Forest Sci., Vol. 25, No. 2, 1979, pp. 261–265

Susceptibility of Native Conifers to Laminated Root Rot East of the Cascade Range in Oregon and Washington

GREGORY M. FILIP
CRAIG L. SCHMITT

ABSTRACT. Of six native conifer species in eastern and central Oregon and Washington, *Tsuga mertensiana* exhibited the most infection and mortality caused by *Phellinus weirii*, while *Pinus contorta* was least affected. Tree mortality was the most common indicator of infection in susceptible species. Internal decay (butt rot) was more common in disease-resistant species. Healthy trees in infected plots were exposed to large quantities of fungus inoculum as indicated by inoculum indexes. FOREST SCI. 25:261–265.

ADDITIONAL KEY WORDS. *Phellinus weirii, Poria weirii,* infection indicators, inoculum index, mortality.

DESTRUCTIVENESS OF LAMINATED ROOT ROT caused by *Phellinus weirii* (Murr.) Gilbertson (=*Poria weirii* Murr.) in Pacific Northwest forests is well documented (Buckland and others 1954, Childs and Shea 1967, Childs 1970). Current management recommendations include planting or favoring resistant conifer species in areas of high disease incidence (Wallis 1976a, Hadfield and Johnson 1977). Susceptibility of some conifer species has been observed in forests and under artificial conditions (Buchanan 1948, Wallis and Reynolds 1965, Childs 1970), but quantitative data on species susceptibility in central and eastern Oregon and Washington are lacking.

Objectives of this investigation were to (1) determine susceptibility of native conifer species to *P. weirii* infection and mortality in mixed-conifer forest types east of the Cascade Range and (2) determine common indicators associated with advanced infection.

MATERIALS AND METHODS

A square, 0.09-hectare plot was established in each of ten *P. weirii* centers in five locations in Oregon and Washington (Table 1). Plots were located at elevations of 1,000 to 1,500 meters. All plots met the following criteria:

1. At least 15 percent of all trees were dead or dying from infection by root pathogens.
2. At least three native conifer species were present.
3. *Phellinus weirii* was the dominant root pathogen (>90 percent of infected trees).

Authors are Plant Pathologist and Forestry Technician, Forest Insect and Disease Management, USDA Forest Service, Portland, Oregon. Thanks to J. Hazard, T. Gregg, B. Lane, P. Brewster, and R. Harvey for technical assistance and to E. Nelson, W. Thies, E. Hansen, L. Weir, and D. Goheen for manuscript suggestions. Manuscript received 21 June 1978.

TABLE 1. Description of plots (0.09 ha) examined for native conifer susceptibility to Phellinus weirii.

Nearest location	Number of plots	Conifer species present[a]	Trees per plot: Number	Trees per plot: Percent infected
Republic, Washington	2	DF, WL, PP	93	35
		DF, WL, PP	90	27
Rimrock, Washington	1	GF, WL, DF, PP, LP	132	15
Kamela, Oregon	3	GF, WL, LP, DF, ES	251	34
		GF, WL, LP, DF, ES	169	19
		GF, WL, DF	170	28
Simnasho, Oregon	2	GF, DF, WL, PP	195	41
		GF, PP, WP	69	22
Union Creek, Oregon	2	MH, RF, LP, WP	184	24
		MH, RF, LP, WP	217	20

[a] DF = Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), WL = western larch (*Larix occidentalis* Nutt.), LP = lodgepole pine (*Pinus contorta* Dougl.), GF = grand fir (*Abies grandis* (Dougl.) Lindl.), RF = Shasta red fir (*Abies magnifica* var. *shastensis* A. Murr.), MH = mountain hemlock (*Tsuga mertensiana* (Bong.) Sarg.). Data for Englemann spruce (ES), western white pine (WP), and ponderosa pine (PP) were excluded later since only 10, 27, and 6 trees of each species, respectively, were found in infected plots.

These criteria were selected to (1) insure a high level of pathogenicity to test host susceptibility, (2) evaluate several conifer species exposed to the same level of pathogenicity on the same site, and (3) eliminate the phenomenon associated with mixtures or complexes of root pathogens.

The following was recorded for all plot trees $\geqslant$2.5 cm dbh: (1) species, (2) dbh, (3) root disease symptoms and signs, (4) tree condition (live, dead, standing, down), and (5) azimuth and distance from plot center. Dbh of trees with missing or disintegrated stems was approximated from diameter at ground line.

TABLE 2. Natural infection and mortality caused by Phellinus weirii *in six native conifer species. Species are listed in decreasing order of susceptibility based on tree mortality.*

Species	Trees examined	Healthy trees	Infected[a] trees	Infected trees: Live	Infected trees: Dead	Infected trees: Total	Other dead trees[b]
	Number			Percent			
Mountain hemlock	176	95	67	6 A[c]	32 A	38 A	8 A
Grand fir	840	526	256	8 AB	23 B	31 B	7 A
Douglas-fir	184	118	46	5 A	20 B	25 B	11 A
Western larch	100	61	27	14 B	13 B	27 B	12 A
Shasta red fir	100	83	13	2 A	11 B	13 C	4 A
Lodgepole pine	127	101	11	7 A	2 C	9 C	12 A
Total	1,527	984	420	7	20	27	8

[a] Only infections near the root collar were recorded.

[b] *Armillaria mellea, Phaeolus schweinitzii, Ceratocystis wageneri, Scolytus ventralis,* and *Dendroctonus ponderosae* were occasionally associated with dead trees; however, the majority had no readily identifiable fungus or insect associations.

[c] Values not followed by the same letter are significantly (P = 0.05) different.

TABLE 3. Indicators of infection caused by Phellinus weirii *in six native conifer species.*[a]

Species	Total infected stems	Tree mortality	Ectotrophic mycelium	Laminated decay	Butt rot	Windthrow	Two or more indicators
	Number	*Percent*					
Mountain hemlock	67	84 A[b]	55 A	45 A	0	31 A	85 A
Grand fir	256	75 A	54 A	59 A	7 A	36 A	75 A
Douglas-fir	46	80 A	39 A	83 B	15 A	28 A	89 A
Western larch	27	48 B	30 A	56 A	41 B	15 A	59 AB
Shasta red fir	13	85 A	31 A	46 A	8 A	46 A	69 AB
Lodgepole pine	11	18 B	27 A	9 C	82 C	18 A	36 B
All infected stems	420	74	49	57	11	33	76

[a] Only infections near the root collar were recorded.
[b] Values not followed by the same letter are significantly ($P = 0.05$) different.

On all trees the root collar and two or three major roots were exposed for a distance of 0.3 m from the stem. Signs of root infection, especially ectotrophic mycelium, were recorded. In addition, a small piece of root bark was removed to detect mycelial fans and/or wood decay. Two increment borings were made at the base of all living trees to determine presence of advanced butt decay. Isolations from decayed wood were placed on plates containing 2 percent malt agar and incubated for 1 month in the dark at room temperature.

Location of all trees was plotted, and from this an inoculum index (Ii) was calculated for each apparently healthy, nonsymptomatic tree (no root collar infections). Ii, a modification of that proposed by W. G. Thies (personal communication, PNW Forest and Range Experiment Station, Corvallis, Oregon), is a combination of a rating given to inoculum trees of various sizes and that given to the distance of inoculum trees from healthy trees as follows:

Dbh (cm) of inoculum tree	*Rating*	*Distance (m) from inoculum tree to healthy tree*	*Rating*
2.5–12.7	1	0–1.5	4
12.8–25.4	2	1.6–3.0	3
25.5–38.1	4	3.1–4.5	2
38.1+	8	4.6–6.0	1

Total Ii exposure of each healthy tree was the total of Ii's from all infected trees within 6 m of the healthy tree. Ii was used to measure relative quantity and proximity of inoculum in order to test host susceptibility.

Data were subjected to chi-square analysis ($r \times 2$) to test tree species against condition (Table 2) and indicators (Table 3).

Results and Discussion

Fifteen hundred and twenty-seven trees of six conifer species were examined on ten 0.09-ha plots (Table 1). Ranking of species by susceptibility to infection by *Phellinus weirii* corresponded very closely to other published observations (Childs 1970, Hadfield and Johnson 1977). Mountain hemlock had significantly ($P = 0.05$) more mortality due to *P. weirii* than other species, while lodgepole

TABLE 4. Dbh and inoculum index of healthy trees from six conifer species in Phellinus weirii *centers.*[a]

Species	Trees examined	Average inoculum index	Average dbh
	Number		*cm*
Mountain hemlock	95	16.7	7.4
Grand fir	526	19.8	10.7
Douglas-fir	118	8.9	11.4
Western larch	61	19.0	21.1
Shasta red fir	83	18.9	11.7
Lodgepole pine	101	16.6	10.7
Total	984	17.7	11.2

[a] Only infections near the root collar were recorded.

pine had the least (Table 2). There were no significant differences in mortality caused by *P. weirii* among grand fir, Douglas-fir, western larch, or Shasta red fir. There were no significant differences among species in the number of trees killed by agents other than *P. weirii.*

Tree mortality was the most common indicator of *P. weirii* infection especially in mountain hemlock, grand fir, Douglas-fir, and Shasta red fir (Table 3). More than half of all infected trees had the typical laminated decay (with setal hyphae) associated with *P. weirii.* Laminated decay was significantly ($P = 0.05$) more common in Douglas-fir. Laminated decay was more common in trees that had been dead for several years but was also found in living trees with dead lateral roots or with advanced internal decay. Butt rot caused by *P. weirii* was significantly ($P = 0.05$) more common in lodgepole pine than in other conifer species. Ectotrophic mycelium was detected on 49 percent of all infected trees and was more commonly associated with living or freshly killed trees. Although there were no significant differences in the presence of ectotrophic mycelium among the species, Wallis (1976b) has reported differences between susceptible and resistant species. There were no significant differences in amount of windthrow attributable to *P. weirii* among the species. More than 75 percent of all infected trees exhibited two or more indicators of *P. weirii* infection.

Most healthy trees in infected plots were exposed to large quantities of inoculum as indicated by average inoculum index (Ii) for each species (Table 4). An Ii of 13 indicated that a healthy tree was exposed to at least one infected tree that was at least 39 cm dbh and within 1.5 m. All but one species had an average Ii greater than 13. Although tree age was not recorded in all plots, average dbh for all species exceeded 10 cm indicating that most trees were exposed to inoculum for several years, if not decades, and were of sufficient size to contact adjacent inoculum. Hence, probability that healthy trees were only escapes and not truly resistant was minimized.

Literature Cited

Buchanan, T. S. 1948. *Poria weirii,* its occurrence and behavior on species other than cedars. Northwest Sci 22:7–12.

Buckland, D. C., A. C. Molnar, and G. W. Wallis. 1954. Yellow laminated root rot of Douglas-fir. Can J Bot 32:69–81.

Childs, T. W. 1970. Laminated root rot of Douglas-fir in western Oregon and Washington. USDA Forest Serv Res Pap PNW-102, 27 p. Pac Northwest Forest and Range Exp Stn, Portland, Oreg.

CHILDS, T. W., and K. R. SHEA. 1967. Annual losses from diseases in Pacific Northwest forests. USDA Forest Serv Res Pap PNW-20, 19 p. Pac Northwest Forest and Range Exp Stn, Portland, Oreg.

HADFIELD, J. S., and D. W. JOHNSON. 1977. Laminated root rot: A guide for reducing and preventing losses in Oregon and Washington forests. Forest Insect and Dis Manage, Region 6, USDA Forest Serv, Portland, Oreg. 16 p.

WALLIS, G. W. 1976a. *Phellinus* (*Poria*) *weirii* root rot. Detection and management proposals in Douglas-fir stands. Can For Serv For Tech Rep 12, 16 p.

WALLIS, G. W. 1976b. Growth characteristics of *Phellinus* (*Poria*) *weirii* in soil and on root and other surfaces. Can J Forest Res 6:229–232.

WALLIS, G. W., and G. REYNOLDS. 1965. The initiation and spread of *Poria weirii* root rot of Douglas-fir. Can J Bot 43(1):1–9.

Forest Sci., Vol. 25, No. 2, 1979, pp. 265–269

A Method for Estimating the Probability of Southern Pine Beetle Outbreaks

R. F. Daniels, W. A. Leuschner, S. J. Zarnoch, H. E. Burkhart, and R. R. Hicks

ABSTRACT. A methodology is presented for estimating a continuous measure of southern pine beetle (*Dendroctonus frontalis* Zimm.) incidence which, under certain sampling conditions, may be interpreted as the probability of outbreak in a stand. Probability of outbreak is predicted from site, stand, and/or insect population variables using a logistic probability function and provides a more general incidence index than categorical classification methods used in the past. The model, estimation procedures, and example calculations are discussed. FOREST SCI. 25:265–269.

ADDITIONAL KEY WORDS. *Dendroctonus frontalis,* hazard index, risk rating.

ESTIMATING THE RISK OF INSECT ATTACKS over large forest areas is important to forest managers so that detection, control, and prevention practices can be deployed more efficiently. Risk ratings can be categorical (e.g., "low," "medium," or "high") or continuous (e.g., estimated probabilities of outbreak) and can apply to individual trees or forest stands. This paper reports a methodology for estimating the probability of southern pine beetle (*Dendroctonus frontalis* Zimm.) outbreak in forest stands that provides a continuous index of incidence.

Early bark beetle hazard indices included Keen's (1936) which ranked individual trees into 16 susceptibility classes and Johnson's (1949) which predicted five categories of "beetle hazard" for entire stands. Recently published bark beetle indices include Safranyik and others (1974), Schmid and Frye (1976), and Amman and others (1977). Safranyik and others (1974) classified British Columbia by five "outbreak hazard" categories based on climatic and topographic variables. Schmid and Frye (1976) assigned forest stands to three risk categories based on physiographic province, mean dbh, basal area, and proportion of canopy in host species. Amman and others (1977) predicted stand susceptibility categories

The authors are Research Associate in Forest Biometrics and Associate Professor of Forest Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; Assistant Professor of Wildlife Biometrics, Michigan State University, East Lansing, MI 48824; Professor of Forest Biometrics, VPI & SU; formerly Associate Professor of Forestry, Stephen F. Austin State University, Nachogdoches, TX, now Associate Professor of Forestry, West Virginia University, Morgantown, WV 26506. This study was partly funded by a U.S. Department of Agriculture program entitled "The Expanded Southern Pine Beetle Research and Applications Program," grant number CSRS 704-15-1. The findings, opinions, and recommendations expressed herein are those of the authors and not necessarily those of the U.S. Department of Agriculture. Manuscript received 2 May 1978.