White Pine Blister Rust

Otis C. Maloy, Emeritus Professor of Plant Pathology, Washington State University, Pullman, WA 99164-6430

Corresponding author: Otis C. Maloy. omaloy@moscow.com

White pine blister rust is probably the most destructive disease of five-needle (white) pines in North America. The causal agent originated in Asia and became established in Europe in the 18th century after highly susceptible American white pines were widely planted. The disease was introduced into North America about 1900 on white pine seedlings grown in European nurseries and by the 1950s had spread to most of the commercial white pine regions. The three most important commercial white pine hosts are eastern white pine (*Pinus strobus* L.), western white pine (*Pinus monticola* Dougl.) and sugar pine (*Pinus lambertiana* Dougl.). Other five-needle pines such as whitebark pine (*Pinus albicaulis* Engelm.) and limber pine (*Pinus flexilis* James) are also affected but generally have had little economic value. The rust has continued to spread into the southwestern forests where these and other five-needle pines occur. The rust fungus cannot spread from pine to pine but requires an alternate host, *Ribes* species, (currants and gooseberries, collectively called "ribes"), to complete the disease cycle. Early blister rust control efforts considered the alternate host to be the weak link in the infection cycle and an extensive and costly eradication program was conducted in the white pine regions of the United States from 1916 to 1967 (8). While the program succeeded in eliminating the major cultivated alternate host, the highly susceptible European black currant (*Ribes nigrum* L.), eradication of wild ribes, especially in the western U.S., did not succeed and was discontinued. An outgrowth of the ribes eradication program was a project to select and improve blister rust-resistant white pines, which promises to become the primary means of managing the disease.

For many years white pines were premium timber species and extensive stands existed, but logging largely depleted stands of eastern white pine before blister rust arrived in North America (8). Harvest of western white pine increased at a rapid pace after blister rust was discovered in the Pacific Northwest and preferential logging of white pine left residual stands of shade-tolerant species such as western hemlock and grand fir that replaced the white pine. White pine regeneration was further impeded by aggressive fire management, which eliminated fire as an ecological factor favorable to establishing white pine. Although natural reproduction occurs, young white pines are subject to rust infection and establishment of pure pine stands is not possible. Reestablishment of western white pine stands using several management tools is the current goal (2).

Symptoms

The earliest symptom of blister rust is a yellow or red spot on needles soon after infection occurs, but this symptom is indistinct and often overlooked. The disease is usually first detected by a slight swelling of the infected branch. As the disease progresses this swollen area becomes a spindle-shaped canker (Fig. 1) sometimes with a detectable difference in bark color at the margin of the canker. Determining the proximal margins of branch cankers is important when evaluating the feasibility of pruning to remove these branches. After 1 or 2 years the fungus produces spores from the canker. Eventually the canker will completely girdle the branch, kill it, and the needles distal to the canker become a distinct red color to produce a blister rust flag (Fig. 2).

Fig. 1. A branch canker on a young western white pine showing the typical spindle-shaped swelling. Removing this branch would probably prevent the fungus from entering the main stem.

Fig. 2. A young western white pine with multiple blister rust infections as indicated by the prominent red foliage ("flags") on several branches. This tree was typical of many in the area.

If the point of infection is on the main stem (i.e., bole or trunk) or relatively close to the main stem on a branch, cankers develop on the main stem. The bark around the margin of these cankers often has a distinct orange color (Fig. 3). Sporulation by the fungus occurs at the margins of these cankers and there may be abundant resin flow from the canker (Fig. 4). When the canker girdles the bole, the portion of the tree above the canker dies and the foliage fades to yellow and finally red. Usually cankers are low enough that the tree is killed but on larger trees only the top or one or more large branches may be killed initially, leaving the lower crown unaffected. These trees may live for many years although the weakened trees are subject to attack by other pests such as bark beetles and *Armillaria*.

Fig. 3. A young canker on the main stem near the base of a western white pine sapling showing the characteristic orange coloration of the bark around the border of the canker. This tree will probably be killed within a few years.

Fig. 4. A blister rust canker that has been excised by rodents feeding on the canker bark. Note the heavy flow of resin below the canker, a typical symptom of blister rust cankers on the main stem.

Causal Agent

White pine blister rust is caused by *Cronartium ribicola* J.C. Fischer, a heteroecious, macrocyclic fungus that requires two different host plants and involves five spore stages to complete its life cycle. White pines are the more important economic host and support the pycnial and aecial stages. *Ribes* species are the alternate hosts on which the uredinial and telial stages are produced. Basidiospores (sporidia) are the fifth spore stage and develop from the teliospores.

Disease Cycle and Epidemiology

Infection of pine occurs in late summer or fall by basidiospores produced from teliospores on ribes leaves. Basidiospore germ tubes enter needles through stomata and the fungus grows into the branches where the fungal mycelium becomes established, forming a blister rust canker that continues to develop and expand. Eventually the fungus may grow into the main stem from branch cankers located near the trunk. Occasionally the main stem of young trees is infected directly via needles attached to the stem and these trees are killed within a few years. Basidiospores are relatively fragile spores and do not spread over long distances but may travel for several miles and remain viable if climate and topography are favorable. In general, cool, moist conditions favor their survival, germination, and entry into the pines.

Pycnia (spermogonia) form at the margin of a canker and pycniospores (spermatia) are produced over the following year or two. Pycniospores function in some way to fertilize compatible receptive hyphae, resulting in mycelium that produces dikaryotic aeciospores the following year. Aecia erupt through the bark and appear as white blisters (Fig. 5). The white membrane ruptures to release masses of yellow-orange aeciospores (Fig. 6). Aeciospores are wind-borne, often for long distances, to infect the alternate hosts (ribes). Within a few weeks of infection, uredinial pustules develop on the lower surface of ribes leaves; urediniospores are the repeating stage and serve to spread the rust to other ribes in the vicinity. Hair-shaped telial columns, consisting of rectangular or fusoid teliospores develop from the lower leaf surfaces of infected ribes, usually emerging from uredinial pustules but occasionally erupting directly from infected leaf tissue.

Fig. 5. A typical blister rust canker on western white pine showing aecia before the peridial membranes have ruptured to release the aeciospores.

Fig. 6. A blister rust canker after the peridial membranes have ruptured showing the yellow-orange masses of aeciospores that are wind-disseminated to initiate infection in ribes leaves.

Management

Nurseries. Blister rust infected pine seedlings from European nurseries carried the disease to North America and management of the disease may be considered in nurseries. However, if all ribes are removed from the vicinity of a

nursery, including a buffer zone of about 1000 feet, impact of the disease should be minimal. The disease should be even less of a concern if rust-resistant stock is being grown.

Ribes Eradication. Although early ribes eradication programs were discontinued as unsuccessful, ribes are still mentioned as a concern in blister rust management (1,3,5,6). Removal of ribes is labor intensive, costly, and may not be feasible in most cases, but may be justified where ribes bushes are not numerous, easy to locate and remove, and of highly susceptible species (Fig. 7). However, in some situations such as high hazard zones, blister rust spores can be blown in from ribes plants outside of a management area, thereby reducing the benefit of local ribes eradication. It should also be noted that not all ribes are equally susceptible to blister rust. Some red-fruited currant varieties are highly resistant or immune to the disease.

Fig. 7. Abundant ribes growing along a stream in the vicinity of the white pines shown in Figs. 2 and 8.

Rust Hazard Zones. In the course of the ribes eradication program it was observed that infection often occurred at distances greater, perhaps a mile or more, than the ribes-free zones established around white pine stands. This long-distance movement of basidiospores was more likely in low-lying areas where cooler air settles. Studies in the Lakes States showed that topographical depressions and forest openings with diameters less than the height of the surrounding trees retain cool most air and maintain conditions favorable for basidiospore deposition and infection of pines (11). These areas are designated as high hazard zones and should be avoided when planting white pine. However, hazard zone guidelines are not universally applicable and must be developed for different areas and regions (1,6).

Pruning. Pruning was considered early as a means of controlling blister rust on valuable ornamental trees (9) and in recent years is recommended for forests and plantations (1,2,3,5,6,10). Like ribes eradication, pruning is labor intensive, costly, and requires a certain degree of judgment and skill. Several pruning operations may be required over a period of time, thereby increasing the cost even more.

Pruning can serve several functions:

(i) There are reports (6,7) that a majority (95% or more) of blister rust infections occur within 3 m (10 feet) of the ground and removing the lower branches eliminates these primary infection points of the pathogen. However, some infections do occur above this height, especially in advanced reproduction and pole stands, making pruning unfeasible in these cases. Guidelines for pruning can be obtained from state and federal foresters in a given area but pruning usually is restricted to the lower 6 to 8 feet of the tree and does not remove more than 50 percent of the live branches.

(ii) Infected branches can be removed before the fungus enters the main stem of the tree (5). Generally, removing cankers beyond 4 to 6 inches from the main stem (depending on size of the branch) can effectively prevent entry of the fungus (6,10). However, if cankers are less than 4 to 6 inches from the bole the chances are great that the fungus is already in the main stem and pruning is not effective. Cankers beyond 24 inches from the bole probably will self-prune before the fungus can reach the main stem and are not a threat to the tree.

Missing a potentially lethal branch canker can negate the benefits of removing infected branches, and trees with multiple branch cankers or cankers close to the bole do not merit pruning. Since blister rust does not spread from pine to pine, these trees do not constitute a hazard to the remaining healthy trees.

(iii) Restriction of air movement and shading by the lower branches promote cool, humid conditions that favor blister rust infection (1). Removing the lower branches increases air circulation and sunlight penetration into the area where most infections occur in younger trees. However, maintaining an overstory over young trees reduces dew formation on needles that is favorable for infection (6).

(iv) In addition to the objective of blister rust management, pruning can improve timber quality by producing clear, knot-free lumber from the pruned portion of the trunk. This requires removal of branches to the height of the first saw log, usually 16 to 18 feet from the ground, necessitating several pruning operations and special equipment.

Disease Resistance. Efforts have been made over the past 50 years to develop rust-resistant white pines and seed of blister rust-resistant western white pine is now available. Information about obtaining seed or seedlings is given by Fins, et al. (2). The level of resistance is reported to be approximately 66 percent (2) and over-planting by about 50% is required to guarantee full stocking at harvest. There is some question about the exact amount of resistance and how these rust-resistant trees will respond over time but in the relatively short term plantings evaluated to date, i.e., 8 to 25 years, the resistant trees have had about half the infection as unimproved trees (2). Rust resistance breeding programs are also being carried out with eastern white pine and sugar pine, but seed of resistant lines of these species is not yet available to the public.

Selection of apparently resistant trees in established stands as a seed source has been recommended (4) but the success of this practice is not known. Such trees often occur in areas where blister rust is severe and selection pressure for disease resistance is high (Fig. 8). It is suggested that progeny from these trees will be sufficiently resistant to survive until merchantable; about 60 years on good sites. However, these apparently resistant trees may simply have escaped infection for one or more reasons and their progeny will be as susceptible as any other white pine. Disease escape poses one of the problems in developing disease resistance in trees, necessitating extensive inoculation testing of the progeny to ensure that lack of disease is due to genetic factors.

Fig. 8. An apparently rust-free western white pine growing in proximity to the ribes shown in Fig. 7. The picture was taken from the location of the ribes.

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