Old needles are eaten first, but older larvae also eat new needles. Larvae attach to bark, needles, twigs, or other objects before changing to pupae.

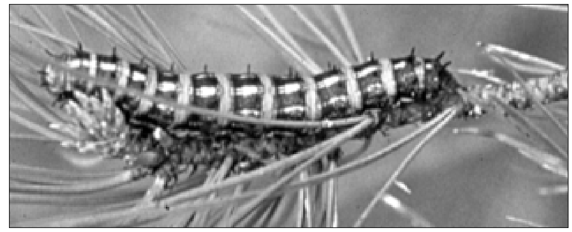
Figure 7.—Adult pine butterfly.

Adults (Figure 7) fly in late summer and lay eggs in rows along needles. The eggs overwinter and hatch in June or about the time of budbreak.

The **pandora moth** *(Coloradia pandora)* is another destructive insect of ponderosa pine, but sometimes also defoliates lodgepole pine, Jeffrey pine, and sugar pine. Severe defoliation can cause tree growth loss, but mortality is uncommon unless trees are stressed by factors such as drought or attack by other pests. Unlike most other insect defoliators in Oregon, the pandora moth has a 2-year life cycle. Populations last three or four generations (6 to 8 years) before a naturally occurring virus causes a population crash.

Tree ring studies have shown that central Oregon has experienced 10 outbreaks of pandora moth in the past 500 years, suggesting that the moth reaches high levels fairly rarely. Nonetheless, the pandora moth is a significant associate of pines in the region. The most recent outbreak subsided in 1995, and defoliation was noted on only 2,000 acres in 1996.

Figure 8.—Pandora moth larvae.



The larvae (Figure 8) hatch in late August and September and climb into trees to begin feeding. During winter, they hibernate in clusters at the base of needles. They feed again from March to early July. Caterpillars then move down the tree and burrow in the soil, where they pupate for 1 year.

In June or July of the second year, the adult moths emerge to mate. Eggs are laid in July and August on foliage, bark, buildings, or other structures.

Because larvae feed on the previous year's needles in the fall, trees at first appear completely defoliated. However, they leaf out again in the spring, creating a thinly foliated appearance.

The **gypsy moth** *(Lymantria dispar)* is introduced periodically into Oregon and usually is eradicated by aggressive aerial spraying with insecticides. There are two forms: a European form and an Asian form. The European gypsy moth is a major pest in the eastern United States, where it was introduced in 1870. It occasionally appears in Oregon, probably as a result of egg masses that are transported on automobiles and recreational vehicles from the east. The European gypsy moth feeds mostly on hardwoods but when introduced into Oregon quickly converted to feeding on Douglas-fir before being eradicated.

The Asian gypsy moth can spread faster than its European cousin because female moths can fly up to 12 miles and the larvae feed on more plant species. The Asian gypsy moth was introduced into Oregon as egg masses attached to Russian grain ships. The population was quickly eradicated with aerial sprays, but this pest remains a threat, especially on unprocessed logs imported from eastern Asia.

Flea beetles

Flea beetles are small, shiny-color, oval beetles that feed on the leaves of hardwoods. One of the most common defoliators of red alder in western Oregon is the alder flea beetle *(Altica ambiens)*. Both the larvae and adults of this beetle consume foliage voraciously. During outbreaks, which normally last 1 to 2 years, stands of alder can be totally defoliated by midsummer. Defoliated trees usually are not killed.

Loopers

Loopers, also known as "inchworms," are larvae that move along twigs with a looping motion. The most destructive loopers in Oregon are the western hemlock looper and the western oak looper (Table 1, pages 6–7).

The **western hemlock looper** *(Lambdina fiscellaria lugubrosa)* often is destructive in mature hemlock forests. Associated Sitka spruce, Douglas-fir, and understory shrubs also can be defoliated. Tree mortality can occur, but trees with up to 75 percent defoliation can recover. Outbreaks last about 3 years.

Feeding begins in May, June, and early July, but this initial defoliation is not noticeable. From the middle of July to October, loopers feed heavily, causing infested trees to appear scorched.

In late summer to fall, loopers drop from silken threads to the ground to pupate in protected places. Adult moths hatch in 10 to 14 days and lay eggs in late September and October. The eggs overwinter and hatch in the spring.

The **western oak looper** *(Lambdina fiscellaria somniaria)* feeds on Oregon white oak and associated trees in Oregon. In the Willamette Valley, white oak stands can be defoliated over extensive areas, but tree mortality is not common. The life cycle is similar to that of the hemlock looper, and outbreaks can last up to 5 years.

Midges

Midges are small flies that feed on needles of conifers. The **Douglas-fir needle midge** *(Contarinia* spp.) lays eggs in new needles of Douglas-fir in spring, and larval feeding results in a discolored area on both surfaces of the needle. The infested needles turn brown during the summer and drop off during winter. Needle midge outbreaks have defoliated hundreds of acres of Douglas-fir in northeast Oregon but usually last only 1 or 2 years.

Figure 9.—Adult larch casebearer.

Miners

Miners are larvae that feed within needles or leaves of attacked trees rather than on the outside. The most damaging miners in Oregon are on pine and larch (Table 1, pages 6–7). The most destructive foliage miners in Oregon are the pine needle-sheath miner, the lodgepole needle miner, and the larch casebearer.

The **pine needle-sheath miner** *(Zellaria haimbachi)* feeds on ponderosa, Jeffrey, and lodgepole pine in both eastern and western Oregon. Defoliation can seriously deform the tops of young trees. After 2 or more years of defoliation, terminal shoots often die and stems become forked.

The adult moth lays eggs on current foliage from late June to early August. After 10 days, the eggs hatch, and larvae bore into needles, where they overwinter.

In spring, when shoot elongation begins, larvae bore out of the previous year's needles, migrate to new growth, and chew small holes in the sheath of young needles, causing them to stop elongating and turn yellow. Needles that are severed at the base tend to droop, die, and fall prematurely. As larvae move among fascicles, they produce a fine silk webbing. Pupation is in June and July.

The **lodgepole needle miner** *(Coleotechnites* sp.) also attacks lodgepole and ponderosa pine and sometimes white fir, sugar pine, and Engelmann spruce. Outbreaks occur predominantly in areas where lodgepole pine is the climax species with an understory of bitterbrush. Defoliation results in tree growth loss.

Eggs hatch in late summer, and the larvae migrate to new needles where they construct mines. The larvae pupate in early July the following year. The adult moths hatch in late July.

The **larch casebearer** *(Coleophora laricella)* was introduced from Europe to the eastern United States in 1886. It gradually spread into Oregon by the 1960s, an unwanted traveler along the Oregon Trail. At one time, it caused considerable defoliation of larch, but recently it has been controlled by the introduction of insect parasites from Europe, one of the most successful biological control efforts in western forests.

Heavily infested trees become reddened as though scorched. Defoliated trees refoliate later in the summer. Repeated defoliation reduces tree growth, and mortality may result when other pests attack the weakened trees.

Adult moths lay eggs on needles from late May until early July. The eggs hatch into larvae, which start life as miners and feed on new foliage. They later live and feed in caselike shelters made of hollowed-out needles, where they eventually overwinter. In spring, they pupate and hatch into moths (Figure 9).

Sawflies

Sawflies get their name from the sawlike ovipositor on adult wasps (Figure 10) that is used to insert eggs in plant tissue. Sawflies are most damaging on hemlock, pine, and larch (Table 1). The most important foliage sawflies in Oregon are the hemlock sawfly, the pine sawfly, the larch sawfly, and the lodgepole pine sawfly.

The **hemlock sawfly** *(Neodiprion tsugae)* is an important defoliator of hemlock in coastal Oregon. The larvae feed chiefly on older needles, causing tree growth loss rather than mortality. Larvae hatch in the spring and feed in late spring and early summer. Cocoons usually are formed in the duff but sometimes on needles and other surfaces. Adults emerge from cocoons in the fall and lay eggs, which overwinter.

The **pine sawfly** *(Neodiprion fulviceps)* can defoliate ponderosa, Jeffrey, sugar, and white pine in Oregon. The life cycle is similar to that of the hemlock sawfly. The **larch sawfly** *(Pristiphora erichsonii)* attacks larch and overwinters as prepupal larvae.

The **lodgepole pine sawfly** *(Neodiprion* sp.) attacks all age classes of lodgepole pine during outbreaks. Defoliated trees have reduced vigor and sometimes are killed by bark beetles.

Figure 10.—Sawfly adults.

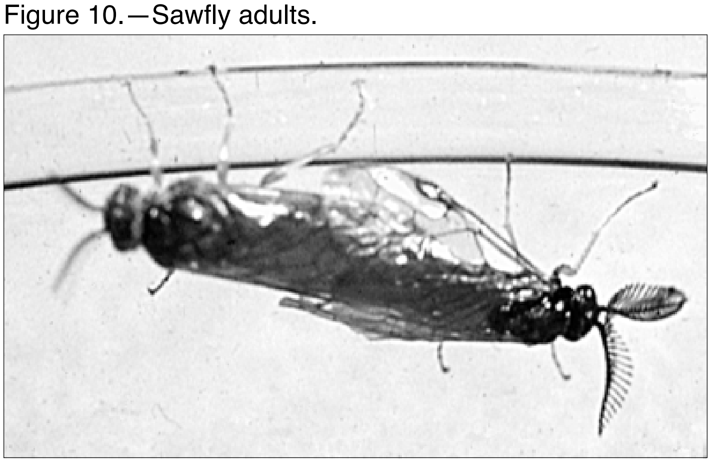


Figure 11.—Black pineleaf scale.

Scale

Scales are sap-sucking insects that often are inconspicuous, have a waxy shell-like covering, and remain fixed in one position until they die (Figure 11). In Oregon, foliage scales have been reported on Douglas-fir, juniper, pine, alder, and willow. In southern Oregon, they can be abundant on pine as a result of mosquito spraying that affects their natural enemies (wasps). The most important foliage scales in Oregon are the pine needle scale and the associated black pineleaf scale.

The **pine needle scale** *(Chionapsis pinifoliae)* attacks all species of pines and sometimes Douglas-fir and hemlock. It often is a pest of ornamentals but also can live in the forest, especially along dusty roads. Heavily infested trees have foliage that appears white from the scales. Young trees can be killed, but usually only growth loss occurs. Eggs are laid in the fall, overwinter under female scales, and hatch in the spring. The feeding nymphal stage is covered with a white shell.

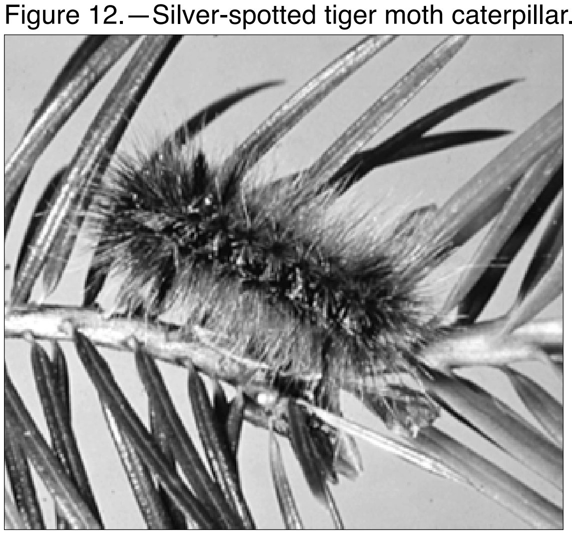
The **black pineleaf scale** *(Nuculaspis californica)* attacks primarily pines and sometimes Douglas-fir. Affected foliage is stunted at the tips of twigs; individual needles are yellowish and encrusted with scales. Eggs are laid in the spring and early summer and hatch into crawlers. These scales are distinguished by the black shell that covers their feeding stage (Figure 11). Severe scale infestation over several years can so weaken trees that they become susceptible to bark beetle attack.

Webworms

Webworms are caterpillars that make large webs over the foliage they feed on. In Oregon, they feed on Douglas-fir, true fir, spruce, pine, and several hardwoods. The most important webworms in Oregon are the silver-spotted tiger moth and the fall webworm.

The **silver-spotted tiger moth** *(Halisodota argentata)* is the most common defoliator of Douglas-fir, true fir, spruce, and pine in western Oregon. Whole branches often are stripped of needles, giving trees an unsightly appearance. Tiger moth caterpillars (Figure 12) are the most common defoliating insects on conifer foliage during the winter. From September to April, the caterpillars cluster inside dense webs covering one or more branches.

Figure 12.—Silver-spotted tiger moth caterpillar.



In May and June, the webs may be present, but the caterpillars abandon the web and disperse over the tree. Between mid-June and August, the pupal, moth, and egg stages predominate, and caterpillars are not present.

The **fall webworm** *(Hyphantria cunea)* is an important defoliator of hardwoods in Oregon. Adults lay eggs in the summer on leaf undersides. The larvae feed together and form large webs. In September, the larvae form thin transparent cocoons in the soil or litter or on tree trunks.

Ecologic roles of foliage-feeding insects

Foliage-feeding insects traditionally were thought to be destroyers of the forest, pests to be controlled and eradicated. Certainly they can and have caused tremendous economic damage to Oregon's forests. Their beneficial roles in forest ecosystems are just beginning to be studied and accepted.

One obvious role is as a source of food for other wildlife, especially birds, but also bats, rodents, spiders, and ants. One study in northeastern Oregon showed that trees where birds and ants were excluded had 10 times as many budworms as trees where birds and ants could feed on budworms at will. Insects are most vulnerable to predators as larvae, but adult moths and butterflies also are an important food source. Pupae also are consumed; for example, ground squirrels eat the large pandora moth pupae.

Another important role of foliage-feeding insects is their ability to recycle nutrients in foliage back to the forest floor as partially consumed foliage and insect frass (boring wood dust). This function is especially important when forest stands are overstocked and soil nutrients become scarce.

For example, western spruce budworms defoliate and kill millions of fir trees in overstocked stands during an epidemic. The surviving pines and resistant firs benefit from the newly created growing space and nutrients from dead needles, branches, trunks, and roots. The accumulation of fuels during budworm outbreaks supports fires that favor the regeneration of nonhost conifers such as pine and larch.

Some research has been done on the site and stand conditions that favor the development of problem situations with defoliating insects, especially western spruce budworm and Douglas-fir tussock moth. Little is known about environmental conditions that favor other species of foliage-feeding insects.

The chief hosts for western spruce budworm and Douglas-fir tussock moth are true firs and Douglas-fir. Fire exclusion and selective harvesting of pine at the turn of the century resulted in an unprecedented abundance of true firs and Douglas-fir in eastern and southern Oregon. Many areas became overstocked with fir, resulting in excessive moisture stress on all trees on the site.

Overabundance of fir foliage, several years of drought, and above-normal temperatures allow defoliator populations to increase. Because food is abundant, larvae develop more quickly, thus limiting predation by birds and ants. Tree mortality is accentuated by bark beetles, other pests, and drought, thus increasing the risk of catastrophic wildfire.

Management of foliage-feeding insects

Management or control of foliage-feeding insects depends on the management objectives for the forest. Where timber production is to be maximized, certain management practices can reduce the impact of insects. Even when other resource values, such as recreation, aesthetics, or wildlife are more important than timber, some management may be needed to prevent the severe epidemics that result in widespread tree mortality.

Direct control measures for foliage-feeding insects traditionally have relied on aerial spraying with insecticides (see page 39). Insecticides applied from either helicopters or fixed-winged aircraft cover large acreages and reach the tops of trees.

Chemicals such as DDT and carbaryl were used in the past, but today's preferred tools include biological insecticides such as *Bt* (short for *Bacillus thuringiensis*), a bacterium that occurs naturally in caterpillar populations and leads to their natural decline. Biological insecticides are applied when larvae or caterpillars are present so that the pests ingest the material as they feed on foliage.

Direct control with insecticides does not alter the stand conditions that support defoliator outbreaks, such as overstocked multistoried stands of susceptible hosts. Thus, indirect control using silvicultural techniques is a better long-term approach. Thinning or harvesting susceptible host trees leaves more space, nutrients, and moisture for residual trees so they are better able to defend against defoliator attacks. In mixed-species stands, nonhost species are retained during thinning or harvesting. When regenerating a new stand, consider whether the species planted is susceptible to foliage-feeding insects.

A third management technique for foliage-feeding insects, called biological control, uses introduced natural enemies. This technique is especially effective against exotic pests such as the larch casebearer. Introduced pests lack natural enemies to keep pest populations at low levels. Natural enemies, such as other insects, are imported from the pest's country of origin and introduced into the pest's new environment. For example, introducing parasitic wasps from Europe into North America may have eliminated the larch casebearer as a damaging insect to western larch. This approach requires a thorough understanding of the ecology of both the pest and the natural enemy.

Shoot- and twig-feeding insects

CHAPTER 3

The important shoot- and twig-feeding insects of Oregon include aphids, beetles, borers, midges, moths, scales, and weevils (Table 2, pages 18–19).

Aphids

Besides foliage, aphids also attack the shoots and twigs of susceptible trees. The most important shoot- and twig-feeding aphids in Oregon are found on spruce and some true firs (Table 2). The most damaging are the balsam woolly adelgid on true firs and the Cooley spruce gall aphid, mentioned previously, on spruce (see Chapter 2).

The **balsam woolly adelgid** *(Adelges piceae)* was introduced from Europe and has caused severe damage and mortality to Pacific silver, subalpine, and grand fir in Oregon (Figure 13). Above 3,500 feet in elevation, noble fir and Shasta red fir are resistant to attack.

This aphid feeds on twigs, branches, and stems. It damages hosts by injecting a salivary substance into the tree that causes calluses and galls on the twigs and branches (gouting), which slowly weakens the tree and reduces seed crops. Bole infestations can be heavy and kill the tree.

In Oregon, there are two to four generations per year, and the crawlers are wind disseminated. All individuals are female.

Beetles

Adult beetles are hard-bodied insects with wings. The most important shoot- and twig-feeding beetles in Oregon are the twig beetles, which include several species of nonaggressive beetles (i.e., they kill only very weak trees). Twig beetles usually bore into the pith or reproduce under the bark of twigs, branches, and stems of susceptible trees.

Figure 13.—Balsam woolly adelgid damage.

The **Douglas-fir twig beetle** *(Pityophthorus orarius)* is the most common twig beetle in Oregon. It bores into the lateral twigs of Douglas-fir.

Borers

Borers get their name from their larvae's habit of boring through the pith of infested twigs and shoots (Figure 14, page 20). The most important shoot- and twig-feeding borer in Oregon is the **western pineshoot borer** *(Eucosma sonomana)*.

The larvae of this species feed in the pith of terminal and lateral shoots of young ponderosa, Jeffrey, lodgepole, shore, and

(continued on page 20)

Table 2.—Shoot and twig-feeding insects of Oregon trees.*

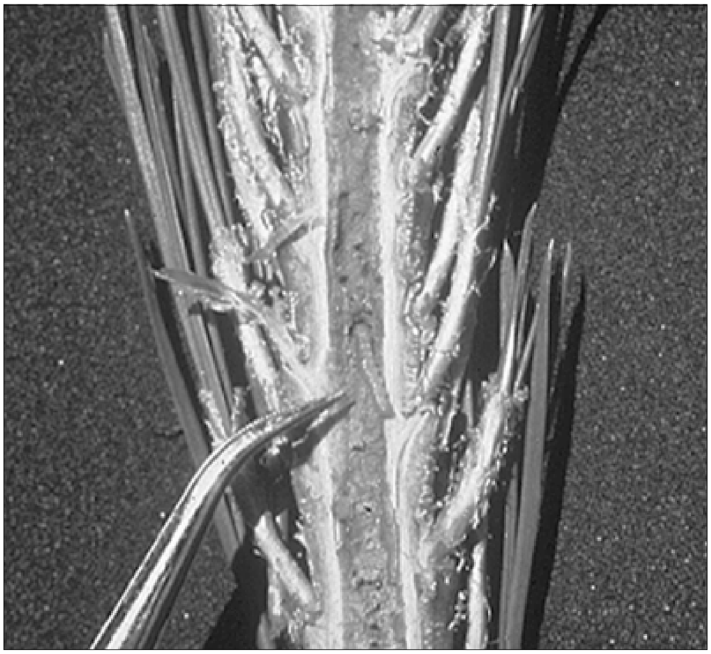
Tree species	Aphids	Beetles	Borers	Midges	Moths	Weevils
Conifers						
Cedar						
Alaska-		x				
Incense-		x	x		x	
Port-Orford-		x			x	
Western red						
Fir						
Douglas-	x	**X**	x		**X**	**X**
Grand/White	**X**	x	x		**X**	x
Noble	**X**				**X**	
Pacific silver	**X**	x			**X**	x
Shasta red	**X**					
Subalpine	**X**	x			**X**	
Hemlock						
Mountain		x	x		x	
Western	x				x	
Juniper		x				
Larch	x				x	
Pine						
Jeffrey	x	x	**X**		**X**	x
Knobcone		x	**X**		x	x
Limber		x				
Lodgepole	x	x	**X**		**X**	x
Ponderosa	x	x	**X**	**X**	**X**	x
Sugar	x	x	x		**X**	
Western white	x	x				
Whitebark		x				
Redwood		x	x		x	
Spruce						
Brewer						
Engelmann	x				x	**X**
Sitka	x	x			x	**X**
Yew						

*Insect groups marked in bold are discussed in text.

Table 2.—Shoot and twig-feeding insects of Oregon trees (continued).

Tree species	Beetles	Borers	Moths	Scales	Weevils
Hardwoods					
Alder	x	x			x
Ash					
Aspen			x		
Birch		x			
Buckthorn	x				
Cherry					
Chinkapin		x			
Cottonwood					
Dogwood					
Madrone	x		x		
Maple		x			
Myrtlewood	x	x			
Oak	x	x		**X**	
Tanoak					
Willow	x	x			x

Figure 14.—Western pineshoot borer damage.



knobcone pine. In ponderosa pine, infested terminals usually are stunted but survive, while infested lateral shoots usually die. In lodgepole pine, death of the infested leader is common. The most significant damage is in eastern Oregon. Each attack reduces height growth by 25 percent.

Midges

The most important twig and shoot midge is on ponderosa pine; it is the **gouty pitch midge** *(Cecidomyia piniinopis)*. It frequently infests open-grown ponderosa pine, where old damage appears as scattered dead branch tips or flags. Heavy pitch midge infestations retard tree growth, deform branches, and damage tree form. Eggs are laid on new shoots in spring and hatch into minute red larvae that bore into the vascular tissue, creating pitch pockets.

Moths

Moths get their name from the adult, but it is the larvae that damage shoots and twigs. The most important stem- and twig-feeding moths in Oregon are the ponderosa pine tip moth and the fir coneworm.

The **ponderosa pine tip moth** *(Rhyacionia zozana)* attacks open-grown ponderosa pine seedlings and occasionally lodgepole, sugar, and Jeffrey pine. Repeated attacks on seedlings result in growth loss and stem deformities. There is one generation per year. During the summer, the orange larvae of this insect can be found boring in the shoot tips of infested pine.

The **fir coneworm** *(Dioryctria abietivorella)* is very destructive of cones and shoots of true firs and Douglas-fir in Oregon. The larvae bore into the cambium of the trunk, branches, shoots, and cones. Feeding on Douglas-fir terminal shoots in May and June can sever the stem or result in distorted growth. The larvae pupate and hatch into bluish gray moths that measure about ½ inch long.

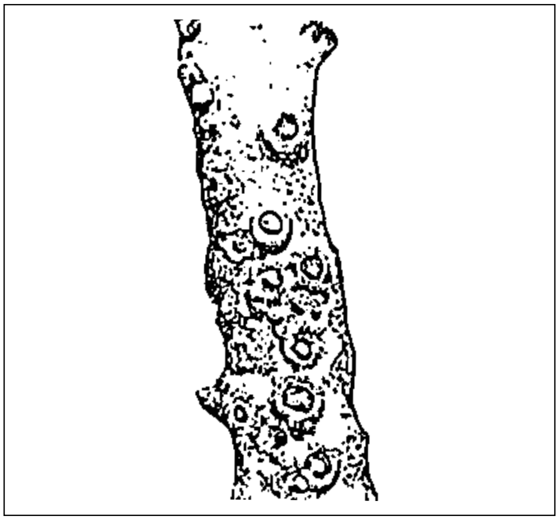
Scale

The **oak pit scale** *(Asterolecanidae)* is an introduced insect that is a serious pest of Oregon white oak. The adult scale is only 1⁄16 inch in diameter and appears as a thin brown to dull green plate surrounded by a ring of swollen bark (Figure 15). The pits are observed most easily on 2- or 3-year old branches. Badly infested trees have dead branches, thin crowns, and a proliferation of adventitious growth (new leaf growth on boles).

Weevils

Adult weevils are recognized by a snout-like downward-curved extension of the head. Important shoot- and twig-feeding weevils in Oregon are the white pine weevil and the Douglas-fir twig weevil.

Figure 15.—Oak pit scale.



The **white pine weevil** *(Pissodes strobi)*, which locally is called the Sitka spruce weevil, is the most important pest of Sitka spruce in Oregon. It limits the commercial production of Sitka spruce in areas more than 1.5 miles from the coast. The weevil also attacks Engelmann and ornamental spruces. Curiously, white pines in the West are not affected. Repeated weevil attacks slow growth and produce severe stem deformations.

From April to June, adult weevils are on terminals. Eggs are laid in the terminal shoot during May and June. Damage is noticed first in the summer, when terminals suddenly yellow and lose their needles. In July, the leader starts to wilt as larvae feed in the inner bark (Figure 16).

Larvae excavate chip cocoons (pupation chambers) in the wood. From August to September, leaders turn red, and new adults bore out through the bark and overwinter in the duff.

The **Douglas-fir twig weevil** *(Cylindrocopturus furnissi)* is a minor pest of young, open-grown Douglas-fir in western Oregon. The weevil is a problem mainly during drought years or on stressed sites.

Figure 16.—White pine weevil damage on Sitka spruce.

Twig weevil damage appears as scattered dying of young branches and the tops of trees. On older trees, damage is concentrated on laterals with 2-year-old growth.

Adult weevils most commonly are found on trees from June to August. From August to June, the immature stages of the weevil can be found under the twig bark near where the dead twig joins the live branch. In winter, they bore into the pith.

Ecologic roles of shoot- and twig-feeding insects

As with foliage-feeding insects, shoot- and twig-feeding insects traditionally were thought to be pests to be eradicated. Like defoliators, they can and have caused tremendous economic damage to Oregon's forests. Exotic introductions such as the balsam woolly adelgid lack the environmental restraints that limit severe epidemics in their native range.

The beneficial roles of native shoot- and twig-feeding insects in forested ecosystems are just beginning to be studied and accepted. Shoot- and twig-feeding insects are a source of food for other wildlife. However, unlike foliage-feeding insects, shoot- and twig-feeders often live under the bark or within the pith and so are not as accessible to birds and rodents.

Shoot- and twig-feeding insects also recycle nutrients in foliage and twigs back to the forest floor as dead foliage, twigs, and insect frass. The dead twigs and deformed branches provide a special niche for wildlife that normal, healthy branches do not.

Almost no research has been conducted on environmental conditions that favor "problem" situations with shoot- and twig-feeding insects in Oregon. It has been observed that the fastest growing trees, such as those in open-grown plantations, are more susceptible to attack by the western pineshoot borer and the white pine weevil. Trees in understory situations that are growing more slowly seldom are attacked by these pests. The exact reasons for this phenomenon are unknown.

Management of shoot- and twig-feeding insects

In some cases, shoot-infesting insects attack healthy, fast-growing trees planted on appropriate sites. As with defoliating insects, management or control of shoot- and twig-feeding insects depends on the management objectives for the forest.

Direct control of shoot- and twig-feeding insects with insecticides has not been as effective nor as warranted as it is for foliage-feeding insects. For this reason, indirect control is more effective. Some indirect control measures are:

- Favoring resistant tree species is recommended for balsam woolly adelgid and white pine weevil.
- Planting Sitka spruce trees close together stimulates height growth, benefits tree form, and creates a less favorable environment for white pine weevils.
- Growing spruce or ponderosa pine in the understory (uneven-age management) reduces damage from shoot borers and weevils. However, the reduction in height growth due to suppression must be weighed against the reduction in height growth that insects might cause.
- Maintaining tree vigor reduces damage from twig beetles and weevils. Mating disruption using synthetic pheromones reduces shoot infestations by the western pineshoot borer by 70 to 80 percent in the year of application.
- If terminal branches are killed, all but the best lateral branch can be pruned to form a new leader.

Trunk- and large-branch-feeding insects

The most important trunk- and large-branch-feeding insects in Oregon forests are aphids, pitch moths, flatheaded borers, and bark beetles. Bark beetles are the most damaging of this group.

Aphids

Several species of aphids feed on stems and branches of Oregon firs, hemlocks, and willows (Table 3, pages 24–25), but only the balsam woolly adelgid (see Chapter 3) is economically important.

Pitch moths

Pitch moths are named for the copious amounts of pitch that infested trees produce (Figure 17). The two important pitch moths in Oregon are the sequoia pitch moth and the Douglas-fir pitch moth.

The **sequoia pitch moth** *(Synanthedon sequoiae)* infests ponderosa, lodgepole, shore, sugar, and many ornamental pines in Oregon. Wounds created by the larvae can degrade the wood. Attacks on large trees are not damaging, but on infested small trees, wind can break wounded limbs.

Pitch moths often are associated with pruning wounds. Wounds can be reinfested for several years. The adult moths are unusual in that they mimic yellow jackets and fly during the day. They lay eggs in bark crevices or wounds from July to August. Larvae bore into the cambial area, where they feed for 1 or 2 years. Larvae pupate near the surface of the pitch mass, where empty pupal cases often are found.

Figure 17.—Pitch from pitch moth infestation.

The **Douglas-fir pitch moth** *(Synanthedon novaroensis)* is similar to the sequoia pitch moth except that it attacks Douglas-fir, Sitka spruce, and Engelmann spruce as well as ponderosa and lodgepole pine.

Insecticides have not proven effective in controlling pitch moth attacks. Instead, remove pitch masses and destroy the larvae or pupae. Also, avoid wounding trees or pruning branches in spring or summer. Prune between October and February for fewer attacks.

(continued on page 26)

Table 3.—Trunk- and large-branch-feeding insects of Oregon trees.*

Tree species	Aphids	Bark beetles	Flatheaded borers	Moths
Conifers				
Cedar				
Alaska-		x		
Incense-		**X**		x
Port-Orford-		**X**		
Western red		x		
Fir				
Douglas-	x	**X**	**X**	**X**
Grand/White	**X**	**X**	**X**	
Noble	x	x	**X**	
Pacific silver	**X**	x	**X**	
Shasta red		**X**		
Subalpine	**X**	x		
Hemlock				
Mountain		x		
Western	x	x	**X**	x
Juniper		x		
Larch		**X**		x
Pine				
Jeffrey		x	**X**	
Knobcone		x		
Limber		x		
Lodgepole		**X**		**X**
Ponderosa		**X**	**X**	**X**
Sugar		**X**	**X**	**X**
Western white		**X**		x
Whitebark		**X**		
Redwood		x		x
Spruce				
Brewer				
Engelmann		**X**	**X**	**X**
Sitka		**X**	**X**	**X**
Yew				

*Insect groups marked in bold are discussed in text.

Table 3.—Trunk- and large-branch-feeding insects of Oregon trees (continued).

Tree species	Aphids	Bark beetles	Borers	Moths
Hardwoods				
Alder		x	x	x
Ash		x		x
Aspen		x		x
Birch		x	x	
Buckthorn				
Cherry		x		
Chinkapin				
Cottonwood			x	x
Dogwood				
Madrone		x	x	
Maple				
Myrtlewood		x		
Oak		x	x	x
Tanoak		x		
Willow	x	x	x	x

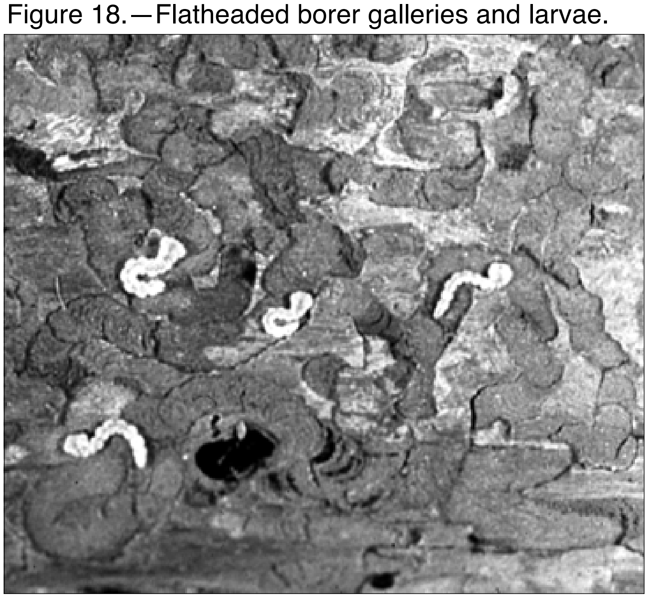
Flatheaded borers

Two species of flatheaded borers in Oregon infest the cambial area of conifers, much as bark beetles do. Sapling-size and larger trees can be susceptible to borer infestations. Infestations are common on harsh sites or in areas where other factors such as disease, defoliation, or fire have weakened trees. Sometimes borer attacks kill individual branches or portions of a tree's crown.

The **flatheaded fir borer** *(Melanophila drummondi)* infests Douglas-fir, true firs, spruce, and western hemlock. In spring, the female beetle lays eggs in bark crevices, and the larvae bore in the inner bark, making broad, irregular galleries (Figure 18). There are no external signs of borer attacks such as boring dust or pitch tubes. It is difficult to detect borer attacks before the tree's crown yellows.

In southwest Oregon, the **California flatheaded borer** *(Melanophila californica)* commonly attacks Jeffrey and ponderosa pine growing on harsh sites. Flatheaded borer infestations often are associated with pine bark beetles. The biology and appearance of the California flatheaded borer is similar to that of the flatheaded fir borer.

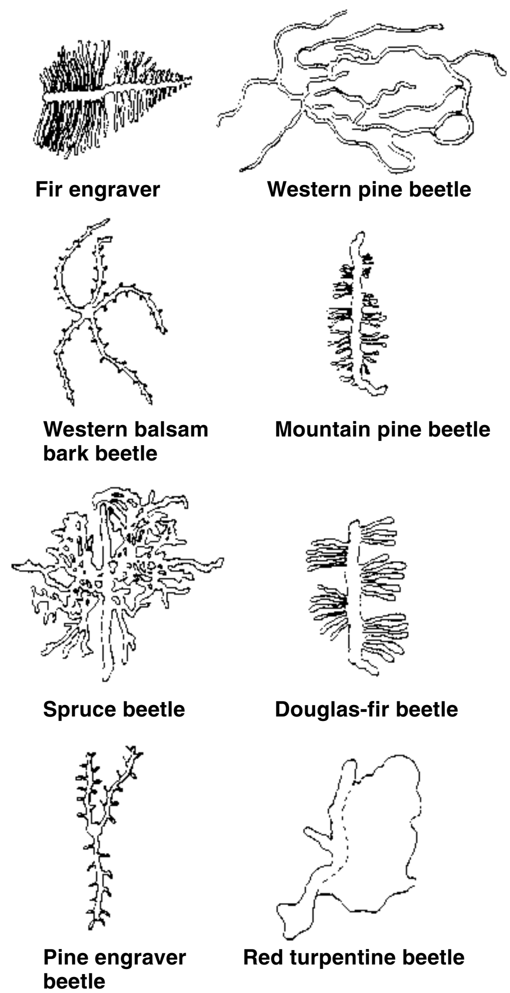
Figure 18.—Flatheaded borer galleries and larvae.



Bark beetles

Bark beetles are by far the most important forest tree insect pests in Oregon. All Oregon tree species, except yew and several hardwood species, are attacked by bark beetles (Table 3). The most damaging bark beetles, however, infest firs, pines, and spruces. These pests include the mountain pine beetle, western pine beetle, pine engraver beetle, red turpentine beetle, fir engraver beetle, Douglas-fir beetle, and spruce beetle. Several bark beetle species attack young trees or the crowns of mature trees, and often are identified by their distinctive gallery patterns (Figure 19).

Figure 19.—Bark beetle gallery patterns.



The **mountain pine beetle** *(Dendroctonus ponderosae)* is one of the most destructive bark beetles in Oregon. The beetle causes severe mortality in lodgepole, ponderosa, western white, sugar, and whitebark pine. Lodgepole pines larger than 6 inches dbh (diameter at breast height), more than 80 years old, and growing in dense stands are most susceptible. Young ponderosa pines (at least 6 inches dbh) are susceptible if in dense stands. The threat of beetle infestation in older, unmanaged pine stands is great enough to influence forest management decisions in much of eastern Oregon.

The beetle carries spores of a blue-stain fungus that infects the sapwood and colors it blue (Figure 20). The blue stain may help kill the tree and make it more suitable for the beetles. Blue stain does not weaken or decay wood but increases the cost of pulping the wood and causes a lower lumber grade. On the other hand, blue-stained wood often is sold for specialty interior paneling and furniture.

Adult beetles attack trees in July and August, sometimes leaving a pitch tube or bubble where each beetle enters the bark (Figure 21). Dry boring dust also may appear in the bark crevices below the pitch tubes. Adult beetles form a vertical gallery in the inner bark and deposit eggs that hatch into larvae. Larvae form horizontal galleries.

From May to July of the year after attack, infested trees turn red. The larvae pupate and form adults that emerge from infested trees in July.

The **western pine beetle** *(Dendroctonus brevicomis)* is an important cause of mortality in second- and old-growth ponderosa pine. The beetle often is associated with trees weakened by drought, root disease, soil compaction, or mechanical damage. The western pine beetle often is associated with other species of bark beetles attacking the same tree. The

Figure 20.—Blue stain in lodgepole pine.

Figure 21.—Pitch tubes on ponderosa pine.

western pine beetle has two generations per year in most of Oregon except in the southwest, where three generations per year are common.

The first sign of attack, months before any change in foliage color, is the appearance of small pitch tubes on the outer bark. Pitch tubes consist of white to red-brown masses of resin that often are associated with fine boring dust collected in bark crevices. Attacks are confirmed by removing the bark from dying trees to expose the winding, crisscrossing egg galleries that resemble chicken wire (Figure 19). The sapwood of infested trees is blue-stained from fungal infection.

The **red turpentine beetle** *(Dendroctonus valens)* also attacks pines stressed by drought or other factors. It attacks ponderosa, sugar, western white, lodgepole, and many ornamental pines in Oregon. Attacks are concentrated on the lower trunk or root collar of infested pines. Infested trees are attacked at the same time in the upper bole by other species of bark beetles. Trees usually are not killed unless infested by other species of beetles. There is only one generation per year in most of Oregon except in the southwest, where two generations are possible.

Large pitch tubes on the bark usually are the first sign of attack. If you remove the bark, you may be able to see the adult beetles (the largest in Oregon) or the larvae. Adult beetles can be found between May and September.

The **pine engraver beetle** *(Ips pini)* attacks sapling- to pole-size pines or the tops of larger trees, especially during drought years. It prefers to infest green slash or wind breakage but will infest and kill standing green trees when beetle populations are high. In most areas in Oregon, *Ips* have two generations per year. In southwest Oregon, four or five generations per year can occur.

From April to early June, adult beetles infest green slash that is 2 to 8 inches in diameter. Orange-brown boring dust in the bark crevices of the slash is the first sign of activity. From June to August, new adult beetles leave the slash and can infest standing live trees if there is not a fresh supply of green slash. Adult galleries are Y- or H-shape (Figure 19).

The **fir engraver beetle** *(Scolytus ventralis)* is a significant cause of mortality of grand, white, and Shasta red fir in Oregon. It also is found on Douglas-fir and Engelmann spruce. Fir engraver beetles breed in logging slash and may attack adjacent standing green trees, especially if trees are stressed by drought, defoliation, root disease, or overstocking. The fir engraver beetle has one generation per year.

If the tree does not die, beetle attacks often result in patch kills: only part of the trunk is killed. This causes a wound that may become infected with fungi, resulting in stain, ring-shake, or decay.

From June to September, adult beetles bore into firs, often causing a stream of pitch at the entrance hole. Brown boring dust often collects in bark crevices. Fir engraver attacks can be confirmed by removing a patch of bark and finding the beetle or its distinctive horizontal adult gallery (Figure 22). Larval galleries are vertical above and below the adult gallery.

From September to June, individual branches, tree tops, or entire trees turn yellow-green and eventually red. Adult beetles carry a brown-stain fungus that helps kill the tree.

The **Douglas-fir beetle** *(Dendroctonus pseudotsugae)* is one of the most important causes of Douglas-fir mortality in both western and eastern Oregon. Western larch also can be attacked but only if trees are extremely weakened or windthrown. Beetles introduce a brown stain into the sapwood.

In western Oregon, attack is associated with windthrown Douglas-fir or root disease. One to 2 years after windthrow, beetle populations increase to a level where nearby green standing trees are attacked. In eastern Oregon, attack often is associated with defoliation from the western spruce budworm or the Douglas-fir tussock moth.

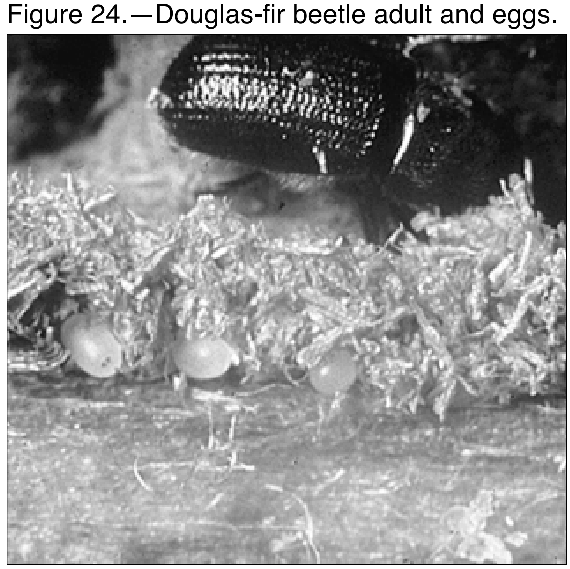
From April to June, reddish or yellowish boring dust is the first sign of beetle attack. When standing trees are attacked, boring dust is found in bark crevices or at tree bases. Streams of resin may be visible at middle to upper boles where attacks have occurred. Removing the bark of infested trees reveals the beetle, larvae, or their galleries (Figures 23 and 24). In eastern Oregon, trees attacked the previous year turn red in the spring. From July to October, about half of the attacked trees in western Oregon fade from green to yellow and eventually to red. The remainder fade the next spring.

Figure 22.—Fir engraver galleries.

The **spruce beetle** *(Dendroctonus rufipennis)* is the primary pest of mature Engelmann spruce in eastern Oregon. Sitka spruce also is attacked. Most outbreaks occur when beetles breed in windthrow and attack adjacent green trees. High-hazard trees are those greater than 16 inches dbh growing in stands with a spruce component of 65 percent or more.

Figure 23.—Douglas-fir beetle galleries.

Figure 24.—Douglas-fir beetle adult and eggs.



Adult beetles emerge from May to October to attack windthrown trees. During the first summer of attack, piles of boring dust in bark crevices or around tree bases are the first signs of attack. Adult beetle galleries run parallel to the wood grain; larval galleries radiate to the sides.

From fall to winter, trees still are green, but woodpeckers may partially debark the bole in search of beetle larvae. During the second summer following attack, spruce needles turn yellow and then red.

Some bark beetles often infest young trees or the crowns of mature trees. Two of the most common beetles in this category, the pine engraver and fir engraver, were discussed on page 28. Another engraver beetle, the **California fivespined Ips** *(Ips paraconfusus)*, infests ponderosa, sugar, and western white pine in southern Oregon. This beetle has two to three generations per year and an appearance and life cycle similar to that of the pine engraver beetle.

Young Douglas-fir or the crowns of mature trees under environmental stress often are infested by either the **Douglas-fir pole beetle** *(Pseudohylesinus nebulosus)* or **Douglas-fir engraver beetle** *(Scolytus unispinosus)*. Both of these bark beetles have one generation per year.

The branches and crowns of stressed or low-vigor incense-cedar often are infested by the **cedar bark beetle** *(Phloeosinus* sp.). These beetles are abundant in southern Oregon. They become evident during droughts and may have more than one generation per year on warmer sites. These beetles also infest Port-Orford-cedar trees that have been affected by Port-Orford-cedar root disease.

Ecologic roles of trunk- and large-branch-feeding insects

As with many forest insects, trunk and large-branch-feeding insects, especially bark beetles, traditionally were thought of as serious pests to be controlled. Bark-beetle-caused mortality has caused tremendous economic damage to Oregon's forests. These insects' beneficial roles in forested ecosystems are just beginning to be studied and accepted.

Bark beetles serve as a source of food for wildlife, especially birds. In fact, an obvious sign of bark beetle attack is the partial bark removal caused by larvae-foraging birds.

Another important role of trunk- and large branch insects is their ability to recycle nutrients of entire trees back to the forest floor. This function is especially important when forest stands are overstocked and soil nutrients become scarce. Following defoliator outbreaks, bark beetles kill millions of overstocked fir trees during an epidemic. The surviving trees of other species such as pines benefit from the newly created growing space and the nutrients from dead needles, branches, trunks, and roots.

Bark beetles play an important role in forest succession. For some species, such as westside Douglas-fir, bark beetles and their associated root diseases are the only biological agent that results in mortality. Gaps created in the canopy by beetle-caused mortality allow other tree species such as hemlock and cedar to become dominant.

In lieu of periodic low-intensity fires, bark beetles are natural thinning agents, attacking and killing the largest trees first. Beetle-killed stands are at high risk of catastrophic wildfire, a quick and efficient nutrient recycler.

Much research has been conducted regarding the site and stand conditions that favor the development of “problem” situations with bark beetles. For example, fire exclusion policies initiated at the turn of the century resulted not only in an unprecedented abundance of true firs and Douglas-fir, especially in eastern and southern Oregon, but also an overstocking of other species on their sites.

Firs defoliated by western spruce budworm or tussock moth in eastern Oregon subsequently are attacked by either Douglas-fir beetles or fir engravers. In western and southern Oregon, drought-affected stands are attacked by Douglas-fir beetles and flatheaded fir borers.

Overstocked stands of lodgepole pine are attacked by mountain pine beetles. Dense stands of ponderosa pine are attacked by either western pine beetles, mountain pine beetles, pine engravers, or all three.

Management of bark beetles

The following strategies may help prevent or reduce bark beetle-caused mortality.

Maintain tree vigor

All species of bark beetles prefer to attack and may kill trees that are weakened by other causes such as drought or defoliation. You can minimize the detrimental effects of many of these weakening factors by thinning or spacing trees to provide growing room, sufficient nutrients, and water.

Maintain mixtures of tree species

Growing mixtures of tree species is good management for many insect and disease problems, including bark beetles, which usually are species specific. For example, Douglas-fir beetles attack and kill Douglas-fir but not pine or spruce. Growing a mixture of tree species ensures the increased survival of those species not attacked by bark beetles. When mixing pine with other conifer species, follow the density guidelines for pine; in overstocked stands with a pine component, pines often are attacked before the other species.

Remove or destroy infested trees before beetles emerge

Bark beetle populations can be reduced if infested trees are harvested or destroyed (burned) before beetles emerge. This removal must be done in the spring. Exact timing depends on beetle species. There are at least two limitations to this technique. Timing is critical to remove all of the infected trees before the beetles emerge, and timing may change depending on the weather. The technique is effective only over large areas such as watersheds; beetles are strong fliers and can invade from long distances.

Salvage or treat windthrown trees

Removal of windthrown trees before the next spring for Douglas-fir beetle or within 1 year for the spruce beetle prevents population buildup on down trees and subsequent attacks on standing green trees. If a large blowdown of Douglas-fir occurs between August and February and cannot be salvaged, it is possible to treat down logs with an aerial application of an anti-aggregative pheromone (beetle repellent). This technique prevents the beetles from breeding in down logs and keeps beetle populations from increasing to a level at which green trees are attacked. Beetle-repellent techniques are relatively new, and a special-use permit is required.

Create logging or thinning slash only in late summer and fall

Thin white fir or pine stands from August to December when bark beetles are not flying. Material less than 3 inches in diameter can be thinned anytime, however, because small branches and stems do not afford a large enough breeding area to produce large beetle populations.

If you must create slash between January and June, and if the operation is large, a technique called the "green chain" may help avoid damage to leave trees. This technique creates new slash at 2-week intervals or continuously during July and August. The new slash, which *Ips* prefer to attack, soaks up the beetles as they emerge from the slash created between January and June. If fresh slash is not available in July and August, the beetles may attack green trees. During severe fire-danger periods in summer, woodland workers might not have access to the forest to perform these treatments.

Treat slash to make it unsuitable for beetles

Treat logging or thinning residues to make them unattractive to bark beetles, especially the pine and fir engravers. Cull logs and tops should be limbed, cut into short lengths, and left exposed to sunlight. This treatment of slash facilitates rapid drying and makes the material unsuitable for beetle reproduction. Leave large slash in the sun to dry, and do not leave it around the bases of green trees. Piling of slash is not recommended until the slash has dried sufficiently to no longer be suitable for engraver beetles.

Avoid cutting firewood from newly infested trees

If firewood is cut in May and June from pines that have yellow crowns, adult beetles may emerge from the logs to attack standing green trees. Store such logs away from green trees and cover the logs with plastic to kill the emerging beetles.

Use chemical sprays or pheromones on high-value trees

Individual high-value trees may be sprayed with insecticide to protect the trees from beetles. Spray before beetle flight, which occurs from April to June. A 2-percent active ingredient solution of carbaryl (Sevin) sprayed to runoff on the trunk is an effective preventive treatment. Spray insecticides from the tree base (for turpentine beetles) to as far up the trunk as possible and to a height of at least 30 feet. Applications may have to be repeated annually. Trunk sprays are not registered for forest use.

Plastic-encased pheromones called bubble-caps can be attached to high-value green Douglas-fir trees to make them less attractive to beetle attack. This "beetle repellent" prevents beetles from attacking and killing treated trees. A special-use permit is required.

Root-feeding insects

The most important root-feeding insects in Oregon forests are beetles and weevils (Table 4, page 34). These insects are important not only for the damage they cause by feeding but for a fungus they introduce into the root system that results in black stain root disease (Figure 25). Douglas-fir, pine, and hemlock are the known hosts in Oregon.

The vectors (carriers) of this disease in Douglas-fir are the bark beetle *Hylastes nigrinus* and two species of weevils, *Pissodes fasciatus* and *Steremnius carinatus* (Figure 26). The bark beetle *Hylastes macer* may be a vector of black stain root disease of ponderosa pine. Once established by the insects, black stain root disease spreads from root to root on its own without further need for insect vectors.

Root-feeding bark beetles

Root-feeding bark beetles *(Hylastes* spp.) are most successful in attacking Douglas-fir whose roots are injured or stressed from logging injury, road building, soil compaction, or thinning shock. The beetles carry the spores of the black stain root disease fungus *(Leptographium wageneri).*

Adult beetles burrow through the soil to roots in the spring and may feed on wounded roots of several trees or stumps before they construct galleries. This feeding may result in introduction of the fungus.

Beetle populations increase dramatically in young Douglas-fir that are thinned between September and May. Because the main beetle flight in Oregon is in May, stands thinned before June are readily attacked by emerging beetles. Thinning slash and stumps thinned after August still are fresh at this time and may be attacked in the spring. Although *Hylastes macer* is thought to spread black stain root disease in ponderosa pine, its role as a disease vector in Douglas-fir is not as well known as that of *Hylastes nigrinus.*

Root- and root-collar-feeding weevils

Two species of **root-** and **root collar-feeding weevils** spread black stain root disease of Douglas-fir: *Pissodes fasciatus* and *Steremnius carinatus*. Their life cycles take 1 to 2 years and they spread fungal spores much as the root-feeding bark

Figure 25.—Black stain in an infected ponderosa pine.

Figure 26.—Beetles and weevils that spread black stain.

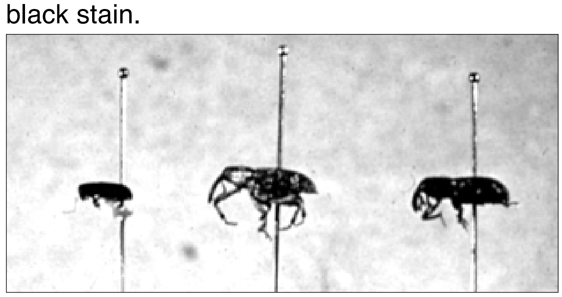


Table 4.—Root-feeding insects of Oregon trees.*

Tree species	Beetles	Weevils
Conifers		
Cedar		
Alaska-		
Incense-		
Port-Orford-		
Western red		x
Fir		
Douglas-	**X**	**X**
Grand/White	x	
Noble		x
Pacific silver		
Shasta red		x
Subalpine		
Hemlock		
Mountain	x	x
Western	x	x
Juniper		
Larch		
Pine		
Jeffrey	x	x
Knobcone		x
Limber		
Lodgepole	**X**	**X**
Ponderosa	**X**	**X**
Sugar	x	
Western white	x	x
Whitebark		
Redwood		
Spruce		
Brewer		x
Engelmann	x	
Sitka		
Yew		

Tree species	Beetles	Weevils
Hardwoods		
Alder		
Ash		
Aspen		
Birch		
Buckthorn		
Cherry		
Chinkapin		
Cottonwood		
Dogwood		
Madrone		
Maple		x
Myrtlewood		
Oak	x	
Tanoak		
Willow	x	

* Insect groups marked in bold are discussed in text.

beetles do. *Pissodes* can fly, whereas *Steremnius* is flightless but can walk up to 500 feet in 7 weeks. Both weevils breed in freshly cut stumps and can be very abundant 2 years after harvest or thinning operations.

Steremnius also is called a conifer seedling weevil because its maturation feeding frequently girdles and kills small-diameter Douglas-fir seedlings. Seedling damage, particularly to plugs, occurs shortly after planting in areas that lack herbaceous vegetation. Larger diameter Douglas-fir seedlings are not damaged significantly by weevil feeding.

Pissodes fasciatus is related to the white pine weevil *(Pissodes strobi)*, which kills the leaders of spruce. Like the white pine weevil, *Pissodes fasciatus* larvae form chip cocoons. In this case, the cocoons are found in the inner bark of infested root collars and boles.

Ecologic roles of root-feeding insects

As with other insects that cause tree mortality, root-feeding insects and the disease fungus they carry convert living biomass to dead biomass and create snags and down woody debris. As a result, they help release nutrients. Because black stain root disease is fairly species-specific, other tree species and plants take advantage of the spaces left by the dead host trees. Pure stands of either infested Douglas-fir or ponderosa pine eventually become mixed species stands as nonsusceptible plants fill in the gaps left by the dead trees.

Areas with black stain root disease commonly are along roadsides, in stands that have been thinned, and in stands with a history of soil disturbance from tractor logging. The insect vectors are attracted to volatile chemicals emitted from the damaged trees or stumps.

Management of root-feeding insects

Managing root-feeding insects also reduces the establishment of black stain root disease. If black stain is already on a site, other tree species should be favored or planted. For instance, if Douglas-fir is affected, hemlock, cedar, or alder should be favored. If ponderosa pine is infested, white fir or Douglas-fir should be favored. The disease does not spread from ponderosa pine to Douglas-fir because there are two different strains of the fungus, one on Douglas-fir and one on pine and hemlock.

The potential for establishing new black stain root disease centers can be minimized by reducing site disturbance and tree injury. In high-hazard areas (areas within a mile of known disease centers), tractor logging should not be used as a harvest system; instead, use systems that minimize soil compaction and root wounding such as horse logging or light cable systems. Favor mixed species in areas of highest risk. Avoid activities that result in tree wounding. Complete precommercial thinning between June and early August after the main flight of the beetles.

CHAPTER 6

Effects of forest practices on insects

Precommercial thinning

Precommercial thinning (PCT) has been practiced for many years in Oregon. There are advantages and disadvantages to precommercial thinning in terms of effects on forest insects but few have been scientifically tested. Advantages are:

- Wounded and infested trees can be eliminated.
- Growth response is excellent if live crown ratios and previous height growth are good.
- Shorter rotation ages can be used.
- Insect-tolerant species can be favored.
- Residual trees are more resistant to certain insects because of increased vigor.

Some disadvantages of PCT include:

- Sunscalding can occur on some species (true firs) on certain sites if spacing is too wide.
- Slash creation increases risk from fire, stem-wounding, and bark beetle attack.
- Stumps can become infested by root-feeding bark beetles, which are vectors of black stain root disease.
- Residual trees are more susceptible to certain insects because of the trees' increased vigor.

Precommercially thinning overstocked ponderosa and lodgepole pine stands can prevent outbreaks of mountain pine beetles and pine engraver beetles. Thinning slash must be properly disposed of to prevent attack by pine engravers. In eastern Oregon, precommercial thinning has been shown to increase radial growth of grand fir that is lightly to moderately defoliated by the western spruce budworm, especially if trees also are fertilized with urea.

Commercial thinning, seed tree harvesting, and shelterwood harvesting

The effects of commercial thinning, seed tree harvesting, or shelterwood systems on insect populations and damage have been documented in the interior West. The advantages and disadvantages of precommercial thinning also apply to commercial thinning. In eastern Oregon, studies have shown that thinning can increase vigor and resistance of lodgepole pine and ponderosa pine to mountain pine beetle. The increased distance between trees may affect insect response to pheromones, and the altered microclimate also can affect beetle movement in thinned stands.

Sanitation-salvage harvesting

The term "sanitation-salvage" harvesting or cutting is a combination of several closely related terms. *Salvage cuttings* are made chiefly to harvest trees that have been or are in imminent danger of being killed or damaged by agents other than competition between trees. *Sanitation cuttings* remove trees that have been attacked or appear in imminent danger of attack by pests; the objective is to prevent spread from one tree to another.

These operations are not necessarily confined to the removal of merchantable trees. Sanitation-salvage harvesting therefore is the removal of dead and dying trees to recover economic value that otherwise would be lost as a result of mortality from some pest.

There are several economic benefits to sanitation-salvage harvesting as it relates to forest resources, benefits especially—but not only—to timber values:

- Sanitation-salvage harvesting reduces fire hazard by removing dead and dying trees.
- Stands can be regenerated to a more healthy condition.
- Infested and high-risk trees are removed.
- The economic value of dead and dying trees is captured.

Several classifications guide tree marking during sanitation-salvage harvesting. These classifications relate to the risk of attack by insects or disease pathogens. In 1960, a classification for ponderosa pine in the Pacific Northwest was developed that uses crown size and form to predict attack from western pine beetle. Similar risk-rating systems based on crown form have been developed for fir engraver beetles in white and Shasta red fir. The most severe ratings have been shown to indicate a likelihood of reduced tree growth and can be a guide for decisions concerning tree removal.

Entering stands, including for sanitation-salvage harvesting, can increase mortality due to root diseases, especially annosus root disease. Infection by the annosus root disease fungus, *Heterobasidion annosum*, occurs when living trees are harvested with dead trees, because spores require freshly exposed living wood, such as a freshly cut stump or fresh trunk wound, to germinate and infect. In forests with repeated defoliation, many trees believed to be killed and thus marked for removal actually are still alive, and the freshly cut stumps are ideal infection courts for windblown spores of *H. annosum*. True firs are especially susceptible.

Clearcutting and regeneration

For pest management, clearcutting usually presents fewer problems than other types of harvesting because it leaves no residual trees to be windthrown, to infest regeneration, or to damage regeneration when they are removed later. Nevertheless, susceptible regeneration can become infested with insect defoliators from adjacent border trees or unmerchantable residuals. On the other hand, some insects such as the western pineshoot borer and the white pine weevil are favored by clearcutting; they are most abundant on open-grown fast-growing trees.

In reality, the effect of clearcutting on pest populations and damage is mainly hypothetical in Oregon, and research is needed to determine actual impacts.

The method of regeneration determines the amount of potential pest damage. Planting allows the establishment of pest-resistant species. Natural regeneration may foster the spread of certain insects if susceptible species are allowed to regenerate. Advance regeneration already may be infested with pests before the overstory is harvested; therefore, this method poses the greatest risk of future pest-caused losses.

Uneven-age management

Uneven-age management, in the strict sense, has not been practiced widely in Oregon. Although many forests have an uneven-age appearance, many are "uneven-size" rather than uneven-age.

This is especially true for shade-tolerant species such as the true firs, where suppressed understory trees may be the same age as their overstory neighbors.

Root diseases, stem decays, dwarf mistletoes, and defoliating insects are affected by stand structure and composition. Silvicultural systems that produce and maintain multistoried stands and climax tree species (especially true fir) generally allow these forest pests to increase. Thus, from a pest management perspective, uneven-age management is more appropriate in ponderosa pine forests than in mixed-conifer forests because fewer pests are associated with pine.

Defoliating insects such as the western spruce budworm and Douglas-fir tussock moth prefer shade-tolerant species such as true fir and Douglas-fir. Multistoried stands are most susceptible because:

- The shade-tolerant conifers that are most vulnerable to defoliation are plentiful in the understory.
- A higher percentage of crowns of dominant and codominant trees are exposed to sunlight, creating a more favorable environment for defoliator development.
- Insects can disperse effectively to other hosts in the understory.
- Defoliation increases with the variations in height, diameter, and age of trees.

You can take measures to reduce pest-caused damage in uneven-age multistoried stands:

- Favor and regenerate nonsusceptible tree species.
- Improve and maintain tree vigor through stocking-level control.
- Reduce tree wounding through well-planned harvesting operations.

Uneven-age management in most cases requires more care than even-age management and may be impractical in severely diseased stands. Nevertheless, it can be effective in many stands to meet land-use objectives while still preventing or reducing the adverse effects of forest pests. More research is needed to determine the short- and long-term effects of uneven-age management in Oregon.

Prescribed burning

Prescribed burning has been a silvicultural practice for many years in Oregon. It is used to reduce fuel loads and to remove unwanted understory vegetation. The effects of prescribed burning on insects have not been well studied in Oregon, but some studies have been conducted in neighboring areas.

Fire has a direct and obvious effect when insects and their natural enemies are burned. Prescribed burning could decrease several pests, including seed and cone insects, defoliators such as sawflies and pandora moth, and a few other pests, such as the western pineshoot borer, that overwinter on the forest floor. Many insects, including bark beetles and weevils, breed under the bark of logging slash and can be killed by prescribed burning. Most of these insects, however, require fresh slash for a major portion of their life cycle, and burning old slash accomplishes little in terms of direct pest control.

Prescribed fires also can be used to “thin” stands to increase the vigor of residual trees and reduce infestation rates of bark beetles. In the process, however, other trees are partially burned and subsequently might be infested with bark beetles or decay fungi.

Fertilizing

Some research on the effects of fertilizer on forest insect pests has been reported in Oregon. The most comprehensive study to date was in eastern Oregon to assess the effects of urea fertilizer on western spruce budworm in thinned stands of white fir. This four-part study involved the hand application of urea fertilizer, which significantly increased the weight of budworm. Furthermore, parasitization of late larvae and pupae was reduced significantly in 1 year of the study. Fertilizer treatments, however, resulted in significantly reduced defoliation and significantly heavier biomass of shoot and foliage for the final 3 years of the study. Height and radial growth of fertilized trees was significantly greater than that of unfertilized trees 3 to 5 years after treatment. Other areas in Oregon with heavier defoliation, however, do not show the same tree growth responses to fertilizers.

Aerial insecticide application

Aerial insecticide applications to manage defoliating insects in the forest have been common in eastern Oregon for many decades. Few studies have been done to determine the long-term effects of aerial insecticide applications on hosts, insects, or natural enemies. A summary report of aerial insecticide treatments for western spruce budworm in Oregon and Washington from 1982 to 1992 showed that 2 years after treatment, defoliation usually returned to pretreatment levels and that defoliation levels in treated and untreated areas were nearly identical.

Another study was conducted in eastern Oregon to determine the effects of treatment with carbaryl on populations of western spruce budworm and growth of host trees. Overall, little difference in the basic pattern of budworm population behavior was apparent between treated and untreated sites. Parasitoid production was reduced temporarily in carbaryl-treated sites, but recovered within three seasons after treatment. Host defoliation seemed to be reduced by the carbaryl treatment, but annual ring widths of host trees in treated areas near the study sites did not reveal any growth response.

Some research on other insecticides has begun, but results are not yet available. In 1988, several areas in northeastern Oregon were treated aerially with *Bacillus thuringiensis (Bt)*, a natural bacterium that reduces defoliator populations. Several formulations of *Bt* significantly reduced defoliator densities when compared to nontreated areas, but long-term effects still are being monitored.

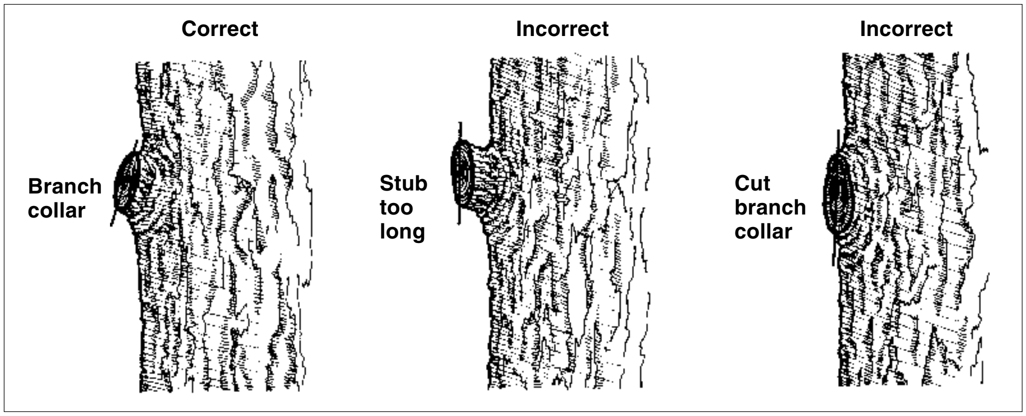
Artificial branch pruning

Artificial pruning of lower crown branches, both living and dead, is used in Oregon to improve wood quality and value. Artificial pruning usually is combined with stand thinning to increase tree growth and sealing of branch stubs.

Advantages of pruning include increased wood quality and value, improved stand access, and removal or prevention of certain disease pathogens. Disadvantages of pruning include increased stem decay, ring shakes, frost and sun cracks, wetwood, cankers, bark and pitch pockets, and insect attack *if done improperly*; reduced tree growth if too many branches are removed; sunscalding of thin-barked species; and formation of epicormic branches (new branches that grow from dormant buds).

Trees have a very effective protection system in the branch corewood, including a protective zone at the base of the

Figure 27.—Proper and improper pruning.



branch. In natural branch pruning, decay fungi spread downward until they reach this zone, and the decay facilitates branch shedding.

The old thought was that longer lengths of clear wood could be obtained by severing the swollen branch collar and cutting branches flush to the trunk. However, a flush cut removes the protective zone at the base of the branch (Figure 27). Although a flush cut stimulates callus formation, the amount of decay may be much worse than with a proper cut, especially in nonresinous species such as true firs or hardwoods. Thus, quality is much worse, not better. On the other hand, improper pruning that leaves stubs may provide dead wood and resources for decay fungi to penetrate the living tree and cause decay.

Sequoia pitch moth and Douglas-fir pitch moth can attack areas around trunk injuries or improperly pruned branches. If branch protection zones are removed, the tissues below the branches are weakened, and the insects take advantage of the situation. The larvae bore into the cambium, causing masses of pitch to form, often with serious damage to young trees.

Conclusions

It generally is much easier to prevent the undesirable feeding activities of forest insects than to control damaging insect populations directly. By integrating forest insect management with forest resource management, the overall health and productivity of Oregon's forests can be improved and maintained.

Many forest practices are used in Oregon, but their long-term effects on forest insects are not well known. We do know, however, that healthy forests can be maintained through intelligent, active forest management that manipulates stand structure and species composition, thus increasing tree vigor and resistance to forest insect pests. Natural enemies of insects and their associated tree pathogens also are influenced by forest practices. The overall result is improved quality of Oregon's natural resources.

For more information

OSU Extension publications

Aphid and Adelgid Pests of Conifers in Oregon, EC 1444 (1994), 8 pages.

Biology and Control of Douglas-fir Needle Midge in Christmas Trees, EC 1373 (revised 1994), 2 pages.

Forest Disease Ecology and Management in Oregon, Manual 9, (1995), 60 pages.

Forest Health in Eastern Oregon, EC 1413, (1992), 6 pages.

An Introduction to Forest Protection, EC 1253, (reprinted 2002), 12 pages.

Pacific Northwest Insect Control Handbook, INSECT (revised annually), 2003 edition 482 pages.

Trees to Know in Oregon, EC 1450, (revised 2003). 128 pages.

Using Precommercial Thinning to Enhance Woodland Productivity, EC 1189, (reprinted 1997), 12 pages.

For information about current prices and availabilities, call Publication Orders at 541-737-2513 or send e-mail to puborders@oregonstate.edu.
Or, visit our online catalog at http://eesc.oregonstate.edu/

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Other publications

Common Insect and Mite Galls of the Pacific Northwest, by H. Larew and J. Capizzi (Oregon State University Press, 1983). 80 pages.

Western Forest Insects, Miscellaneous Publication No. 1339, by R.L. Furniss and V.M. Carolin (USDA Forest Service, Washington, DC, 1977). 654 pages.

Glossary

Abiotic—Nonliving.

Advance regeneration—Regeneration that occurs before any special measures are undertaken to establish new growth.

Adventitious growth—New leaf growth on the bole of a tree.

Alternate host—An organism that serves as a host for an insect during part of the insect's life cycle. (See also **host**.)

Bacillus thuringiensis **(Bt)**—A naturally occurring bacterium that occurs in caterpillar populations and leads to their natural decline.

Biological control—Controlling pests through the action of living organisms (whether naturally occurring or brought in by humans) rather than by the application of chemicals. For example, introduced parasites have been successful in controlling the larch casebearer.

Biotic—Living.

Blue stain—A fungus discoloration of sapwood that is spread by bark beetles.

Bole—The main trunk of a tree.

Boring dust—Particles of wood or bark created by insects, especially bark beetles, as they bore into or out of a tree. (See also **frass**.)

Branch collar—The portion of a branch that surrounds the branch as it enters the trunk of a tree. Artificial branch pruning is properly done just to the outside of the branch collar.

Cambium—The thin layer of tissue in a plant that gives rise to new cells and is responsible for secondary growth.

Canker—A sunken and dead area under the bark of a tree stem or branch, usually caused by pathogenic fungi.

Climax species—Those species of trees found in dominant positions in a fully mature forest.

Codominant trees—Trees with crowns forming the general level of the crown cover and receiving full light from above but comparatively little from the sides.

Commercial thinning—Selectively removing trees that have commercial value. (See also **precommercial thinning**.)

Complete metamorphosis—Insect life cycle in which insects change from eggs to larvae to pupae to adults. The larvae are completely different from the adults in appearance and habits. (See also **incomplete metamorphosis**.)

Dominant trees—Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side.

Duff—Forest litter and other organic debris in various stages of decomposition on top of the mineral soil.

Epicormic branch—New branch that grows from a dormant bud.

Flag—A dead branch that still retains its foliage.

Forest succession—The predictable pattern of forest regeneration after a disturbance such as a fire or a clearcut.

Frass—Particles of wood, bark, or foliage created by insects.

Gall—A pronounced localized swelling of greatly modified structure that occurs on plants as a result of irritation by a disease or insect.

Gallery—A passage or burrow excavated by an insect under bark or in wood for feeding or egg-laying purposes.

Genus (pl. **genera**)—A class, kind, or group of organisms marked by one or more characteristics. For example, pine belong to the genus *Pinus*. (See also **species**.)

Gouting—A swelling of bark and wood tissue on a tree stem or branch, usually caused by insects such as aphids.

Green chain—Continuous creation of new slash to attract certain species of bark beetles in order to prevent them from attacking green trees.

Group-selection harvest system—A tree harvesting system designed to create an uneven-aged stand by repeatedly cutting groups or patches of mature trees at short intervals over an indefinite period of time.

Honeydew—A sweet, sticky substance produced by aphids. It attracts ants and is a good medium for sooty mold.

Host—An organism, such as a tree, on or in which a pest is living and from which it is obtaining its food. (See also **alternate host** and **secondary host**.)

Incomplete metamorphosis—Insect life cycle in which the insect changes from egg to nymph to adult. The nymph resembles the adult. (See also **complete metamorphosis**.)

Instar—Stage of larval development.

Lateral branch—A branch on a tree, especially a conifer, that grows laterally from the stem of the tree.

Live crown ratio—The proportion of a living crown height to total tree height, usually expressed as a percentage.

Nonaggressive—Refers to insects, especially bark beetles, that prefer to attack trees that are dead or severely weakened.

Overtopped—See **suppressed**.

Parthenogenic—Reproducing asexually.

Pitch tube—A hardened piece of resin or pitch that forms at the boring holes of insects, especially bark beetles. Pitch tubes indicate an attack on a vigorous tree that exudes pitch as a self-defense mechanism.

Pith—The center portion of a stem or branch.

Precommercial thinning—Removing trees too small to have commercial value in order to achieve better spacing for the rest of the trees in the stand. (See also **commercial thinning**.)

Prescribed burning—The use of regulated fires to reduce or eliminate the unincorporated organic matter of the forest floor or low, undesirable vegetation.

Residual stand—Trees left in a stand after thinning to grow until the next harvest. Also called “reserve stand” or “leave trees.”

Ring shakes—Separation of wood along the annual rings between the boundaries of decay or defect columns. Ring shake usually is observed after the tree has been cut and the wood begins to dry.

Salvage cutting—Harvesting trees that have been or are in imminent danger of being killed or damaged by injurious agents other than competition from other trees.

Sanitation cutting—Harvesting trees that have been or appear to be in imminent danger of being attacked by pests, in order to prevent spread of pests from one tree to another.

Sanitation–salvage cutting—See **salvage cutting** and **sanitation cutting**.

Sapwood—The light-colored wood that appears on the outer portion of a cross section of a tree. Composed of dead cells; serves to conduct water and minerals to the crown. Also called **xylem**.

Secondary host—A tree or plant that is infected to a much lesser degree than a primary host.

Seed-tree harvest system—Removal of mature trees in one cutting except for a small number of seed-producing trees left singly or in small groups.

Shelterwood harvest system—Removing mature trees in a series of cuttings over a relatively short portion of the rotation. This practice encourages establishment of essentially even-aged reproduction under the partial shelter of seed trees.

Simple metamorphosis—See **incomplete metamorphosis**.

Slash—Tree tops, branches, bark, and other debris left after a forest operation.

Sooty mold—Black encrustation caused by honeydew from aphids that becomes infected with black fungi or mold.

Sp., Spp.—Abbreviations. Sp. means one species, spp. means two or more species within the genus named.

Species—A subcategory of organisms with one or more characteristics in common. For example, a species of pine is lodgepole pine, *Pinus contorta*. (See also **genus**.)

Sunscald—Death of cambial tissue on one side of a tree, caused by exposure to direct sunlight.

Suppressed trees—Trees with crowns entirely below the general level of the overstory cover, receiving no direct light either from above or from the sides. Also called "overtopped."

Susceptible—Likely to become damaged as a result of contact with an insect pest.

Terminal branch—The uppermost branch or leader on a tree, especially conifers.

Top-kill—Mortality of the top portion of the crown of a tree.

Uneven-age management—A silvicultural system designed to produce a stand in which three or more age classes are represented.

Vascular—Refers to the water-conducting tissue in plants and trees.

Wetwood—Wood that is altered by microorganisms so that discoloration, moisture, pH, and mineral content increase, and certain parts of the cell walls may be eroded.

Xylem—See **sapwood**.

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Introduction

CHAPTER 1

Good forest health is a condition that implies a resiliency to natural disturbances. Disease is one of many natural disturbances that can affect forest health. Whereas forest health is the condition of populations of trees and other associated organisms, tree health is a status of individual trees. A tree with poor health does not mean that the forest is unhealthy, but poor forest health implies that a majority of trees are unhealthy.

While forest health relates to forested landscapes, tree health is more appropriate for intensively cultured populations of trees such as in nurseries, Christmas tree plantations, or urban settings. The term tree health also applies to valuable groups of native trees found in developed recreation areas and to nonnative ornamental trees.

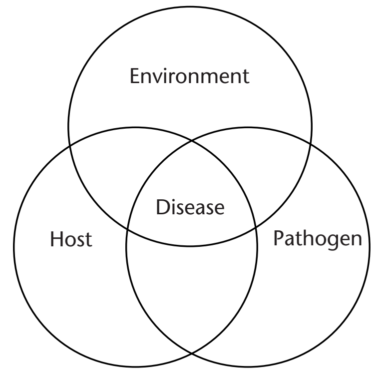
Definition and causes of disease

Disease can be defined as "a sustained disturbance to the normal function or structure of a tree as provoked by biological (biotic), chemical, or physical (abiotic) factors of the environment." A pathogen is an entity, usually biological (such as a fungus), that can cause disease. But disease does not simply result from the meeting of a pathogen and a tree. Disease is the product of three interacting factors: the host (tree), the pathogen, and the environment. The relationship among these factors has been called the disease triangle (Figure 1).

If any one of the three factors is missing or unfavorable, disease will not occur. For example, a susceptible tree species is present, and spores from a canker fungus have been released, but there is no wound on the tree for the spores to infect. In this case, the environment for infection is not proper—there is no wound—so disease does not occur even though the host and fungus are present.

Agents that cause disease usually are divided into two groups: nonliving (abiotic) or living (biotic). Abiotic diseases are caused by nonliving factors such as water stress, temperature extremes, chemicals, or soil compaction. Biotic diseases are caused by living organisms such as fungi or parasitic seed plants (mistletoes). Although nematodes, bacteria, and viruses can cause serious plant diseases, they rarely are involved in tree diseases in Oregon.

Figure 1.—The disease triangle.



Important disease groups

There are several economically and ecologically important tree diseases, which usually are grouped by the part of the host they affect. These include root diseases, stem decays and diseases, and foliage diseases. Other diseases include rusts, mistletoes, and abiotic diseases.

Diseases of hardwood or deciduous trees have not received much attention in Oregon. This situation is changing as species previously considered noncommercial or "weeds" gain commercial or ecological value.

Effects of biotic and abiotic factors on disease

Once a disease is in a forest or a tree, the course of the disease can be altered by other biotic or abiotic factors. For instance, a pathogen such as dwarf mistletoe attacks and becomes established in a Douglas-fir branch. A second biotic agent, a butterfly larva, feeds on the mistletoe plants, killing them. This is what is termed biological control. In another case, a root pathogen infects the roots of a ponderosa pine tree and weakens the tree. Disease occurs but does not kill the tree. Then a serious drought occurs, and the weakened pine tree dies.

Several other biotic or abiotic factors can affect disease. Wind by itself or with snow and ice can result in changes to already diseased trees. Wind can topple trees with root disease more easily, because decayed major roots are insufficient for support. Wind can snap trees off at places where stem decay is present in tree trunks. This may kill the tree, depending on where the trunk snaps and how much live crown is left. Wind can break branches with dwarf mistletoe brooms, especially if the abnormally large branches are loaded with snow and ice.

Figure 2.—Galleries of the bark beetle *Scolytus ventralis,* the fir engraver, under the bark of a killed grand fir.

Insects often are associated with tree diseases. Probably the best example is the relationship between root disease and bark beetles (Figure 2). Root disease weakens trees, predisposing them to bark beetle attack. Some root pathogens and stem-decay fungi actually are spread by bark beetles. Many bark beetles carry spores of fungi that cause black stain root disease. The fungi infect trees, make the trees more suitable for beetle colonization, and provide better habitat for beetle reproduction.

Biology of fungi that cause disease

The most common living agents that cause tree diseases are fungi. Fungi can infect needles, leaves, cones, stems, and roots—essentially all parts of a tree. Fungi do not have chlorophyll and therefore cannot make their own food. They have a mycelial (threadlike) growth form and can reproduce by microscopic spores. The individual microscopic threadlike filaments of all fungi are called hyphae (Figure 3). Hyphae are the basic units of fungi. A mass or collection of hyphae is called mycelium. When hyphae aggregate into a specialized structure for producing spores, the structure is called a fruiting body or sporophore. Mushrooms and conks are fruiting bodies. The fruiting bodies produce microscopic spores that are the principal reproductive units of fungi. They are produced on hyphae and are dispersed via wind, water, or insects. Under the proper conditions, spores germinate and produce new hyphae.

Fungi obtain nourishment through hyphae that penetrate within and among cells of the host plant. The hyphae secrete enzymes that dissolve all or part of the tissues they have penetrated. The dissolved material then diffuses into the hyphae where it is converted to usable energy for normal cell processes and growth of the fungus. Many fungi in the forest are beneficial and play a major role in nutrient cycling by decomposing wood and organic matter. However, some fungi obtain food from living trees and in the process injure, deform, weaken, or kill the tree. The result is disease. How we evaluate the disease—as being beneficial or detrimental—may depend on the management objectives for the tree (such as fiber production, nutrient recycling, or wildlife habitat) and for the forest. For example, wood decay aids nutrient recycling but is detrimental to fiber production.

Figure 3.—Hyphae of a wood-invading fungus in a wood cell (magnified 600 times).

Root diseases

CHAPTER 2

Root diseases as a group are the most difficult to identify, quantify, and manage in Oregon's trees and forests. Root diseases can be caused by abiotic factors such as flooding or soil compaction, but the most important root diseases are caused by fungi. These fungi attack and destroy the tree's root system, resulting in growth retardation, decay, death, or windthrow of infected trees. Trees affected by root disease also are more susceptible to insect pests, especially bark beetles.

Identification

Root diseases usually are indicated by groups of dead, dying, and windthrown trees called disease patches or centers or canopy gaps. These groups of trees become larger over time as disease-causing fungi spread from tree root to tree root. The result is altered areas in the forest that can range from a few trees to hundreds of acres.

Trees in a disease patch show a progression of symptoms; they do not die at the same time, nor will they be in the same stage of decline. Some near the middle of the disease patch are dead, while those at the edge may show only a slight reduction in height or slight yellowing of the foliage (chlorosis). In contrast, groups of trees killed by insects or fire usually are in the same stage of decline, indicating that all trees died at about the same time.

Trees affected by root diseases can be recognized by several symptoms and signs (Table 1). Symptoms are the reaction of the host tree to the disease. Signs are the actual parts of the pathogen present or near the diseased tree.

Most root diseases cause foliar yellowing and thinning of the crown. These symptoms result from destruction of the root system and the subsequent reduced supply of water and nutrients to the foliage. Abundant, undersize cones, called a distress cone crop, often are produced by trees in advanced stages of decline. Trees with these symptoms usually die within 1 or 2 years.

Crown symptoms can reliably indicate root diseases, but they are not sufficient to distinguish among specific root diseases. This can be done only by examining roots. Accurate identification is extremely important because management prescriptions may vary depending on which root disease is present.

Table 1.—Symptoms and signs of five important root diseases in Oregon.*

	Laminated root rot	Armillaria root disease	Annosus root disease	Black stain root disease	Port-Orford-cedar root disease
Symptoms					
Reduced height	√	√	√	√	
Crown thinning	√	√	√	√	√
Yellow foliage	√	√	√	√	√
Distress cones	√	√	√	√	
Basal resin (sap)		√		√	
Brown stain in inner bark					√
Black stain in sapwood				√	
Laminated decay	√		√		
Yellow, stringy decay		√			
Signs					
Mycelial fans		√			
Leathery conks			√		
Mushrooms at base		√			
Setal hyphae	√				
Ectotrophic mycelium	√		√		

**From Hadfield et al. 1986*

Table 2.—Relative susceptibility of Oregon trees to damage by root disease.*

Tree species	Laminated root rot	Armillaria root disease	Annosus root disease	Black stain root disease	Other root diseases
Conifers					
Cedar, Alaska	3	2	3	4	Port-Orford-cedar root disease
Incense-	4	3	3	4	
Port-Orford-	4	3	3	4	Port-Orford-cedar root disease
Western red	3	2	3	4	Yellow root rot
Fir, coastal Douglas-	1	2	3	1	Schweinitzii root/butt rot
Inland Douglas-	1	1	3	2	Schweinitzii root/butt rot
Grand or White	1	1	1	4	Schweinitzii root/butt rot
Noble	2	2	2	4	Schweinitzii root/butt rot
Pacific silver	2	2	1	4	Schweinitzii root/butt rot
Shasta red	2	2	2	4	Schweinitzii root/butt rot
Subalpine	2	2	2	4	Schweinitzii root/butt rot
Hemlock, mountain	1	2	1	3	Yellow root rot
Western	2	2	2	3	Schweinitzii root/butt rot
Juniper	4	2	3	4	
Larch	2	3	3	4	Schweinitzii root/butt rot
Pine, Jeffrey	3	2	2	2	Schweinitzii root/butt rot
Knobcone	3	2	2	3	Schweinitzii root/butt rot
Limber	3	2	3	4	Schweinitzii root/butt rot
Lodgepole	3	2	2	3	Schweinitzii root/butt rot
Ponderosa	3	2	2	2	Schweinitzii root/butt rot
Sugar	3	1	3	4	Schweinitzii root/butt rot
Western white	3	2	3	4	Schweinitzii root/butt rot
Whitebark	3	2	3	4	Schweinitzii root/butt rot
Redwood	4	3	3	4	
Spruce, Brewer	4	?	3	4	
Sitka	3	2	3	4	Tomentosus root rot
Yew	4	3	?	4	Port-Orford-cedar root disease

(table continues on next page)

*From Hadfield et al. 1986

1 = severely damaged 2 = moderately damaged 3 = seldom damaged 4 = not damaged

Host susceptibility

Susceptibility to infection and to associated damage by root pathogens varies with tree species (Table 2). Susceptibility is the likelihood that a tree species will become damaged if it contacts inoculum of the root disease fungus. Damage susceptibility is rated on a scale of 1 to 4. Ratings are based on field observations in Oregon. The susceptibility of some tree species (especially hardwoods) to some fungi is unknown. Hardwoods are not affected by laminated root rot, black stain root disease, or Port-Orford-cedar root disease, three of the five most important root diseases in Oregon. This is why hardwoods are recommended to plant or, if already present, to favor in many root-diseased areas.

Laminated root rot

From the standpoint of wood fiber production, laminated root rot is the most damaging root disease in Oregon. It is found in both western and eastern Oregon. The disease is caused by the fungus *Phellinus* (=*Poria*) *weirii*.[1] It affects all conifer species to some degree but is most damaging to Douglas-fir, grand and white fir, and mountain hemlock. Hardwoods are immune to this disease.

The disease affects trees by decaying their root systems, causing death, growth loss, and windthrow. One of the best indicators of the disease is the presence of root balls, which form when roots decayed by *Phellinus* break near the root collar leaving an abnormally small "ball" of roots on fallen trees. In contrast, healthy trees blown over by wind have a large mat of mostly undecayed roots.

Wood decayed by *Phellinus* characteristically separates into sheets along annual growth rings, hence the name "laminated" root rot (Figure 4). Decayed wood is pale yellow-brown with numerous small oval holes or pits on both sides of the wood sheet. The

Figure 4.—The laminated root rot fungus causes wood to separate at the annual rings.

Table 2 (continued). Relative susceptibility of Oregon trees to damage by root disease.

Tree species	Laminated root rot	Armillaria root disease	Annosus root disease	Black stain root disease	Other root diseases
Hardwoods					
Alder	4	3	3	4	
Ash	4	?	?	4	
Aspen	4	2	?	4	Ganoderma rot
Birch	4	3	?	4	Ganoderma rot
Buckthorn	4	?	?	4	
Cherry	4	3	?	4	
Chinkapin	4	3	?	4	Ganoderma rot
Cottonwood	4	2	3	4	Ganoderma rot
Dogwood	4	3	?	4	
Madrone	4	3	2	4	
Maple	4	3	3	4	Ganoderma rot
Myrtlewood	4	?	?	4	Ganoderma rot
Oak, California black	4	3	3	4	
Oregon white	4	2	?		
Tanoak	4	2	?	4	
Willow	4	3	?	4	

[1] As scientific research advances, organisms' names and classifications are continually changing. In this publication, the current scientific name for an organism is the first one given; sometimes, former names also are given, as "(=*Poria*) *weirii*," for example.

pits look like shot holes and are about 1 millimeter wide. A very close examination of the decayed wood with a hand lens reveals the key diagnostic indicator of laminated root rot: setal hyphae. Setal hyphae are small, wiry, reddish brown hairs found between sheets of decayed wood. The presence of setal hyphae is proof of laminated root rot.

Another good indicator of laminated root rot, especially on young living trees, can be found on the surface of roots after the soil has been scraped away. The surface of healthy conifer roots is reddish brown. In contrast, roots infected with *Phellinus* are covered with a white to grayish crust of fungal growth called ectotrophic mycelium. The growth is only on the outside of the root, not in the wood or between the bark and wood. Setal hyphae also may be seen mixed with ectotrophic mycelium on the root surface.

Armillaria root disease

Armillaria root disease is the most widespread root disease in Oregon and the most damaging to hardwoods, especially Oregon white oak. This disease also affects hardwood and fruit trees throughout the world. The species of *Armillaria* affecting most hardwoods has not been determined, although *Armillaria bulbosa* has been reported on Oregon white oak.

Armillaria root disease is caused by the fungus *Armillaria ostoyae* (=*Armillaria mellea* or *Armillaria obscura*). At least two other species of *Armillaria* have been identified in Oregon, but they are mostly saprophytes that decay dead wood. In western Oregon, the disease commonly affects small groups of 10- to 30-year-old trees, and all tree species are affected to some degree. East of the Cascades and in southern Oregon, Armillaria root disease is more widespread and economically damaging.

Trees infected by *Armillaria* usually produce a flow of pitch or sap just above ground level. This flow is the tree's response to the fungus growing beneath the bark. Extensive growth of the fungus beneath the bark eventually girdles and kills the tree. Chopping into the bark reveals white to cream-color sheets of fungus called mycelial fans. Fans are inside the bark—never outside—in the lower main stem of the tree, close to the ground, or in roots. Fans have a rubbery texture and sometimes can be peeled from the wood like latex paint. They are a positive indicator of Armillaria root disease. *Armillaria* mushrooms occasionally appear in autumn and can be a useful indicator of the disease. Mushrooms also serve as food for humans and wildlife.

Black stain root disease

Black stain root disease is unique among the root diseases affecting Oregon's forests because it is spread by root-feeding insects. Two forms of the disease are in

Figure 5.—Black stain in an infected ponderosa pine.

Oregon; one attacks fir and the other attacks pine. This disease is caused by the fungus *Leptographium wageneri* (=*Verticicladiella wageneri* or *Ophiostoma wageneri*) and affects mainly young (10- to 30-year-old) Douglas-fir. In eastern Oregon, ponderosa pine is affected at any age. Other conifers seldom are affected.

Black stain is a wilt disease, similar to Dutch elm disease, that kills trees rapidly by plugging the water-conducting tubes of the root wood. Black stain is most severe, to the point of being epidemic, in parts of southwestern Oregon; 25 to 50 percent of 10- to 30-year-old Douglas-fir stands in this region have the disease to some extent. In western Oregon, black stain is most common along roadsides, in stands that have been precommercially thinned, and in stands with a history of soil disturbance from tractor logging. It frequently occurs in association with other root diseases.

Like Armillaria root disease, black-stain-affected trees often produce resin at the base of the main stem. Affected trees, however, do not have white mycelium on the root surface or inside the bark. Black stain is diagnosed by chopping into the wood of roots or of the root collar of dying or recently killed trees. Black to brown streaks in the most recent growth rings should be apparent (Figure 5). This stain is the result of the darker hyphae growing in the water-conducting tubes of the sapwood. Hyphae plug the tubes and disrupt the water supply to other parts of the tree.

Long-distance spread of the black stain fungus is by insects, mostly root-feeding bark beetles and weevils. The spores of the fungus form in the insect tunnels, stick to the insects, and are spread when the insects fly or walk. The insects feed and breed in low-vigor trees and are attracted to freshly cut stumps. Once the insects introduce the fungus into a tree, the mycelium can spread to other trees across root grafts or by growing short distances through the soil. The fungus does not live long after the tree dies.

Annosus root disease

Annosus root disease is one of the more difficult root diseases to diagnose because it often causes only a butt rot and has signs that are difficult to detect. The disease is caused by the fungus *Heterobasidion annosum* (=*Fomes annosus*). There are two forms in Oregon: an “S-group” that primarily affects fir, hemlock, and spruce, and a “P-group” that chiefly affects pine.

Heterobasidion also causes a stem decay (see page 14). In western Oregon, the fungus causes serious degrade in western hemlock due to decay and stain in the valuable butt log. The disease usually is identified by the appearance of decayed wood that contains silvery white mycelium and small black flecks about the size of rice grains.

Brown leathery conks with white undersides occasionally are found in rotten stumps and among roots of windthrown trees. A conk is a specialized structure produced by wood-decay fungi to disperse spores, which are the chief means of spreading the disease. Spores need freshly cut stump surfaces or fresh tree wounds to infect and colonize the wood. After stumps are infected, the fungus grows through the root system and can infect living trees through root contacts.

In eastern Oregon, annosus root disease is most damaging to true fir and ponderosa pine. Stands partially cut over many years show the most disease. In many areas, groups of pine are killed without substantial decay, especially on very dry sites. A progression of symptoms usually is present: long-dead trees near the center of the opening and recent kills near the perimeter.

Annosus root disease has been reported on bigleaf maple, red alder, and Pacific madrone. Annosus root disease has not been reported on other hardwoods, but that may be because no surveys have been conducted to determine host ranges.

Port-Orford-cedar root disease

In southwestern Oregon throughout the range of Port-Orford-cedar, the principal host, this disease is very damaging. It is believed that the disease may have been introduced into Oregon, possibly on ornamental cedars. The disease also affects Pacific yew and Alaska-cedar when they grow with Port-Orford-cedar. In some areas, the disease threatens the commercial status of Port-Orford-cedar.

Port-Orford-cedar root disease is caused by the fungus *Phytophthora lateralis*. This fungus causes a discoloration of the foliage from light green to yellow to red and finally to brown. The disease is best identified by the brown inner bark that abruptly joins white, healthy inner bark at the base of infected trees. This symptom is most apparent on trees with yellow foliage.

Roots are infected by special swimming spores called zoospores that are produced by the fungus. Zoospores spread downslope or downstream in water. Tree mortality often is seen within riparian zones or along roadsides, especially the downhill side. The disease spreads mainly by human activity: infested soil on machinery, tires, or on transplanted seedling roots can spread the fungus from one site to another. The disease can spread upslope through root contacts.

Other root diseases

Schweinitzii root and butt rot is caused by *Phaeolus schweinitzii*, often called the velvet-top fungus. It is one of the most important causes of butt decay in old-growth trees, especially Douglas-fir (Table 3, page 13). Sometimes it will kill young trees. Infected trees usually show no aboveground symptoms; the only reliable way to diagnose the disease is by the red-brown conks that are produced on or near the tree base. When these conks are older, they resemble "cow-pies." This disease often is associated with trees that have old fire scars, and the fungus has been associated with nesting cavities of woodpeckers in larch.

Tomentosus root rot, caused by the fungus *Inonotus tomentosus*, is the most important root disease of Engelmann spruce in Oregon. It also causes substantial stem decay. The best way to identify the disease is by the mushrooms. The fungus forms small (1 to 3 inches in diameter) yellow to rusty brown tough and leathery mushrooms. They are produced during wet periods in the autumn. Spores can infect tree roots, but most infection occurs as a result of root-to-root spread from one tree to another. Infected trees will not die until they have been infected for several years. Infected trees often are windthrown.

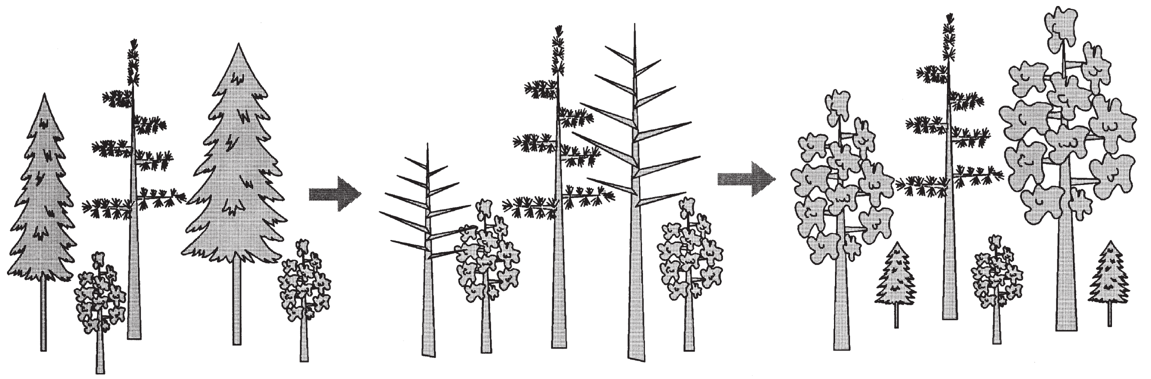
Other root diseases of conifers include **yellow root rot** caused by *Perreniporia subacida*. Other root and butt rots reported on Oregon hardwoods include **Ganoderma rot** caused by *Ganoderma applanatum* on bigleaf maple, black cottonwood, quaking aspen, birch, and myrtlewood; *Ganoderma oregonense* on chinkapin; and *Inonotus dryadeus* on bigleaf maple and tanoak.

Ecologic roles

The ecologic roles of root diseases in undisturbed forests in Oregon have not been well studied. Much of what we know is mainly from observations. Because root diseases can cause widespread mortality in many forest ecosystems, they are important in creating gaps in the forest canopy. These gaps or openings change the light, moisture, and temperature in the forest and thus change the habitat for plants and animals. Some plants and animals require more light than others and thus are favored by these openings. Other plants and animals favor the edges of the openings. Still other plants and animals prefer closed canopies. Root diseases provide a variety of openings within the forest and thus create habitat for a wide variety of organisms.

Many animals and birds require dead standing trees (snags) and down trees for their habitat. Because root diseases kill trees of all sizes, snags are continually formed as the disease progressively kills trees over many decades. Root-disease-killed trees often are windthrown because of decayed root systems, and these fallen trees provide habitat for a different set of animals and plants than did the snag.

Figure 6.—Disease pathogens can either advance or reverse forest succession by selectively killing certain tree species. This illustration shows succession reversal.



Many of the root pathogens continue to live in roots and stumps for 50 years or more after trees have died or been harvested. These root pathogens continue to decay the stump and major roots, thus returning nutrients to the soil and providing habitat for a wide variety of animals.

Root diseases also affect the successional pattern of forest development. After a disturbance—either natural, such as a fire, or artificial, such as a clearcut—forest vegetation goes through a predictable series of species changes until the next disturbance. This is called forest succession. Root diseases can affect forest succession by selectively killing certain tree species (Figure 6). For example, in coastal forests, Douglas-fir commonly regenerates sites after disturbance and can live 500 years or more. Western hemlock will grow in the understory of Douglas-fir forests but will not attain full height until the overstory of Douglas-fir dies. Laminated root rot is one of the few biological agents that kill Douglas-fir. Because western hemlock is more resistant to laminated root rot than Douglas-fir, hemlock survives in openings created by root disease and eventually becomes the dominant, or climax, tree species. The rate at which laminated root rot spreads and kills the Douglas-fir determines the rate at which the hemlock becomes dominant.

Management

Managing root diseases is based on two important factors. The first is the means of spread. All root diseases spread by root contacts when the causal fungus grows from an infected root of a tree or stump to a healthy tree. In general, disease patches expand radially about 1 to 2 feet a year this way. One strategy to stop spread is to break the chain of root contacts between healthy and infected trees by cutting the "bridge tree." However, it is difficult to determine whether a tree is healthy or infected if there are no aboveground symptoms; in other words, it's hard to tell where the "bridge" is if you can't see the water.

Fungal survival is the second factor. Many root-disease fungi can survive in roots for decades after infected trees have died. If a diseased stand is harvested and replanted without considering the disease, seedlings eventually will become infected. Damage in the new stand may be worse than in the preceding stand. One exception to long-term survival in roots is black stain root disease; the causal fungus dies within 1 to 2 years of tree death. Because this disease is spread by bark beetles and weevils, management aims at thinning stands soon after bark beetles have completed their seasonal flight, usually after July in most areas.

Based on our understanding of how root-disease fungi spread and survive in roots, the preferred management approach is to take advantage of the differences in tree species' susceptibility to root diseases (Table 2, pages 4 and 5). By planting resistant species or by favoring them during thinning or partial cutting, root disease losses can be greatly reduced. Some root diseases seriously affect only certain tree species; for example, tomentosus root rot on spruce, Port-Orford-cedar root disease on Port-Orford-cedar, and different forms of black stain root disease on Douglas-fir and on pine. Armillaria root disease, laminated root rot, and annosus root disease can cause severe mortality rates in several tree species, especially grand fir, white fir, and Douglas-fir.

Disease-tolerant and disease-resistant species (damage classes 3 and 4 in Table 2) can be favored during a variety of silvicultural operations including planting, precommercial thinning, commercial thinning, prescribed burning, and seed tree, shelterwood, and group selection harvest systems. If tolerant or resistant tree species are planted or regenerated for 50 years or more and ingrowth of more susceptible species (damage classes 1 and 2) can be periodically removed, root disease fungi should die out over most of the infected area. Subsequent rotations of susceptible species can be grown with little probability of reinfection. If tree species in damage class 2 are used, many trees will become infected but at lower levels than if tree species in damage class 1 had been grown. Planting or favoring hardwood species, especially on sites affected by laminated root rot, can greatly reduce inoculum on the site.

Incidence of root disease on an infected site will decrease with time, even in highly susceptible tree species, if operators remove or chemically treat the principal inoculum sources in infected areas, primarily the infected stumps from harvested or dead trees. The effects of stump treatments on root disease are discussed on page 38. Many stump treatments can be used during commercial thinning, miniclearcuts, and group selections, and when favoring resistant species and cutting bridge trees.

Stem decays

More than 25 percent of disease-caused losses in timber values in Oregon result from decay in living, often overmature, trees. Wood decay is caused by various species of fungi that enter trees through wounds or stubs of small branches (Figure 7). Decay fungi usually do not kill trees, and small amounts of decay will not significantly affect tree growth. However, decay greatly diminishes the value of forest products. In addition, decayed trees are structurally weakened and are likely to break during windstorms or harvesting. Decayed trees can become serious hazards when near buildings or in developed recreation areas.

On the positive side, decay of living trees is a natural forest process that recycles nutrients and creates important wildlife habitat as standing trees and as down logs both on land and in streams.

Many decays can be recognized by the presence of conks on the stem of the tree. Conks usually indicate considerable wood decay behind the conk. In general, the more conks or the bigger the conk, the more decay. The amount of decay associated with conks (and other external indicators) varies among the different species of wood-decay fungi and among different tree species.

General principles of stem decays

Each stem-decay disease has its own characteristics, but the diseases in general have the following characteristics in common.

- The amount of decay increases with frequency of tree wounding. Wounds both activate dormant infections and provide entry courts for spores.
- The amount of decay increases with wound size and age. In trees of the same size and age, basal wounds will have more decay than upper-stem wounds.

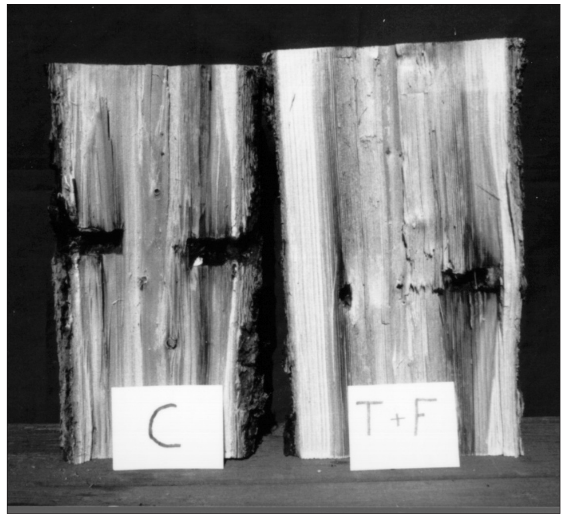


Figure 7.—Wood decay is caused by fungi that enter trees through wounds or small branches as shown here in artificially infected stems of 85-year-old white fir. The specimen at far left is a control tree that received no treatment. The specimen at near left is a tree from a stand that was thinned and fertilized.

- The amount of decay increases with tree age and diameter, assuming diameter is directly proportional to age.
- Live trees "compartmentalize" decay; that is, decay columns will not exceed the diameter of the tree at the time it was wounded unless additional wounding takes place.
- The amount of decay is greater in nonresinous tree species such as true fir, hemlock, and hardwoods. Resinous species such as pine, Douglas-fir, and larch are more resistant to decay.
- The amount of decay is influenced by tree genetics: some trees within a species are more resistant than others to decay, all other factors being equal.
- Decay may be caused by a single species of decay fungus, but infections by two or more species are common.
- The percentage of tree volume that is decayed is less in trees that have been thinned and/or fertilized than in trees in unmanaged stands.

Indian paint fungus

The Indian paint fungus (*Echinodontium tinctorium*) is responsible for nearly 80 percent of the decay in old-growth grand fir and white fir in eastern and southern Oregon. Other species affected include mountain hemlock, western hemlock, noble fir, Shasta red fir, Pacific silver fir, subalpine fir, and rarely, Douglas-fir and Engelmann spruce. Incidence of Indian paint fungus appears to be decreasing as old-growth forests are replaced by younger forests.

The most conspicuous sign of the Indian paint fungus is the conk, which is large and woody with a black, cracked upper surface, a gray, toothed, lower surface, and a brick-red interior. Native Americans used the red interior for paint. Conks produce spores throughout the year but mostly in spring and fall. Spores do not infect mechanical wounds or old branch stubs as was once thought. Instead, spores infect small (less than 2 millimeters in diameter) exposed branchlet stubs just before the stubs are overgrown. Trees or branches whose growth has been suppressed seal branchlet stubs very slowly, thus allowing more time for infection. Once branchlet stubs are overgrown, the fungal mycelium from germinated spores enters a dormant state, which can last 50 years or more without causing decay.

Dormant infections are activated immediately by mechanical injuries, frost cracks, or formation of large branch stubs that allow air to enter the trunk interior. The larger the injury, the more likely that one or more dormant infections will be activated and cause decay. Decay first appears as elongated areas of wood that are stained light brown or yellow. Advanced decay appears yellow to reddish yellow and fibrous or stringy. Extensive decay columns may occur after several dormant infections become active, cause decay, and subsequently coalesce. After extensive decay, conks are produced, often at old branch stubs or wounds. When conks are single and small, decay usually extends 8 feet above and below the conk. When there are two or more conks, decay can extend 20 feet above the highest and 20 feet below the lowest conk on the bole.

Red ring rot

Red ring rot is caused by the fungus *Phellinus pini*. It is the most common cause of stem decay in Douglas-fir in westside forests and affects several conifer species in eastside forests (Table 3). A related fungus, *Phellinus cancriformans*, causes sunken cankers on white fir in southern Oregon.

The fungus forms hoof-shape to bracketlike perennial conks on stems that often are at knots or branch stubs. The upper surface of the conk is rough, dull grayish to brownish. The lower surface is a rich brown with small circular to large sinuous openings. Decay in the early stages varies by tree species. In the late stages, decay appears as spindle-shape, white pockets with firm wood in between ("white speck"). Decay may be spread uniformly but often forms crescents or rings. Swollen knots or punk knots may form on tree boles. The extent of decay varies with tree age and species; for example, decay is 4 feet above and below the conks for Douglas-firs of 150 years, and 22 feet above and below the conks for trees 350 years old. Decay extent is less for other tree species.

Although wounds, either natural or human-caused, and branch stubs provide openings for infection by other decay fungi, we do not know how *Phellinus pini* enters trees. Conks are closely associated with old, dead branch stubs. It is believed that the fungus does not spread downward through the dead and dying branches, but rather that the fungus infects the protective wood in the trunk that forms after branches die. The fungus has no competition from other organisms in the resin-soaked protective wood and continues to grow there as a canker-type fungus. The crescent or ring-type decay pattern allows the tree trunk to retain enough integrity that it does not break, and at the same time it allows the fungus to exist in a living tree.

Table 3.—Relative susceptibility* of Oregon trees to damage by stem decays.

Tree species	Indian paint fungus	Red ring rot	Schweinitzii butt rot	Brown crumbly rot	Gray-brown sap rot	Other decays
Conifers						
Cedar, Alaska-	4	3	3	3	4	Brown-cubical butt rot
Incense-	4	3	3	3	3	Pecky rot
Port-Orford-	4	3	4	4	3	
Western red	4	3	3	3	4	Brown-cubical butt rot
Fir, Douglas-	3	1	1	1	1	Yellow-brown top rot
Grand or White	1	1	1	1	1	Annosus decay
Noble	2	2	2	1	2	Annosus decay
Pacific silver	1	1	1	1	1	Annosus decay
Shasta red	2	2	2	1	2	Annosus decay
Subalpine	2	2	2	1	2	Annosus decay
Hemlock, mountain	1	1	2	1	2	Annosus decay
Western	3	2	2	1	2	Annosus decay
Juniper	4	4	4	4	4	Juniper pocket rot
Larch	4	2	1	1	2	Brown trunk rot
Pine	4	2	2	2	2	Brown trunk rot
Redwood	4	4	4	4	4	
Spruce	3	2	2	1	2	Annosus decay
Yew	4	3	3	4	4	
Hardwoods						
Alder	4	4	4	2	4	Hardwood trunk rot
Ash	4	4	4	4	4	
Aspen	4	4	4	2	4	
Birch	4	4	4	3	4	Hardwood trunk rot
Buckthorn	4	4	4	4	4	Hardwood trunk rot
Cherry	4	4	4	4	4	Hardwood trunk rot
Chinkapin	4	4	4	4	4	Hardwood trunk rot
Cottonwood	4	4	4	2	4	Hardwood trunk rot
Dogwood	4	4	4	4	4	Hardwood trunk rot
Madrone	4	4	4	4	4	Hardwood trunk rot
Maple	4	4	4	2	4	
Myrtlewood	4	4	4	4	4	
Oak	4	4	3	4	4	Inonotus trunk rot
Tanoak	4	4	4	4	4	
Willow	4	4	4	4	4	Hardwood trunk rot

** 1 = often infected   2 = occasionally infected   3 = seldom infected   4 = not infected*

Brown crumbly rot

Brown crumbly rot is caused by the fungus *Fomitopsis pinicola*, commonly called the redbelt fungus. It's the most common cause of decay of dead woody material in Oregon (Table 3, page 13). Conks occasionally are on dead parts of living trees, especially Sitka spruce. They usually are produced at least 2 years after tree death. Conks are hard, woody, perennial, shelf- to hoof-shape (2 to 10 inches wide), with a smooth gray to black upper surface often with a wide red margin. The undersurface is white to yellowish.

One way the disease spreads is through windborne spores released from the conks. The fungus also has been isolated from the Douglas-fir beetle, which may transmit the fungus while attacking dying trees. The fungus causes a brown cubical rot of the sapwood and heartwood. Small logs, which are mostly sapwood, can completely decay in 10 years, whereas large logs with mostly heartwood may take 30 or more years for complete decay.

Gray-brown sap rot

Gray-brown sap rot is caused by the fungus *Cryptoporus volvatus*, often called the pouch fungus. The fungus causes a soft, grayish sap rot of slash and dead trees. The conks develop on trees that have been dead 12 to 18 months. They occur on most conifers but are most common on beetle- or fire-killed Douglas-fir, true fir, and ponderosa pine. The conks are white to tan, leathery, round, and annual. A leathery membrane completely encloses the brown pore layer. The fungus has been isolated from bark beetles, which may aid in spreading the disease.

Other stem decays

There are many other stem decays of conifers and hardwoods (Table 3).

- **Annosus decay**, caused by *Heterobasidion annosum* (which also causes annosus root disease) can be very damaging to true fir, hemlock, and spruce.
- **Brown trunk rot**, caused by *Fomitopsis officinalis* or the quinine fungus, occurs in old-growth Douglas-fir, larch, and pine, especially trees with broken tops or other wounds.
- **Brown cubical rot** is caused by *Laetiporus sulfureus*, or the sulfur fungus, which is edible. The rot occurs on most conifers and on oak.
- **Brown-mottled white rot** is caused by *Pholiota limonella*, or the yellow-cap fungus, and occurs on several conifers and hardwoods.
- **Dry pocket rot** or **pecky rot**, caused by *Oligoporus amarus*, is the most important stem decay of incense-cedar in Oregon.
- **Brown cubical butt rot**, caused by *Oligoporus sericeomollis*, is the most damaging decay of Alaska-cedar and western redcedar.
- **Juniper pocket rot**, caused by *Pyrofomes demidoffii*, is the chief stem decay of living juniper.
- **Ganoderma rot** is found in many conifers and hardwoods and is caused by *Ganoderma applanatum*, the artist's conk.
- **Yellow-brown top rot**, caused by *Fomitopsis cajanderi*, is the most common decay affecting young, broken-topped Douglas-fir.
- **Yellow pitted rot** is caused by *Hericium abietis*, or the coral fungus, which is edible. It attacks fir, spruce, and hemlock.

Many species of fungi cause decay in living hardwoods; other species are found only on dead trees, dead portions of trees, or in stumps. Probably the most important heart rot fungus of Oregon hardwoods is **hardwood trunk rot**, caused by *Phellinus igniarius*. **Inonotus trunk rot** occurs on oak and is caused by *Inonotus dryophilus*.

Many other species of decay fungi have been reported on only one hardwood species. For example:

- *Bondarzewia berkeleyi* and *Oxysporus populinus* on bigleaf maple

- *Sistrotrema brinkmannii*, *Pholiota adiposa*, *Trametes* spp., and *Meruliopsis corium* on red alder
- *Fomitopsis cajanderi* and *Perreniporia subacida* on Pacific madrone
- *Perreniporia fraxinophilus* on Oregon ash
- *Fistulina hepatica* on tanoak
- *Collybia velutipes* and *Phellinus tremulae* on quaking aspen
- *Spongipellis delectans* and *Pholiota destruens* on black cottonwood
- *Laetiporus sulfureus*, *Hydnum erinaceus*, and *Bjerkandera adusta* on California black oak

Ecologic roles

Ecologic roles of stem decays in living trees in Oregon have not been well studied. Much of what we know is drawn mainly from observation.

The living but decayed tree provides habitat for cavity-nesting birds that require a certain degree of wood decay in order to excavate for nesting. The pileated woodpecker in eastern Oregon, for example, requires rotten larch or ponderosa pine for its cavities. Secondary cavity-nesting birds (those that cannot excavate) depend on the primary cavity-nesters such as the pileated woodpecker to make nest sites. Northern spotted owls, and perhaps other owls, use cavities created by decay fungi in living trees. Several mammal species also use cavities vacated by the primary cavity-nesters. Large decay columns and hollows created by the Indian paint fungus in grand fir are used as roosting sites and hiding cover by several bird and mammal species.

Inoculating live trees with fungi to promote decay and create habitat for cavity-nesting birds has been successful in Oregon. The idea is that living, decayed trees should stand longer and provide useful habitat longer than decayed snags.

Stem decays can lead to tree mortality through stem breakage at or below the living crown and therefore may be important in creating small gaps in the forest canopy. As with root-disease-caused gaps, these openings change the light, moisture, and temperature in the forest and thus change the habitat for plants and animals. Some plants and animals require more light than others and so are favored by these openings. Many animals and birds require dead standing trees (snags) and down trees for their habitat. Large woody debris also is important for providing habitat for fish and other animals in rivers and streams and adjacent riparian areas.

The role of stem decay fungi in dead trees or in their broken parts, such as tops and branches, has been well studied. Some stem decay fungi such as *Echinodontium tinctorium* or *Phellinus pini* are adapted to grow in live trees. After those trees die, the stem decay fungi are replaced by other fungi that are more adapted to decaying the wood of dead trees.

Other fungi such as *Cryptoporus volvatus* or *Fomitopsis pinicola*, which infect living trees as they are being killed by other agents, continue to decay wood well after the tree has died. These fungi are important in recycling nutrients to the soil, and the trees they decay provide critical habitat for a variety of plants and animals. For example, ants require decaying logs for habitat, and the ants are an important food source for many bird species. Ants also are important predators of the larvae of defoliating insects such as the western spruce budworm.

Management

Management of stem decays depends on the objectives for the stand or forest. If timber production is the main goal, follow guidelines to minimize stem decays. Or, if a certain amount of stem decay is desirable—both in living trees and as an agent for creating snags and downed woody material—then do the reverse of the decay-minimizing guidelines.

Manage on short rotations. Keep rotations short—that is, under 125 years—especially for nonresinous species such as true fir. Stem decay has been shown to increase with tree age.

Do not avoid or delay early thinning out of concern about potential decay losses. Growth increases due to thinning will outweigh decay losses in most cases. Increased tree vigor will prevent infection by certain decay fungi. Thin early so that if decay columns develop as a result of wounding, they will be relatively small due to compartmentalization.

Select crop trees that are vigorous and undamaged. Crop trees should be the best in form and height, with good live-crown ratios, good current leader growth, and no wounds or top damage.

When pruning or topping, be sure to make cuts properly. Cut living or dying branches as close as possible to the branch collar, but do not make flush cuts, or remove the branch collar, or leave stubs (see Figure 15, page 39). All of these may result in stem decay.

Minimize wounding. Prevent wounds when thinning, burning, disposing of slash, or removing the overstory because of potential losses due to decay and other defects associated with injuries. The following actions during both planning and the actual operation can prevent decay.

- Avoid spring and early summer logging when bark is soft.
- Match the size and type of operating equipment with topography, tree size, and soil type and condition.
- Mark "leave" trees rather than "cut" trees.
- Plan skid trails before logging.
- Match log length with final spacing.
- Log skid trails first.
- Cut low stumps in skid trails.
- Use directional falling.
- Limb and top trees before skidding.
- Remove slash from around crop trees if stands are to be underburned.
- Gain the cooperation of the operator. Explain the effects of tree wounding and ask the operator's help in preventing it.

Rust diseases

Rust diseases are so named because the fungi that cause them often give a rusty color to infected stems or foliage. Some rust diseases cause abnormal stem swellings called galls; for example, western gall rust of lodgepole pine. Several important rust diseases affect Oregon trees: white pine blister rust, western gall rust, comandra blister rust, stalactiform rust, and several foliage and broom rusts.

Stem rusts

Several rust fungi attack the stems of Oregon pines, true firs, and Engelmann spruce. No other tree species are affected by stem rusts.

White pine blister rust

This is the most destructive stem rust in Oregon. It affects five-needle pines: western white pine, sugar pine, and whitebark pine. It is caused by the fungus *Cronartium ribicola*. Since its introduction from Europe in the early 1900s, white pine blister rust has killed millions of five-needle pines throughout western North America. White pine is desirable because it is highly resistant to laminated root rot and is a preferred species for planting in root-disease centers.

White pine blister rust is an example of the complex life cycle typical of many, but not all, rust diseases (Figure 8). The disease cycle begins when windborne spores infect the needles. The fungus then grows within the needle and into the main stem where it kills the bark and produces orange to yellow masses of spores. These spores are dispersed by wind and can infect leaves only of *Ribes* (gooseberry and currant plants). These plants are called alternate hosts. The fungus then produces spores on the undersides of *Ribes* leaves. These spores are windblown and, under the right environmental conditions, infect pine needles, completing the cycle. Spores from pine cannot infect other pines; they can infect only *Ribes*, and only spores from *Ribes* can infect pines.

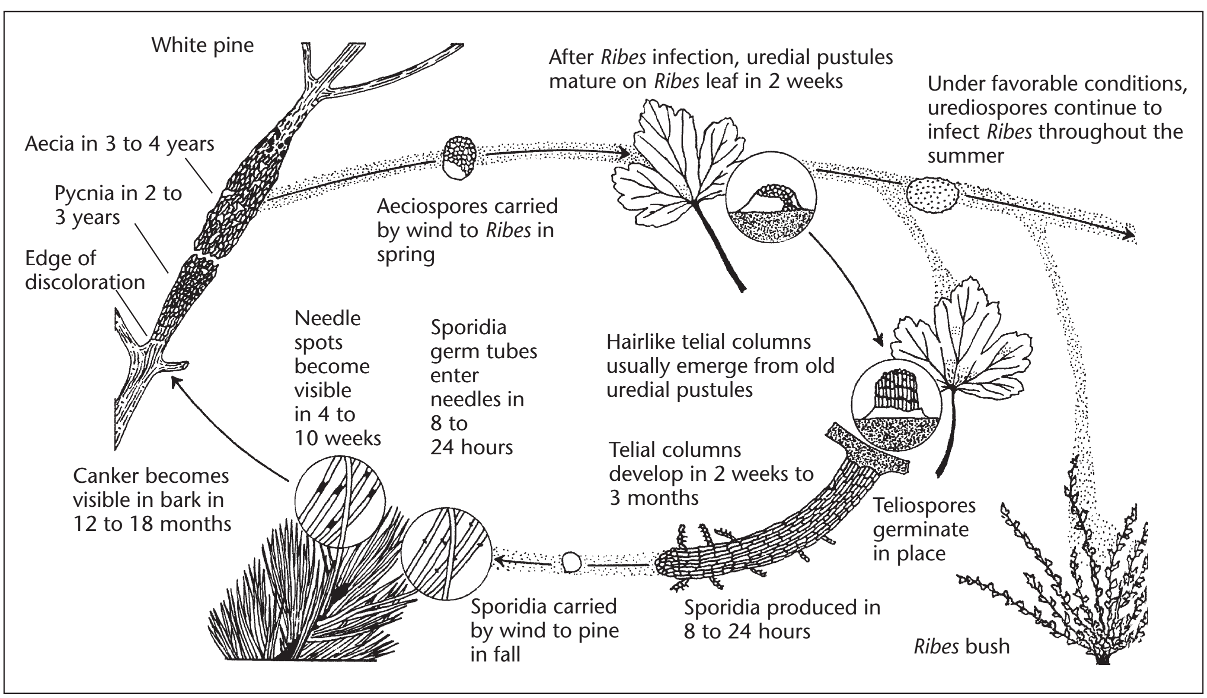


Figure 8.—Life cycle of white pine blister rust *(Cronartium ribicola).*

Figure 9.—Comandra blister rust has killed the crown of this ponderosa pine.

Despite early concerns about extinction of white pine, it is once again a viable species provided that disease management is rigorous. Tree improvement programs have developed resistant trees that can tolerate infection by the fungus.

Western gall rust

This disease affects two- and three-needle pines, especially lodgepole, knobcone, and ponderosa pine. The disease is caused by the fungus *Endocronartium (=Peridermium) harknessii,* and is probably the most common disease of lodgepole pine in Oregon. Severe infection causes stem malformation, breakage, and tree mortality, especially in seedlings. The disease causes round to pear-shape galls on branches or stems. Galls on main stems may continue to grow for years, forming large burls. Yellow-orange spore pustules (aecia) are produced each spring. Spores are windborne and infect other two- or three-needle pines; *no alternate host is required*. Moist conditions stimulate spore release and favor infection on succulent stem tissue. The fastest growing trees are more susceptible than suppressed trees. Moist sites, such as those at the lower edge of a slope, can have extremely high rates of infection.

Comandra blister rust

Like western gall rust, this disease also affects two- and three-needle pines but is more serious on ponderosa pine. The disease gets its name from its alternate host, bastard toadflax (*Comandra umbellata*), which is required to complete the disease cycle. The disease is caused by the fungus *Cronartium comandrae*. It produces spindle-shape swellings on pine stems and branches. The swellings break open and produce a cracked and pitted canker with abundant resin flow. Dead branches with red foliage and dead tree tops are common (Figure 9). The fungus grows slowly down infected stems causing progressive dying. Trees can die, especially seedlings and saplings.

In spring, dark orange spore pustules (aecia) are produced on the bark of infected pines. The spores are windborne and infect the leaves of bastard toadflax. Infections appear as yellow spots and brown hairlike structures throughout the summer. Pines are infected by spores produced on the toadflax leaves in late summer or fall.

Stalactiform rust

Stalactiform rust affects mainly lodgepole pine and is caused by the fungus *Peridermium stalactiforme* (*=Cronartium coleosporiodes)*. Infections cause stem malformation and breakage but seldom kill the tree. Damage can be severe in very young trees. New infections appear as spindle-shape swellings on stems and branches. Older infections appear as diamond-shape cankers that can be 30 feet long. Cankers are resin soaked and yellow. Bark on the cankers frequently falls off, leaving ridges. Yellow spore pustules (aecia) form on the edges of active cankers from May through August. Spores infect the alternate hosts, Indian paintbrush and other members of the plant family Scrophulariaceae. Orange spore pustules are produced on leaves of the alternate host, and the spores infect pines in late summer and fall.

Broom rusts

Broom rusts are so called because they cause large, conspicuous, dense branches known as witches' brooms.

Fir broom rust affects true fir and is caused by the fungus *Melampsorella caryophyllacearum*.

Spruce broom rust affects spruce and is caused by the fungus *Chrysomyxa arctostaphyli*.

On both spruce and fir, the needles on broomed twigs are yellow, and the broomed foliage dies in the fall, so the broom looks dead in the winter. The brooms often are confused with those caused by dwarf mistletoes; however, the brooms contain no mistletoe plants. Severe broom rust infection results in stem malformation, growth loss, and occasionally tree death. The fungi cause a leaf or shoot blight of chickweed (for fir) and a purple-brown leaf spot of kinnikinnick (for spruce), which are their alternate hosts.

White to yellow spore pustules (aecia) occur on foliage of brooms in the summer. Orange to brown spore pustules (uredia and telia) occur on the alternate host's leaves in the spring and summer. Spores are windborne and require moist conditions for infection.

Foliage rusts

Although several species of foliage rust occur in Oregon, their economic importance in native forests is insignificant. However, their impact can be great on agricultural, landscaping, nursery, or Christmas tree businesses.

Needle rusts

Several species of needle rust affect true fir: *Uredinopsis* spp., *Melampsora* spp., *Milesina* spp., and *Pucciniastrum* spp. The fir–fireweed rust, *Pucciniastrum epilobii*, probably is the most damaging needle rust of true fir, causing discoloration and death of current-year needles.

Spruce is affected by two species of needle rust: *Melampsora* spp. and *Chrysomyxa* spp. Infection results in needle discoloration, death, and premature defoliation. Cones also are affected, resulting in damage to seeds.

Pine is affected by two species of needle rust: *Coleosporium* spp. and *Melampsora* spp. Both cause needle discoloration and premature defoliation.

Hemlock is infected by *Pucciniastrum vacinii*, the hemlock–blueberry rust; *Melampsora epitea*, the hemlock–willow rust; and *Melampsora medusae*, the aspen rust.

Douglas-fir and larch are infected by several species of poplar rust: *Melampsora medusae, Melampsora albertensis*, and *Melampsora abietis-canadensis* on quaking aspen; and *Melampsora occidentalis, Melampsora medusae,* and *Melampsora larici-populina* on black cottonwood. The disease causes needle discoloration and death. The fruiting bodies of the rust fungus form on the current year's needles and occasionally on the cones. Several of these rusts have caused severe damage in hybrid poplar plantations.

Incense-cedar often is infected by *Gymnosporangium libocedri*, Alaska-cedar by *Gymnosporangium nootkatense*, and juniper by several species of *Gymnosporangium*. Serviceberry is the alternate host for incense-cedar and juniper rust, and mountain ash is the alternate host for yellow cedar rust.

Leaf rusts

Leaf rusts caused by *Melamsoridium* spp. and *Pucciniastrum* spp. have been reported on red alder. *Puccinia* sp. occur on buckthorn. *Pucciniastrum* spp. have been found on Pacific madrone, *Cronartium* spp. on oak and tanoak, and *Melampsora* spp. on willow, aspen, and cottonwood. Hybrid poplars (black cottonwood x eastern cottonwood) are highly susceptible to leaf rusts caused by *Melampsora larici-populina* (alternate host, larch), *Melampsora medusae*, and *Melampsora occidentalis.* (Alternate hosts for the latter two fungi include several conifer species.)

No rusts have been reported on yew, redwood, western redcedar, Port-Orford-cedar, cherry, dogwood, maple, ash, myrtlewood, or chinkapin in Oregon.

Table 4.—Selected rust diseases in Oregon trees.

Host tree species	Stem rusts	Broom rusts	Foliage rusts
Conifers			
Cedar	None	None	Incense-cedar rust, yellow cedar rust
Douglas-fir	None	None	Poplar rust
Fir, true	Fir broom rust	Fir broom rust	Fir–fireweed rust
Hemlock	None	None	Hemlock–blueberry rust, hemlock–willow rust, aspen rust
Juniper	None	None	Juniper rust
Larch	None	None	Poplar rust
Pine, Jeffrey	Western gall rust, comandra rust, stalactiform rust	None	Pine needle rust
Knobcone	Western gall rust, comandra rust, stalactiform rust	None	Pine needle rust
Lodgepole	Western gall rust, comandra rust, stalactiform rust	None	Pine needle rust
Ponderosa	Western gall rust, comandra rust, stalactiform rust	None	Pine needle rust
Limber	White pine blister rust	None	Pine needle rust
Sugar	White pine blister rust	None	Pine needle rust
Western white	White pine blister rust	None	Pine needle rust
Whitebark	White pine blister rust	None	Pine needle rust
Spruce	Spruce broom rust	Spruce broom rust	Spruce needle rust, spruce cone rust
Hardwoods			
Alder	None	None	Alder leaf rust
Aspen	None	None	Aspen rust
Birch	None	None	Birch leaf rust
Buckthorn	None	None	Buckthorn leaf rust
Cottonwood	None	None	Poplar rust
Madrone	None	None	Madrone leaf rust
Oak/Tanoak	None	None	Cronartium rust
Willow	None	None	Willow leaf rust

Ecologic roles

White pine blister rust, unlike most other conifer rusts in Oregon, is an introduced disease and therefore has dramatically altered the ecology of the five-needle pines throughout western North America. Because most five-needle pines have not developed resistance to the disease, tree mortality has been so widespread that the five-needle pines are no longer part of the ecosystem in many areas. These areas have succeeded to climax species in many cases. At low elevations, sugar pine has been replaced by white fir. At middle elevations, white pine has been replaced by white or grand fir. At upper elevations, white pine has been replaced by Shasta red fir or Pacific silver fir, and whitebark pine has been replaced by subalpine fir or mountain hemlock. Dead pines provide habitat for birds and mammals as standing snags and as down woody debris.

Ecologic roles of the native rust diseases are much more subtle. Mortality usually is not so widespread as to affect tree species' abundance or to alter forest succession. Individual dead trees or affected tree parts provide habitat for wildlife.

Management

Probably no other forest disease in western North America has received as much attention as white pine blister rust. Millions of dollars were spent trying to eradicate the alternate host in order to control the disease, but eradication proved impossible. Chemical control also failed. Recent efforts have focused on breeding resistant trees and relying on natural resistance to manage the disease. Pruning infected branches or uninfected lower branches (see page 39) or excising around stem cankers also helps reduce impact of the disease. *Ribes* removal on a small scale, such as in pine plantations or near ornamentals, is useful in reducing disease incidence. Some attempts have been made to rate sites for hazard of rust infection based on presence or absence of various species of *Ribes* plants. Low-hazard sites are planted with susceptible pines, medium-hazard sites are planted with pine of low or questionable resistance, and the most resistant stock is planted in high-hazard sites.

Attempts to control western gall rust have focused on developing genetically resistant stock.

For all other rusts, management has focused on removing infected trees during normal silvicultural operations. Foliage rusts can be controlled with chemical sprays in agricultural, nursery, landscape, or Christmas tree settings.

CHAPTER 5

Other fungal diseases

Several other tree diseases in Oregon affect the foliage, stems, or entire seedlings. These diseases are important in high-yield forestry, Christmas tree plantations, ornamental landscaping, and seedling nurseries.

Foliage diseases

Several fungi attack the foliage of conifer and hardwood trees (Table 5, pages 25–26). Infected leaves lose some photosynthetic efficiency and drop from the tree prematurely. The net effect is reduced tree growth and vigor as well as an unappealing appearance. Foliage diseases often are most severe in offsite plantings or following years when wet weather continues through spring into summer.

Brown felt blight

This disease is caused by two species of fungi: *Herpotrichia juniperi* on conifers other than pine, and *Herpotrichia coulteri* on pine. The disease is common at high elevations. Lower branches are covered with dense cobwebby growths of brown to black mycelium that kill foliage. Fungi develop on foliage under snow when high humidity and relatively mild temperatures foster growth. Fruiting bodies form on the mycelium and produce spores that are windborne and infect susceptible foliage.

Rhabdocline needle cast

This disease of Douglas-fir is caused by the fungi *Rhabdocline pseudotsugae* and *Rhabdocline weirii*. Windborne spores are released in May and June from fruiting bodies on the undersurfaces of infected needles. Only the current year's needles are susceptible, and they are not cast until the following year. Coastal Douglas-fir is less susceptible than inland Douglas-fir, but resistance varies considerably within natural stands.

Swiss needle cast

Swiss needle cast of Douglas-fir is caused by the fungus *Phaeocryptopus gaumanni*. It is very common in western Oregon and is especially damaging along the north Oregon coast. Premature needle loss and tree growth retardation are common in severely affected plantations, and trees occasionally have died. Spores released from fruiting bodies on 1-year-old needles in April and May infect the newly emerged needles. Succulent foliage, dense stocking, moist conditions, and offsite plantings favor infection. The disease is recognized by the yellowing and browning in the late winter or early spring of infected previous year's needles shortly before the current year's needles emerge. Casting of 1- and 2-year-old needles usually begins in the lower part of the crown and progresses upward.

Elytroderma needle blight

This disease is caused by the fungus *Elytroderma deformans*. It affects ponderosa, Jeffrey, knobcone, and, rarely, lodgepole pine. It causes the 1-year-old needles to turn red in the spring. The disease also affects the twigs and causes a witches' broom with upward-turning branchlets. Windborne spores are produced on infected needles in the spring and infect current-year needles during periods of high humidity and cool temperatures. The fungus grows from infected needles to woody tissues and remains active for many years by infecting new needles. In severely infected trees, entire tree tops may be misshapen, growth is retarded, and, occasionally, entire trees die or are predisposed to bark beetles. This disease often is confused with dwarf mistletoe, but *Elytroderma*-broomed branches do not have mistletoe plants.

Lophodermella needle casts

These needle casts affect several species of pine in Oregon. The most common are caused by the fungus *Lophodermella morbida* in ponderosa pine, *Lophodermella arcuata* in five-needle pines, and *Lophodermella concolor* in lodgepole pine. New needles are infected by windborne and rain-splashed spores in early summer. Infected needles turn brown the next year. Damage can be spectacular in offsite ponderosa pine, especially in young or small trees. Onsite trees are not seriously damaged or killed. Lophodermella needle cast is a serious problem on the knobcone–Monterey pine hybrid (the KMX pine).

Lophodermium needle casts

These diseases affect all species of pine in Oregon and are caused by several species in the *Lophodermium pinastri* complex of fungi. Another species, *Lophodermium decorum*, causes a needle cast of true fir. *Lophodermium juniperi* occurs on juniper and incense-cedar, *Lophodermium crassum* on Brewer spruce, and *Lophodermium piceae* on Sitka and Engelmann spruce. The diseases caused by these fungi are quite common but cause little damage except in offsite trees. The fungi's fruiting bodies appear on needles 3 years old or older. They are dull to shiny black, elliptical structures that occur in rows or lines. Infected needles remain on the tree several years after dying.

True fir needle diseases

Three species of fungi cause needle diseases in true fir: *Lirula abietis-concoloris*, *Virgella robusta*, and *Phacidium abietis* (snow blight). Infections develop on young expanding needles. For *Lirula abietis-concoloris* and *Virgella robusta*, elongate dark brown or black fruiting bodies form in either one or two rows on needles 2 years old or older. *Phacidium abietis* attacks needles of all ages while they are under the snow. In the summer and fall, dark brown oval fruiting bodies appear on the undersides of needles. These diseases are of little economic importance except in ornamental settings, Christmas tree plantations, or nurseries.

Red band needle blight

Red band needle blight is caused by the fungus *Mycosphaerella (=Dothistroma) pini*. It affects ponderosa, Jeffrey, knobcone, KMX, and lodgepole pine in Oregon. Windborne spores are released from May to November and can affect needles of all ages. The disease is recognized by yellow to tan spots and bands that appear on needles in July. Infected needles drop in late summer, fall, or in some cases spring of the following year. Twigs may have only a few healthy needles concentrated at the outer ends of branches or near tops.

Davisomycella needle blight

Several species of pine are affected by this blight. *Davisomycella lacriformis* occurs on knobcone pine, *Davisomycella montana* on lodgepole pine, and *Davisomycella medusa* on ponderosa, Jeffrey, and lodgepole pine. This disease can be serious locally, retarding tree growth. The elongate, black, raised fruiting bodies mature on infected needles in June, and spores are released in summer and fall. Spores infect the current year's needles. The fungus remains dormant 2 to 4 years before symptoms appear.

Bifusella needle cast

This disease occurs in the five-needle pines in Oregon. It is caused by several species of fungi in the genus *Bifusella*. The fungus forms shiny, black, elongate fruiting bodies of variable lengths on 2- to 3-year-old needles. Because the disease is on older needles, it is not considered serious.

Larch needle blight and larch needle cast

Two common needle diseases of western larch are the needle blight, caused by the fungus *Hypodermella laricis,* and the needle cast caused by the fungus *Meria laricis*. Spores from previously killed needles infect new foliage in the spring during moist weather. Needle cast affects the tips or some other part of the needles; in contrast, needle blight affects the whole needle, making it look as if scorched by fire, and all needles on a spur are affected. Needles infected by *Meria* are cast early; needles affected by *Hypodermella* are retained 1 year or more. Infected crowns usually refoliate, but repeated infection may cause growth retardation.

Cedar leaf blight

This blight, caused by the fungus *Didymascella* (=*Keithia) thujina*, affects western redcedar seedlings and saplings. Infected foliage, especially lower foliage in dense stands, appears scorched in the spring. In the fall, infected leaf twigs drop, leaving the branches bare. In the spring following infection, circular to elliptical brown to black fruiting bodies are formed on the upper surfaces of infected leaves.

Many species of fungi cause leaf spots, lesions, or leaf mortality in Oregon hardwoods (Table 5). Except perhaps for the leaf rusts and anthracnose diseases of ash and maple, most leaf diseases are of little economic importance.

No serious foliage diseases have been reported in Oregon on redwood or Port-Orford-cedar.

Canker diseases

Canker diseases are caused by fungi that attack tree stems and branches. Canker diseases usually are indicated by dead branches or tops along with localized dead areas on the stem or branches. These dead, often sunken areas of infected bark are referred to as "cankers." Branch death occurs when the fungus penetrates and kills inner bark tissues, cutting off the flow of water and nutrients to the rest of the branch. Most canker diseases occur sporadically and usually affect trees on unfavorable sites or trees weakened by water stress or low-temperature injury.

Atropellis canker

Two species of fungi, *Atropellis piniphila* and *Atropellis pinicola*, cause this disease of pine. The disease occurs in many lodgepole pine stands, but relatively few trees are severely infected. The disease also affects western white, whitebark, ponderosa, and sugar pine. Infection can reduce wood quality, break stems, and occasionally kill the tree. Windborne spores infect throughout the growing season through unbroken bark in the internodal region, though some infection occurs through branch stubs. Small, black or dark brown fruiting bodies form on dead bark in the cankers. The disease is best identified by the bluish stain in the wood behind the canker.

Cytospora canker

Cytospora canker is caused by several species of fungi in the genus *Cytospora: Cytospora abietis* on true fir and sometimes on Douglas-fir; *Cytospora sordida* on black cottonwood; *Cytospora chrysosperma* on quaking aspen; *Cytospora ambiens* on Oregon ash; and an unidentified species on alder, birch, and willow. The disease usually is associated with some sort of environmental stress or wounding and seldom causes serious damage except when associated with dwarf mistletoe. Spores are carried by wind, insects, birds, or splashing rain. New hosts are infected through wounds, dead twigs, or dwarf mistletoe infections. The fungi produce slightly sunken cankers that result in branch or stem mortality.

Phomopsis canker

This disease of Douglas-fir is caused by the fungus *Diaporthe* (=*Phomopsis) lokoyae*. Infection can result in top-killing and death of small trees, but damage usually is not serious. Spores infect small shoots and cause distinct round or oval sunken cankers with brown bark. This bark sloughs off in the following growing season. Small dead branchlets frequently are in the center of cankers.

(text continues on page 27)

Table 5.—Foliage and canker pathogens (except rusts) in Oregon trees.

Host tree species	Foliage pathogens		Canker pathogens	
Conifers				
Cedar	*Lophodermium juniperi*	*Didymascella thujina*	None	
Douglas-fir	*Herpotrichia juniperi* *Phaeocryptopus gaumanni*	*Rhabdocline* spp. *Rhizosphaera kalkhoffi*	*Cytospora abietis* *Dermea pseudotsugae*	*Diaporthe lokoyae* *Sclerophoma pythiophila*
Fir, true	*Herpotrichia juniperi* *Lirula abietis-concoloris* *Lophodermium decorum*	*Phacidium abietis* *Virgella robusta*	*Cytospora abietis* *Grovesiella abieticola*	*Nectria fuckeliana*
Hemlock	*Epipolaeum tsugae*	*Herpotrichia juniperi*	*Sirococcus strobilinus*	
Juniper	*Didymascella thujina*	*Lophodermium juniperi*	None	
Larch	*Hypodermella laricis*	*Meria laricis*	*Lachnellula* sp.	
Pine (Jeffrey, knobcone, lodgepole, ponderosa)	*Davisomycella* spp. *Elytroderma deformans* *Herpotrichia coulteri*	*Lophodermella* spp. *Lophodermium* spp. *Mycosphaerella pini*	*Atropellis* spp.	*Sclerophoma pythiophila*
Pine (limber, sugar, white, whitebark)	*Bifusella* spp. *Herpotrichia coulteri*	*Lophodermella* spp. *Lophodermium* spp.	*Atropellis* spp.	*Sclerophoma pythiophila*
Spruce	*Herpotrichia juniperi* *Lophodermium* spp.	*Rhizosphaera kalkhoffii*	*Sirococcus strobilinus*	
Yew	*Lophodermium juniperi* *Macrophoma taxi* *Mycosphaerella taxi*	*Phoma hystrella* *Sphaerulina taxi*	*Diploidia taxi*	
Hardwoods				
Alder (red)	*Cercosporella alni* *Gnomonia alni* *Gnomoniella tubiformis* *Hyposila californica*	*Microsphaera alni* *Septoria alnifolia* *Taphrina japonica*	*Cytospora* sp. *Didymosphaeria oregonensis*	*Hymenochaete agglutinans* *Nectria* spp.
Alder (white)	*Gnomonia alni* *Phyllactinia guttata*	*Taphrina occidentalis*	*Nectria cinnabarina*	
Ash	*Apiognomonia errabunda* *Mycosphaerella* spp.	*Phyllactinia guttata*	*Cytospora ambiens* *Hysterographium fraxini*	*Nectria cinnabarina*
Aspen	*Erysiphe cichoracearum* *Marssonina populi*	*Uncinula salicis* *Venturia macularis*	*Ceratocystis fimbriata* *Cryptosphaeria populina*	*Cytospora chrysosperma*
Birch	*Cylindrosporium betulae* *Phyllactinia guttata*	*Septoria betulicola* *Taphrina* spp.	*Cytospora* sp.	*Nectria* sp.
Buckthorn	*Phyllosticta rhamnigena*	*Septoria blasdalei*	*Nectria cinnabarina*	
Cherry	*Taphrina flectans*		*Nectria cinnabarina*	
Chinkapin	*Coronellaria castanopsidis* *Dothidella janus* *Microsphaera alni*	*Sphaerulina myriadea* *Taphrina castanopsidis*	None	

(table continues on next page)

Table 5 (continued).—Foliage and canker pathogens (except rusts) in Oregon trees.

Host tree species	Foliage pathogens		Canker pathogens	
Hardwoods (continued)				
Cottonwood	*Marssonina* spp. *Septoria* spp.	*Taphrina populisalicis* *Venturia populina*	*Cytospora sordida* *Dothichiza populea* *Fusarium* spp.	*Hypoxylon mammatum* *Nectria galligena* *Septoria musiva*
Dogwood	*Discula destructiva*	*Phyllactinia guttata*	*Nectria* spp.	
Madrone	*Ascochyta hanseni* *Cryptostictus arbuti* *Didymosporium arbuticola* *Disaeta arbuti* *Elsinoe mattirolianum*	*Exobasidium vaccinii* *Mycosphaerella arbuticola* *Phyllosticta fimbriata* *Rhytisma arbuti*	*Botryosphaeria dothidea* *Hendersonula toruloidea*	*Phytophthora cactorum*
Maple	*Microsphaera alni* *Phyllactinia guttata* *Phyllosticta* sp.	*Rhytisma* spp. *Uncinula* spp.	*Nectria galligena*	*Verticillium albo-atrum*
Myrtlewood	*Botryosphaeria* sp. *Capnodium tuba* *Chaetasbolisia falcata* *Colletotrichum gleosporiodes*	*Kabatiella phoradendri* *Mycosphaerella arbuticola* *Phaeosaccardinula* spp. *Vertixore atronitidum*	*Nectria galligena*	
Oak	*Gnomonia quercina* *Microsphaera* spp. *Septoria quercicola*	*Sphaerotheca* spp. *Taphrina caerulescens*	None	
Tanoak	*Capnodium coffeae* *Ceathocarpum conflictum* *Chaestasbolisia falcata* *Limacinia lithocarpi*	*Pestolotia castagnei* *Phaeosaccardinula anomola* *Protepeltis lithocarpi*	None	
Willow	*Cylindrosporium salicinum* *Rhytisma salicinum*	*Septoria* spp.	*Cytospora* spp.	*Nectria* spp.

Fruiting bodies appear as fine black pimples on dead bark. The disease is associated with drought.

Dermea canker

Dermea canker occurs on young Douglas-fir in Oregon. It is caused by the fungus *Dermea pseudotsugae*. The trunk cankers often girdle the tree resulting in top-kill and tree death. Trees are predisposed to Dermea canker by drought or frosts. The disease is recognized by sunken cankers that have tiny, black fruiting bodies that appear on the dead bark a year after infection.

Sclerophoma canker

This canker affects all species of pine and Douglas-fir. The causal fungus is *Sclerophoma pythiophila*. Infections cause twig and top dieback; some trees die. The fruiting bodies are small, round, and embedded in the needles or bark. The infected wood is stained a bluish black.

Grovesiella canker

Grovesiella canker affects true fir and is caused by the fungus *Grovesiella (=Scleroderris) abieticola*. Infections result in annual cankers and twig dieback. Small, black fruiting bodies form on the dead wood of the canker.

Nectria canker

This disease affects true fir and hardwoods. Cankers are caused by the fungus *Nectria fuckeliana* in true fir; by *Nectria galligena* in bigleaf maple, myrtlewood, willow, dogwood, and black cottonwood; by *Nectria cinnabarina* in ash, white alder, cherry, and buckthorn; by *Nectria coccinea* in dogwood; by *Nectria corylis* in willow; and by an unidentified species of *Nectria* in red alder and birch. Fruiting bodies are formed at the margins of conspicuous trunk cankers.

Sirococcus tip blight

The fungus *Sirococcus strobilinus* causes a tip blight in hemlock and spruce seedlings and saplings. Small grayish green to black fruiting bodies form on shoots, needles, or cones. Spores may be seedborne.

Other canker diseases

Other canker diseases of hardwoods are caused by several species of fungi.

- *Verticillium albo-atrum* causes branch flagging in bigleaf maple.
- The fungi that cause cankers in red alder are *Didymosphaeria oregonensis* and *Hymenochaete agglutinans*.
- Three species of fungi cause cankers in Pacific madrone: *Botryosphaeria dothidea, Phytophthora cactorum*, and *Hendersonula toruloidea*.
- *Hysterographium fraxini* causes a canker in Oregon ash.
- *Dothichiza populea, Fusarium* spp., *Hypoxylon mammatum,* and *Septoria musiva* cause cankers in black cottonwood.
- Cankers in quaking aspen are caused by *Ceratocystis fimbriata* and *Cryptosphaeria populina*.

No fungi have been reported to cause serious cankers in cedar, juniper, redwood, tanoak, oak, or chinkapin in Oregon.

Seedling diseases

All root, rust, foliage, and canker diseases discussed previously can affect seedlings and more frequently kill seedlings than more mature trees. In addition, the following diseases typically affect only seedlings in nurseries or greenhouses.

Damping-off

Several genera of fungi cause damping-off: *Phytophthora*, *Pythium*, and *Fusarium*. All species of conifers and some species of hardwoods are susceptible. Damping-off fungi are soil inhabitants and survive either as dormant spores or as mycelium in organic matter. Seedlings may fail to emerge due to infection or decay of seeds, or infection may occur in succulent stem tissue at or just below the ground line. The disease spreads by movement of infested soil or seedlings.

Fusarium root rot

The rot caused by the fungus *Fusarium oxysporum* is the most serious disease in Oregon bareroot nurseries. The disease can affect all conifer seedlings. Spores infect succulent young roots in warm, moist conditions. In older seedlings it causes typical root rot symptoms: rootlet deterioration, foliage yellowing, general decline, and death. Soil and seedling movement spread the disease.

Stem cankers

Cankers caused by *Fusarium* sp. and *Phoma eupyrena* are particularly damaging to bareroot Douglas-fir. *Diaporthe lokoyae* and *Sirococcus* spp. also cause cankers and tip dieback on Douglas-fir and spruce respectively. Damage usually is noticed when seedling tops turn brown. Closer inspection reveals dead portions on the stem where the fungus killed the cambium.

Gray mold

This disease, caused by the fungus *Botrytis cinerea*, is especially common in container nurseries and in dense 2-year-old and older beds in bareroot nurseries. All conifer species, especially Douglas-fir, hemlock, and cedar, are affected. The fungus is a common soil inhabitant that infects by windborne or water-splashed spores, especially during cool, moist conditions. The disease is recognized by a brownish gray mycelium on infected portions of seedlings. Spores are released when seedlings are agitated. Infection turns foliage yellow and brown, causing seedling dieback and death.

Phytophthora root rot

Several species of fungi in the genus *Phytophthora* cause this rot. Most conifer and some hardwoods are susceptible. The fungus invades roots through the soil. Mycelium and spores require high soil moisture to spread and can be moved on plants, machinery, or animals to uninfested areas. The disease often is confined to wet, low-lying areas, along drainages, or where drainage is poor. Stunting, yellowing, and wilting usually precede seedling mortality. Red to brown discoloration of root cambium is a common symptom.

Management

Management of foliage, canker, and seedling diseases usually is not warranted nor practical in forest settings. In many cases, environmental conditions contribute to disease expression. To reduce disease impact, maintain vigorous plants through spacing, thinning, balancing nutrients and pH, maintaining adequate soil moisture, preventing wounds, increasing biodiversity, and especially by avoiding offsite planting. In forest nurseries, Christmas tree farms, or agricultural, greenhouse, or ornamental settings, foliar sprays may help prevent or reduce infection.

Mistletoes

CHAPTER 6

All mistletoes are flowering, seed-bearing plants. They have stems, roots, and foliage and reproduce and spread by seeds (Figure 10).

Dwarf mistletoes *(Arceuthobium* spp.) do not have enough chlorophyll to produce their own food. They rely totally on the host tree for nutrients and water, which they extract through rootlike structures that penetrate into the bark and wood of stems and branches. When the host tree dies, the mistletoe plant also dies. Infections reduce tree growth and vigor, lower wood quality, and kill trees.

Dwarf mistletoes are one of the most damaging diseases of Oregon's conifer forests. On the other hand, they provide habitat for several owl species and for other birds and mammals.

True mistletoes *(Phoradendron* spp.) are not as damaging as dwarf mistletoes.

General biology

Dwarf mistletoes

Dwarf mistletoes complete their life cycle in about 4 to 6 years. In late summer, fruits of female plants mature. Small, sticky seeds are explosively ejected from fruit and can travel as far as 40 feet from the tree. A few seeds land on and adhere to needles. Rain allows the seed to slide down the needle and lodge against the stem at the needle base. The following spring or summer, the seeds germinate and sink roots into the stem. No symptoms are visible at this time.

During the second year, the first visible symptom—swelling of infected branches—appears. This swelling continues to enlarge in the third year when the first (sterile) shoots of the dwarf mistletoe plants appear. The characteristic aerial shoots, complete with flowers, usually appear in the fourth year and produce seed by the end of the fifth year. Shoots might not appear if, as in

Figure 10.—Dwarf mistletoe stems and seeds on an infected ponderosa pine.

dense understory stands, there is insufficient light. These are called latent infections and will not form shoots until overstories die or are removed. Severe, long-term dwarf mistletoe infection often stimulates host trees to produce dense clumps of branches called witches' brooms (Figure 11, page 30). The brooms serve as "sinks" for nutrients that otherwise would be used to grow wood and foliage.

True mistletoes

True mistletoes bear seeds in white fruits. Seeds are not forcibly discharged as in dwarf mistletoes. Instead, birds eat the fruits, digest the pulp, and excrete the living seed on branches where birds perch. The seeds germinate, and infection occurs in the young, thin bark. True mistletoes make most of their food through photosynthesis but get water and nutrients from their hosts.

Douglas-fir dwarf mistletoe

Douglas-fir dwarf mistletoe *(Arceuthobium douglasii)* probably is the most damaging disease of Douglas-fir in central, southern, and eastern Oregon. The primary host is Douglas-fir; infection also has been reported in true fir (Table 6, page 31).

Douglas-fir dwarf mistletoe has rather small (about 0.25 to 0.5 inch long) leafless, olive-green shoots near the ends of infected branches in witches' brooms. Usually only a small portion of a witches' broom has visible mistletoe plants. Witches' brooms usually are the last portion of the tree to die, and death may take several decades even in severely infected trees. Growth losses of 50 to 60 percent have been reported in severely infected trees.

Hemlock dwarf mistletoe

Hemlock dwarf mistletoe *(Arceuthobium tsugense)* causes substantial economic damage on several conifer species besides western and mountain hemlock. There are two subspecies: *Arceuthobium tsugense* subsp. *tsugense* attacks mainly western hemlock and true fir; and *Arceuthobium tsugense* subsp. *mertensianae* attacks mainly mountain hemlock and the true fir. Both subspecies of hemlock dwarf mistletoe severely damage Pacific silver fir and noble fir. In true fir, several species of canker fungi, especially *Cytospora abietis*, infect near the mistletoe infections and kill twigs and branches. Eventually, if enough branches are affected, the weakened trees are attacked by bark beetles and die.

Hemlock dwarf mistletoe has green to reddish shoots about 2 inches long. Witches' brooms are common on older trees. Infected trees with good crown ratios grow better than trees with poor crowns. Severely infected trees have volume growth rates about half those of uninfected trees.

Figure 11.—Dwarf mistletoe causes large witches' brooms in Douglas-fir, as in the fir at the left in this view.

Larch dwarf mistletoe

Larch dwarf mistletoe *(Arceuthobium laricis)* probably is the second most economically destructive mistletoe in Oregon. Its principal host is western larch; subalpine fir and lodgepole pine are occasional hosts, and whitebark pine is a rare host.

Larch dwarf mistletoe has dark purple shoots 1.5 to 4 inches long. Witches' brooms are common and often break off with snow and ice in winter. Severely affected trees often resemble telephone poles because of the loss of infected branches. Occasionally, severely infected and suppressed trees are broken or bent by the snow and ice.

Pine dwarf mistletoes

Pine dwarf mistletoes include *Arceuthobium americanum* primarily on lodgepole pine; *Arceuthobium campylopodum* on ponderosa, Jeffrey, and knobcone pine; *Arceuthobium monticola* on white pine, *Arceuthobium cyanocarpum* on whitebark pine; and *Arceuthobium siskiyouense* on knobcone pine.

Lodgepole pine dwarf mistletoe has olive-green shoots about 2.5 inches long. Large witches' brooms are common. This is economically the most important disease of lodgepole pine. *Arceuthobium campylopodum*, also called western dwarf mistletoe, has olive-green to yellow shoots that are very large (3 to 8 inches long). Witches' brooms generally are not as large as in Douglas-fir or lodgepole pine. They often are confused with witches' brooms caused by Elytroderma needle blight, but the latter do not have the mistletoe plants.

Arceuthobium monticola, white pine dwarf mistletoe, occurs only in southern Oregon. Its dark brown shoots are 3 to 4 inches high. *Arceuthobium cyanocarpum,* limber pine dwarf mistletoe, has yellow-green shoots 1 to 2 inches high. *Arceuthobium siskiyouense,* knobcone pine dwarf mistletoe, has yellow to brown shoots 2 to 3 inches high.

Table 6.—Occurrence of mistletoes on Oregon trees.

Tree species	Primary* host	Secondary* host	Occasional* host	Rare* host
Conifers				
Cedar Alaska	None	None	None	None
Incense-	Incense-cedar mistletoe	None	None	None
Western red	None	None	None	None
Fir Douglas-	Douglas-fir dwarf mistletoe	None	None	None
Grand or White	White fir dwarf mistletoe	None	None	Hemlock,[1, 2] Douglas-fir, and larch dwarf mistletoes
Noble	Hemlock dwarf mistletoe [1, 2]	None	None	None
Pacific silver	Hemlock dwarf mistletoe [1, 2]	None	None	White fir and Douglas-fir dwarf mistletoes
Shasta red	Red fir dwarf mistletoe	None	None	None
Subalpine	Hemlock dwarf mistletoe[1]	None	Larch dwarf mistletoe	Douglas-fir dwarf mistletoe
Hemlock Mountain	Hemlock dwarf mistletoe[1]	Limber pine dwarf mistletoe	None	Hemlock dwarf mistletoe[2]
Western	Hemlock dwarf mistletoe[2]	None	Hemlock dwarf mistletoe[1]	None
Juniper	Dense mistletoe, juniper mistletoe	None	None	None
Larch	Larch dwaf mistletoe	None	None	None
Pine Jeffrey	Western dwarf mistletoe	None	None	Knobcone and white pine dwarf mistletoes
Knobcone	Knobcone pine dwarf mistletoe	Western dwarf mistletoe	None	None
Limber	None	None	None	None
Lodgepole	Lodgepole pine dwarf mistletoe	None	Larch and western dwarf mistletoes	Hemlock dwarf mistletoe[1]
Ponderosa	Western dwarf mistletoe	None	Lodgepole pine dwarf mistletoe	Knobcone pine dwarf mistletoe
Shore	None	None	Knobcone pine dwarf mistletoe	None
Sugar	None	White pine dwarf mistle-toe	None	None
Western white	White pine dwarf mistletoe	None	Hemlock dwarf mistletoe[1]	None
Whitebark	Limber pine dwarf mistletoe	Hemlock dwarf mistletoe[1]	None	Larch dwarf mistletoe
Redwood	None	None	None	None
Spruce Brewer	None	White fir dwarf mistletoe	White pine dwarf mistletoe	Hemlock dward mistletoe[2]
Engelmann	None	None	None	Hemlock dward mistletoe[2]
Sitka	None	None	None	Hemlock dward mistletoe[2]
Yew	None	None	None	None
Hardwoods				
Oak	Oak mistletoe	None	None	None

*Primary = >90% infected secondary = 50–90% infected occasional = 5–50% infected rare = <5% infected.

[1]Mountain hemlock subspecies [2] Western hemlock subspecies

Although limber pine dwarf mistletoe has been reported on whitebark pine, it has not been found on limber pine in Oregon.

True fir dwarf mistletoe

True fir dwarf mistletoe is caused by *Arceuthobium abietinum*. One variety infects white and grand fir, and another variety infects Shasta red fir. True fir mistletoe occurs only in the Cascade Range and in southern Oregon. As with noble and Pacific silver fir that are infected with hemlock dwarf mistletoe, trees infected with true fir mistletoe frequently are attacked by canker fungi that enter through old mistletoe infections. Branch mortality leading to bark beetle attack and tree mortality are especially common in central Oregon. Old true fir mistletoe infections also serve as entry points for stem decay fungi.

True fir mistletoe is identified by the yellow-green shoots that are 3 to 8 inches long. Witches' brooms generally do not form, but branch dieback in true fir usually is a symptom of true fir dwarf mistletoe. Trees with good live crowns are better able to withstand infection than trees with poor crowns.

"True" or leafy mistletoes

"True" or leafy mistletoes, *Phoradendron* spp., are found on conifers and hardwoods. "Dense" mistletoe (*Phoradendron densum*) and juniper mistletoe (*Phoradendron juniperinum*) infect western juniper. Incense-cedar mistletoe (*Phoradendron libocedri*) attacks incense-cedar. *Phoradendron villosum* attacks both Oregon white oak and California black oak. Oak mistletoe often is collected and used during Christmas.

Ecologic roles

The destructive role of dwarf mistletoes from a timber management perspective has been recognized for decades in Oregon. Tree growth retardation, lower wood quality, and tree death are the results of severe dwarf mistletoe infections. Other roles that dwarf mistletoes play in forest ecosystems are not well known, and only very recently have we begun to recognize the importance of dwarf mistletoes from a nontimber viewpoint.

Wildfire probably is the primary natural ecological factor governing the distribution and abundance of dwarf mistletoes in Oregon. Wildfire suppression during this century has led to an increased frequency of dwarf mistletoes especially in central, southern, and eastern Oregon. Increased infections create mistletoe brooms that eventually die and fall to the ground. This creates a fuel ladder for fire and increases fire around the bases of trees, resulting in more tree mortality even in thick-barked species such as ponderosa pine.

Associations between dwarf mistletoe and vertebrates in Oregon are now being realized and increasingly reported. During bad weather, porcupines often use Douglas-fir that are infected with dwarf mistletoe; the witches' brooms offer protection from snow and wind. The northern spotted owl, the great gray owl, and the long-eared owl have been shown to select dwarf-mistletoe-infected Douglas-fir for nest building. Other bird species also use the witches' brooms for roosting. Hemlock mistletoe brooms may be used by the marbled murrelet.

The ecologic roles of true mistletoes are not well known, except that they provide food for birds.

Management

To aid timber production and wildfire prevention, dwarf mistletoe eradication treatments have been used for decades in Oregon. Clearcutting or selectively removing or girdling infected overstory trees is very effective because dwarf mistletoes spread most rapidly from tall trees to nearby small ones. Dwarf mistletoes require a living host to survive; once a tree dies, the dwarf mistletoe dies. Infected green trees that are left in clearcuts can and will infect susceptible regeneration.

Another strategy to reduce the impact of dwarf mistletoes is to favor resistant or nonhost species in mixed-species stands during thinning or partial cutting. Except for hemlock dwarf mistletoe and western dwarf mistletoe, each mistletoe seriously affects only one host species; for example, Douglas-fir dwarf mistletoe will not infect ponderosa pine.

Thinning also can be used to reduce dwarf mistletoe infections to acceptable levels consistent with management objectives. Thinning has been shown to improve growth rates even in moderately infected ponderosa pine, Douglas-fir, and larch in Oregon. The key is to remove infected overstory trees to prevent further infection of crop trees, and then space residual trees to improve growth and vigor. Crop trees should not be thinned until at least 5 years after overstory removal in order to allow enough time for latent infections to appear.

Branch pruning also is a mistletoe control option. This has been done with young trees, ornamental trees, and trees in developed recreation areas. However, as the economic benefits of pruning are realized in Oregon, pruning to remove mistletoe-infected branches will become more practical as a regular operational control strategy.

As we realize the beneficial role of dwarf mistletoe in wildlife habitat, managing for dwarf mistletoe has become more acceptable. Infected trees can be protected as wildlife trees with the trade-off being reduced tree growth and vigor and an infection source for adjacent susceptible trees.

CHAPTER 7

Abiotic diseases

Abiotic (nonliving) factors of the environment can directly injure trees, or they can predispose trees to damage by other pests. The most important abiotic diseases in Oregon are caused by water stress (such as from drought), soil compaction or site disturbance, and low temperatures. Air pollution damage, sun scald, and damage from nutrient deficiencies are examples of other important abiotic diseases.

Water stress

Water stress in trees usually results from soil moisture deficiency caused by periods of below-normal precipitation (drought). The severity of water stress is influenced by soil types, competing vegetation, soil disturbance, and other factors. Symptoms of water stress include reduced growth, yellowing needles, loss of foliage, and dead branches. Symptoms generally progress from the top of the tree downward and from the outside to the inside of the crown. Symptoms usually appear first on tree parts farthest from the water-absorbing roots.

Although water stress can kill trees, its most important effect is that it predisposes trees to injury by insects and fungi. Stressed trees have reduced vigor and are less able to produce defensive chemicals to ward off attacks by many pests. Many canker diseases damage trees that are experiencing water stress. As a result, the occurrence of pest-caused damage rises dramatically during and for a few years after drought.

Soil compaction and site disturbance

Soil compaction can reduce water penetration and impede gas exchange in roots, which increase mortality of the fine, nutrient-absorbing roots. As a result, trees on compacted soils or with damaged roots have many of the symptoms previously described for water stress. Regardless of tree size, most water-absorbing roots are in the uppermost layers of soil, many within a few inches of the surface. In fact, 90 percent of a tree's fine roots are in the top 2 feet of soil. Livestock and heavy equipment easily damage roots and compact soils in this zone.

Low-temperature injury

Unseasonably low temperatures can directly kill tree tissues. Late-spring frost can kill succulent new foliage soon after it emerges. Very low temperatures after an unseasonably warm period in winter can cause top-kill in large trees. Winter drying occurs when warm winds blow over very cold or frozen soil. The warm winds cause foliage to lose water rapidly, while cold soil slows water uptake by roots. The result is dehydration and needle browning, often affecting trees over large areas.

Damage reduction

Prevention is the key to reducing damage from abiotic factors. This can be accomplished by maintaining proper tree densities, managing competing vegetation, and proper livestock management. Avoid unnecessary disturbance and soil compaction. Compacted soil can be tilled, but living tree roots may be damaged. Plant only tree species that are adapted to the site and from the appropriate seed zone. This will ensure that trees are better able to resist extreme changes that may occur.

Effects of forest practices on disease

CHAPTER 8

Precommercial thinning

Precommercial thinning—removing trees too small to have commercial value in order to achieve better spacing in the rest of the stand—has been done for many years in Oregon, especially in Douglas-fir and ponderosa pine. Scientific research to date has shown some advantages and disadvantages to precommercial thinning as a disease-control measure.

Advantages include:

- Wounded and infested trees can be eliminated.
- Residual trees, if wounded during early thinning, will develop small decay columns rather than the large columns created if thinning is done when trees are larger.
- Excellent growth response will result if live-crown ratios and previous height growth are good.
- Shorter rotation ages can be used.
- Disease-tolerant species can be favored.
- Residual trees are more resistant to certain diseases because of increased vigor.

Some disadvantages are:

- Some species (for example, true fir) can be sunscalded on certain sites if spacing is too wide.
- Slash creation increases risk from fire, stem-wounding, and bark beetle attack.

In central Oregon, precommercial thinning increases volume growth in ponderosa pine and Douglas-fir that is moderately infected with dwarf mistletoe. Douglas-fir mortality after 10 years is less than 1 percent of the thinned trees. Less infected trees significantly increase in radial growth after thinning; more heavily infected trees do not.

In eastern Oregon, precommercial thinning increases vigor of true fir which decreases tree susceptibility to infection and stem decay caused by the Indian paint fungus. In the Cascade Range, precommercial thinning neither increases nor decreases mortality from Armillaria root disease in ponderosa pine (Figure 12), Douglas-fir, true fir, or hemlock. Precommercial thinning in Douglas-fir stands with black stain root disease may increase root disease.

Commercial thinning

Commercial thinning is selectively removing trees that can be used commercially. As utilization standards improve, trees that were precommercially thinned yesterday may be of commercial value today.

Advantages of commercial thinning are similar to those for precommercial thinning, but there are additional disadvantages because the trees are larger. Those include:

- Wounded trees lead to larger decay columns.
- Stumps can become inoculum sources for annosus root disease.
- Windthrow can increase, especially in stands with root rot.

Volume growth in larch decreases as the severity of dwarf mistletoe infection increases. Thinning from above (removing dominant and codominant trees) increases

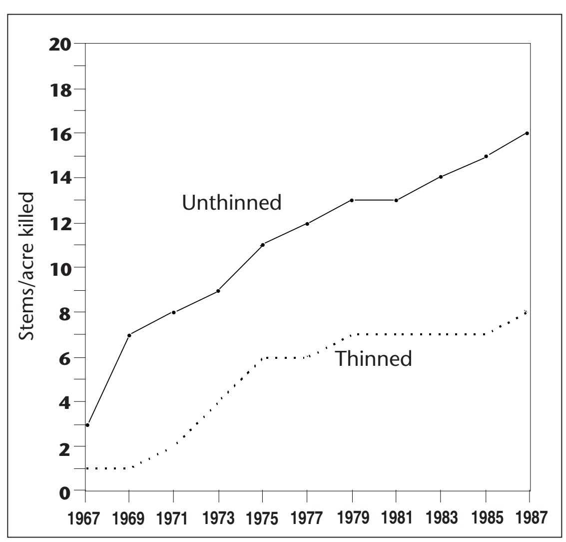


Figure 12.—Cumulative mortality of crop trees caused by Armillaria root disease in thinned and unthinned plots of 30-year-old ponderosa pine in central Oregon.

mortality from snow and ice damage to infected residual trees. Thinning from below (removing intermediate and suppressed trees) is recommended to increase volume growth and vigor in lightly to moderately infected residual larch trees and to reduce new infections by removing severely infected trees. The effect of commercially thinning mistletoe-infested stands of other tree species has not been studied but probably is similar to larch.

Commercial thinning can increase the incidence of stem decay if measures are not followed to reduce tree wounding. On the other hand, the *percentage* of decay in thinned trees is less because of the extra volume growth added after thinning. Commercial thinning has been thought to increase the incidence of windthrow in stands with root disease, but few data support this claim.

Sanitation–salvage cutting

The term sanitation–salvage cutting is a combination of several closely related terms. Salvage cuttings are chiefly for the purpose of harvesting trees that have been or are in imminent danger of being killed or damaged by injurious agents other than competition among trees. Sanitation cuttings are to remove trees that have been attacked or appear in imminent danger of attack by pests to prevent spread from one tree to another. These operations are not necessarily confined to removing merchantable trees.

There are several economic benefits to sanitation–salvage cutting, benefits especially but not exclusively related to timber values. Sanitation–salvage cutting reduces fire hazard by removing dead and dying trees. Stands can be regenerated to a healthier condition. Infested and high-risk trees are removed. The economic value of dead and dying trees is partially recovered.

It has been suggested, but not conclusively demonstrated, that sanitation–salvage cutting increases other pest problems such as root diseases. Living trees have defense mechanisms that prevent root pathogens from advancing along root systems to the root collar, which results in tree death. Dead trees lack these defense mechanisms, and infection from *Armillaria* or annosus quickly spreads throughout the entire root system after living infected trees are killed or harvested. This causes an increase in inoculum potential and can result in increased infection and mortality of adjacent living trees.

Partially harvested stands, including seed tree and shelterwood harvests and those with sanitation–salvage cutting, may have increased mortality due to root diseases, especially annosus root disease. This occurs when living trees are harvested with dead trees. Spores from the annosus root disease fungus, *Heterobasidion annosum*, require freshly exposed living wood, such as in a freshly cut stump top or fresh trunk wound, to germinate and infect. In forests with repeated defoliation by insects, many trees thought dead and marked for removal actually are still alive, and the freshly cut stumps are ideal infection courts for windblown spores of *Heterobasidion annosum*, especially stumps of true fir and hemlock.

Clearcutting and regeneration

For pest management, clearcutting usually presents fewer problems than other types of regeneration harvesting, because it leaves few trees to be windthrown, to infect regeneration, or to damage regeneration upon subsequent removal. However, susceptible regeneration can become infested with dwarf mistletoe from adjacent border trees or unmerchantable residuals, or root disease can spread from infested stumps to susceptible regeneration within the unit.

The type of regeneration—planted, natural, or advance—will determine the potential pest damage. Planting allows the establishment of pest-resistant species, but seedlings need to be from appropriate seed transfer zones or else they can be severely damaged from disease. Natural regeneration may foster the spread of certain diseases if susceptible species are allowed to regenerate. Advance regeneration (Figure 13) may already be infested with pathogens, such as the Indian paint fungus, before the overstory is harvested, and therefore advance regeneration poses the greatest risk of future pest-caused losses. Also, new practices that retain living trees and snags within clearcuts will influence disease populations and the amount of new host trees in the future stand.

Uneven-age management

Uneven-age management, in the strict sense, has not been widely practiced in Oregon. Although many forests have an uneven-age appearance, many actually are uneven in size rather than uneven in age. This is especially true for shade-tolerant species such as true fir, where suppressed understory trees may be the same age as their overstory.

From a pest management perspective, uneven-age management is more appropriate in some forest types, such as pure ponderosa pine, than in others, such as true-fir-dominated forests, because of the fewer pests associated with pine. Root diseases, stem decays, and dwarf mistletoes are affected by stand structure and composition. Silvicultural systems that produce and maintain multistoried stands and climax tree species (especially true fir) generally will allow these forest pests to increase.

All the important root pathogenic fungi, the principal causes of root disease, spread underground through root contacts or grafts. In addition, annosus root disease spreads quite effectively by airborne spores, and black stain root disease is spread by insects. Live healthy trees eventually contact infected stumps. Harvesting large, live, infected trees may aggravate root disease on a site. If uneven-age management creates stands by repeatedly harvesting and establishing susceptible regeneration, root disease may be perpetuated and made worse.

Stem decay fungi spread as airborne spores that either enter fresh wounds or are stimulated by wounding if already on infected stems. True fir that have been suppressed are more prone to infection by the Indian paint fungus than are vigorous trees. Therefore, if uneven-age management increases tree wounding through increased stand entry, or increases tree suppression, then stem decay might increase.

Figure 13.—Advance Douglas-fir regeneration in an area where trees died of laminated root rot.

Dwarf mistletoe affects most conifer species in Oregon. Spread is by seeds that rely on forceful ejection, wind, and gravity to contact susceptible hosts. Multistoried and single-species stands foster effective mistletoe spread. Therefore, if uneven-age management creates these kinds of stands, dwarf mistletoe severity can increase.

Measures can be taken to reduce pest-caused damage in multistoried stands that result from uneven-age management.

- Nonsusceptible tree species can be favored and regenerated.
- Tree vigor can be improved and maintained through thinning.
- Tree wounding can be reduced by properly planning harvest operations.
- Freshly cut stumps can be treated to prevent infection from root pathogens.

Uneven-age management in most cases requires more care than even-age management. That might be impractical in severely diseased stands but can be effective in many stands to meet land-use objectives and still prevent and reduce the adverse effects of forest diseases. More research and testing are needed to determine the short- and long-term effects of uneven-age management in several plant communities in Oregon.

Prescribed burning

Prescribed burning has been used in silviculture for many years, especially in eastern Oregon. It has been used to reduce fuel loads and to remove unwanted understory vegetation. However, more research is needed in Oregon on prescribed fires and their effects, both positive and negative, on the incidence of root and stem decays and associated bark beetles in residual trees and in subsequent regeneration.

In central Oregon, ash leachates from prescribed burns in ponderosa pine decrease the growth of *Armillaria ostoyae*, cause of Armillaria root disease. These leachates increase the growth of *Trichoderma* spp., which in turn reduces the growth and rhizomorph formation of *Armillaria ostoyae*. However, the effects of fire on infection and mortality from Armillaria root disease still are largely unknown.

In southern Oregon, underburning white fir stands scorches trees enough to cause cambial death that is associated with stained and decayed wood even 2 years after burning.

Nitrogen fertilizing

Some research on the effects of fertilizer on forest diseases has been reported in Oregon. Fertilizing with urea significantly improves tree growth and vigor. This should shorten rotation ages and decrease decay volumes by increasing sound wood volumes. Though fertilizing does not affect wound closure and cross-sectional area of decay, the *percentage* of decay is significantly less in trees that have been both thinned and fertilized. Effects of fertilizing on dwarf mistletoes and hosts are mostly unknown. In one study with artificially infected ponderosa pine seedlings, height growth of fertilized and infected seedlings was significantly greater than that of unfertilized and infected seedlings.

Most research on fertilizer has involved root diseases. Low levels of certain soil nutrients are associated with infection and decay caused by Armillaria root disease. Where fertilizer has been applied to infected stands, results have been conflicting. In some cases, Armillaria root disease has increased; in others, it has decreased. Differences may depend on whether trees already are infected when fertilized.

Figure 14.— Root diseases can be managed by excavating infected stumps with heavy machinery.

Stump treatments for root disease

Stump treatments have been used both experimentally and in actual operations to prevent and reduce damage caused by root pathogens in Oregon. Two treatments have been tried: removing the stump from the soil (Figure 14), and treating the stump with chemicals or biological agents. By removing the principal inoculum sources in infected areas—primarily, infected stumps from harvested or dead trees—incidence of root disease on an infested site should decrease with time, even in highly susceptible tree species. Some studies have demonstrated this and even have shown increased seedling growth after stump excavation.

Applying borax (sodium tetraborate) has been shown to protect stumps from root pathogens. Operationally, it is used only for annosus root disease in Oregon. However, more recent studies in northeastern Oregon suggest that freshly cut stumps of true fir already may have annosus root disease, and the effectiveness of borax in preventing *additional* stump infection may be questionable, especially in stands that have been harvested previously. Also, boron's effects on nontarget organisms, such as ants and mammals, is being questioned.

Applying biological control agents, such as antagonistic fungi, to stumps looks promising but needs further testing to become operational. More research is needed in Oregon to assess the frequency of live tree root infections and the effectiveness of treating previously harvested stands with chemicals or biologicals. Using fungicides to protect living trees from underground infection by other root pathogens such as *Armillaria ostoyae* has been shown to be ineffective.

Fumigation to eradicate some root pathogens from infected stumps and even from living trees shows more promise than protectant fungicides. Fumigants such as chloropicrin, methyl bromide, Vapam, Vorlex, or carbon disulfide can eliminate *Armillaria ostoyae* from small stumps of ponderosa pine. Chloropicrin, allyl alcohol, Vapam, or Vorlex can eliminate *Phellinus weirii* from Douglas-fir stumps. Experiments have had some success in controlling laminated root rot with antagonistic soil fungi such as *Trichoderma* spp. instead of with fumigants.

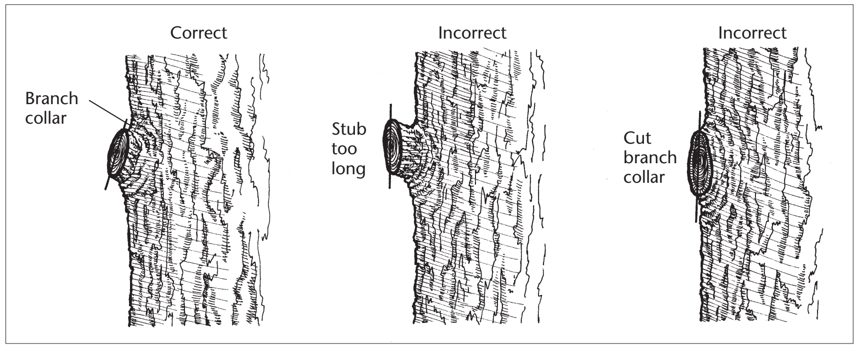
Artificial branch pruning

Natural or self-pruning is a slow process. The presence of saprophytic fungi, which hasten decay of the dead branches, is the most important factor in determining the rate of natural branch shedding. Artificially pruning lower crown branches, both living and dead, has been used to improve wood quality and value. Pruned live branches seal faster than pruned dead branches. Artificial pruning usually is combined with stand thinning to increase tree growth and sealing of branch stubs.

Advantages of artificial pruning are:

- Increased wood quality and value, because pruning creates tight knots or no knots in outer wood rather than the loose knots that form from dead branches in the natural pruning process
- Improved stand access during thinning operations
- Removal or prevention of infection from stem rusts and dwarf mistletoe

Figure 15.—Prune branches properly to minimize damage to the branch collar.



Disadvantages of pruning are:

- Risk of increased stem decay, ring shakes, frost and sun cracks, wetwood, cankers, bark and pitch pockets, and insect attack because of improper pruning
- Tree growth reduction if too many live branches are removed
- Sunscalding of thin-barked species
- Formation of epicormic branches

Pruning has been used most successfully to prevent white pine blister rust. Basal and stem cankers most often are the cause of death of blister-rust-infected pines. These infections are in trees 2 to 5 feet high, where lower branches are infected. Pruning the lower half of the live crown drastically reduces the likelihood of infection. Also prune infected branches in the remaining crown. Do *not* prune trees with cankers on the main stem, because these trees probably will die within the next few years.

For other stem rusts and for mistletoe infections, it usually is necessary to remove only infected branches.

Improper pruning can seriously damage trees through decay, cracks, and cankers. Branches should not be cut flush with the stem but flush with the branch collar (Figure 15). Stubs beyond the branch collar also should be removed because, on both living and dead branches, these provide entry courts for decay fungi. After pruning, cuts do not need to be painted; in fact, wound dressings have been shown to increase decay in some cases.

Conclusions

Tree diseases generally are much easier to prevent than to correct. By integrating disease management with forest resource management, the overall health and productivity of Oregon's forests can be improved and maintained.

Many forest practices are used in Oregon, but their long-term effects on forest diseases are not well known. Natural enemies of pathogens and associated insects also are influenced by forest practices. Healthy forests cannot be maintained solely through preservation. Intelligent, active forest management can manipulate forest diseases to improve and maintain the quality of Oregon's natural resources.

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Glossary

Abiotic—Nonliving.

Abiotic diseases—Diseases caused by nonliving factors such as water stress, temperature extremes, or soil compaction.

Advance regeneration—Regeneration that occurs before any special measures are undertaken to establish new growth.

Aecia—Yellow-orange spore pustules of a rust fungus.

Agent—Something that produces or can produce an effect, such as disease. Example: the fungus *Armillaria ostoyae* is the agent for Armillaria root disease. (See also **abiotic diseases** and **biotic diseases**.)

Alternate host—An organism that serves as a host for a parasite during part of the parasite's life cycle. (See also **host**.) Example: plants in the *Ribes* family (gooseberry and currant) are alternate hosts for the fungus that causes white pine blister rust.

Antagonistic fungi—Fungi that are damaging to other fungi. Example: the fungus *Trichoderma* is damaging to the root pathogen *Armillaria*.

Biological control—Controlling pests through the action of living organisms (whether naturally occurring or brought in by humans) rather than by the application of chemicals. Example: certain butterfly larvae feed on mistletoe plants, causing them to die.

Biotic—Living.

Biotic diseases—Diseases caused by living organisms such as fungi or parasitic seed plants (mistletoes).

Bole—Trunk or main stem of a tree.

Cambium—The thin layer of tissue in a plant that gives rise to new cells and is responsible for secondary growth.

Chlorosis (adj. **chlorotic**)—An abnormal yellowing or graying of plant parts, such as leaves, due to partial destruction of their chlorophyll. Chlorosis can be a symptom of plant disease.

Climax species—Those species of trees found in dominant positions in a fully mature forest.

Commercial thinning—Selectively removing trees that have commercial value. (See also **precommercial thinning**.)

Conk—The sporophore of a wood-invading fungus. Usually, conks look woody or leathery and grow on tree trunks or branches.

Disease—A sustained disturbance to the normal function or structure of a tree as provoked by biological (biotic), chemical, or physical (abiotic) factors of the environment.

Distress cone crop—An abundance of undersize cones produced by diseased trees as a symptom of advanced disease and decline.

Ectotrophic mycelium—A white to grayish crust of fungal growth on root surfaces, a sign of laminated root rot.

Elongate—Stretched out; lengthened.

Entry court—An opening in a host organism, such as a wound on a tree, through which disease organisms can enter.

Epicormic branches—Branches that form on the **bole** of a tree after increased light allows dormant buds in the bark to sprout. These branches can create knots that degrade lumber value.

Forest succession—The predictable pattern of forest regeneration after a disturbance such as a fire or a clearcut.

Fruiting body—See **sporophore**.

Fungus (pl. **fungi**)—A single- or many-celled organism that lacks chlorophyll and therefore cannot make its own food; it feeds on dead or living plant or animal matter.

Gall—Abnormal stem swelling. A sign of disease, such as western gall rust of lodgepole pine.

Genus (pl. **genera**)—A class, kind, or group of organisms marked by one or more characteristics. Example: pines belong to the genus *Pinus*. (See also **species**.)

Group-selection harvest system—A tree harvesting system designed to create an uneven-age stand by repeatedly cutting groups or patches of mature trees at short intervals over an indefinite period of time.

Host—An organism such as a tree, on or in which a parasite is living and from which it is obtaining its food. (See also **alternate host** and **secondary host**.)

Hyphae—The individual, microscopic, threadlike filaments of fungi.

Inoculum—The pathogen or pathogen part (such as spores or mycelium) that infects plants.

Internodal—Between the points on the stem at which a leaf or leaves emerge. **Internodal length** is the space between each year's twig bud scars.

Laminated decay—A **symptom** of laminated root rot in which decayed wood separates into sheets along annual growth rings.

Live crown ratio—The proportion of a living crown height to total tree height, usually expressed as a percentage.

Mycelial fans—White to cream-color sheets of fungus found inside the bark on the lower main stem of a tree or in roots. They are a **sign** of Armillaria root disease.

Mycelium (pl. **mycelia***)***—**The mass of interwoven threads (hyphae) making up the vegetative body of a fungus.

Offsite planting—Trees that are transplanted to a geographical area different from the one in which they originally grew, especially if the site characteristics are different.

Pathogen—An entity, usually biological such as a fungus, that can cause disease.

Pathogenic—Causing or capable of causing disease.

Precommercial thinning—Removing trees too small to have commercial value in order to achieve better spacing for the rest of the trees in the stand. (See also **commercial thinning**.)

Prescribed burning—The use of regulated fires to reduce or eliminate the unincorporated organic matter of the forest floor or low, undesirable vegetation.

Rhizomorph—An aggregation of hyphae into a cordlike or rootlike strand.

Salvage cutting—Harvesting trees that have been or are in imminent danger of being killed or damaged by injurious agents other than competition from other trees.

Sanitation cutting—Harvesting trees that have been or appear to be in imminent danger of being attacked by pests, in order to prevent spread of disease from one tree to another.

Sanitation–salvage cutting—See **salvage cutting** and **sanitation cutting**.

Saprophyte (adj. **saprophytic***)***—**An organism that lives on dead or decaying organic matter.

Secondary host—A tree or plant that is infected to a much lesser degree than a primary host.

Seed tree harvest system—Removing mature trees in one cutting except for a small number of seed-producing trees left singly or in small groups.

Seed zone—A geographical area containing trees that produce seed requiring the same site conditions as found in that area for optimum seedling growth and survival.

Setal hyphae—Small, wiry, reddish brown hairs found between sheets of decayed wood. The presence of setal hyphae is proof of laminated root rot.

Shelterwood harvest system—Removing mature trees in a series of cuttings over a relatively short portion of the rotation. This practice encourages establishment of essentially even-age reproduction under the partial shelter of seed trees.

Sign—The actual parts of the pathogen present or near the diseased plant. For example, mushrooms at the base of a tree may be a sign of Armillaria root disease. (See also **symptom**.)

Sp., **Spp.—**Abbreviations. Sp. means one species; spp. means two or more species within the genus named.

Species—A subcategory of organisms with one or more characteristics in common. Example: a species of pine is lodgepole pine, *Pinus contorta*. (See also **genus**.)

Spore—The principal reproductive unit of fungi and other lower-order plants, containing one or more cells.

Sporophore—In a fungus, a mass of **hyphae** in a specialized structure for producing **spores**.

Susceptible—Likely to become damaged as a result of contact with a disease **agent**.

Symptom—The reaction of the **host** plant to disease. Example: yellowing foliage may be a symptom of root disease. (See also **sign**.)

Telia—The final-stage **spores** in the life cycle of a rust fungus.

Uredia—An orange to brown mass of **hyphae** and **spores** of a rust fungus, forming pustules that break the outer surface of the **host** plant.

Witches' broom—An abnormal development of many brushlike, weak branches or shoots at one point on a tree. A **sign** of disease, such as broom rust or dwarf mistletoe.

Zoospore—A **spore**, such as from a fungus, that can move independently through water.

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