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Fir Broom Rust

By Roger S. Peterson [1]

Fir broom rust on true firs (*Abies* species) is caused by the fungus *Melampsorella caryophyllacearum*. The disease is native in almost the entire range of firs in Eurasia and North America. The rust fungus occurs on its alternate hosts (chickweeds) beyond this range to 70° N. and 50° S. latitude. The disease is seldom more than a curiosity in the Eastern States, where few epidemics have been reported since it was first recorded in 1856. But in

[1] Forest pathologist, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture field headquarters at Logan, Utah, maintained in cooperation with Utah State University.

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Figure 1.—Rust witches'-brooms and associated dead tops are abundant in many stands of subalpine fir.

the Rocky Mountains and Great Basin, many stands are heavily disfigured because a few to dozens of yellow witches'-brooms occur on almost every fir (fig. 1). Similar brooms on spruce are caused by a different rust fungus, not discussed in this leaflet.

Symptoms and Damage

The most conspicuous and easily identified symptoms of fir broom rust are the bushy, upright branch proliferations or witches'-brooms, which bear annual, yellow needles (fig. 2). There are other brooms on fir, caused by mistletoes in the Pacific Coast States and the Southwest or by another rust (*Milesia pycnograndis*) in the Northeast, and occasional brooms of unknown origin, but only *Melampsorella* causes marked loss of chlorophyll and annual casting of all broom needles. By midsummer the new crop of needles is covered with orange rust spores. The infected branch or trunk becomes swollen at the base of a broom into a spindle-shaped or sometimes a nearly spherical gall or burl (fig. 3). The bark on old swellings, particularly on trunks, usually dies and becomes cracked, and open cankers may develop. Swellings and cankers may

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***Figure 2.*—In *Melampsorella* brooms, needles develop earlier in spring than healthy needles do, and are shed in autumn.**

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Figure 3.—**Cull due to trunk infections is the major economic loss caused by fir broom rust in Europe, but cull may be less important than other forms of damage in America.**

still be seen where the brooms have long since died and fallen.

Damage due to fir broom rust may be considered under three headings: timber volume loss, growth loss, and tree mortality. In central Europe, where the disease has been a major factor in fir management for more than a century, volume loss is regarded as the most important. Swellings or cankers in the merchantable trunk must generally be cut out; this creates odd or unusable log lengths. Cankers can provide infection courts for decay fungi that eventually enlarge the unusable section of the trunk. Top-kill by the rust also adds to cull. Infected wood is distinctive in grain and physical characteristics; it is one-third heavier, less easily split, but more brittle than normal wood. Thus, inclusion of even slight swellings in logs to be sawed results in defective boards.

Growth losses due to branch brooms have frequently been described as "noticeable" or "evident" in North America, but have not been adequately studied. Stunting is obvious in heavily broomed trees, but the extent of growth loss for different intensities of infection has not been determined.

Mortality can be caused by fir broom rust both directly and indirectly. Direct kill occurs when a large part of the tree crown is infected—from one broom on a seedling to a hundred or more on a large tree. Indirect kill occurs when the wind breaks trees at trunk infections, or when certain insects invade weakened trees.

Life History of the Causal Fungus

Melampsorella caryophyllacearum requires two types of hosts to complete its life cycle. Fir hosts in the United States include nearly all the native true fir (*Abies*) species. Subalpine fir (*A. lasiocarpa*), white fir (*A. concolor*), and California red fir (*A. magnifica*) are heavily attacked in some parts of their ranges. The alternate hosts are chickweeds: *Stellaria*, *Cerastium*, and other genera of the pink family or Caryophyllaceae. ("Chickweed" strictly applies to *Stellaria media*, but is here used to include related species and the mouse-eared chickweeds.)

Firs of all ages are infected from windborne basidiospores produced

on chickweeds. Infection probably occurs only in springtime when these spores alight on tender twig tissue recently exposed by the opening bud. A mesh of fungus threads develops in the host tissues after penetration by a germ tube from the basidiospore. Where the fungus grows into dormant buds, it stimulates their growth, giving rise in a year or more to the abnormal branches that form a broom. The fungus also stimulates cambial cells, so that infected tissue becomes active 2 to 4 weeks earlier in the spring than normal. The increased cellular activity causes swellings on stems and branches.

The fungus penetrates the live bark, the wood, and central pith, and derives energy from these tissues for its own growth and sporulation. Brooms usually die in 15 to 30 years, but by this time the rust may have penetrated the trunk or a larger branch. There it can survive and grow for many decades. If it should contact other buds, new brooms would be formed.

As long as the fungus lives in a broom, it produces annual crops of reproductive bodies on the needles, starting the year after infection. Reproductive bodies are of two sorts. The sexual spores are produced in droplets having a sickening sweet smell that attracts insects, which aid in fertilization. After fertilization, spore sacs (aecia) are produced (fig. 4). These rupture during moist periods from June to September and free the orange aeciospores.

Aeciospores are blown about by wind. Only those that happen to land on chickweeds under moist conditions cause infection. After 9 days to 2 weeks, urediniospores capable of spreading infection to other chickweeds are produced (fig. 5). The fungus overwinters in the bases of perennial chickweeds, and in the spring infects all their new growth. Large numbers of basidiospores are formed on the lower chickweed leaves for several weeks in May, June, and (at high elevations) July. Basidiospores are windborne and can infect fir tissue.

Thus the fir broom rust fungus has the same kinds of spores as the familiar *Cronartium* species that cause pine stem rusts. However, *Melampsorella* bears them at different seasons and is also unusual in being perennial on both types of hosts.

Millions of aeciospores per broom are produced in summer, yet in most areas they infect only a small percentage of chickweeds. On the other hand there are regions (such as Arizona and much of eastern America) where great numbers of basidiospores are produced, but they cause little infection on fir. Infection requires not only definite conditions of temperature and moisture but also a coincidence in proper development of fir shoots and of the short-lived basidiospores, so that years of abundant infection are probably rare.

Control

Silvicultural control of fir broom rust has long required major effort in intensively managed European

silver fir stands. At usual infection levels (2 to 15 percent of trunks in central Europe) a schedule of three thinnings is enough for gradual elimination of the disease without creating excessive openings. Cutting trees because they are broomed and extensive pruning of brooms are favored by some European foresters, but the general practice is to ignore brooms except insofar as they are indicators of trunk infection. Broom removal would in any event be regarded as only an indirect way of reducing trunk cankers, because in Europe the brooms themselves are not believed to be harmful.

Control of fir broom rust has not been attempted in the United States, and it is doubtful that it can or should be until intensive management of fir is justified in areas where broom rust is abundant. Better evaluation of damage (such as the abundance of cankers, their relation to decay, and the effects of brooms on growth rate) is needed to help foresters decide at what level of management intensity the control of broom rust becomes worthwhile.

In selectively cut stands, trees bearing rust cankers in the merchantable bole or brooms close to the bole should be removed where practical. Such trees are a poorer

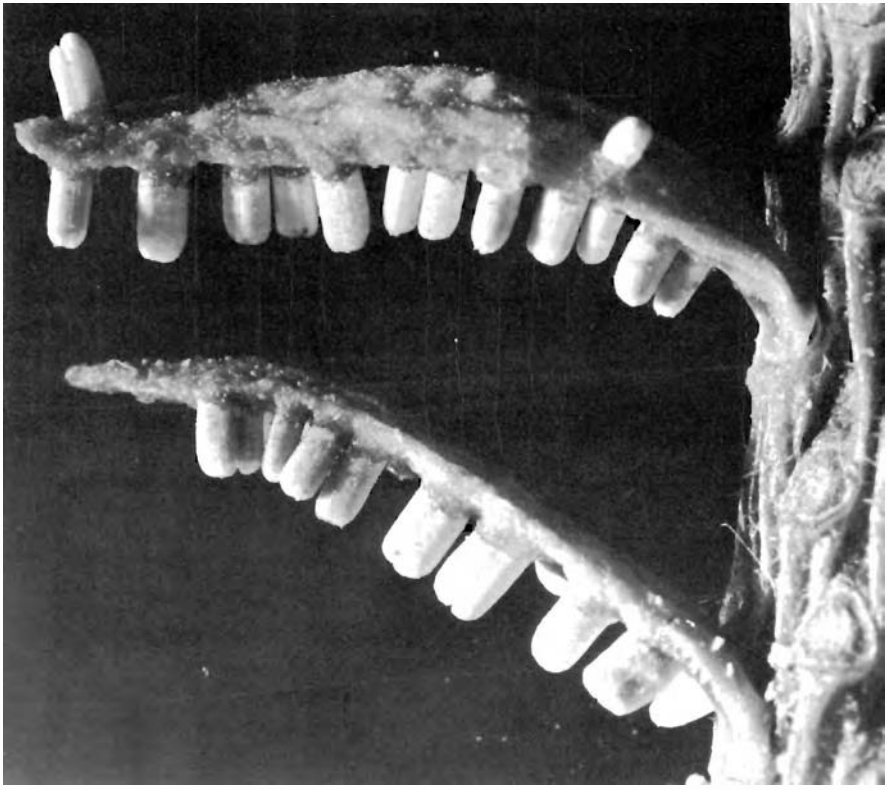

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***Figure 4.*—Aecia are produced on the needles in witches'-brooms. The aeciospores can infect chickweeds, but not fir.**

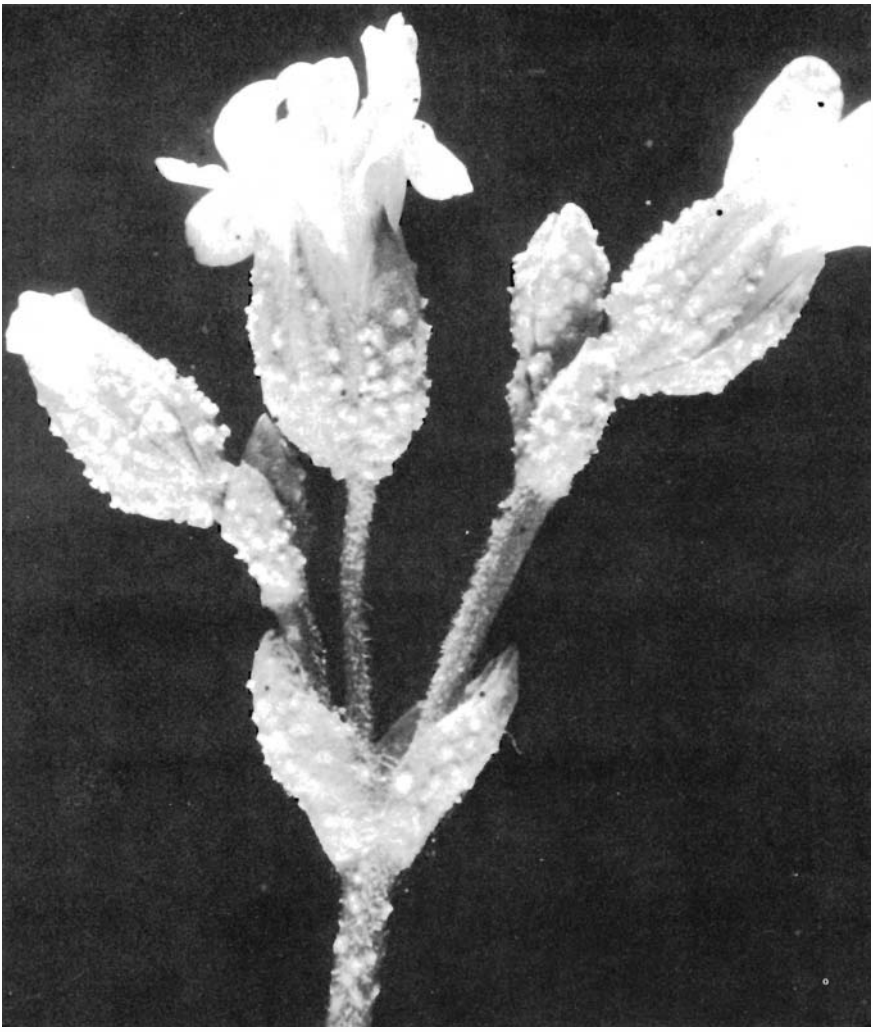

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***Figure 5.*—Urediniospores of the fir broom rust fungus are produced on leaves, stems, bracts, and flowers of its chickweed hosts (in this photo, *Cerastium arvense*). The basidiospores that infect fir are usually borne only on the lower leaves.**

investment for future harvest than are uninfected trunks. This statement probably applies also to trees bearing many brooms, regardless of trunk infection.

Except in Christmas tree plantings (where broom rust has been reported to be a problem on white fir) or in other intensively managed units, cutting out the brooms appears impractical. Chemical sprays have not yet proved to be effective against broom rust on fir.

Chickweeds, the alternate hosts, can be controlled by herbicidal sprays in agriculture, but at costs far higher than forest managers can afford for protecting fir. Mainte-

nance of closed forest stands presumably restricts growth of chickweeds, and this should be considered in thinning. But in the areas where fir broom rust is most abundant in the Intermountain area, fir forests and rangeland intermingle, and nearly all basidiospores of the rust fungus are produced on chickweeds growing in the rangeland rather than in fir stands. Grazing, burning, rodent control, and herbicide treatments affect abundance of chickweeds in various ways, but it is not known whether any control of fir broom rust could be achieved by range management practices.

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