Root Diseases and Blister Rust Associated with Bark Beetles (Coleoptera: Scolytidae) in Western White Pine in Idaho — Source link

David L. Kulhavy, A. D. Partridge, R. W. Stark

Institutions: Stephen F. Austin State University, University of Idaho

Published on: 01 Jun 1984 - Environmental Entomology (The Oxford University Press)

Topics: Cronartium ribicola, Dendroctonus, Phaeolus schweinitzii, Bark and Western white pine

1984

Root Diseases and Blister Rust Associated with Bark Beetles (Coleoptera: Scolytidae) in Western White Pine in Idaho

David Kulhavy
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, dkulhavy@sfasu.edu

A.D. Partridge

R.W. Stark

Root Diseases and Blister Rust Associated with Bark Beetles (Coleoptera: Scolytidae) in Western White Pine in Idaho

DAVID L. KULHAVY,[1] A. D. PARTRIDGE,[2] AND R. W. STARK[2]

Environ. Entomol. 13: 813–817 (1984)

ABSTRACT Root systems of western white pine, *Pinus monticola* Douglas, were excavated with explosives and examined for pathogens. Data were also recorded on portions of the crown killed by blister rust caused by *Cronartium ribicola* Fisch. Statistical tests revealed a significant association between the bark beetles *Dendroctonus ponderosae* Hopkins and *Pityogenes fossifrons* (LeConte), and the root pathogen *Armillariella mellea*. (Vahl. ex Fr.) Karst and between beetles and all root diseases. Ninety-two percent of the trees attacked by bark beetles had root diseases, and 97% had either root diseases or blister rust. A discriminant analysis correctly classified 88% of the sample trees into two categories, trees infested with *D. ponderosae* or trees not infested with *D. ponderosae*, using the variables age (stump), diameter at 1.3 m in height, and percentage of the primary roots infected with pathogens. Major pathogenic organisms isolated from the roots included *A. mellea*, *Phaeolus schweinitzii* (Fr.) Pat., *Resinicium bicolor* (Fr.) Parm., *Verticicladiella* spp., and a *Europhium* strain. A hypothetical sequence of host tree invasion by blister rust, followed by infection by root diseases, and finally attacks by bark beetles, is postulated.

RECENTLY, investigators have concluded that root diseases and crown defoliation or injury predispose some conifers to attack by bark beetles (Coleoptera: Scolytidae). Cobb et al. (1974) found bark beetles in ponderosa pine, *Pinus ponderosa* Lawson, and white fir, *Abies concolor* (Gord. and Glend.) Lind., weakened by root diseases. Partridge and Miller (1972) associated root rots with bark beetles attacks in Idaho. Hertert et al. (1975) concluded that endemic populations of the fir engraver, *Scolytus ventralis* LeConte, were maintained in root-diseased grand fir, *Abies grandis* (Douglas) Lindl. Cobb et al. (1974) concluded that the incidence of disease was directly related to bark beetle infestations on an individual tree and in an area.

Bedard[3,4] suggested that root-diseased *P. monticola* were trees with low vigor. Investigations of root diseases of western white pine, *Pinus monticola* Douglas, have failed to establish a relationship between bark beetles and root diseases (Ehrlich 1939, Partridge and Miller 1972). These workers, however, apparently examined only the root crown and larger buttress roots, and did not mention occurrence of blister rust, *Cronartium ribicola* Fisch., in the tree crown, nor damage to smaller lateral roots.

The objectives of this study were to determine whether a relationship between bark beetles and diseases exists in western white pine, and, if such a relationship exists, to describe it.

Methods and Materials

Nine plots of 10 trees each were examined in western white pine stands in the *Abies grandis/Pachistima myrsinites* and the *Thuja plicata/P. myrsinites* habitat types (Daubenmire and Daubenmire 1968) of Clearwater County, Idaho, in 1975. Each plot, ca. 0.5 ha in area, consisted of five dying or discolored white pines paired with apparently healthy white pines. Trees from 10 to 70 cm in diameter at 1.3 m above the ground were sampled.

After felling, each tree was cut into 4.1-m sections. Bolts less than 10 cm in diameter were discarded. Trees with diameters less than 10 cm at 4.1 m in height were treated as one section. A 30.5 by 30.5 cm section of bark was removed from the lower third of each section. Bark beetle galleries were counted and life stages present were recorded. Insects from all samples were collected and identified.

A visual examination of the entire tree was made for all forms of insect damage and presence of blister rust. Data on portions of the crown killed by blister rust were recorded as percentage of the total crown killed. At the time of root excavation, the roots and root collar were inspected for insects and disease. Boles of sample trees were dissected with a chainsaw in order to measure the extent of and to identify diseases and decays. Roots were excavated with 20% dynamite following the procedures of Hertert et al. (1975), and examined for diseases and decay.

[1] School of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX 75962.

[2] Dept. of Forest Resources, College of Forestry, Wildlife and Range Sci., Univ. of Idaho, Moscow, ID 83843.

[3] Bedard, W. D. 1939. A study of mountain pine beetle infestations in western white pine. Forest Insect Lab., U.S. Dep. Agric., Coeur d'Alene, Idaho, 23 Feb. Unpublished. (Available through the USDA For. Serv. Exp. Stn., Moscow, Idaho.)

[4] Bedard, W. D. 1940. A summary of four years' exploratory study of mountain pine beetle infestations in western white pine. Forest Insect Lab., U.S. Dep. Agric., Coeur d'Alene, Idaho, 27 Mar. Unpublished. (Available through the USDA For. Serv. Exp. Stn., Moscow, Idaho.)

Table 1. Results of two-way tests of independence between the incidence of attack by bark beetles and the presence of root fungi

Organism(s) present[a]		Contingency table cell[b]				Chi-square
Beetles	Fungus	a	b	c	d	
All	All	38	32	3	17	11.32
Dp	All	25	45	2	17	3.39
Im	All	12	58	1	19	1.14
All	Am	36	15	5	34	27.45
Dp	Am	24	27	3	36	7.67
Pf	Am	14	37	1	38	8.96
Pf	All	14	56	1	19	1.55
All	Ht rt	11	18	27	34	0.01
Dp	Ht rt	9	20	18	43	0.01

Chi-square tabular values exceeding 10.82 and 6.63 are significant at ($P < 0.001$ and 0.01, respectively).

[a] All, all species combined; Dp, *Dendroctonus ponderosae*; Im, *Ips montanus*; Pf, *Pityogenes fossifrons*; Am, *Armillariella mellea*; Ht rt, heartwood and butt rot decays.

[b] a, Both beetles and fungi present; b, fungi alone; c, beetles alone; d, neither beetles nor fungi present.

Table 2. Associations of particular combinations of bark beetles and diseases in western white pine in northern Idaho

Associations observed in experimental trees	Dying trees (fading crown)	Living trees (green crown)	Total
Root diseases, *Cronartium ribicola*, and bark beetles:			
Armillariella mellea and *Dendroctonus ponderosae*	8	3	11
A. mellea and *Pityogenes fossifrons*	5	1	6
A. mellea and *Ips latidens*	2	0	2
A. mellea and *D. valens*	2	0	2
Phaeolus schweinitzii and *D. ponderosae*	1	0	1
P. schweinitzii and *P. fossifrons*	1	0	1
Disease combination[a] and *D. ponderosae*	1	0	1
Total	20	4	24
Root diseases and bark beetles:			
A. mellea and *D. ponderosae*	10	3	13
A. mellea and *D. valens*	0	1	1
Total	10	4	14
Root diseases and *Cronartium ribicola*:			
A. mellea	2	11	13
A. mellea and *P. weirii*	1	0	1
A. mellea, *Resinicium bicolor*, and *P. schweinitzii*	0	1	1
A. mellea and *Verticicladiella* sp.	0	1	1
A. mellea, *R. bicolor*, and others[b]	0	2	2
R. bicolor	0	2	2
P. weirii	0	1	1
P. schweinitzii	0	4	4
Total	3	22	25
Root diseases alone:			
A. mellea	0	5	5
A. mellea and *R. bicolor*	0	1	1
A. mellea and *P. weirii*	0	1	1
Total	0	7	7
Bark beetles and *Cronartium ribicola*:			
D. ponderosae	0	1	1
P. fossifrons	1	0	1
Total	1	1	2
Bark beetles only:[c]	1	0	1
Total	1	0	1
No diseases:	0	9	9
Total	0	9	9

[a] *Inonotus tomentosus*, *Phellinus pini*, and *Phellinus weirii*; *I. tomentosus* and *F. pini*; *F. pini* and *P. weirii*.

[b] *F. pini* and *Polyporus sericeomollis*.

[c] *D. ponderosae* and *P. fossifrons*. This tree was declining due to basal injuries from logging debris.

Data on diseases in the root system were recorded as percentage of infection of the primary (buttress) roots, secondary roots, and total root system. Causal agents of the destruction of the primary, secondary, and total root systems were recorded.

Samples of decayed wood scored by visual identification were taken to the laboratory for confirmation of the cause of decay by culturing on malt agar slants (Nobles 1948). Cultures were incubated at room temperature (22°C) for up to 6 months. Fungi were identified using reference cultures from the University of Idaho's forest pathology culture collection and herbarium.

Data were analyzed using χ^2 test of independence with Yates' correction on 2 × 2 contingency tables, and discriminant analysis. Discriminant analysis was used to determine if there were any variables separating trees infested with the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, from healthy ones. Trees less than 20 cm DBH were not included in this analysis as they did not harbor *D. ponderosae*. Tree variables were analyzed using a stepwise discriminant analysis (Nie et al. 1975) to select a combination of independent variables that maximized the differences between trees with and without *D. ponderosae*.

Results

Eight species of bark beetles and one weevil (Curculionidae) were found attacking western white pine. *Dendroctonus ponderosae*, *Ips montanus* (Eichhoff), and *Pityogenes fossifrons* (LeConte) were found most frequently. *Dendroctonus ponderosae* was found in 66% of the infested trees; *I. montanus*, always in combination with *D. ponderosae*, was found in 30%; and *P. fossifrons* was found in 35%. *Pityogenes fossifrons* was often in a portion of the tree crown weakened by *C. ribicola*. Less frequently found species included *Ips latidens* (LeConte); a root feeder, *Pityophthorus* spp.; and the weevil *Pissodes affinis* Rand. More than 10 root-disease fungi were collected. *Armil-*

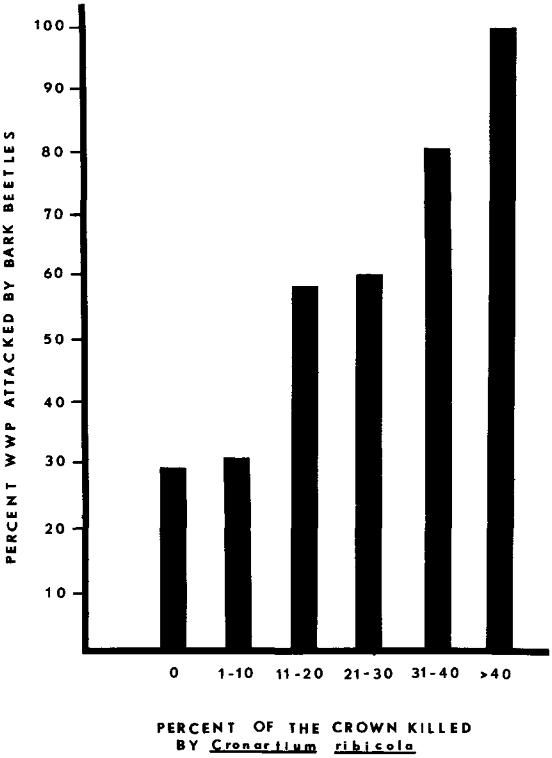

Fig. 1. Relationship between the percentage of the crown of western white pine defoliated by *C. ribicola* and attacks by bark beetles.

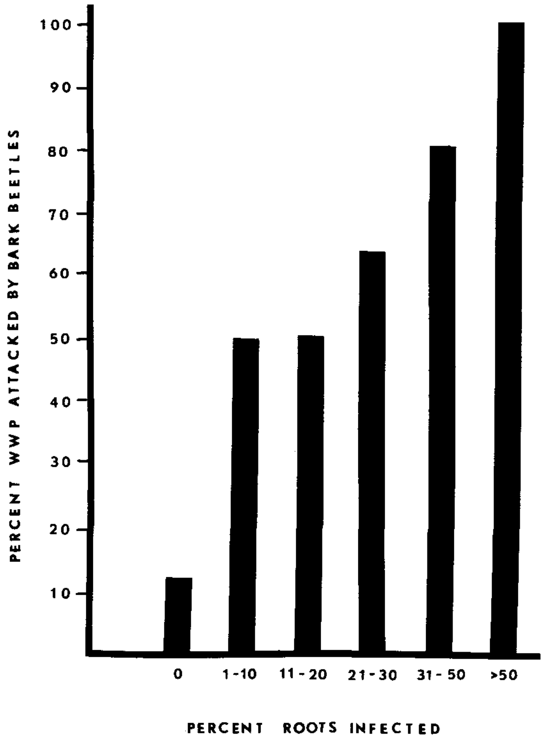

Fig. 2. Relationship between percentage of the roots of western white pine infected by diseases and attacks by bark beetles.

lariella mellea (Vahl. ex Fr.) Karst, *Phaeolus schweinitzii* (Fr.) Pat., and *Resinicium bicolor* (Fr.) Parm. were the most prevalent. *Phellinus weirii* (Murr.) Gilbertson, *Phellinus pini* (Thore ex Fr.) Pilat, and a species of *Europhium* were less frequently encountered. *Fomitopsis annosa* (Fr.) Karst and a species of *Hydnum* were encountered only once as a root pathogen. Species of *Verticicladiella* were isolated from roots, but their role as root pathogens was not ascertained (Kulhavy et al. 1977).

We found a strong association between the presence of all species root-decaying fungi and bark beetle attacks (Table 1). Ninety-two percent of the trees attacked by bark beetles showed some degree of root decay, 61% of the attacked trees had a portion of the crown killed by *C. ribicola*, and 97% of the attacked trees had either root decay or blister rust (Table 2). Two of the three trees without root decay, but attacked by bark beetles, had extensive portions of the crown killed by blister rust. The third was injured by mechanical means. Forty-five percent of the root-diseased trees were not attacked by bark beetles.

Trees with large portions of crown killed by blister rust were more likely to be attacked by bark beetles (Fig. 1). Those with more than 40% of the crown killed were invariably overcome by bark beetles. The percentage of *P. monticola* attacked by bark beetles was also directly related to the percentage of roots destroyed per tree (Fig. 2).

A significant relationship was shown between all bark beetles combined and *A. mellea*, between *D. ponderosae* and *A. mellea*, and between *P. fossifrons* and *A. mellea* (Table 1). *Ips montanus*, however, was only found in white pines previously attacked by *D. ponderosae*. *Dendroctonus ponderosae* and *P. fossifrons* showed no relationship with the fungi *P. schweinitzii*, *R. bicolor*, *P. pini*, and *P. weirii* either singly or collectively. White pine with root rot and attacked by bark beetles had over 85% of the root system destroyed (by *P. schweinitzii*) and 20% of the crown killed by blister rust.

Table 3. Means and standard deviations of western white pine attacked and not attacked by *Dendroctonus ponderosae*

Variables[a]	Attacked		Not attacked	
	Mean ±	SD	Mean ±	SD
DBH (cm)[b]	44.2	13.8	35.6	12.7
AGS	113.9	26.1	86.7	30.6
IPR (%)	68.0	36.3	23.4	29.0

[a] Variables used in discriminant analysis (see equation 1).
[b] DBH, diameter in centimeters at 1.3 m; AGS, age at the stump; IPR, percentage of primary roots infected with disease.

Discriminant analysis resulted in the statistically correct classification of 88% of the sample trees. Eighty-one percent of the white pine suitable for colonization by *D. ponderosae* and 93% of the sample white pine not suitable for colonization by *D. ponderosae* were correctly classified. The following equation, based on stump age (AGS), diameter (cm) at 1.3 m (DBH), and percentage of the primary roots infected (IPR), was based on a pooled covariance matrix and was significant at the 0.01 level (Wilks' λ).

$$\hat{D} = 0.0166 \text{ DBH} + 0.0107 \text{ AGS} + 0.0205 \text{ IPR} - 2.525 \quad (1)$$

The mean discriminant, D, is 0.151. Calculated values of $\hat{D}$ less than D were classified as white pine not suitable for attack by *D. ponderosae*, while calculated values of $\hat{D}$ greater than or equal to D were classified as susceptible to attack by *D. ponderosae*. The group means and standard deviations are given in Table 3.

Discussion

We hypothesize that endemic populations of bark beetles are maintained in western white pines in northern Idaho that have been weakened by root diseases and blister rust. Previous researchers (Bedard 1939, 1940, Ehrlich 1939, Partridge and Miller 1972) did not detect this relationship since they neither excavated the entire root system nor made mention of blister rust in the crown.

In our study, *A. mellea* was the major root disease associated with bark beetles (Tables 1 and 2). This fungus, often present in patches on main roots as well as occurring in small dark depressions on the lateral roots, weakened the tree by killing small feeder roots, probably disrupting flow and storage of nutrients.

An examination of the major root pathogens in trees not infested with bark beetles indicate a great amount of *A. mellea*, *P. schweinitzii*, *I. bicolor*, and *P. weirii* in apparently healthy trees (Table 2). Although *R. bicolor* and *P. schweinitzii* were rarely implicated as major factors predisposing white pines to bark beetles (Table 2), field observations indicated that *A. mellea* may invade root systems of white pines following invasion by these diseases. The role of *Verticicladiella* as a predisposing agent to bark beetle attack was not determined.

Armillariella mellea, unable to overcome vigorous resistance by the host (Thomas 1934), becomes a pathogen as host vigor decreases, and often attacks at multiple loci (Garrett 1970). Decreased host resistance following girdling of branches and the tree bole by blister rust increased susceptibility to root diseases, particularly *A. mellea*. Wargo (1975) found decreased resistance to *A. mellea* following defoliation of hardwoods. He postulated that the hosts were less able to produce enzymes capable of lysing the hyphal wall of *A. mellea*, and that *A. mellea* grows well in the presence of reducing sugars that are the products of rapid starch conversion in defoliate trees (Wargo 1972).

Previous research on the association of root disease and bark beetle did not implicate *A. mellea* as a major disease predisposing conifers to bark beetles (Cobb et al. 1974, Hertert et al. 1975). In those studies *A. mellea*, although present, probably became established after more aggressive root pathogens and complexes of root pathogens had weakened the host. Leach (1939) showed that *A. mellea* best colonizes those hosts showing a gradual decline in vigor, whereas more aggressive root pathogens (e.g., *F. annosa*) can invade roots resistant to attack from *A. mellea* (Garrett 1970). In western white pine, a gradual decline in host resistance following girdling by blister rust, or senescence, enables *A. mellea* to become established earlier than other root diseases.

The mountain pine beetle, due to its aggressive behavior, invaded western white pines with less than 40% of their roots diseased and less than 40% of their crowns defoliated (Figs. 1 and 2). Less aggressive beetles (*I. montanus*, *I. latidens*, and *P. fossifrons*) colonized western white pine previously attacked by *D. ponderosae*, attacked portions of the crown weakened by blister rust, or colonized western white pines with more than 80% of the root system destroyed. Hertert et al. (1975) found that *S. ventralis* was unable to attack successfully and kill grand fir with less than 80% of its roots destroyed. We conclude that bark beetle populations in western white pine will respond more rapidly to increases in root diseases than will *S. ventralis*. Western white pines attacked by *D. ponderosae* were larger in diameter, older (stump age), and had a greater percentage of the primary roots infected with disease (Table 3).

As host resistance in western white pine is decreased through the combined effects of root diseases, blister rust, and senescence, these trees may serve as hosts to bark beetles. During periods of catastrophic decline (i.e., drought) these root disease centers may become focal points for bark beetle outbreaks.

Acknowledgment

This research was supported by funds from McIntire–Stennis Project No. 11, and Forest Utilization Project No. 3, administered by the Forest, Wildlife, and Range Exp. Stn., Univ. of Idaho, Moscow, Idaho 82843. Published with the approval of the Director, Forest, Wildlife, and Range Exp. Stn. as Contribution No. 264, Univ. of Idaho, Moscow.

References Cited

Cobb, F. W., Jr., J. R. Parmeter, D. L. Wood, and R. W. Stark. 1974. Root pathogens as agents predisposing ponderosa pine and white fir to bark beetles, pp. 8–15. *In* E. G. Kuhlman [ed.], Proceedings of the Fourth International Conference on *Fomes annosus*, Athens, Georgia. IUFRO Sec. 24, Forest Protection.

U.S. Dep. Agric. For. Serv. Southeast For. Exp. Stn., Asheville, North Carolina.

Daubenmire, R., and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Wash. State Univ. Agric. Exp. Stn. Tech. Bull. No. 60.

Ehrlich, J. 1939. A preliminary study of root diseases in western white pine. U.S. Dep. Agric. For. Serv., Northern Rocky Mtn. Forest and Range Expt. Stn. Pap. No. 1.

Garrett, S. D. 1970. Pathogenic root-infecting fungi. Cambridge University Press, London.

Hertert, H. D., D. L. Miller, and A. D. Partridge. 1975. Interaction of bark beetles (Coleoptera: Scolytidae) and root-rot pathogens in grand fir in northern Idaho. Can. Entomol. 107: 899–904.

Kulhavy, D. L., R. J. Chacko, and A. D. Partridge. 1977. Decay and disease fungi isolated from western white pine in northern Idaho. Plant Dis. Rep. 64: 322–336.

Leach, R. 1939. Biological control and ecology of *Armillaria mellea* (Vahl.) Fr. Trans. Br. Mycol. Soc. 23: 320–329.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent [eds.]. 1975. SPSS statistical package for the social sciences. McGraw-Hill, New York.

Nobles, M. K. 1948. Studies in forest pathology. VI. Identification of cultures of wood-rotting fungi. Can. J. Res., Sect. C 26: 281–431.

Partridge, A. D., and D. L. Miller. 1972. Bark beetles and root rots related in Idaho conifers. Plant Dis. Rep. 56: 498–500.

Thomas, H. E. 1934. Studies on *Armillaria mellea* (Vahl.) Quil. infection, parasitism, and host resistance. J. Agric. Res. 48: 187–218.

Wargo, P. M. 1972. Defoliation-induced chemical changes in sugar maple roots stimulate growth of *Armillaria mellea*. Phytopathology 62: 1278–1283.

1975. Lysis of the cell wall of *Armillaria mellea* by enzymes from forest trees. Physiol. Plant Pathol. 5: 99–105.

Received for publication 10 August 1983; accepted 28 February 1984.