Identifying Infected Ponderosa Pine Stumps To Reduce Costs of Controlling *Armillaria* Root Rot

Lewis F. Roth, Leonard Rolph, and Sally Cooley

ABSTRACT—Root rot of ponderosa pine (Pinus ponderosa *Laws.) caused by* Armillaria mellea *(Vahl. ex. Fr.) Quél. can be controlled by removing the stumps that support the fungus in the soil. Concentration of effort on those old-growth stumps and roots most likely to be infected can help reduce control costs. In studies in south-central Washington, identification of infectious stumps was uncertain when based on appearances of the stumps alone. Some distinction was possible on the basis of age, older stumps being infected more often than recent stumps. Small dead trees near the stumps, or at the fringe of root spread, accurately indicated infection in the stump, but often seedlings remained uninfected around diseased stumps. Root rot is most evident in pole-sized timber; most large stumps in or near pockets of disease in this timber are infected and, in stands under management, are appropriate for treatment.*

After repeated cutting of old-growth ponderosa pine in forests of the Pacific Northwest, *Armillaria* root rot sometimes becomes severe enough to limit further productivity (Shaw et al. 1976, Shaw and Roth 1976). Survey data and observations from several national forests (Filip 1977, Filip and Goheen 1978, USDA Forest Service 1978) indicate an increasing problem.

While much remains to be learned about spread, we know that *Armillaria* grows from tree to tree when living roots contact dead roots colonized by the fungus in its saprophytic state (Shaw 1974). *Armillaria* survives from one tree generation to the next in infected main roots of stumps and snags (Adams 1972, Shaw and Roth 1976). Its spores seldom cause infection (Shaw and Roth 1976), however, and hence its potential for fast, wide dissemination is limited.

The disease can be controlled by land clearing to remove infectious roots (Roth et al. 1977, Roth and Rolph 1978). As general clearing is expensive—and also wasteful where it destroys timber of premerchantable size—less costly, selective means are needed.

Filip and Roth (1977) killed *Armillaria* in small stumps by injections of soil fumigants, but further development is needed to make the method economically feasible. Roth et al. (1977) combined root rot control and commercial thinning to improve well-stocked stands and to protect them against serious losses. Infected or threatened trees were salvaged by pushing them from the ground, or by logging with subsequent stump removal to expose roots to the dry air and thus kill the fungus (Munnecke et al. 1976). In addition to meeting thinning and salvage objectives, trees were selected so as to remove as much infected root material as possible and to create zones of root-free soil as barriers to disease spread (*fig. 1*).

While big stumps, the primary source of infection in young stands, can be removed with heavy equipment, the costs will be high, removal usually will be partial, and the site may be seriously damaged (*fig. 2*). In spite of these drawbacks the measures might be justified if the effort can be concentrated on a small number of

Figure 1. Old-growth ponderosa pine stump surrounded by young timber, much of which is being killed by Armillaria *persisting in the stump.*

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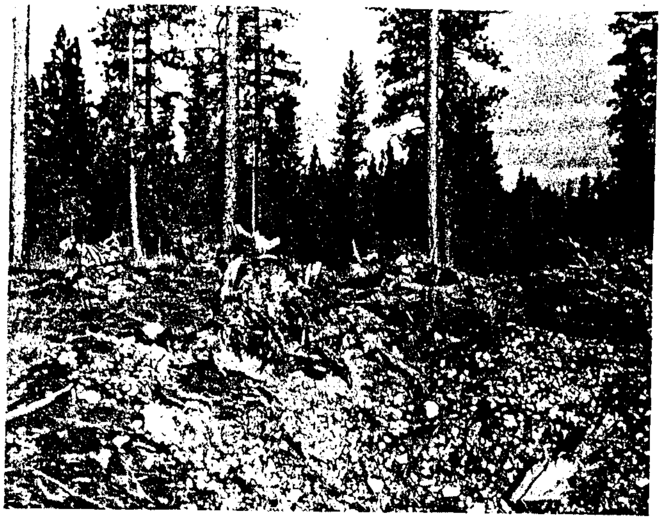

Figure 2. Old-growth stumps removed to control Armillaria *root rot. The site has been badly damaged by displacement of the topsoil, exposure of underlying rock, and resulting unevenness.*

critically located stumps and can be accompanied by some site restoration. This paper describes an attempt to rate stumps of old-growth pine according to probability of their being infected.

Methods

The study was on the Glenwood management block of the St. Regis Paper Company's lands in Klickitat County, south-central Washington.

One hundred old-growth stumps scattered through a 60-year-old stand that had been marked for commercial thinning and root rot reduction (Roth et al. 1977) were numbered and classified as accurately as possible by time of cut. Most of the old growth had been removed in an initial harvest in 1942 and in three smaller intermediate cuts in 1953, 1966, and 1974. These old trees had been marked for cutting according to generally employed risk-class principles with respect to attack by bark beetles (Keen and Salmar 1942, Smith 1962). Included in the sample were roots of 16 old-growth snags of trees that had died prior to 1942. Half of the stumps were in a lightly infected part of the stand. Twelve were in an area that appeared to be intermediately diseased, and the remainder were in a heavily diseased location.

Reliable indicators of *Armillaria* infection are absent from old-growth stumps. Mycelial fans that dependably occur in dying trees between bark and wood at ground level do not develop in vital but diseased trees, nor in their stumps. Distinctive black, string-like rhizomorphs occur too irregularly to be of much value in detection. Fruiting is uncommon and irregular. Excessive production of pitch, common in young trees, is lacking. Since the stumps offered no visible clues to their condition, the surroundings of each one were examined for indirect evidence:

I. General characteristics of stocking
   A. Presence of natural openings or of artificial openings caused by earlier logging
   B. Stand composition
   C. Size of surrounding trees
II. Infection condition as judged from symptoms in surrounding trees
   A. Infection pockets in pole timber as opposed to general distribution of infection
   B. Mortality of saplings established near the stump or at the limits of the natural openings.
III. Location of the stump with respect to diseased or threatened young-growth trees appropriate for removal during sanitation thinning (Roth et al. 1977).

Each stump was rated as infected or uninfected on the basis of these observations.

The stumps were pushed, or partially excavated and then pushed, from the ground with a D-8 tractor and the roots of each were described as to exent of deterioration and these signs of *Armillaria:* (1) white fungal growth under the bark of roots, (2) distinctive soft, wet, somewhat fibrous, golden decay of the roots, or (3) other notable features. Cultures were made of samples from symptomatic root systems, from the decay in systems that were questionably symptomatic, and from systems situated in suspected locations with regard to sources of infection.

Results

No notable differences in frequency of infection were found between root systems of stumps from locations that were lightly and intermediately diseased, as judged from mortality in nearby young growth. Data in these categories were therefore combined as "light."

Diagnosis based on symptoms was augmented by the cultures, which confirmed the presence of *Armillaria* in 10 of 20 root systems where infection had been uncertain and added 3 asymptomatic systems to the list of those infected. Culturing failed to disclose the fungus in only 3 of 35 clearly symptomatic systems. Success of obtaining *Armillaria* in culture decreased among older, more decomposed stumps. All isolation attempts from the newest infected stumps (*fig. 3A*) were successful. They were 91 percent successful where the larger roots had not yet extensively decomposed (*fig. 3B*). Where the roots had deteriorated to the digitate and truncate stages (*fig. 3 C, D*) the fungus was recovered from 55 percent of the stumps attempted (*table 1*).

Forty-three percent of all root systems were infected in the lightly diseased areas and 84 percent in the heavily diseased areas. Both infection frequency and degree of decomposition increased with time since cut. Frequency of infection in the less diseased parts of the stand increased from 29 percent in the most recent stumps to 60 percent in the snags (*table 2*). Two-year-old stumps showed almost no decay whereas the snags, then the 35-year-old stumps, were most highly decomposed. In the heavily diseased areas differences among ages were obscured; here nearly all stumps were infected except for about one-third of the most recent.

Infection was so general in the heavily diseased area that aboveground indicators (stump age and location) used to classify the stumps showed little sensitivity.

At either level of disease severity, no differences emerged that could be used for rating the probability of infection of the stumps when comparisons were made between stands of pure pine as opposed to mixed; poles as opposed to saplings; or dense stocking as op-

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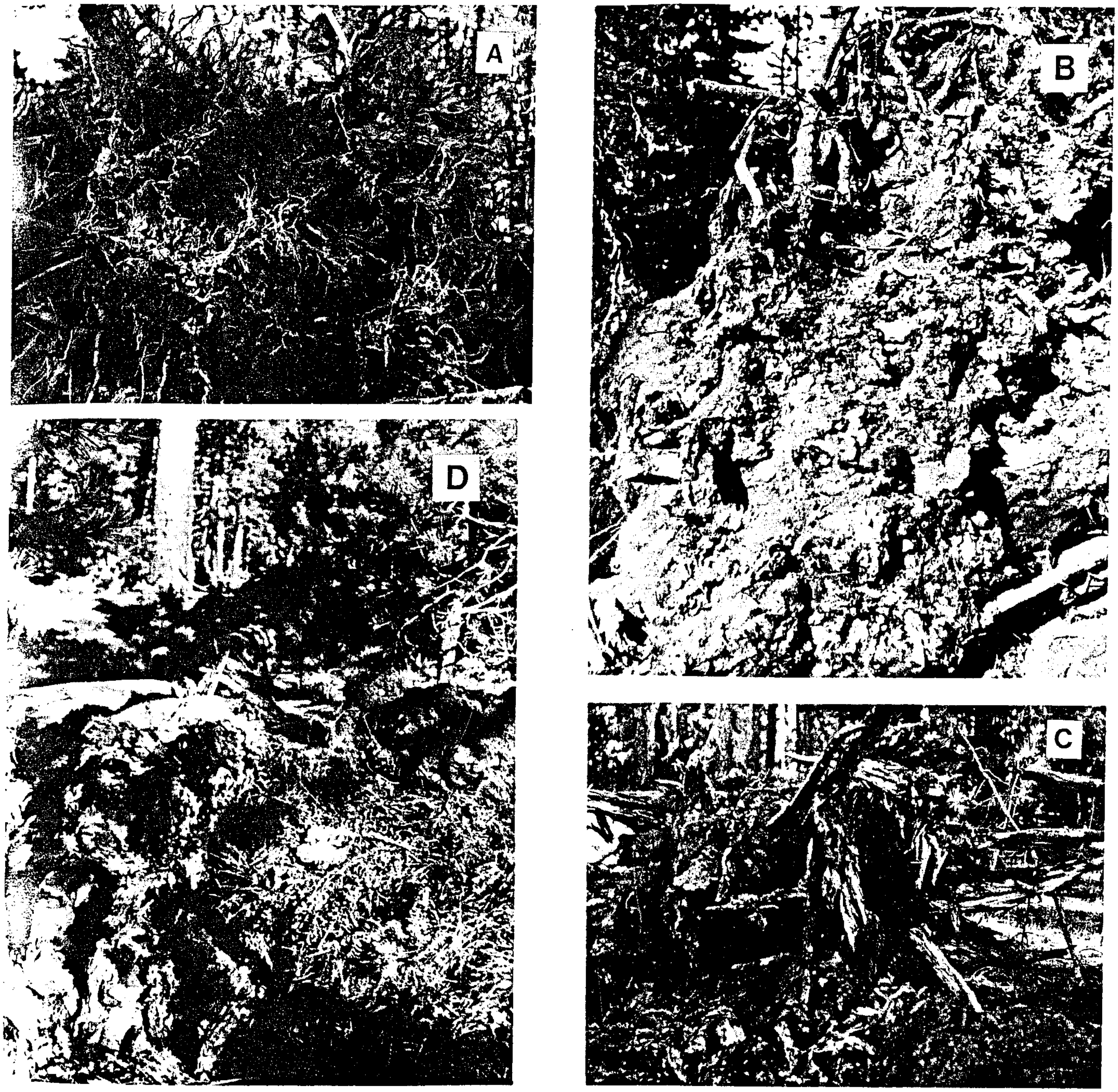

Figure 3. (Read clockwise) *Progressive decomposition over time of root systems (stumps) of old-growth pines infected with* Armillaria: A, *full rooted, 2 years old (since cut);* B, *large rooted, 5-20 years old;* C, *digitate, 35 years old; and* D, *truncated, over 35 years old. White flecks or patches in* B *and* D *are fungus exposed by stripping of the bark during excavation.*

Table 1. Recovery of *Armillaria* in laboratory culture from infected pine root systems.

Stump age (years since cut)	Total root systems examined	Degree of root decomposition[1] Complete (truncated)	Extensive (digitate)	Moderate (large rooted)	Little (full rooted)	Positive culture of *Armillaria*, all degrees of decomposition
	— — —	— — —	*Number*	— — —	— — —	*Percent*[2]
35 -	16	10	4	2	0	69
35	27	15	10	2	0	44
5-	16	2	10	4	0	55
2[3]	41	0	1	15	25	100
		— — —	— — — *Percent*	— — —	— — —	
Positive cultures[2] of *Armillaria* all ages		55	55	91	100	

[1]All root systems.
[2]Percent based on symptomatic and suspect root systems only.
[3]Few stumps of this age were symptomatic and suitable for isolations, but all with symptoms yielded the fungus.

Table 2. Frequency of *Armillaria* infection in excavated old-growth pine stumps as reflected by stump age (years since cut) and by disease severity on site.

Stump age (years) (1)	Lightly diseased: Stumps studied (2)	Lightly diseased: Proportion infected (3)	Heavily diseased: Stumps studied (4)	Heavily diseased: Proportion infected (5)
	Number	*Percent*	*Number*	*Percent*
35+ (snags)[1]	5	60	11	91
35	22	55	5	80
5-20	9	44	7	100
2	27	29	14	71
All ages	63	43	37	84

[1]*Trees killed prior to 1942 by unknown causes but probably by* Armillaria.

posed to open. Infection frequency was unexplainably lower where there had been considerable machine activity during previous logging.

As the intact stumps themselves and stand features failed to give clues of infection, the presence of recently killed trees nearby was examined as a promising alternative. Eighty-two percent of the stumps that had dead saplings within the area occupied by roots of the stump were infected, but saplings were too inconsistently present to be practical indicators. However, infection regularly was present in old pine stumps where disease was evident in surrounding pole size timber and usually was absent elsewhere.

Implications for Managers

In this study, examination of the intact stumps and their immediate, undisturbed surroundings disclosed no usable specific indicators of infection.

General health of the young timber now common in ponderosa pine stands under management appears to be the first and most useful indirect indicator of *Armillaria* in the old-growth stumps and therefore of areas with stumps in need of treatment. Treatable sites may be recognized by groups of dead trees of pole size or larger, located around old stumps. These indicator trees may be distinguished by the presence of distinctive white mycelial fans between the bark and wood, rhizomorphs, and pitch at the tree base, along with progression of mortality through the stand. Patches of infected trees are sometimes large enough to appear as circular openings with fallen trees, snags, and dying trees in succession between a central opening and surrounding green timber. When infected patches are closely distributed over a large area, old-growth stumps on the entire area should be treated. Infectious old stumps scattered through less conspicuously diseased timbered areas may require removal or possibly are appropriate for chemical treatment (Filip and Roth 1977).

While our results showed that it is not possible directly to associate the dangerous stumps with specific indicators of *Armillaria*, an effective indirect approach is available in the timber marking rules published by Roth et al. (1977) for reducing *Armillaria* in combination with thinning of young stands. The rules, which are based on signs of *Armillaria* in the young timber alone and on distances from infection sources (Shaw 1974), allow the marker to identify and remove living but usually infected trees between reserve trees and recognizable sources of infection. An assertive control program will treat all old-growth stumps within the immediate area where the marking rules apply.

Stump age offers a third indicator of need for treatment. *Table 2* (columns 2 and 3) shows that nearly twice as many of the oldest stumps as of the youngest were infected in lightly diseased stands. In spots of heavy disease incidence (columns 4 and 5), nearly all stumps were infected, and differences were obscured. While a difference with age may be partly due to unknown features of infection biology, it appears more likely to be associated with the incidental removal of high percentages of infected trees in the early cuts, thus decreasing the ratio of diseased to healthy trees in the later and final cuts. Such situations resulted from marking the old growth on the basis of clear but poorly understood symptoms of trouble, i.e., "risk class" with respect to attack by bark beetles (Keen and Salmar 1942, Smith 1962). The high incidence of *Armillaria* in the high-risk trees, those cut first, suggests that infection is a contributor to risk of beetle attack.

Costs of control can be reduced by treating only the most dangerous stumps. After areas of heavy infection have been treated, managers with limited budgets might consider concentrating on the oldest stumps (20 years or more), as they have the highest incidence of infection and, being greatly weakened by decay, can be removed with smaller, less costly machinery than is needed for the more sound recent stumps. However, they may be a lesser threat to surrounding timber than the newer stumps with more expansive infectious roots.

The fact that unrecognizable infected stumps may occur in the forest away from evident concentrations should concern the forest manager only secondarily. For unknown reasons these stumps are now existing without significant effect on, and probably without dangerous threat to, the surrounding timber.

As of this writing, control directed at the large stumps appears to be most cost-effective if it is aimed at (1) stumps in stand locations recognized as generally infected, (2) stumps with dead saplings close by, (3) stumps formed in the early cuts of a series of selection cuts, and (4) those in areas where marking for root rot control during thinning was done, or is appropriate.

Possibilities of biological control should be further explored. *Trichoderma,* the familiar fungal antagonist of *Armillaria mellea,* was frequently observed on unearthed roots, and was particularly prevalent on those old digitate systems from which culture of *Armillaria* was unsuccessful. Of interest also was the tunneling of literally handfuls of undetermined insect larvae in the root cambium near the collar of 63 percent of the most recent stumps. *Armillaria* in the cambium failed to spread distally into or beyond the point of insect activity. By restricting lateral extension of the fungus through the root system these larvae may decrease reliability of sapling health as an indicator of stump infection but may also limit spread of the disease.

Would no action at all be most cost-effective? We suspect not, at least until the forest is genuinely under short-rotation management. For the present, *Armillaria* persists as the principal fungus in the old pine root systems it infects, ultimately completely degrading them (*fig. 3D*). Its presence in approximately 50 percent of the oldest stumps remains highly, though decreasingly, dangerous to surrounding young timber. As old roots rot away toward the stump the extent of

(*Continued on page 151*)

humanities and social science courses than shown, however, and most allow the student more electives. The primary alternatives for accommodating the fire concentration are adding a fifth year to BSF curricula or reducing nonfire requirements substantially; clearly, both present difficulties.

Lesser problems are lack of trained faculty (use of adjunct faculty should be explored) and need for texts, particularly on fire management fundamentals, use, and ecological effects of fire.

Interagency Curriculum

The second half of the model curriculum is comprised of courses that would be developed by NWCG. More advanced treatment would be given the topics introduced at the university level, and agency-specific skills and knowledge would be added. Courses would be taken in a sequence specified in the full study report.

Numbered according to their larger subject areas, the courses are as follows:

General Fire Management Courses (M)
- M-201, Fire Mangement Data Collection, Display, Verification, and Analysis
- M-202, Fire Management Data Use
- M-203, Fire Management Finance and Contract Administration
- M-204, Fire Management Laws, Regulations, and Policies
- M-301, Personnel Management and Training
- M-302, Fire Management Equipment
- M-501, Advanced Fire Management

Fire Prevention Courses (P)
- P-101, Introduction to Fire Prevention
- P-201, Fire Prevention Information
- P-202, Land Use Practices in Fire Prevention
- P-203, Sociology and Psychology of Fire Prevention
- P-204, Fire Prevention Education
- P-301, Fire Prevention Engineering
- P-302, Fire Prevention Law Enforcement
- P-401, Fire Prevention Planning Systems
- P-402, Fire Prevention Management

Vegetation Manipulation Courses (F)
- F-201, Fire Ecology and Effects
- F-202, Fire Use
- F-301, Vegetation Manipulation and Treatment

Presuppression Courses (A)
- A-201, Communications Systems
- A-202, Detection Systems
- A-401, Presuppression Planning for Fire Management

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the infectious root mass is lessened, but our data and observations indicate that remnants of *Armillaria* will be present in the old-growth stumps for at least 50 years after cutting. In the absence of control some infested areas will go completely out of production during this interval. ■

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