THE ROLE OF RED ALDER IN REDUCING LOSSES FROM LAMINATED ROOT ROT

E. E. NELSON, Supervisory Research Plant Pathologist
Forestry Sciences Laboratory
Pacific Northwest Forest and Range Experiment Station
Corvallis, Oregon

E. M. HANSEN, Associate Professor
Botany Department
Oregon State University
Corvallis, Oregon

C. Y. LI, Soil Microbiologist
Forestry Sciences Laboratory
Pacific Northwest Forest and Range Experiment Station
Corvallis, Oregon

J. M. TRAPPE, Supervisory Research Plant Pathologist
Forestry Sciences Laboratory
Pacific Northwest Forest and Range Experiment Station
Corvallis, Oregon

ABSTRACT

*Red alder, in mixture with conifer or preceding stands of conifers, may be useful in reducing damage from laminated root rot (*Phellinus weirii*) on infested sites. This benefit could result from changes in soil nitrate, pH, fatty acids, phenolic compounds and microbial populations brought about by alder, as well as physical separation of susceptible root systems in mixed stands. Survey data tend to support this hypothesis. Disease incidence may be limited by reducing saprophytic survival of the pathogen or inhibiting its spread along conifer roots. Evidence for the former is greater than for the latter. Long-term experimental plots have been established to provide more definitive answers.*

Red alder is an unusual western forest tree species--not only as a hardwood with commercially valuable growth and form but, through a symbiotic relationship, it fixes atmospheric dinitrogen. Like other hardwoods, it is not damaged by *Phellinus* (*Poria*) *weirii*, cause of laminated root rot. It has also been hypothesized to function as a natural biological control of laminated root rot. In this paper, we critically evaluate present evidence regarding alder as a root rot control.

Importance of Laminated Root Rot

Laminated root rot is the most damaging disease of young-growth Douglas-fir in the Northwest. The annual loss is estimated at 32 million cubic feet in western Oregon and Washington (*2*). This includes the volume of trees killed by the fungus as well as the additional volume of timber that could have grown on root rot sites in the absence of the disease.

BIOLOGY OF THE PATHOGEN

Phellinus weirii is characterized by its slow spread, long survival time, and wide host range. These attributes lead to formation of slowly expanding infection pockets with long-dead trees in the center, a fringe of recently killed trees, and infected but still living trees around the perimeter. *Phellinus weirii* spreads along live roots from tree to tree increasing the radius of infection centers by about 1 foot a year (*17*). Spread is relentless but often erratic, governed by the pattern of susceptible root contacts beneath the stand. When live roots are not present, e.g. after harvest or a fire, the fungus can wait where it is for roots of the new generation to grow in contact with the old infected ones. The fungus remains viable in most infected stumps for 20 years and then slowly dies out (*6*). All western conifers are attacked, but pines and Cupressaceae tolerate the infection. Douglas-fir, the true firs, mountain hemlock, and in some situations western hemlock are very susceptible.

Laminated root rot is not evenly distributed through the Douglas-fir region; but where found, it often limits production of Douglas-fir. We suspect that intensive Douglas-fir management aggravates the problem. In natural forests, *P. weirii* must occur in a balanced state, slowly expanding around the perimeter of infection centers but dying out at its center in brush-filled openings as stands age. Root rotted trees often fall over, pulling much of the infective, rotted roots from the ground. A managed forest, on the other hand, is characterized by short generation times, stumps with infected roots left in the ground, and eradication or reduction of brush which might otherwise temporarily replace susceptible conifers.

CONTROL OPTIONS

No quick and easy control options are available to the forester. Fungicides don't reach the fungus below ground and fumigation is slow and costly. Physical removal of infected stumps greatly reduces residual inoculum but is feasible only on gentle slopes and with small stumps. The only real options for many managers are to accept the inevitable losses or to grow a less susceptible tree species. Of the *Phellinus*-tolerant conifers, only western red-cedar is suitable for most of the westside Douglas-fir region, and we don't know how to establish and manage this species. This brings us back to red alder.

The resistance of red alder to infection by *P. weirii* is possible due in part to its phenolic and lipid content. The combination of phenolic compounds found in roots of red alder inhibits *in vitro* growth of *P. weirii*

(*13, 19*). Linoleic acid, an unsaturated 18-carbon fatty acid isolated from alder, also inhibits *P. weirii* (*12*).

Effects of Red Alder on Soil

The dinitrogen fixation by nodules on alder roots leads to substantial nitrogen accretion in the soil. Most of the fixed nitrogen is transferred from the nodules to the host tree and is then cycled to the soil by rain throughfall, litterfall, and death of roots and nodules. The most striking net result over time is a buildup of NO_3^- ions in soil under alder as compared to conifers (*1*).

The higher NO_3^- levels under alder may be important in limiting activity of *P. weirii*. It cannot utilize NO_3^- as a nitrogen source for lack of the enzyme nitrate reductase (*10*), but many of its potential microbial competitors in the soil can. Fertilization with either NO_3^- or NH_4^+ has been shown to reduce survival of *P. weirii* in soil (*15*). Alder has the advantage over fertilization of adding nitrogen to the soil each year and maintaining relatively high levels after initial buildup.

A number of phenolic compounds and fatty acids have been shown to inhibit *P. weirii in vitro* (*9, 18, 19*). Alder roots and litter contain twice as high a concentration of phenolics as do those of Douglas-fir (*13*). Shrubs common to many red alder stands, such as *Rubus spectabilis* and *Sambucus racemosa*, also produce *P. weirii*-inhibiting phenolics (*7*). The soil under alder reflects this combined production in having far higher levels of phenolics than soil under Douglas-fir although these levels are not high enough to inhibit *P. weirii in vitro*.[1] Total fatty acids of soils under alder do not vary appreciably from those under Douglas-fir, but the kinds of fatty acids do differ markedly between the two kinds of stands (*8*). Most fatty acids are probably not found in quantities which inhibit *P. weirii*. For example, the absolute amount of linoleic acid in alder soil is 100 times lower than the amount necessary for inhibition *in vitro*. Inhibition in soil, however, where nutrients are less available to the fungus, probably occurs at concentrations below those effective *in vitro*.

Soil under alder is considerably more acid than under conifer stands on similar sites (*1, 16*). Growth of *P. weirii* is reduced in an acid medium (*11*). This difference in environment could have indirect effects on the activity of *P. weirii* as well since competing microorganisms would also be effected.

The net effects of increased organism inhibitors of *P. weirii* associated with alder soils are virtually impossible to separate from those of nitrogen, pH, and activity of microbial antagonists. The chemistry and biological activity of such compounds may be synergistic. The compounds themselves are subject to transformation by soil organisms. In any event,

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[1]Li, C. Y. Unpublished data, Pacific Northwest Forest and Range Experiment Station.

the increased amounts of such inhibitors under alder will not likely benefit *P. weirii*.

The comparative soil microbiology of conifer and alder stands, has been studied only at the Cascade Head Experimental Forest on the central Oregon coast. As might be expected in view of their chemical differences, alder soils differ substantially in microbial populations and activities. Most notably, the alder soils contain higher populations than conifer soils of some organisms with strong potential for antagonism against *P. weirii*. *Trichoderma viride*, a demonstrated antagonist against *P. weirii*, was characteristic of the alder soil but rare under conifers (*21*). Alder and conifer soils differed in populations of several other microfungi, but their antagonism against *P. weirii* remains to be assessed.

Mechanisms for Disease Control

• The hypothesis that alder somehow reduces incidence of *P. weirii* infection developed from scattered observations in the field. Laboratory findings have tended to support it. Red alder could reduce disease incidence in three ways: (1) by reducing survival of *P. weirii* in stumps and roots following logging, (2) by occupying the site in place of susceptible conifers until the pathogen has died out, or (3) by inhibiting spread of the fungus along living roots. The first two suggests control through crop rotation; the third through mixed stands.

REDUCING SURVIVAL OF PATHOGEN

Nelson (*14*) buried wood cubes colonized by *P. weirii* in soil under 40-year-old stands of alder, mixed alder and conifers, and conifers (mainly Douglas-fir) on the Cascade Head Experimental Forest. Three plots were located in each of the three stands and 18 cubes were buried on each plot to a depth of 9 inches with minimal soil disturbance. Three cubes were removed after 3 months and after 6 months to test for survival of the fungus. Six cubes were removed similarly after 12 and 18 months. *P. weirii* survived in some cubes buried in "conifer" soil through 18 months, in "mixed" soil only through 12 months, and in "alder" soil only through 6 months.

The results were encouraging but the design of the experiment was relatively insensitive for detecting differences. As a followup, Nelson (*16*) established 12 pairs of plots on the Cascade Head Experimental Forest. This time, 12 cubes containing viable *P. weirii* were buried on each plot of a pair in soil supporting pure alder or pure conifer stands. Cubes were buried 8 inches (20 cm) with minimal soil disturbance. After 12 months, soil samples were taken at the depth of the cubes and all cubes were then removed. Although the fungus survived somewhat better under conifer than alder stands, (24 vs 22 per cent) the difference was not significant at the 95-percent level of confidence. Soil samples showed a significantly higher level of NO_3 and lower pH under alder stands. Either of these factors could affect disease development without affecting survival of the fungus in stumps and decaying root systems.

Beginning in 1974, Hansen (*6*) excavated *P. weirii*-infested Douglas-fir stumps left 20, 30, and 50 years after logging. Initially, he looked at old stumps in young Douglas-fir stands and found that with age the fungus had died in many stumps. Where it hadn't, it was no longer viable at the extremities of roots.

Presently, infested Douglas-fir stumps in stands of young alder are being examined to determine if *P. weirii* remains infective there for a shorter time than in young Douglas-fir stands. A summary of data is shown in table 1.

Table 1--*Survival of* Phellinus weirii *in old stumps and roots on sites now occupied by Douglas-fir or red alder*

Stump age	Current stand	Stumps examined	Stumps with live *P. weirii*		Roots with live *P. weirii*	Average root diameter at limit of live *P. weirii*
Years		- -Number- -		Percent	Number	cm
20	fir	69	65	94	--	12.5
30	fir	65	38	58	87	18.9
50	fir	24	6	25	6	23.7
20	alder	45	33	73	102	11.0

In work completed, the fungus survived in 21 percent (94 vs 73 percent) fewer stumps under alder than it did under fir after 20 years. *P. weirii* remained viable, however, in somewhat smaller roots than it did in stands of Douglas-fir.

In British Columbia, Wallis (*20*) found viable *P. weirii* in old-growth stump roots as small as 4-cm diameter in 40-year-old mixed alder-Douglas-fir stands. But he also observed that in inoculum used to infect roots artificially, the fungus survived better in Douglas-fir stands than in mixed stands.

Alder seems to have some effect on *P. weirii* survival, but that effect is not dramatic and apparently requires a long time. How it happens, we have already hypothesized. How consistently it happens, what factors influence its effectiveness, and how long it takes, we have yet to learn.

INHIBITING SPREAD OF PATHOGEN

Let's look at the second possibility of alder reducing disease incidence. Microbiological and chemical changes in soil under alder have already been suggested. It is reasonable to expect them to inhibit development of some organisms such as *P. weirii*. Even if alder-induced changes are not of the magnitude to significantly inhibit root disease, the physical presence of a non-host species acting as a spacer between host species should reduce spread dependent upon root to root contact.

What would happen if young mixed stands of alder and Douglas-fir reforested infested sites? Hansen (*5*) examined four such stands on the Siuslaw National Forest in the Oregon Coast Ranges. Systematically selected healthy and diseased Douglas-fir were sampled in stands ranging from 10 to 17 years old. In each case, it was determined whether or not an alder was present within 5 feet of the tree or within a distance equal to the height of the Douglas-fir being sampled.

Overall proximity to alder did not seem to affect chance of infection judging from either measure. Infections in young stands are initiated by contact with old, infested stump roots. The failure of alder in even-age mixture with Douglas-fir to prevent these initial infections is not surprising, considering the extreme infection hazard and short time for soil modification.

In 1972, Trappe and Wortendyke[2] examined Douglas-fir and adjacent mixed alder-Douglas-fir stands which met certain criteria:

1. *Phellinus weirii* was endemic in the area.
2. Stand age was between 30 and 100 years and was similar for each stand of a pair.
3. Conifers in the mixed stand were not dominated by the alder.
4. Sites for each stand of a pair were similar. Extensive scouting produced only six pairs of stands meeting these criteria, all in southwestern Washington.

Transects 8-ft (2.4-meters)-wide were run through each paired stand. The length of the transects ranged from 600 to 2,600 ft (183-792 meters) depending on the limits of the stand but were the same for each stand of a pair. All standing trees within each transect (1,300 in all) were examined for signs of *P. weirii* infection.

Data shown in table 2 were analyzed by Wilcoxon's signed rank test (*3*). This is a nonparametric test: it neither assumes a normal distribution of the measure variable nor uses quantified data. With only six paired stands the test indicated no significant difference in *P. weirii* incidence between pure Douglas-fir and mixed alder-Douglas-fir transects. If we assume equal variance and normal distribution (without evidence this is so) and use percentage of infection in a Student's t test, we find that the chance of a

[2]Unpublished Survey Data, Pacific Northwest Forest and Range Experiment Station.

greater percentage of conifers being infected in pure stands than in mixed is significant (P<5 percent). Even if the assumption were valid, the sample used was limited geographically. What occurs in southwestern Washington may not occur throughout the range of red alder.

Table 2--*Laminated root rot in pure conifer stands vs. alder-conifer mixtures*

Pair no.	Trees with infection		Phellinus centers	
	Pure conifers	Alder-conifer mixtures	Pure conifers	Alder-conifer mixtures
	- - -Percent- - -		- - -Number- - -	
1	9.3	2.3	6	2
2	2.6	3.1	2	2
3	5.3	1.7	4	1
4	1.4	0.0	1	0
5	12.5	0.0	6	0
6	1.4	0.0	1	0
Average	5.41	1.18	3.3	0.8

Wallis (*20*) inoculated roots of Douglas-fir in pure and mixed alder-Douglas-fir stands in British Columbia. In addition to reduced survival of *P. weirii* in the inoculum that he used in mixed stands, he achieved only one-third the percentage of successful infections in mixed stands than in pure Douglas-fir stands. In other instances, however, *P. weirii* infections of Douglas-fir roots in 40-year-old mixed stands did not appear to be inhibited.

Thus the case for alder reducing disease incidence by inhibiting infection and spread on conifer root systems is equivocal. Until more evidence is examined, mixed stands cannot be recommended as a solution to *P. weirii* problems.

Research Needs

Many questions remain about the role of alder in root rot control, but the over-riding need is to determine if it is effective under field conditions. Much could be learned from old root rot centers that regenerated to alder and have since been reconverted to fir. But apart from being nearly impossible to find, such existing situations lack the documented disease histories necessary for quantifying changes in disease incidence. Long-term experimental plantings on documented disease sites seem to be the only way to satisfactorily test alder's capabilities. Existing stands are being used to answer the more limited question "How long does *P. weirii* survive in old infected stumps on sites regenerated to alder?" This project will be completed in 1977.

A series of long-term experimental plantings have been established to test the effectiveness of alder alone and in mixtures with Douglas-fir or hemlock as a means of reducing subsequent root rot losses (table 3). Each test was established and replicated on carefully documented root rot centers. They represent a major, long-term commitment to test alder as a biological control agent.

In the meantime, forest managers must depend upon established guidelines based upon our present knowledge of laminated root rot (*4*, *20*).

Table 3--*Established, long-term plots evaluating alder as a control agent for laminated root rot*

Study	Duration	Location	Landowner	Other cooperators
Effect of alder-hemlock mixed stand on incidence of laminated root rot	1974-2014	Mapleton, Oregon	Mapleton R.D. Siuslaw N.F. USFS	Pacific Northwest Forest & Range Exp. Station
Effect of alder-Douglas-fir mixed stands on incidence of laminated root rot	1975-2035	Shelton, Washington	Port Blakely Mill Company	Pacific Northwest Forest & Range Exp. Stn., Oregon State University
Effect of crop rotation with alder or cottonwood in disease incidence in succeeding stands	1975-2035	Rainier, Oregon	International Paper Co.	Pacific Northwest For. & Range Exp. Stn., Oregon State Univ., Longview Fibre, Crown Zellerbach

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