Buffer Removal

Buffer removal, or cutting a strip of trees between an expanding laminated root rot center and the adjacent portion of the stand that is judged to be healthy, is a mitigative strategy suggested for laminated root rot. Because it is believed that the fungus requires live roots to spread, cutting trees to create a buffer zone of dead roots around an infection center should protect the rest of the stand from becoming infected. Buffer removal is not a new concept as evidenced by its many previous names: (1) clearcutting—cutting out the larger foci and about 20 meters (66 feet) into the surrounding stand (Childs 1955); (2) narrow clearcuts—clearcutting narrow areas at the edge of infection centers (Childs 1963); (3) surround cutting—cutting a swath of at least two trees beyond symptomatic trees (Wallis 1976); (4) patch-cut—cutting all susceptible trees in disease pockets and those within about 15 meters (50 feet) of visibly infected trees or stumps (Hadfield and Johnson 1977); (5) removing pathway trees—cutting all symptomatic host trees and neighboring nonsymptomatic host trees occurring within a zone that extends two normal tree spacings beyond trees with sparse, yellow foliage (Hadfield 1985); and (6) bridge tree removal—cutting all trees (likely infected trees plus bridge trees) within 10 meters (33 feet) of laminated root rot center boundaries (Sturrock and Fraser 1994).

An early test of the buffer removal concept looked at the effect of trenching on the spread of laminated root rot in a 20-year-old Douglas-fir stand (Wallis and Buckland 1955). Two trenches, each 30 centimeters wide and 45 centimeters deep (12 by 18 inches), were dug: the first was around a disease center; the second, parallel to the first and 8 meters (25 feet) away, isolated a buffer of nonsymptomatic trees. When the trial was terminated 20 years later, the trenches were credited with having prevented the spread of the fungus into the isolation zone despite the fact that some trees within the zone had died from laminated root rot. One explanation of this anomaly is that there were some nonsymptomatic-infected trees in the isolation zone at the time of trenching. This result should serve to caution resource managers that the establishment of buffers around disease centers may not completely isolate the disease and protect the uninfected portion of the stand.

A root disease survey should be conducted before buffer removal is seriously considered. If the survey shows that the disease occurs in discrete centers and final harvest is more than 10 years away, buffer removal will likely prevent spread of the disease and may be worth doing. If distribution of the fungus is diffuse, then infected trees outside of centers will serve as foci for disease spread and buffer removal may waste resources and unnecessarily sacrifice potential crop trees.

developed for proper handling and introduction of antagonists into stumps, and where necessary, treatments must be developed to enhance the activity of antagonists. Although progress has been made, development of practical biological controls likely will take many years.

Reforestation choices—

Species manipulation—Tree species that are of low-susceptibility (tolerant or resistant) or immune to *P. weirii* (see table 1, p. iii) can be established on sites infested with the fungus to reduce inoculum or to hold the effects of the disease within acceptable limits. The choice of alternate species for infested sites will be limited by both site conditions and the silvics of the species. It is apparent that conifer species differ in their susceptibility to the pathogen. The susceptibility ratings in table 1 are based on inoculation tests and field observations and trials over several years, and represent a near consensus of pathologists working in western North America.

The attractiveness of planting low-susceptibility species to reduce the impact of laminated root rot has caused considerable effort to be focused on this approach in the last two decades. Concepts that have been or are currently being tested include planting low-susceptibility species: planting a mixture of immune or low-susceptibility species with susceptible species to break continuity of susceptible root systems and thereby slow spread of the disease; and rotating the conifer crop with immune species (hardwoods).

Preliminary results from planting low-susceptibility species show little or no mortality from laminated root rot. Preliminary results from mixed species plantings suggest that this approach does not significantly reduce mortality of susceptible species (Wallis 1976). Of hardwoods used in field trials, red alder has received the most attention because of its hypothesized function as "a natural biological control of laminated root rot" (Nelson and others 1978). Red alder functions as a productive occupier of the site by keeping susceptible host species out while producing desired benefits (fiber, cover, and site enhancement), thus allowing time for *P. weirii* inoculum to die. Studies with red alder continue.

As a practical matter, while research continues on other strategies, species manipulation remains the strategy of choice on sites heavily infested by *P. weirii.* With the crest of the Cascade Range in the United States and the crest of the Coast Range in British Columbia as dividing lines, to the west red alder, bigleaf maple, western redcedar, and western white pine are planted, and to the east, pines (lodgepole, ponderosa, and western white), western larch, incense-cedar, and hardwoods are used as alternative species. In southwest Oregon, the recommended alternative species, depending on the site, include ponderosa pine, sugar pine, western white pine, incense-cedar, western redcedar, and hardwoods.

In northern Idaho, western Montana, and the Blue Mountains of Oregon and Washington, increasing species diversity is the strategy of choice for reducing losses to *P. weirii.* Commercial tree species resistant to or tolerant of *P. weirii* include western white pine, ponderosa pine, lodgepole pine, western larch, and western redcedar. Although western hemlock may prove to be resistant to killing by *P. weirii,* it often develops extensive butt rot. Uncertainty about the ability of this species to survive for extended periods in the presence of the pathogen suggests caution when using this species on infested sites.

Resistant Douglas-fir-Given the long life of a natural stand, the near ubiquitous distribution of *P. weirii* in Douglas-fir and grand fir timber types, and the ability of the fungus to survive in Stumps and roots for extended periods, it might be expected that highly susceptible species, such as Douglas-fir, would have been reduced to scattered pockets. Yet, this is not the case; these species thrive in extensive stands. The total area of commercial forests with reduced fiber production due to laminated root rot is significant, but less than might be expected, given the spread rate of the pathogen. The cause for moderation in disease losses is undetermined but may be associated, at least in part, with variable resistance within host species.

Differential resistance of Douglas-fir to attack by *P. weirii* is reported by Buckland and others (1954), who suggest that trees showing tolerance to the fungus are those able to compensate for killed roots by producing callus tissue and adventitious roots (fig. 6) and thus maintain their vigor. Differential resistance of rooted cuttings to infection by *P. weirii* was observed among selected Douglas-fir clones (Entry and others 1994). Another host response to infection may be the active production of either mechanical or chemical defenses, which limit the wood colonized by the pathogen. Evidence of this can be seen in stumps having centers hollowed by P. *weirii* (fig. 20), but excavation and examination reveal no sign of the fungus in any of the major roots. These are only two of likely many forms of host adaptation to P. weirii. Whether these responses are genetically controlled, environmentally controlled, or a combination of the two is not known. Additional research is needed on *P. weirii* -host interactions. As yet, tree improvement programs have not been established to select trees with apparent resistance to *P. weirii.*

Spacing strategy-Proper spacing and location of seedlings may greatly reduce laminated root rot development in infected coastal Douglas-fir stands. Observations made during stump and root excavations in three coastal stands each growing on sites with deep soils, led to the conclusion that there are few root contacts between Douglas-fir aged 60 years or less and spaced at least 4 meters (13 feet) apart.[6] Thus, if trees in regenerating stands are at least 4 meters apart and growing in deep soil, their roots should not frequently come in contact until sometime after stand age 60. The following spacing strategy is proposed for infested coastal stands with deep soils: plant seedlings at a normal spacing, then thin as soon as possible after the stand is considered established but before stand age 10 years. Select as crop trees those seedlings furthest from residual stumps and spaced at least 4 meters apart. Stands may have to be treated at 5-year intervals to remove volunteer seedlings of host species. The goal of this strategy is to lengthen the normal time to closure of the root systems in the replacement stand. Although some seedlings will contact residual inoculum and die from laminated root rot, secondary infections, which would normally occur across root contacts in a dense stand, will be reduced. Rooting habit of Douglas-fir will differ depending on the soil type. This strategy is less likely to be successful where the soil conditions encourage a shallow, spreading root habit.

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[6] Unpublished data, Walter G. Thies.

Modeling

Over the past two decades, significant progress has been made to incorporate the effects of root diseases into growth and yield models. In the Western United States, the Western Root Disease model, an extension of the Forest Vegetation Simulator model (formerly called PROGNOSIS) has been developed. In British Columbia, two models—the Tree and Stand Simulator (TASS) and the *P. weirii* Root Rot Simulator (ROTSIM)—have been linked to predict spread and impact of laminated root rot (Mitchell and Bloomberg 1987). Users supply information on stand structure, site, disease, and inoculum condition as either keywords or numeric input to the models. Based on host presence and stand information, the models then calculate the rate of spread of the fungus and the number of trees within diseased areas that will become infected. The models can simulate the combined effects of root disease, windthrow events, or management activities such as stump removal that may reduce inoculum in stands. The Western Root Disease model also can simulate the combined effects of root disease and bark beetle attack. With the development of user-friendly guides and training sessions, resource managers in the United States are able to integrate the Western Root Disease model into their stand analyses (Stage and others 1990). Validation of the TASS-ROTSIM model is currently underway in British Columbia, with the goal of producing managed-stand yield tables for use by resource managers.

Excavator Specifications
(minimum)

Operating weight: 20,000 kilograms (45,000 pounds)

Power: 118 horsepower

Bucket reach: 11 meters (36 feet)

Bucket width: 1.0 meter (3 feet)

Bucket capacity: 1 to 1.75 cubic meters (1 to 2 cubic yards)

Machine width: 3.2 meters (10 feet)

Track pad width: 80 centimeters (30 inches)

Hydraulic thumb

Source: Thies 1995.

Equipment—The History

The equipment recommended for stump removal has changed significantly since the mid-1970s as a result of both research and operational activities. Traditionally, stumps were removed by using a bulldozer with a solid blade, which moved more soil than was desirable. Large holes were created and topsoil was mixed with subsoil. A bulldozer with a toothed (brush) blade successfully removed stumps but with little movement and mixing of soil. Use of log forks on a bulldozer caused even less soil disturbance. Log forks, with 1 meter (3 feet) long, tusklike projections that point forward and curve up slightly, were pushed into the soil on either side of a stump, and pushed or pried the stump from the soil. As the stump was lifted and shaken, much of the soil clinging to the roots fell back into the hole. Forks produced smaller holes, moved and mixed less soil, and probably removed more infested roots than did blades. A vibrating stump puller combines lift and vibration to separate stumps and root systems from the soil with little site disturbance (Arnold 1981). This equipment has been successful at removing stumps up to 50 centimeters (20 inches) in diameter. Recently, excavators with a standard bucket and a hydraulically operated gripping thumb (fig. 25) have been recommended for stump removal for both operational and research purposes (Bloomberg and Reynolds 1988; Thies 1987, 1995). This equipment can dig or lift stumps while its tracks remain stationary, thereby causing less compaction and disruption than equipment that relies on a pushing force. Much of the site and soil damage caused by older techniques resulted from tracks moving and slipping when the force necessary was applied to push the stumps out.

Synopsis

Laminated root rot, caused by *P. weirii* is a serious root disease affecting Douglas-fir and other commercially important species of conifers in northwestern North America. The disease is estimated to reduce timber volume and growth by over 4 million cubic meters (157 million cubic feet) annually.

Laminated root rot is often first detected during ground surveys when stand openings with windthrown and standing dead diseased trees are observed. These opening or disease centers differ in size from one to several hectares and may be occupied by hardwoods or disease-tolerant conifer species.

Crown symptoms caused by *P. weirii* include reduced terminal growth, yellowing, and stress-induced cone crops. Specific signs of the fungus include ectotrophic mycelia on roots, reddish-brown stain in infected roots or on Stump tops, laminated decay, and distinctive setal hypha associated with ectotrophic mycelia or advance decayed wood.

Phellinus weirii is only known to spread by root contact between infected trees or infected stumps and susceptible trees. The fungus infects and decays host roots, which results in reduced uptake of water and nutrients and weakened structural support. As the fungus spreads and kills more trees, characteristic stand openings appear and expand at about 30 centimeters (1 foot) annually.

When infected trees die, the pathogen may continue to live saprophytically for at least 50 years in colonized, old-growth stumps and for several decades in second-growth stumps. The inoculum potential of colonized stumps decreases with time. Basidiospores dispersed by the fungus are believed to be unimportant in initiating new infections.

The occurrence and distribution of *P. weirii* and the effect it has on any one stand will depend on several factors, including site conditions, stand age, and the disease history of the stand. The presence of *P. weirii*-infected trees may increase other pest problems in a stand, such as bark beetle activity. Accurate assessment of disease distribution in stands through a root disease survey is a necessary precursor to the selection of disease management strategies.

There are several management strategies for laminated root rot. A resource manager will choose an appropriate strategy based on several factors, including stand age and site conditions, local economic or other constraints, and desired outcomes. Strategies may be applied during stand development through modifications to planting or thinning regimes. Most strategies for managing laminated root rot are best conducted at the time of stand regeneration when inoculum can be reduced through stump removal or other means or when tree species that are immune or of low susceptibility to the fungus can be planted. Research continues on management strategies and on integrating knowledge of laminated root rot into growth and yield models.

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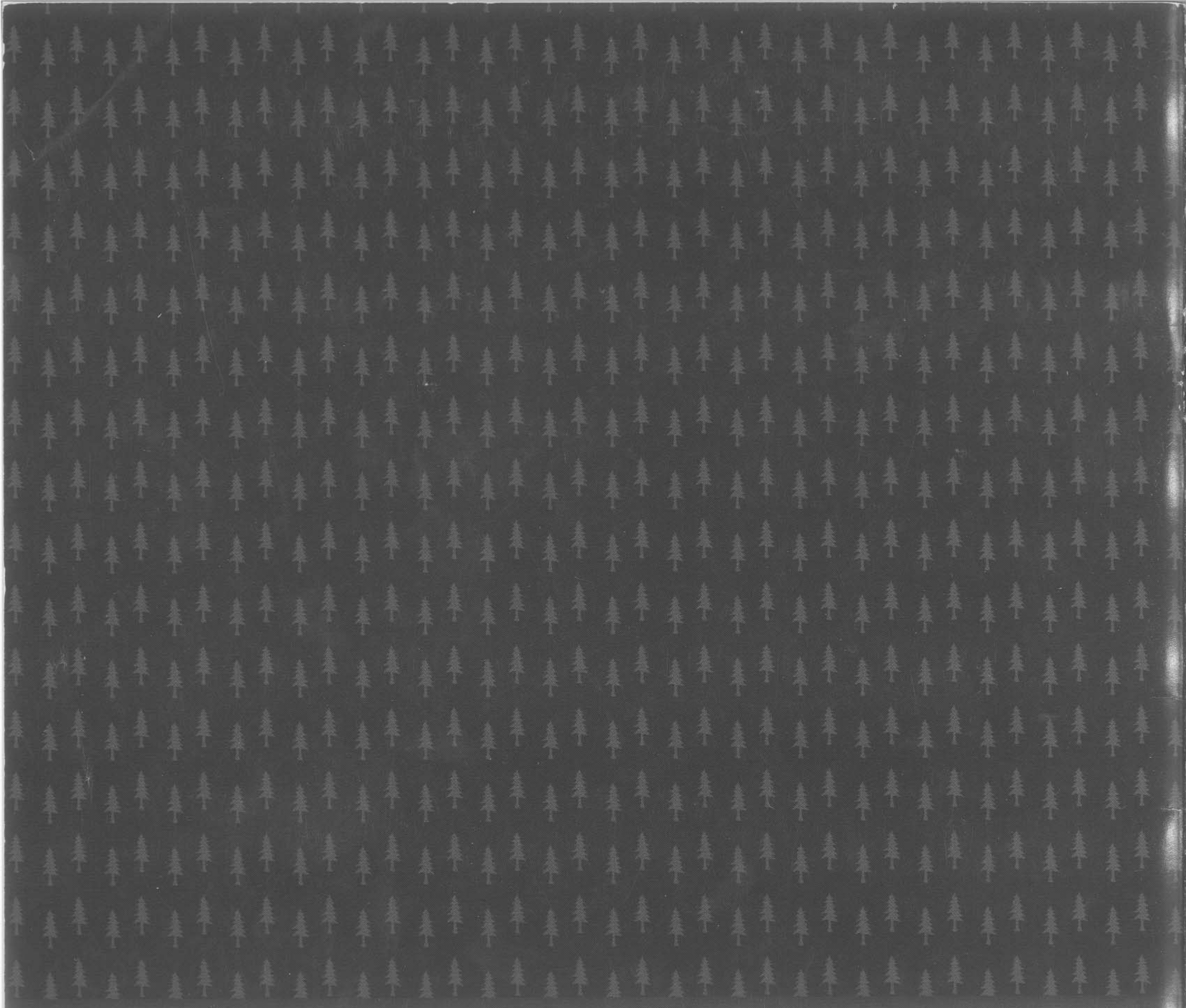

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