U.S. DEPARTMENT OF AGRICULTURE
Forest Service

FOREST PEST LEAFLET 50
September 1960

Western Gall Rust on Hard Pines

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Western gall rust (*Peridermium harknessii* Moore) causes trunk cankers and branch galls on most of the species of two- and three-needled pines in the West. It is particularly common on lodgepole, ponderosa, and Digger pines. On these hosts its range extends from the Mexican border to Alaska, and on jack pine it is reported eastward as far as Quebec.

Damage from gall rust in commercial stands occurs chiefly on lodgepole pine in the Rocky Mountains and, locally, in ponderosa pine from the Black Hills of South Dakota to the Pacific Northwest. Forest plantations, particularly of ponderosa and Scotch pines, have also been attacked severely.

Unlike the introduced white pine blister rust, which can eradicate its pine hosts, gall rust is a native pathogen which occupies a fairly stable niche in living forests. It affects the form, lumber content, and growth rates of pines, and kills individual trees, but it is not known to wipe out whole stands.

The Parasite

Like all other rusts, *Peridermium harknessii* is an obligate parasite: it does not grow in nature except in live hosts. In a pine gall or canker, thousands of fungus strands (hyphae) enmesh the cells of the inner bark, and penetrate inward along the wood rays as far as there is living tissue.

The first fruiting bodies, called pycnia, are produced inside the bark; they become apparent only when the pycnial fluid oozes out between bark fissures in the spring. In some regions gall rust pycnia are rare or lacking. Pycniospores cannot give rise to new infections, but they may aid in cross-fertilizing the fungus.

Other fruiting bodies, the aecia, are produced in spring and early summer of the second or third year after infection of the host, and usually every year thereafter so long as the rust lives, which may be for a century or two. Aecia develop under bark scales, and when mature appear as little white mounds of irregular shape on galls or at the edges of cankers (fig. 1). Aecia rupture during periods of high humidity, and thousands of orange aeciospores are liberated from each fruiting body. So many spores remain on the galls that one observer likened infested pine stands to "orange groves." Most aeciospores, however, are carried away by wind. Spore dissemination lasts from 3 to 8 weeks in a locality—in Rocky Mountain ponderosa pine it is completed by early July, but in high-elevation lodgepole pine spore dispersal continues through August. In dry habitats, production of aecia is closely related to times when moisture is plentiful. For instance

[1] Maintained by the Forest Service, U.S. Department of Agriculture, at Fort Collins, Colo., in cooperation with Colorado State University.

F—493460

FIGURE 1.—Rust gall from lodgepole pine bearing white spore sacs (aecia).

on Coulter pine near Julian, Calif., sporulation is ordinarily in April, but unseasonal rain or fog can bring forth an additional crop of aecia as late as June.

Gall rust aeciospores can infect pines, giving rise to new galls and cankers. In some regions this appears to be the only way in which infection occurs. Because the spores are minute and some of them can remain viable for more than a year, they can be windborne to infect distant stands.

Whether aeciospores can also infect alternate hosts, besides pine, remains to be proved. It has been reported that Indian paintbrushes (*Castilleja*), owl-clovers (*Orthocarpus*), cow-wheat (*Melampyrum*) and certain other plants of the family Scrophulariaceae are susceptible to gall rust, and that on these hosts the fungus gives rise to fruiting bodies (uredinia, telia, basidia) in a sequence parallel to that of white pine blister rust on *Ribes*. If this is true, as seems probable, then basidiospores from these hosts may cause much of the infection on pine, in late summer and early fall. Basidiospores of this genus of rusts are generally short-lived, and must be produced within a few hundred yards of susceptible pines in order to cause much damage.

Gall rust cannot be identified on Scrophulariaceae because no means is known for distinguishing it on these hosts from limb rust and stalactiform rust (called, on pine, *Peridermium filamentosum* and *P. stalactiforme*, respectively). All three rusts have gone under the name *Cronartium coleosporioides*, although they differ distinctly in their appearance on pine. Gall rust has also been called *Cronartium harknessii*.

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FIGURE 2.—Gall rust canker on lodgepole pine. The original gall is partially buried at the center; only the newest galls at the edges support spore sacs of the fungus.

Two other fungi easily confused with *Peridermium harknessii* are coastal gall rust, known tentatively as *P. cerebroides*, on Monterey, bishop, and knobcone pines, and eastern gall rust, *P. cerebrum*, on jack, Virginia, shortleaf, and other eastern hard pine species.

Effects on Pine

When gall rust invades pine bark, the cambial cells of the host begin to divide rapidly. The result is a woody gall, which at first is rather soft. Within a few years resin and other materials are deposited; these wastes solidify, and the gall becomes harder and more decay-resistant than normal wood.

Galls on branches and stem leaders become subglobose, pear shaped, or spindle shaped. Usually galls live but a few years, because when they produce aecia they disrupt the host bark and kill the shoots which bear them.

On larger trunks, which may become infected through branches or wounds, a gall may continue to develop for many years, forming a large burl which slowly encompasses the stem. More frequently this primary gall dies before the whole stem is girdled; rust hyphae invade tissue at each side of the original gall, and secondary ridges of swollen tissue develop. These in turn die, and the process is repeated, usually progressing laterally from the point of infection (fig. 2). Bark above and below the row of galls usually dies, so that old cankers are often vertically elongate.

On most pine species gall rust produces branch galls but few or no trunk cankers. This is true for

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FIGURE 3.—This ponderosa pine crown contained several hundred galls. Such trees are conspicuous because of their dying branches.

knobcone, jack, Digger, Jeffrey, Coulter, and Scotch pines. Trunk cankers are also uncommon on lodgepole and ponderosa pines in some areas, as northern Idaho. Cankers are especially abundant on lodgepole pine in the Continental Divide area of the central and northern Rocky Mountains and in northeastern Utah and southern Idaho. Cankers are prevalent on ponderosa pine in the Black Hills. Large trunk galls seem to be more common on ponderosa than on other pines.

Mortality, growth losses, and cull are the principal forms of damage caused by gall rust. The relative importance of these injuries varies by region and by host species.

Ponderosa and lodgepole seedlings are sometimes killed at the rate of thousands per acre in the Northwest, but such severe outbreaks are limited to only a few acres' extent. In these areas, trees that survive the seedling stage may continue to accumulate branch galls—often hundreds or thousands in a single tree (fig. 3). Where a large proportion of the branches is killed, annual increment decreases to a negligible figure, and trees finally die because of lack of photosynthetic surface.

Trunk cankers also can cause mortality, but they cause only slight growth loss before death. Normal increment usually continues until a tree is completely encircled by the rust. Girdling by cankers is not usually important in timber management because mortality from this cause is largely restricted to stagnated and overmature trees.

Cull caused by gall rust is entirely due to trunk cankers. Lodge-

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FIGURE 4.—A lodgepole pine made useless by trunk cankers. Cull in otherwise merchantable trees is the principal loss due to gall rust in much of the Rocky Mountain region.

pole pine trunks are sometimes completely deformed (figs. 4 and 5); such trees occupy space in the forest but produce no wood of value. More frequently cankers are responsible for partial cull and short log lengths. Cankers above stump height will ordinarily prevent use of trees for transmission poles, but utilization for posts, ties, mine props, or pulp may be possible. Cankers form a point of weakness in trunks, giving rise to wind breakage (fig. 6).

Ecology

Gall rust thrives in a variety of habitats, from the shore pine muskegs of Alaska to the edges of southern California deserts and outlying stands of ponderosa pine in Nebraska. Its altitudinal range is from sea level to near timberline, at least to 10,700 feet elevation in Colorado, at both extremes on *Pinus contorta*. The pathogen occurs in both dense and open stands, though it is probably more abundant in the latter.

In limited areas, gall rust may exert a marked effect on its surroundings. For instance, where ponderosa pine seedlings invade grasslands (formerly forested) in north central Idaho, they are apt to be killed back by an excessive number of galls, thus tending to maintain the area in grass.

Gall rust infects pines of all ages. Where injury is largely from trunk cankers, however, little damage results from infection after a stand is about 40 years old. This is true primarily because the mer-

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FIGURE 5.—Rust-twisted lodgepole pines left standing after a timber sale was completed.

chantable parts of trunks are no longer susceptible to direct infections at that age.

Vigorous pines are more apt to be infected by gall rust than are weak trees. This results in part from the greater surface area of new shoots on the faster growing trees, providing greater chance for infection. There are also differences in individual susceptibility to the parasite, at least among ponderosa and Scotch pines. In plantations of these species, heavily infected trees often grow with their branches interlacing those of rust-free trees.

Most infections occur on twigs of the current season. Less commonly, gall rust invades wounds in older tissues. A characteristic trunk canker does not penetrate to the centermost annual ring; this does not mean that an old stem was infected, but rather, the rust spread to the trunk from a gall on a branch base (fig. 7).

Favorable conditions for mass infection by gall rust do not occur frequently. An interval of 5 to 15 years between major rust outbreaks is typical of lodgepole pine in the Rocky Mountains. A certain year may be favorable for the rust throughout an area as large as a State. More frequently, however, attacks are not widespread; localized outbreaks can be discerned in

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FIGURE 6.—Trunk broken by wind at a gall rust canker. Transmission line poles, one of the chief uses for lodgepole pine, are seldom cut from infected trunks because of their susceptibility to breakage.

various parts of a single national forest. In an even-aged lodgepole stand, a majority of trunk cankers are apt to be at a particular height above the ground—the height of the branch whorls formed during the year of a rust outbreak. In most infested stands the height of cankers is 20 feet or less. Occasional stands have a concentration of trunk infections as high as 40 feet from the ground. In a few stands, many trunks are so markedly disfigured—with 10 to 20 cankers per tree—that no special periods of infection can be determined.

Galls and cankers are often gnawed by rodents, especially squirrels, chipmunks, and porcupines. Piles of small branch galls, which have been stripped to the wood by these animals, are common in some lodgepole stands. Rust hyphae and spores are probably carried to healthy trees by rodents, but wound infections that might have resulted from their chewing are not common.

Insects are also frequently associated with gall rust. Some devour aeciospores, and are thus beneficial; others such as the red turpentine beetle can also carry spores to other trees, and may spread the rust. A few fungi parasitize the aeciospores, thus depriving them of infective power, but natural control of the rust by this means seems to be slight.

Control

Removal of infected trees during thinning operations and in intermediate cuts is now the only practical way to control gall rust damage in forests. Presence of a few branch galls is not sufficient cause for cutting a tree; only cankered trunks need be removed.

Pruning branch galls has been practiced in plantations. As a means of preventing damage, pruning is probably seldom economic.

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FIGURE 7.—Infection spreading from a branch base. Most cankers in old trunks originated from branch galls near the main stem.

On the other hand, removal of basal branch galls to prevent spread of the parasite to trunks might be worthwhile if the operation could be carried out within 3 or 4 years of a rust outbreak.

At nurseries, seedlings bearing galls should be destroyed. This is particularly important where outplanting will be in regions free of gall rust. However, detecting 1-year-old galls on seedlings is difficult; aecia are lacking, and often the swelling is slight. Infection of nursery seedlings has been eliminated in one instance by removal of an isolated, nearby pine host of the rust. This method might not be practical where the rust is more generally present.

Experiments in the control of gall rust with antibiotic sprays are in progress. Results with related rusts have proved the usefulness of this method. Possibilities of breeding rust-resistant ponderosa pine are also being explored.

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U.S. GOVERNMENT PRINTING OFFICE: 1960 O—551080

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