# PROCEEDINGS OF THE 33rd ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

**Olympia, Washington**
**September 1985**

# Proceedings of the 33rd Annual Western International Forest Disease Work Conference

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**Compiled by:**
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Proceedings of the Thirty-Third Western International Forest Disease Work Conference
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WIFDWC BUSINESS MINUTES AND COMMITTEE REPORTS

## HIGHLIGHTS AND COMMENTS

WIFDWC activities began with a pre-conference sailboat excursion on Puget Sound organized by Ken Russell and Ed Wood. Twelve sailors manned 3 boats skippered by Russell, Wood, and Bob Harvey. The trip yielded an increased sense of camaraderie, and a wealth of good stories.

The Thirty-third Annual Western International Forest Disease Work Conference was held September 19-24, 1985, at the Westwater Inn in Olympia, Washington. There were 100 registered participants, the largest number to attend any WIFDWC.

Three key members of the program were unable to attend. Our conference chairman, Fields Cobb, developed severe back problems a week before the conference. Fields' welcoming remarks were read to the conference by the secretary and are included in these proceedings. Dick Waring could not chair his panel due to a last minute conflict, but our conference program chairman filled in very effectively. Dick's paper was read to the conference (just to prepare the audience for the panel), and is included in these proceedings. Karl Stozek was injured in a hunting accident shortly before the conference and was unable to present his invited paper.

The program this year included two panels, three workshops, 15 special papers, 15 posters, an informative field trip, and a reasonably crisp business meeting. Panels dealt with silvicultural and ecological considerations of pathology. Workshops were hands-on opportunities: Two workshops presented models used to integrate pathology considerations into land management decisions. This was the first use of computers at a WIFDWC workshop. The third workshop provided an opportunity to discuss, examine, and compare in culture different "species" of the genus Armillaria.

The banquet was most enjoyable. The food, the impromptu program, and the bits of nostalgia were woven into an evening of fun in good taste unparalleled in recent WIFDWC history.

The field trip started with a lively tour of downtown Tumwater on the way to a root rot control demonstration area. The tour continued up the Toutle River drainage, stopping to examine plantations on private land, then on to the Mt. St. Helens blowdown and blast area to examine regeneration in the area affected by the volcano. The tour concluded in the evening with a salmon barbeque, T-shirt contest, homebrew (and commercial), and wine tasting.

At the business meeting the members decided to retain the WIFDWC name unchanged, meet in Nanaimo, B.C., in 1987 and to elect Ken Russell as chairman and Sally Cooley as secretary. Neil Martin presented a special compass to Ken Russell on behalf of the conference for use in conducting future tours.

The week was capped by a post-conference field trip to examine Armillaria root rot at Glenwood, Washington. The group discuss white pine blister rust management at Baby Shoe Pass on the way to the Flying-L Guest Ranch. At the ranch Armillaria root rot was discussed in the evening around the cook stove and the next day examined gopher fashion in the field. Many samples were collected, including a dried specimen that Terry Shaw carried home in his briefcase for further examination.

The conference now has 39 Honorary Life Members. Each HLM was requested to provide a brief update of their recent activities. These letters were typed, copied and made available to the conference members. The HLM update was well received.

A word about the proceedings. All committee reports were delivered shortly after the conference and most papers and abstracts were given to the conference secretary at or before the meeting. I want to thank all of you who followed the preparation guidelines and met the deadlines thus allowing me to get these proceedings out in a timely manner. There were only two recalcitrants who held things up. I recommend that next year all submissions made after the close of the conference be accompanied by a check for $50 made out to the conference secretary and a note from your mother explaining why with eight months notice one still needs "just one more week".

As a general trend our conferences seem to be getting better. This was perhaps the best yet. The conference was well attended by interested individuals who came prepared to listen and to be involved. Papers were well prepared and generlly well illustrated. The atmosphere was relaxed, informal, and, as usual, very friendly. Sessions started on time moved along crisply and were usually attended by more people than were registered for the conference. A salient feature of our meeting is interaction. There was discussion during each session that carried late into the scheduled day and into the evening. Our meeting room was used evenings for many informal discussions. The participants make the meeting and this meeting was a success!

Walt

## In Memorium

During 1985, we learned of the deaths of three of our colleagues, friends, and long-time members of WIFDWC.

Ernest Wright died in Portland, Oregon on June 25 at the age of 85. Ernie was born in Rossland, B.C. on September 23, 1899. He earned a B.S. in forestry from Oregon State University in 1923, a Master's from the University of California in 1928, and a Ph.D. from Nebraska in 1941. In 1942, he returned to Oregon as a pathologist with the PNW Forest and Range Experiment Station. In 1957, Ernie joined the faculty at his alma mater (OSU) and retired in 1963. He moved to Woodburn, Oregon and began a period of active civic endeavors, serving in a number of elected offices for the next 20 years. Two years ago he moved to Portland where he remained until his death. Ernie made many substantial contributions to his community, to forest pathology, and to WIFDWC.

George Harvey died in Corvallis, Oregon on March 2 at the age of 62. George was born in Essex, Connecticut on May 16, 1922. He earned his Baohelor's from Antioch College, Yellow Springs, Ohio, in 1946, his Master's from Yale University in 1948, and his Ph.D. from Oregon State University in 1974. George began his career with the University of Idaho in 1948, joined the Division of Forest Pathology at Gulfport, Mississippi shortly thereafter, was transferred to the PNW in Portland and to Corvallis in 1962 were he worked until his retirement in 1976. Perhaps his heart gave out because he gave so much of it to his fellow human beings; he contributed much to his profession, to WIFDWC, and to all of us.

Dwight Hester died in Colorado on February 10, 1983 at the age of 72. We apologize for the more than 2 years that passed before we learned of his passing. Dwight may have been a native son of Colorado. At least he spent practically all of his life there. He earned his BS in forestry from Colorado State University in 1937 and immediately began his career with the Bureau of Entomology and Plant Quarantine in Ft. Collins. He transferred to the USFS in 1941, came to the Division of Timber Management, Regional Office in Denver in 1957, and retired as the Branch Chief, Forest Pest Control, in 1971. He was an early and enthusiastic contributor to WIFDWC in its formative years.

We, the members of WIFDWC, greatly appreciate the many contributions that these members made during their lifetimes, and we will miss them. They will be with us in spirit and in the tradition of excellence that they have helped establish for our profession. We wish to extend our sincere sympathies to those who survive them.

## CHAIRMAN'S WELCOME

Ladies and gentlemen, honored guests, conference members old and new, and especially my bald-headed comrades, I am probably establishing another first. I am asking our friend and secretary of this renowned organization to extend to you my warmest greetings and welcome to the 33rd annual meeting of W.I.F.D.W.C. I trust that you all will be on your best behavior--as always--in my absence, and that you will have the usually, highly successful event.

For one-third of a century, this conference has served its members and our profession extremely well. It has provided a means of communication, a medium of cooperation, a forum to address problems and a unique environment to gain social achievements on an equal albeit sometimes "low" level. With a constant infusion of younger colleagues determined to carry on the traditions, the next 33 years will surely be as productive as the last.

WIFDWC was organized as a special forum for the forest pathologists of western North America. It has served that purpose well and with continued interest and vigilance should continue to do so. However, as we meet here in Olympia, there may be some dark clouds on the horizon that we might wish to address.

There are symptoms throughout North America that could indicate a decline in support for forest pathology. For example, positions in research and education are declining in number at a time when they should be increasing. The number of students being trained is down, and the support for research seems to have peaked. The number of forestry students has fallen dramatically, and even fewer appear to be getting an adequate training in pathology. Furthermore, the trend to separate forest management from forest biology has spread from coast to coast. Many of the forest resource managers seem to be completely ignoring the information we have to give them.

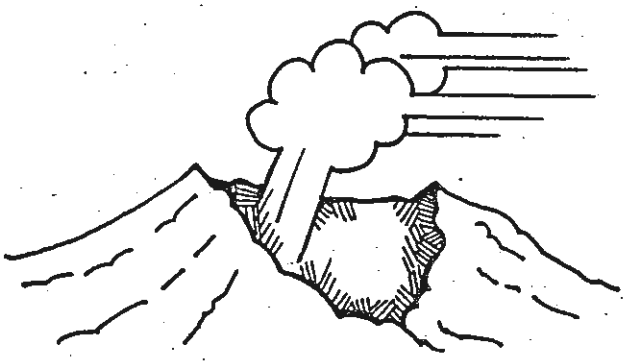
I hope that some of these things can be addressed during the conference. Panels on ecological approaches and integration with silviculture are indications that you will, especially if we can take advantage of our distinguished guest panelists.

Bon voyage. Have a fantastic meeting; my soul will be with you especially as you conduct the Wednesday evening campaign.

Executive Committee for the 33rd conference:

| | |
|---|---|
| Fields W. Cobb | Chairman |
| Walter G. Thies | Secretary-Treasurer |
| Robert L. Edmonds | Program Chairman |
| Kenelm W. Russell | Local Arrangements |

The conduct of the conference and the publication of the proceedings would not have been possible without the dilligent efforts of many folks who worked behind the scenes. In addition to the Executive Committee, the conference extends its thanks and appreciation to the following major contributors: Jim Arthurs and John Browning for numerous chores done during the conference; Amy Charron (Oregon State University, publications department) for the design on the cover of the proceedings and on the mugs; George Shaw (OSU, printing department) for technical support in layout and printing of the proceedings; Ginny Bissell and Sarah Berry for typing letters sent by the secretary and many portions of the proceedings; Oscar Dooling for taking the group photos; Allan Doerkson for printing the group photos; Walt Thies and Bob Harvey for taking and developing conference snapshots; Earl Nelson for recording the minutes of the business meeting; and Paul Hennon for serving as Interim Program Chairman.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

KEYNOTE ADDRESS

## CHANGES IN NATURAL RESOURCES MANAGEMENT

Brian Boyle

Good morning ladies and gentlemen. Welcome to Olympia and to Washington. I always appreciate the opportunity to speak with people who look for answers ... who try to discover ways of solving problems and doing things better.

Remember the Tony winning, Anthony Newley play, "Stop The World I Want To Get Off"? Well, a great many people feel that way at times because of the amount of change in our society.

But most of us in this room are on the leading edge of change and feel comfortable with it. That's the essence of science and scientists. They don't have the time to stop and get off.

This morning I want to discuss changes in public natural resources management in Washington State including our new Forest Land Management Program and our latest state forest on Tiger Mountain, just 15 miles east of Seattle.

Not too many years ago, the Washington State Department of Natural Resources didn't worry much about rapid change. It only had to worry about planting trees, putting out forest fires and selling timber.

But complexities in today's world make managing public lands challenging and almost constantly changing.

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Commissioner of Public Lands. Department of Natural Resources. Olympia, WA

It is always worthwhile to describe what we do on Washington State lands to set the stage for the topic.

Today we manage five million acres of state land --preserving it and keeping it productive -- and generate dollars to support our state's schools and other institutions.

We must provide opportunities for people to purchase resources such as timber, minerals, gravel and shellfish -- to lease land for agriculture, grazing and commercial uses -- and to use the land and water for recreation such as hiking and hunting.

We also do many other things. We still fight forest fires on private and public lands -- regulate forest practices --advise small tree farmers -- operate recreation sites -- regulate oil and gas drilling and surface mining -- and provide geological information.

Our primary concern continues to be to generate income for specific trust beneficiaries ... Our K-12 schools and our colleges and universities.

Given all this responsibility, natural resource managers in Washington State are faced not only with technological advances, but with demands from informed and highly vocal users of the resources. Frequently those users are in conflict with each other.

Which brings me to our Forest Land Management Program. It is a product of three years of thought and planning by more than 100 people in the agency and it was adopted in January of last year.

It replaces a 1979 plan which was written in response to a lawsuit. That plan attempted to justify past practices. Our Forest Land Management Plan is an effort to establish the most forward thinking forestry we can conceive for the next ten years. It looks into the future, rather than reflecting on the past.

We intended it to incorporate the best methods we know to:

1. Prevent degradation of soil productivity.
2. Produce more revenue.
3. Protect the environment, especially water and fish.
4. At the same time protect non-revenue producing values of these public lands.

We have asked our on-the-ground managers to set aside their "cookbook" approach to forestry. Instead, they will look at each site individually for long-term productivity.

In the course of developing the Forest Land Management Program we discovered that our on-the-ground managers needed to be retrained. Resources management had become more sophisticated since many of our people left school.

In addition, dealing with the public has also become more sophisticated than most of these managers had ever dreamed of it becoming.

Our second group of these first-line supervisors soon will begin a four-week course especially designed by the DNR along with the University of Washington.

The training is divided into two sections.

1. The first section emphasizes the forest environment and forest biology and ecology.

2. The second section concentrates on forest management and economics. This also covers planning processes and problem solving techniques.

These lands we manage are public lands as well as trust lands. We must attempt to realize long-term productivity of forests and forest soils that will in turn ensure long-term income for our state's educational institutions.

1. Riparian management zones along major streams will be managed to protect water quality and stream bank integrity. We will harvest wood in these areas, although sometimes at a reduced level.

2. Size of clearcuts will be less than 100 acres, generally.

3. Hand methods of controlling competing vegetation will be evaluated along with herbicides in terms of both costs and surrounding community acceptance in populated areas.

4. Old growth stands will be established for future seed source. In addition, old growth in alpine or other marginally productive areas will not be harvested. Total old growth set-aside is 11,000 acres.

Our annual sales level will be 777 million board feet of timber each year.

We think we now have the ability to manage to a higher standard than before. In fact, school trust needs demand higher standards now to ensure future income in decades to come.

Many of the elements addressed in the Forest Land Management Program are being implemented on our new 13,500-acre Tiger Mountain State Forest, just 15 miles east of Seattle.

This is a working forest so close to the million-plus population of our state's largest community that it can be reached by city bus.

Tiger Mountain is a theater. A stage to show that we can provide recreation, forest education and timber revenues.

Tiger Mountain will demonstrate that timber production and other public uses of the forest can be compatible.

Some background on Tiger Mountain. Its mixed ownership made it difficult to effectively manage. DNR set about to acquire the majority of the land through a series of land exchanges.

Three years ago I named a 19-member citizen's committee to advise the DNR on the management of the Tiger Mountain Area.

Membership included foresters, hikers, hang glider enthusiasts, environmentalists, local government representatives, four wheelers and local residents.

The first and most significant thing the committee did was recommend that Tiger Mountain continue producing timber. It recognized the need to manage Tiger Mountain to produce income for schools and universities and to protect the long-term health of the forest ecosystem.

About 75 percent of Tiger Mountain State Forest will be available for timber harvest at a level which can be sustained from the state forest in perpetuity.

Herbicide Use. The DNR intends to follow the policies in the Forest Land Management Program, which call for the increased use of alternatives to aerial spraying. In practice, aerial spraying of herbicides will be uncommon on Tiger Mountain, and if used, will be in situations where DNR can be confident there is negligible risk.

We believe Tiger Mountain is a valuable resource for education and research on innovative forestry.

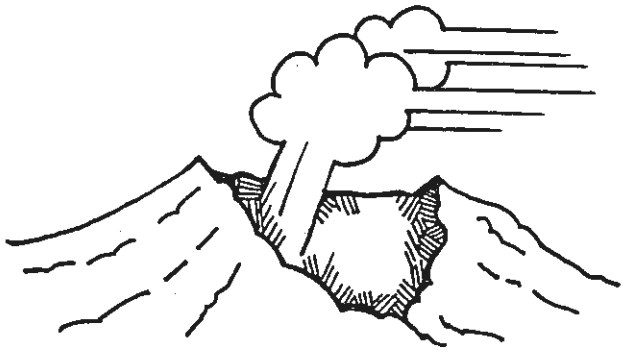
Our management plan calls for research under a management agreement with the University of Washington. It also recognizes the forest's potential for educating our school children.

Planning for Tiger Mountain has been a microcosm of the other big change for natural resources managers in Washington State. Our Forest Land Management Program is an expanded view of the Tiger Mountain State Forest, applied to two million acres. The future portends more advances, but that is the effect of innovative management, operating in a rapidly changing world and having the benefit of inquisitive scientists.

At times maybe some of us wanted to stop the world and get off, but we push forward.

We believe we are taking steps now that will help future generations understand and appreciate the importance of forests to our economy and quality of life.

Those steps also encourage scientists and managers in the future to not step away from a challenge, but to discover those advances that will take us from this exciting decade to the next.



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## DEATH OF A TREE AND ITS EFFECT ON THE FOREST

R.H. Waring

ABSTRACT: When a tree dies, whatever the cause, the environment on the forest floor changes to favor decomposition. This eventually may result in reducing the virulence of pathogens while improving the vigor of the host trees.

### INTRODUCTION

Whether a tree is cut, killed by insects, or by pathogens, the subsequent changes in environment and ecosystem responses are similar. Only the extent of change varies. In many cases, the changes associated with death of individual or groups of trees modifies the environment sufficiently to reduce the probability of additional tree mortality. In this paper the major changes expected are outlined with special reference to how these changes might reduce the virulence of pathogens while improving the vigor of host trees.

Richard H. Waring is a professor of forest ecology, College of Forestry, Oregon State University, Corvallis.

### EXPECTED RATES OF TREE MORTALITY

Assuming a forest has developed a closed canopy, we can expect, on the average, about 1-2% of the trees to die annually. Mortality data is amazingly constant when averaged over decades. Data from yield tables for fully stocked stands document this statement.

Why should the percentage of trees that die each year when averaged over decades be so similar? We know that windstorms, insect and disease attacks can cause high rates of annual mortality. What appears to happen is a reduction in the normal rate of mortality follows a short-term increase.

If we were to thin a forest, we might expect to reduce competition for light and other resources for the remaining trees. As long as thinning was done frequently, we would expect no natural mortality.

Certainly insect and disease attacks create conditions somewhat similar to thinning. In a lodgepole pine forest where bark beetles killed about 30% of the trees over a 3 yr period, surviving trees increased their growth rates by more than 40% and the probability of further mortality was greatly reduced (Waring and Pitman 1985). In a Douglas-fir forest where 30% of the trees were killed over a decade by laminated root rot, the surviving trees increased their growth rates by 30% so that annual production remained essentially constant (Oren et al. 1985).

### ENVIRONMENTAL CHANGES FOLLOWING TREE MORTALITY

Whatever the cause of tree mortality, the removal of canopy has predictable effects on the environment. More radiation will penetrate to the forest floor, the temperature of the litter and soil will increase, and more water will reach the soil.

Predictable chemical changes also occur in the foliage and roots available for microbial decomposition. Fresh-killed foliage and roots have much higher levels of starch, sugars, and nitrogenous compounds than normal litter. This results in decreasing the lignin/nitrogen ratio of the material as well.

## CHANGES IN PHYSIOLOGICAL PROCESSES FOLLOWING TREE MORTALITY

As the lignin/nitrogen ratio decreases, decomposition rates increase proportionately (Melillo et al. 1982). Increases in soil temperature and the availability of soil water further increase microbial activity (Fogel and Cromack 1977). Improved decomposition results in increasing the availability of essential nutrients to trees.

Trees respond to the increased availability of nutrients by reducing carbon allocation to roots and by increasing stem and foliage production (Axelsson 1981). Increased penetration of light, together with improved nutrient status, favor the process of photosynthesis. The result is improved tree vigor and growth (Waring and Pitman 1985).

The viability of pathogens is likely to be reduced as the canopy becomes more open. In part because pathogens attacking foliage, branches, and stem are exposed to a more desiccating environment. In addition, the improved physiological status of free-living microbes, symbiotic associates, and surviving trees reduces the virulence of pathogens in a variety of ways (Marx 1969, Schoneweiss 1977, Bowen 1982).

Within trees, the balance of soluble carbohydrates to amino acids appears particularly critical. Whenever the ratio is extreme, trees appear more susceptible (Matson and Waring 1984). Excess availability of nitrogen coupled with a closed canopy may be as detrimental to tree health as infertile or nutritionally imbalanced soils (Lambert and Turner 1977) because carbohydrate reserves are inadequate to produce defensive compounds (McLaughlin and Shriner 1980).

## OPPORTUNITIES FOR EXPERIMENTATION

Although the general response of forests to the death of individual or groups of trees is predictable, experimentation that incorporates critical studies of functional changes in free-living, symbiotic, and pathogenic microbial organisms with that of the surviving trees has yet to be done. There is a need and an opportunity to do such research. The systems likely to serve as good experimental sites are plantations of one or a few species located on uniform soils. In such situations the fertility can be varied with some degree of replication and inoculation with pathogens techniques are most likely to provide a broader understanding of the key interactions.

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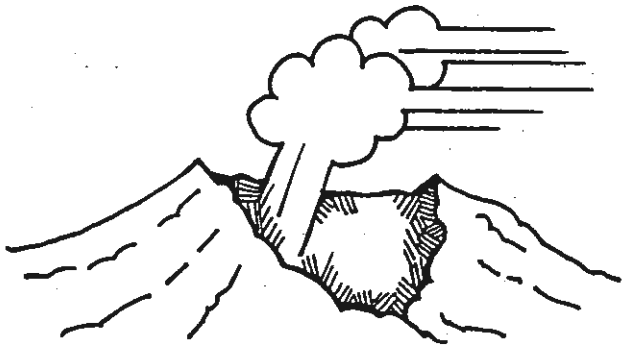

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## FOREST ECOSYSTEM RESPONSES TO PATHOGENS

Kermit Cromack Jr.

## INTRODUCTION

Wave-form dieback or mortality occurs in a variety of temperate forests and appears to be associated with stressed ecosystems (Sprugel 1976, Lambert and Turner 1977, Wardle and Allen 1983, Matson and Boone 1984). Such dieback also occurs in mountain hemlock (Tsuga mertensiana) forests of the Pacific northwest, where it is caused by the root rot Phellinus weirii (McCauley and Cook 1980). Experimental work, using controlled growth chambers at Duke University, has shown that mountain hemlock seedlings from the Waldo Lake area, which were stressed by shading, inadequate nutrients (especially N), or by shading with added nutrients exhibited increased foliage damage when inoculated with P. weirii compared to wounded controls (Matson and Waring 1984). Not only were nutrients inadequate, but starch reserves were significantly decreased in fertilized seedlings stressed by shading (Matson and Waring 1984).

Classic work with tea plants in Ceylon showed that roots depleted of starch reserves were susceptible to internal root rot (Gadd 1929). This research is important in that it indicated depletion of root starch reserves preceded root infection, thus setting the stage for modern physiolgical work concerning allocation of plant reserves to tree growth (Waring 1983) and defenses against insects and disease (Waring and Pitman 1985, Mattson 1980, Bell 1981). Although fertilization may increase plant resistance to disease (Garrett 1944, Bell 1981), excess nutrients such as N can result in greater susceptibility to disease (Hesterberg and Jurgensen 1972). In a key experiment, Wright (1941) obtained a nearly threefold increase in survival of American elm (Ulmus americana L.) seedlings where excess nitrate N was immobilized by applying sugar to the soil in the nursery seedbeds. This is an example of applying microbiological principles to immobilize excess available soil N in order to decrease attack of seedlings by damping-off fungi. Excess available soil N could result in depletion of seedling starch reserves through assimilatory conversion of such reserves to amino acids in larger amounts than can be efficiently utilized as proteins, thus diverting carbohydrate reserves from defense compounds or production of mechanical barriers to pathogens.

## RESULTS AND DISCUSSION

Recent work in moutnain hemlock forests in the Waldo Lake area of the Oregon Cascades has shown ecosystem changes due to large areas of forest

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Table 1--Ecosystem changes following dieback in a mountain hemlock forest. All mean values given are significantly different at at least P 0.1.

| Variable | Zone: old-growth | bare | young regrowth | older regrowth |
|---|---|---|---|---|
| Soil temperature[a] July at 6 cm (°C) | 24.5 | 30.8 | 31.2 | 23.5 |
| %Soil moisture[a] 15-30 cm | 26.0 | 36.9 | 30.8 | 27.8 |
| Tree biomass[a] (mg/ha) | 301 | 67 | 68 | 100 |
| Tree age[a] (years) | 215 | 18 | 35 | 74 |
| Vigor index[b] (g stemwood/$m^2$ of foliage yr) | 27 | 41 | 63 | 30 |
| Fine root % N[b] ( 5 mm) | 0.35 | 0.45 | 0.48 | 0.38 |
| Available soil N[c] 0-15 cm soil (g/ha) | 421 | 1150 | 1500 | 826 |

[a]From Boone (1982).
[b]Unpublished data from R. H. Waring.
[c]From Matson and Boone (1984).

dieback from P. weirii. Preliminary results are available for changes in environment, soil N availability, plant community structure, and tree growth response (Table 1). As a result of dieback, the old-growth mountain hemlock forest is opened up and there is increased soil moisture and temperature (Boone 1982). Tree biomass decreases and community age structure is altered (Boone 1982). Trees recolonizing behind the mortality wave front have increased resources of soil available N (Matson and Boone 1984) and young trees grow more vigorously and have increased concentrations of fine root N.

Improved environmental conditions and increased soil available N result in conditions favoring more vigorous tree growth in the young regrowth zone. In future work it will be of interest to determine whether the young recolonizing mountain hemlock trees are relatively resistant to attack by P. weirii. A series of field experiments have been initiated to modify tree nutrient regimes through fertilization with N alone or with complete fertilizer (N, P, K). In addition to controls, additional experimental trees are being given sugar as a soil amendment to decrease soil N in a system where available N is already low relative to other pumice soils in Oregon (Matson and Boone 1984, Geist 1977). We plan experimental inoculation of these trees to test their possible increased resistance to root rot. We expect to use procedures developed by scientists at the University of Washington and the Pacific Northwest Research Station. I appreciate the use of unpublished data and ideas from R. H. Waring, R. Boone, and P. Matson in this paper.

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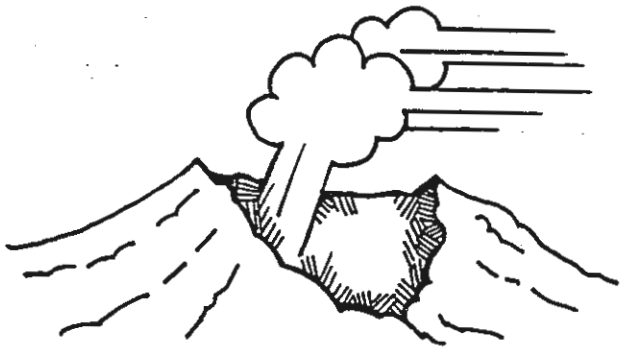

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## Relationship of ecosystem to Phellinus weirii root rot on southern Vancouver Island

W.J. BLOOMBERG and J.D. BEALE

ABSTRACT: Thirteen randomly selected 20-ha second-growth Douglas-fir stands and one 240-ha tract comprising several stands were sampled for Phellinus root rot using the intersection length of root rot centers along parallel transect lines placed 50 - 150 m apart. In addition, ecosystem classification units (site units) and timber type were recorded as length along transect lines. The relationships of root rot to the two variables were determined using number and length of infection centers per 100 m of site unit or timber type length. Site units were based on an edatopic grid matrix using soil nutrient and soil moisture gradients. Stand data were adjusted for differences in site index and age by analysis of covariance. Number and length of centers per 100 m of site unit varied significantly, being least in site units having very dry or wet soils and greatest in those having dry or fresh soils. There was a trend (p=.10) for site units with fresh soils to have greater numbers and length of centers per 100 m than those with dry soils and for rich nutrient to have greater values than poor nutrient in the very dry moisture regime. In the 240-ha tract, trends of root rot length and number of centers per 100 m of site unit length were similar to those for individual stands but were not significant due to variation among site units and timber types. There was also a trend of increasing root rot in timber types with increasing Douglas-fir and decreasing western hemlock content. Timber types with lodgepole pine present, either as dominant or minor species, and western red cedar timber types had no root rot.

W.J. Bloomberg and J.D. Beale are forest pathologists at the Pacific Forestry Centre, CFS, Victoria, B.C. and Vancouver Region, B.C. Ministry of Forests, Burnaby, B.C., respectively. Thanks are extended to the following individuals and organizations for their assistance: D. Hall and G. Reynolds, CFS, Victoria; R.N. Green and C.A. Ray, BCMF, Burnaby; Port Alberni District, BCMF and Horth Forestry Division, Sterling Wood Group Inc., Victoria. Part of the work was funded under a Canada Works contract.

### INTRODUCTION

Little has been reported on relationships of root rot caused by Phellinus weirii (Murr.) Gilbertson to ecological factors in Pacific northwest coastal stands. Childs (1970) concluded that the disease was omnipresent in the Pacific northwest over a range of sites and soil types and Hansen (1979) found no consistent differences in survival of the fungus in stumps over a latitudinal range or between Coast and Cascade mountain ranges. Differences in severity of the disease among stands have been attributed mainly to variation in inoculum load (Childs 1970; Nelson 1980) and relative susceptibility of host species (Wallis and Reynolds 1965). In northern Idaho, strong association was found between occurrence of P. weirii root rot with timber type, soil type, aspect and elevation (Williams and Marsden 1982; Hobbs and Partridge 1979). Elsewhere, other root rot pathosystems have been shown to be affected by ecological factors, especially soil moisture and structure (Whitney 1978), and soil nutrient and pH (Shields and Hobbs 1978).

On general principles, one would expect distribution of P. weirii root rot to be affected by site factors. In fact, some indication of this is provided by the significant correlation of site index with percent infection in stands sampled for the Vancouver Forest Region root rot survey (P. Wood, B.C. Ministry of Forests, Vancouver Region, personal communication). The purpose of our investigation was to ascertain whether there was any evidence that P. weirii root rot incidence and severity was related to ecosystem classifications which are used by the B.C. Ministry of Forests for silvicultural assessment.

### METHODS

Data was obtained from two sources: thirteen randomly selected 20-ha stands included in the Vancouver Forest Region Root Disease Survey and a 240-ha tract, comprising a number of stands, included in silvicultural assessment surveys. Forest ecosystems were recognized within the framework of the Biogeoclimatic Ecosystem Classification system, (Pojar 1983; Klinka et al. 1984). Stands were located within the Wetter Maritime Coastal Douglas-fir biogeoclimatic subzone (CDFb).

A biogeoclimatic subzone is a broad geographical area influenced by similar regional climate, with a characteristic mosaic of vegetation and soils. Biogeoclimatic subzones are defined by zonal (climatic climax) ecosystems. Zonal ecosystems are used to define biogeoclimatic subzones because they most strongly express the influence of climate on the vegetation, soils and other ecosystem components. Zonal ecosystems are typified by intermediate soil nutrient and soil moisture regimes, which generally occur on gentle to moderate slopes, (5-30%), in mid-slope positions that neither receive nor shed an excess of moisture and nutrients, with moderately deep, loamy-textured soils (Pojar 1983).

Whereas climatic variation is recognized by biogeoclimatic subzones, ecosystem associations are used to recognize smaller areas relatively uniform in vegetation and soil factors. An ecosystem association is defined as a group of related ecosystems physically and biologically similar enough that they have or would have similar vegetation at climax. The ecosystem association is similar to the habitat type of Daubenmire (1968) and Pfister et al. (1977) (Pojar 1983). Although ecosystem associations are characterized by the same general floristic structure and composition at climax, there may be considerable variation in soil features. The integrity of an ecosystem association is based upon the fact that plants integrate and reflect most environmental factors -- climate, soil nutrient and soil moisture regimes, and time -- and are a result of the environment, as well as a part of the environment (Pojar 1983).

The two most important site factors used to distinguish ecosystem associations in a biogeoclimatic subzone are soil moisture regimes and soil nutrient regimes, (Klinka et al. 1984). Ecosystem associations can be projected on a two-dimensional edatopic grid matrix (Fig. 1), using the soil nutrient (trophotope), and soil moisture (hygrotope) gradients on the X and Y axis, respectively.

Subdivisions shown on the edatopic grid represent generalized groupings of closely-related ecosystem associations which are similar in productivity potential, species composition and environmental features; and which are used for silvicultural decision making in the Vancouver Forest Region. The nine subdivisions for the CDF zone (Table 1, Fig. 2), termed site units, were used for field identification of ecosystems in this study, with the exception of site units 7 and 8. A brief characterization of the site units is described in the appendix.

Phellinus weirii root rot data and site unit data were obtained from using parallel transect lines placed to span the width of stands or tract at intervals of 50 - 150 m. Intersection lengths of root rot centers were measured along transects (Bloomberg et al. 1980) and site unit intersection

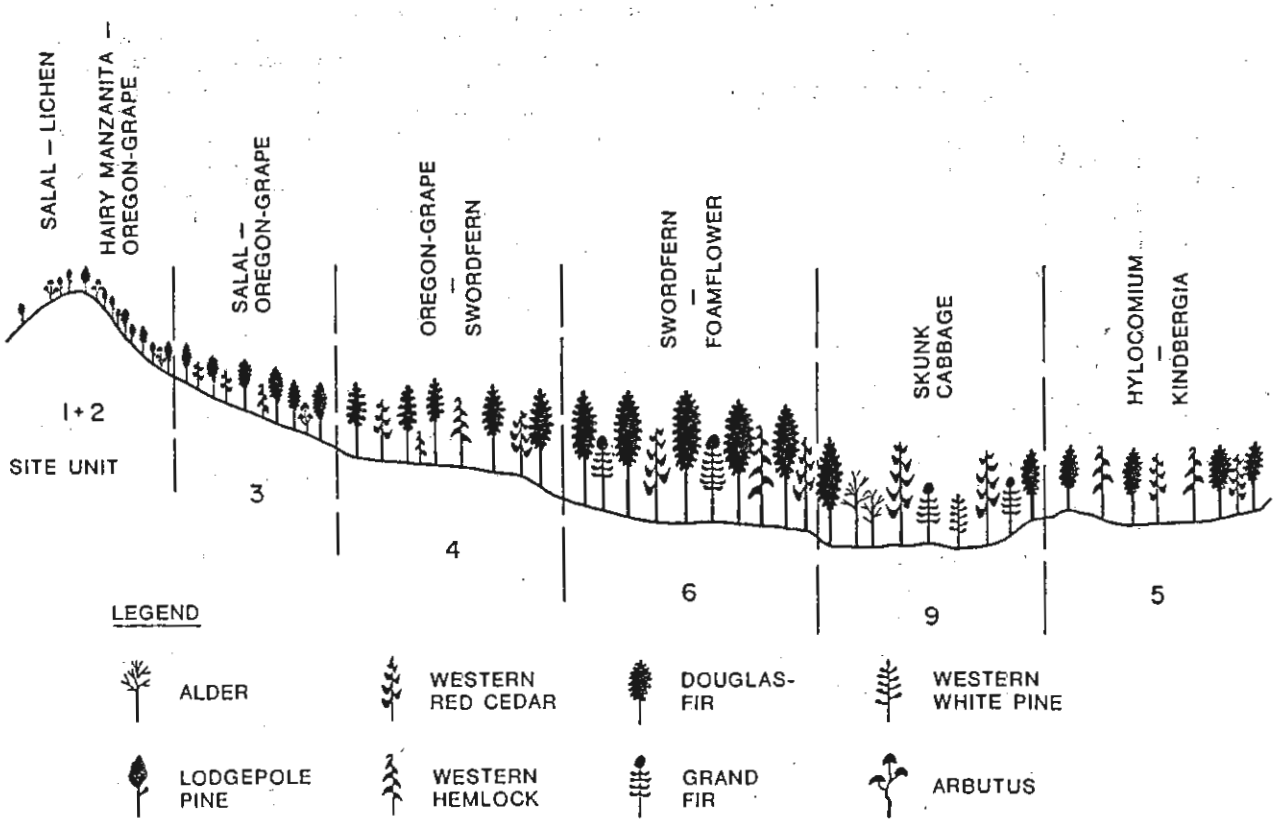


Figure 1--Generalized topographic sequence for the site units recognized in the CDFb subzone.

Table 1. Reference number and informal name for subdivisions of the CDF zone used for silvicultural decision-making in the Vancouver Forest Region.

| Site Unit No. | Name |
|---|---|
| 1 | Salal-Lichen |
| 2 | Hairy manzanita - Oregon-grape |
| 3 | Salal - Oregon-grape |
| 4 | Oregon-grape - Swordfern |
| 5 | Hylocomium - Kindbergia |
| 6 | Swordfern - Foamflower |
| 7 | Alluvial floodplain[1] |
| 8 | Sphagnum[1] |
| 9 | Skunk cabbage |

These site units are depicted in a generalized topographic sequence shown in Figure 2, and described in the Appendix.

[1]not recorded in this study.

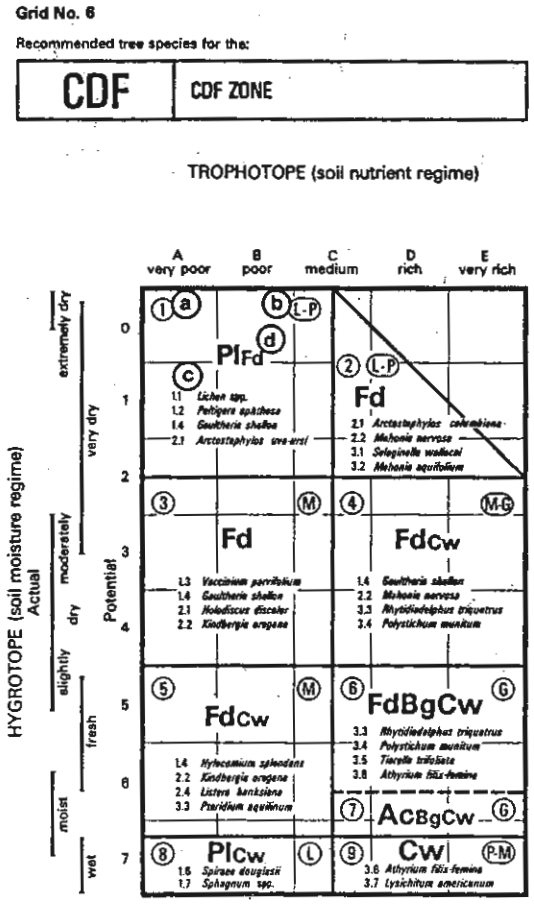


Figure 2--Site units of the CDF zone projected on a two-dimensional edatopic grid matrix (Klinka et al. 1984).
a= Site Unit b= Site Quality c= Edatopic Indicator Species Group d= Recommended Tree Species
L = Low P = Poor M = Medium G = Good

lengths were measured between the estimated boundaries where they crossed transect lines. All stands consisted of Douglas-fir timber type whereas the tract comprised a number of timber types. Intersection lengths of timber types were measured between their boundaries where they crossed transect lines.

The variables used in determining the relationship of P. weirii root rot to site unit and timber type were length and number of infection centers per 100 m of site unit or timber type length. They were calculated by summing root rot intersection lengths within each site unit or timber type, dividing by total length of site unit or timber type and multiplying by 100. One-way analysis of covariance for site unit using stand age and site index as covariates was applied to results for stands and one-way analyses of variance for site unit and timber types were applied to results for the tract. Chi-squared tests were applied for site units within different timber types since distributions of timber type-site unit combinations were too unbalanced to permit two-way analysis of variance.

## RESULTS

### Individual Stands

The covariates site index and age exerted significant, ($p = .001$) positive effects on number and intersection length of infection centers per 100 m ($p = .05$) of transect. Means adjusted for these effects, varied significantly ($p = .05$) among site units (Table 2). Site units having fresh, nutrient-rich soils had more centers per 100 m and greater center length per 100 m than those with very dry, nutrient-poor soils or wet soils. There was a trend ($P = .10$) of increasing root rot with moisture regime from very dry to fresh (Fig. 3) and from poor to rich

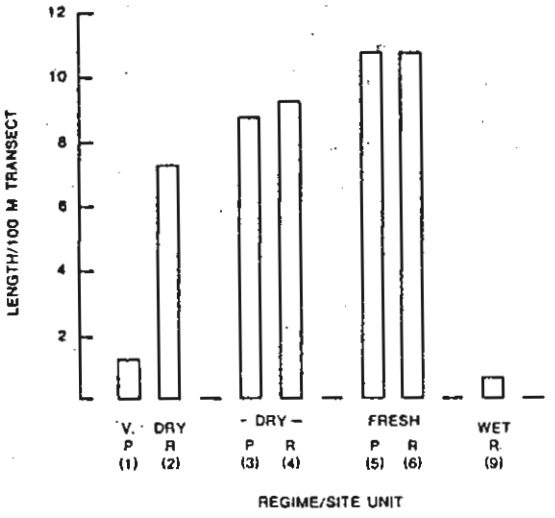


Figure 3--Relationship of Phellinus weirii root rot center intersection length to soil moisture and nutrient regime in Douglas-fir stands. P, R = poor, rich. respectively. Figures in parenthesis denote site units (see text for definition).

nutrient in the very dry regime. Total site unit length was not significantly correlated with number or length per 100 m.

Tract

Number of centers per 100 m and length per 100 m varied widely among site units summed over all timber types (Table 3). Number and intersection length of root rot centers was greatest in site units having fresh soils and least in those with very dry and with wet soils. As in individual stands, there was a trend of increasing root rot with moisture regime from very dry to fresh (Fig. 4). However, owing to the large variation caused by a number of zero values, even in those site units with the highest root rot levels, differences were not significant.

Number of and intersection length per 100 m also varied widely among timber types summed over all site units (Table 4) but again because of variation, differences were not significant. Pure Douglas-fir (>80%) had highest values, with pure hemlock and hemlock-fir mixture having smaller values. Lodgepole pine, whether in pure stands or in >20% mixture with Douglas-fir, had no root rot. As in the individual stands, there was no significant correlation between total site unit length or number of centers or length per 100 m.

Root rot intersection length per 100 m varied widely when stratified by both site unit and timber type (Fig. 5). Generally, length increased with Douglas-fir content of stands and with increasing soil moisture. Root rot was absent in wet soils, but the sample was small.

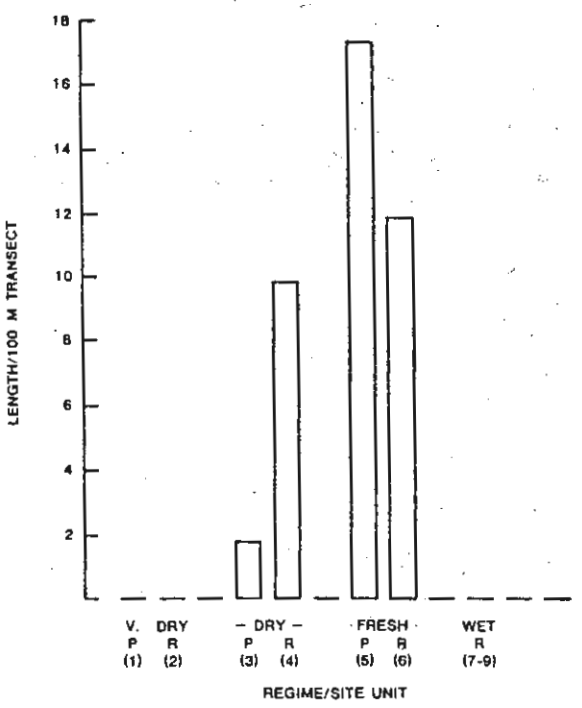


Figure 4--Relationship of Phellinus weirii root rot center intersection length to soil moisture and nutrient regime in a tract containing a range of timber types. P, R = poor, rich, respectively.

Root rot was also absent in stands containing lodgepole pine, regardless of the site unit.

Number of root rot centers and length per 100 m differed significantly ($p = .05$) among age classes summed over site units and timber types. Older age classes generally had higher percentages than younger classes. Number of root rot centers (not shown) and intersection length per 100 m varied significantly among site units stratified by age classes (Fig. 6). Highest values occurred in nutrient-rich, dry or fresh soils in the 81-100-year age class. Root rot was absent from site units with wet or very dry soils, regardless of age class.

## DISCUSSION

In our opinion, sufficient significant differences and consistent non-significant trends were found in the data to justify the conclusion that incidence of P. weirii root rot is at least partly dependent on timber type and particularly with respect to soil moisture regime. Certainly within the individual stand data there is evidence to suggest that soil moisture regime has a stronger effect on the incidence of P. weirii than soil nutrient regime.

Although the sample sizes in each stratum were necessarily unequal, there was no evidence that results were biased in favor of the most frequently occurring as evidenced by the lack of correlation between total length and number of root rot centers and length per 100 m. For example, the greatest center length per 100 m in the tract was found in a relatively infrequent site unit (Table 4), whereas lodgepole pine, pure and in mixture with Douglas-fir, contained no root rot despite having the second largest sample size (Table 5). As might be expected, differences among site units were magnified by increasing stand age.

As Williams and Marsden (1982) have pointed out, separation of effects of site factors and timber type on root rot is confounded by their close relationships. However, there was some indication from their results that site factors exerted independent effects because the disease was not uniformly present over the range of the most frequent hosts (grand fir and Douglas-fir). Our results indicate that on dry sites, probability of disease diminished in spite of presence of the preferred host, whereas presence of lodgepole pine diminished probability in site units which otherwise favor the disease.

Stand history is also an important factor in a root pathosystem which depend on the previous stand for its continuity. In undisturbed ecosystems, stand history is also influenced by site factors through their strong influence on tree species establishment, composition, stand structure and the successionary patterns. Soil nutrient and moisture status affects tree size, which in turn determines the probability of root contact (Reynolds and Bloomberg 1982), and inoculum density in the form of stump biomass.

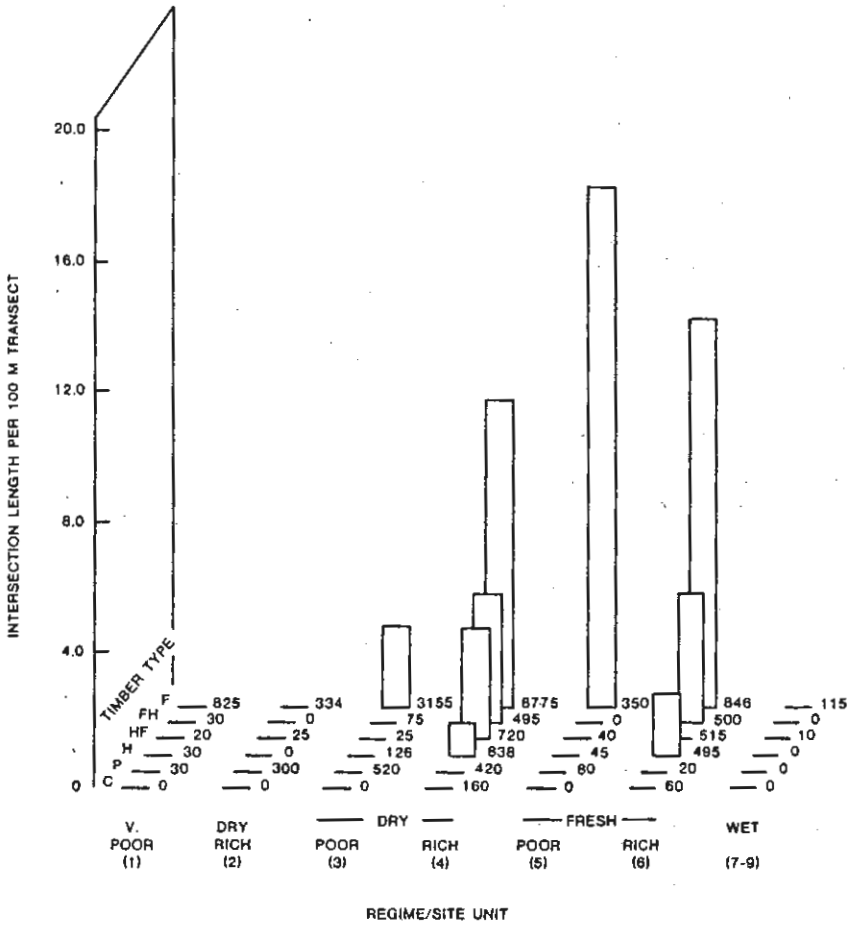


Figure 5--Relationship of Phellinus weirii root rot center intersection length transect to soil moisture and nutrient regime and timber type in a tract containing a range of timber types. Letters F, PL, H, C and D refer to Douglas-fir, lodgepole pine, western hemlock, western red cedar and red alder, respectively. The second species in the timber type denotes that it comprises 20-49% of the type by volume. Numbers show total transect length in each type.

## CONLCUSION

We conclude that definite evidence exists that P. weirii root rot incidence and severity is related to site unit and that further investigation over a broader range of stands and biogeoclimatic subzones is required.

Importance of site factors must be established through their effects on the biology of the fungus and the epidemiology of the disease. Fungus viability, infectivity and ectotrophic growth are examples of the responses to site, as are the root distributions and infection probabilities of different host species. We believe that our results, limited as they are, justify greater research emphasis on the ecological relationships of P. weirii.

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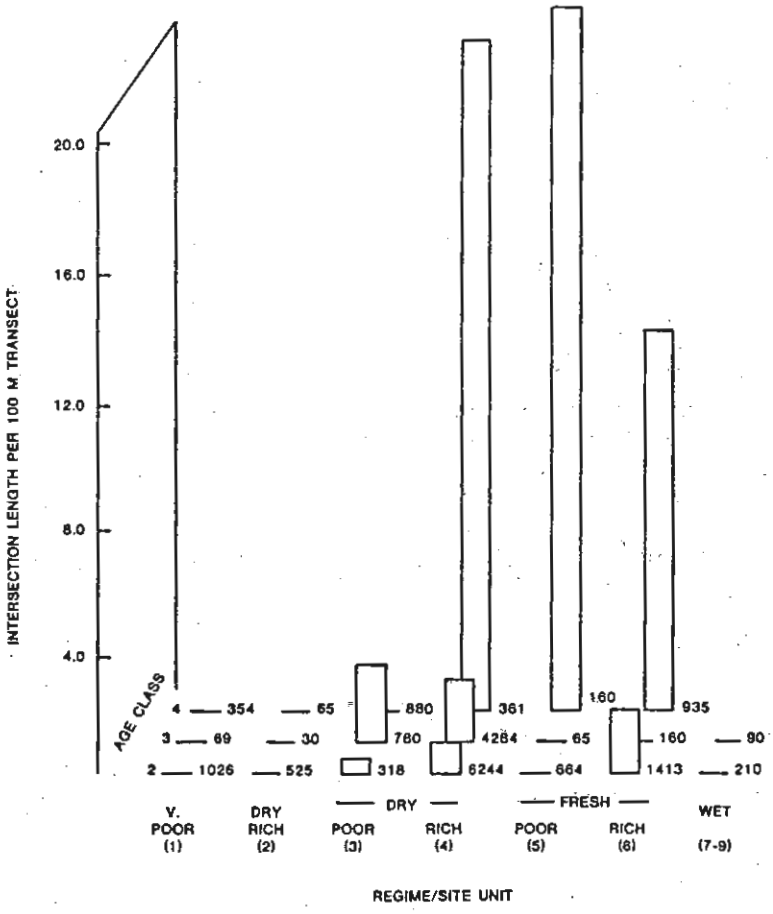


Figure 6--Relationship of Phellinus weirii root rot center intersection length to soil moisture and nutrient regime and age class in a tract containing a range of timber types. Age classes 2, 3 and 4 are 21-40, 41-80 and 81-100 years, respectively. Numbers show total transect length in each age class and type.


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Table 2--Relationship of Phellinus weirii root rot centers to site unit in 13 second-growth Douglas-fir stands.

| Site unit (see Table 1) | Site unit length m (Av./stand) | No. centers/100 m[1/] | Center length/100 m[1/] p =.05 | p =.10 |
|---|---|---|---|---|
| 1 | 164 | 0.11a | 1.53a | a |
| 2 | 404 | 0.55ab | 6.24ab | b |
| 3 | 183 | 0.78b | 8.29ab | b |
| 4 | 716 | 0.65ab | 8.69ab | b |
| 5 | 281 | 0.61ab | 10.28ab | c |
| 6 | 414 | 1.24b | 10.53b | c |
| 9 | 245 | 0.10a | 1.16a | a |

[1/]Means adjusted for differences in stand age and site (see text). Means followed by different letters are significantly different.

Table 3--Relationship of Phellinus weirii root rot centers to site unit averaged over timber types in a tract.

| Site unit (see Table 2) | Site unit length m | No. centers/100 m | Center length/100 m |
|---|---|---|---|
| 1 | 1480 | 0.00 | 0.00 |
| 2 | 650 | 0.00 | 0.00 |
| 3 | 5084 | 0.03 | 0.71 |
| 4 | 12070 | 0.21 | 4.25 |
| 5 | 925 | 0.58 | 10.40 |
| 6 | 3385 | 0.20 | 3.86 |
| 7 | 15 | 0.00 | 0.00 |
| 9 | 285 | 0.00 | 0.00 |

Table 4--Relationship of Phellinus weirii root rot centers to timber type averaged over site units in a tract.

| Timber type[1/] | Type length m | No. centers/100 m | Center length/100 m |
|---|---|---|---|
| F | 14499 | 0.32 | 7.18 |
| F PL | 2215 | 0.00 | 0.00 |
| F H | 1099 | 0.12 | 2.10 |
| H | 1429 | 0194 | 2.06 |
| H F | 1355 | 0.15 | 1.60 |
| PL F | 780 | 0.00 | 0.00 |
| C | 220 | 0.00 | 0.00 |
| D | 2134 | 0.00 | 0.00 |

[1/]Letters F, PL, H, C and D refer to Douglas-fir, lodgepole pine, western hemlock, western red cedar and red alder, respectively. The second species in the timber type denotes that it comprises 20-49% of the type by volume.

APPENDIX

The appendix contains a general brief characterization of the site units recognized in our study (R.N. Green, research pedologist, B.C. Ministry of Forests, Vancouver Region.)

1. Salal--Lichen
   - Physiography:- upper slopes, ridge crests and glacio-fluvial benches.
   - Soils:- shallow, rapidly drained, coarse-textured, Eluviated Dystric Brunisols, (CSSC 1978), with Xeromor or Hemimor humus forms, (Klinka et al. 1981.)
   - Moisture Regime:- extremely dry to very dry.
   - Nutrient Regime:- very poor to medium.
   - Vegetation Layers
     - Tree:- Douglas-fir (Pseudotsuga menziesii), with variable composition of lodgepole pine (Pinus contorta) and Pacific madrone (Arbutus menziesii).
     - Shrub:- Gaultheria shallon, and scattered Arctostaphylos uva-ursi, Mahonia nervosa, and Vaccinium parvifolium.
     - Herb:- Arctostaphylos uva-ursi, Linnaea borealis, Chimaphilla umbellata and Goodyera oblongifolia.
     - Moss & lichen:- Pleurozium schreberi, Polytrichum juniperinum, Rhacomitriumcanascens, R. heterostichum, Peltigera aphthosa, P. membranacea, Cladonia bellidiflora, and Cladina rangiferina.

2. Hairy manzanita--Oregon-grape
   - Physiography:- upper slopes and ridge crests.
   - Soils:- shallow, coarse-textured, Eluviated Dystric Brunisol derived from base-rich igneous parent material (basal, gabbro), rapidly drained with typical Xeromoder humus forms.
   - Moisture Regime:- very dry.
   - Nutrient Regime:- medium to rich.
   - Vegetation Layers
     - Tree:- Douglas-fir, with variable composition of lodgepole pine, and Pacific madrone.
     - Shrub:- Mahonia nervosa, Mahonia aquifolium, Symphoricarpos hesperius, Arctostaphylos columbiana, A. uva-ursi, and Juniperus scoupulorum.
     - Herb:- Chimaphilla menziesii, and Selaginella wallacei.
     - Moss & lichen:- Pleurozium schreberi, and Peltigera aphthosa.

3. Salal--Oregon-grape
   - Physiography:- middle slopes, gently sloping hilltops, and fluvial deposits.
   - Soils:- well-drained, moderately deep, medium-textured Eluviated Dystric Brunisols or Orthic Humo-Ferric Podzols, with Moder or friable Hemimor humus forms.
   - Vegetation Layers
     - Tree:- Douglas-fir is dominant, with variable composition of western hemlock (Tsuga heterophylla) and western red cedar (Thuja plicata) in co-dominant or intermediate canopy positions.
     - Shrub:- Gaultheria shallon, Vaccinium parvifolium, Mahonia nervosa, Rosa gymnocarpa, and Holodiscus discolor.
     - Herb:- Linnaea borealis, Chimaphilla umbellata, Boschniakia hookeri, and Rubus ursinus.
     - Moss:- Hylocomium splendens, Kindbergia oregana, and Homalothecium megaptilum.

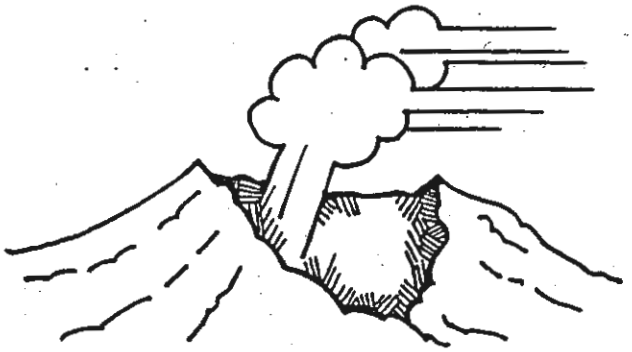
4. Oregon-grape--Swordfern
   - Physiography:- moderate to steep slopes in lower slope positions.
   - Soils:- well-drained, shallow to moderately deep coarse-textured, cobbly colluvial material, Dystric Brunisols, with temporary seepage, and Moder humus forms.
   - Moisture Regime:- moderately to slightly dry.
   - Nutrient Regime:- medium to rich.
   - Vegetation Layers
     - Tree:- Douglas-fir, western red cedar, and a minor component of western hemlock.
     - Shrub:- Mahonia nervosa, and Gaultheria shallon.
     - Herb:- Polystichum munitum, Achylys tripyhlla, Rubus ursinus, and Dryopteris assimilis.
     - Moss:- Kindbergia oregana, Hylocomium splendens, and Rhytidiadelphus triquetrus.

5. Hylocomium-kindbergia
   - Physiography:- shallow draws and depressions, on lower slope positions.
   - Soils:- medium to coarse-textured, Orthic and Gleyed Humo-Ferric Podzol to Orthic and Gleyed Dystric Brunisols, and Hemimor, Humimor or Hydromor humus forms; typically characterized by fluctuating water table, (more or less stagnant), imperfect to poorly drained.
   - Moisture Regime:- fresh to moist.
   - Nutrient Regime:- poor to medium.
   - Vegetation Layers
     - Tree:- Western red cedar, Douglas-fir and Western hemlock.
     - Shrub:- Gaultheria shallon, and Vaccinium parvifolium.
     - Herb:- Pteridium aquilinum, Goodyera oblongifolia, Cornus canadensis,

Blechnum spicant, and Listera banksiana.
Moss:- Hylocomium splendens and Kindbergia oregana.

6. Foamflower--Swordfern
Physiography:- lower, flat slopes.
Soils:- moderately deep to deep, loamy to fine-textured Sombric and Gleyed Dystric Brunisols or Humo-Ferric Podzols with Mull or Moder humus forms; moderately to imperfectly drained soiis; received additional inputs of water and nutrients through subsurface water seepage.
Moisture
Regime:- fresh to moist.
Nutrient
Regime:- medium to very rich.
Vegetation Layers
Tree:- Douglas-fir is dominant, with Western red cedar, grand fir (Abies grandis) and western hemlock occupying the lower canopy.
Shrub:- Rubus spectabilis.
Herb:- Polystichum munitum, Tiareila trifoliata, T. laciniata, Achylys triphylla, Trillium ovatum, Athryium filix-femina, Melica subulata, Adenocaulon bicolor, Galium triflorum, and Carex hendersonii.
Moss:- Plagionium insigne, Leucolepis menziesii and Kindbergia oregana.

7. Skunk Cabbage
Physiography:- occurs exclusively in depressions
Soils:- soils are characterized by fluctuating water tables usually within 30 cm of the surface; typically Humic Gleysols or Terric Humisols, with Hydromull or Saprimuli humus forms, poorly drained.
Moisture
Regime:- wet.
Nutrient
Regime:- medium to rich.
Vegetation Layers
Tree:- Western red cedar is dominant, with Douglas-fir occupying the fringe areas; red alder (Alnus rubra) is a common early seral species, and persists in the wetter microsites; grand fir, western hemlock, and western white pine (Pinus monticola) are common associates.
Shrub:- Rubus spectabilis
Herb:- Lysichitum americanum, Athyrium filix-femina, Viola glabella, Oenanthe sarmentosa, Veratrum viride, and Carex obnupta.
Moss:- Mnium punctatum, Kindbergia praelonga, Conocephalum conicum, Hookeria lucens, and Pellia neesiana.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## ECOLOGICAL GENETICS OF ARMILLARIA - CONIFER INTERACTIONS

Geral I. McDonald

ABSTRACT: This paper is a progress report of results obtained from the study of Armillaria from 120 randomly located plots on 15 National Forests in the Northern Rocky Mountains. The fungus was not found on dry-warm or dry-cold habitat types. Incidence of pathogenicity decreased as productivity of plots increased on pristine plots, but increased when disturbed on the high productivity climax series. Plot samples yielded 419 clean cultures. Clonal determinations reduced these to 297 distinct clones. The plots averaged 3.2 clones each. Preliminary determination of biological species of 70 clones derived from seven of the National Forests produced positive matings with North American species 9. In nine cases, pure cultures were obtained with fans from fading or Armillaria-killed trees. Eight of these showed the same clone was present as pathogenic fans, saprophytic fans, soil rhizomorphs, and epiphytic rhizomorphs on healthy conifers or hardwoods. These results are discussed with reference to the scavenger hypothesis of Armillaria pathogenicity.

### INTRODUCTION

The Intermountain Research Station (USDA Forest Service) began a study of population level genetic and ecological interactions between Armillaria and its conifer and hardwood hosts in 1983. The two primary objectives of this research were (1) to predict risk to Armillaria by geographic location, host species, and stand management history, and (2) to develop the methodology for assessing genetic and physiologic responses of intra- and inter-species host and fungus populations in Northern Rocky Mountain forests.

### WHO IS DOING WHAT TO WHOM AND WHERE?

The study was initiated through the installation of 120 random plots. A system of random coordinate draws was used to select sections within a National Forest. Aerial photos of these sections were obtained, and additional random coordinate points were located on these aerial photos to select a 0.1-acre plot within the selected section. Plots were visited between May 1 and October 1, 1983. Key plant species were identified and used to place individual plots into habitat types (Pfister and others 1977, Steele and others 1981, and Cooper and others, in press). Armillaria was collected from epiphytic rhizomorphs attached to healthy and dead conifers or hardwoods. Fans from pathogenic Armillaria cases, as judged from tree condition and resin production, were also collected and cultured. Occurrences of each kind of sample were recorded by host and plot and identified as Armillaria by culture traits. Each pure culture was put through a series of field culture x field culture challenge tests (Korhonen 1978) to determine their clonal affiliations. A preliminary set of challenges from within plots and between plots in a National Forest created a large data base consisting of culture identification numbers and yes or no answers concerning whether a particular combination grew together. These combinations were sorted by yes and no reactions and the results placed in a large Punnett square for each Forest. The result was a blind (plot not considered) determination of clonal affiliation. These tentative affiliations were then verified by challenging members of each group in all possible combinations. At least three challenges were required between all clones within a National Forest. Each challenge consisted of three replications with each read by at least two observers. Finally, each clone defined from the entire sample population will be tested for biological species affiliation by mating with known haploid tester cultures (Wargo and Shaw 1985).

### RESULTS

The results of the Armillaria occurrence and pathogenicity incidence work are being reported (McDonald and others, in preparation). These results can be summarized as follows: The pattern of occurrence on 0.1-acre plots classified by habitat type on the Boise, Deerlodge, Bitterroot, Flathead, Lolo, Payette, Nezperce, Clearwater, St. Joe, Coeur d'Alene, Kaniksu, Kootenai, Colville, Umatilla, and Wallowa-Whitman National Forests showed that Armillaria was absent from the ponderosa pine series, discontinuous in the ninebark and blue huckleberry habitat types of the Douglas-fir series but absent from the remainder of this series. It was continuous in the sitka alder, mountain maple and queencup beadlily habitat types of the subalpine fir series, discontinuous in the menziesia habitat

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type of the subalpine fir series, and absent from the beargrass and whortleberry habitat types of the subalpine fir series. Habitat types of the grand fir series all showed continuous distributions, except the spirea and pine grass habitat types from which it was absent. The western redcedar and western hemlock series also had continuous distribution of Armillaria for all habitat types. Without specific knowledge about the taxonomic affinities and pathogenicity or the Armillaria occurring in the above situations, one must assume that anywhere Armillaria rhizomorph, rot, or fans are found a risk is present to most conifers!

Pathogenicity incidence seemed related to productivity of the climax series as well as whether or not the plot had been disturbed by a major management activity. Within the high productivity grand fir, western redcedar, and western hemlock series, pathogenicity incidence decreased as productivity increased on pristine plots. It was low on pristine plots and high on entered plots. The opposite was true on the low productivity series of Douglas-fir and subalpine fir climax types. Finally, regarding species susceptibility, attacked western larch, western white pine, and western hemlock were not found. The highest incidence of attack on subalpine fir occurred on this species when growing within its climax series. This was also true for Douglas-fir and grand fir. Other species showing attack were lodgepole pine, ponderosa pine, and Englemann spruce.

The pattern of pathogenicity suggests that an entity or entities of Armillaria capable of being pathogenic on most conifers is present in the climax series as outlined above. The curious thing is a definitive pattern of pathogenicity based on host species, productivity of the climax series, and stand history. Low incidence on high productivity plots until these sites are disturbed can be explained by three possibilities: (1) the pathogenic fungus was absent prior to the disturbance. This possibility is currently rejected, based on our knowledge of the biology of Armillaria. New pathogenic types are not expected to invade new areas quickly (5 years or less). (2) a resident Armillaria is stimulated into a pathogenic mode by the disturbance. (3) the resident host plants are stressed (currently unmeasurable) by the management action such that they are rendered susceptible. Given only the comparison from the high quality sites of disturbed and undisturbed plots, the last two situations cannot be distinguished. But results from the low productivity series do enhance our perspective. If the same taxonomic entity is causing damage in all series, then the high level of pathogenicity on the pristine low productivity plots is most likely the result of natural stress. Since experimental application of stress has increased the amount of Armillaria infection in Japanese larch and grand fir (Redfern 1978) and in sugar maple (Wargo and Houston 1974), a reasonable, tentative conclusion from our results is that Armillaria in the Northern Rocky Mountains is functioning as a scavenger.

The delineation of clones and biological species affiliations will shed considerable light on this question. If a single clone is found to be present on one plot both as a saprophyte and a pathogen, the clone must be classified as a scavenger. If the biological species to which the clone belongs is composed of many clones that are commonly found as simultaneous saprophytes and pathogens, then the biological species must be thought of as a scavenger species. Occurrence of clones only in association with diseased host and proven to be primary pathogens by application of Koch's postulates independent of host condition would argue against the scavenger hypothesis. On the other hand, natural occurrence of clones present in the field both as saprophytes and pathogens is sufficient argument for the scavenger hypothesis.

The initial characterization of the 419 pure cultures obtained in 1983 is as follows. After about 10,000 individual challenges, the population of Armillaria cultures has resolved into 297 clones. The same clone was not found greater than 500 m apart. The study was not designed to determine the maximum extent, so we know only that clones in the Northern Rocky Mountains can be at least 500 m in diameter as was reported for clones in the State of Washington (Anderson and others 1979). Most plots were 10 miles or more apart, and no additional cases of clonal cohabitation have been found. So, the maximum extent of an individual clone must be something less than 10 miles.

This study was designed to obtain some idea of the number of possible clones on a 0.1-acre plot. The average number of clones per plot supporting Armillaria was 3.2. The largest number of different clones was 4, and the most cultures per clone was 9. At this point, the number of clones could be equal to the number of biological species as the challenge of field cultures does not determine biological species. It is also obvious that plot-to-plot variation of number of clones is low since the most clones per plot was four and the average was 3.2.

Fan-derived cultures from conifers apparently killed or damaged by Armillaria provide a uniform picture. Of nine such clones, eight were present in both modes. For example, plot 3 on the Colville NF yielded a single clone. This clone was present as epiphytic rhizomorphs on healthy grand and subalpine firs. Rhizomorphs were found on Armillaria-killed subalpine fir and western larch stumps. No rhizomorphs or fans were found on healthy western larch, healthy mountain maple or Douglas-fir stumps. The clone was present as fans on an apparently healthy Engelmann spruce and on a severely fading subalpine fir. The provisional biological species of this clone is North American 9. But regardless of the eventual species affiliation, it is clear that this entity is operating as a scavenger. Seven other cases similar to this were recorded, but the biological species has yet to be determined. In one case, a single clone was present on a plot in only a pathogenic mode while three additional clones were present as epiphytes or saprophytes; all clones on this plot appeared to mate with species 9. The one case of all members of a clone being pathogenic is more difficult to interpret. Many more samples would be needed to assure this extent was not an artifact of sampling. The question of pathogenicity of a biological

species is less clear. After our tentative mating tests, a single species, North American 9 (see Anderson and Ulrich 1979), was found to contain all the clones from seven of the National Forests. The affinities of the remaining clones are unknown at this time. NA-9 seems to contain clones that are only pathogenic, only saprophytic, and that can function both ways. One result is clear, however. There are clones of Armillaria in the Northern Rocky Mountains that are functioning as scavengers, and the possibility is present that all belong to one biological species.

## SUMMARY

The existence of single Armillaria clones functioning as a saprophyte, an epiphyte, and a pathogen all on a 0.1-acre plot is strong evidence that this fungus behaves as a scavenger. It recycles sick or dead woody plants just as it does in the eastern United States (Wargo and Shaw 1985). Some overriding questions now are--does the entire genus exhibit this behavior or is it restricted to certain taxonomic species, biological species, or clones within species. If an entity is shown to behave as an aggressive primary pathogen in one or a few situations, does it always behave this way? Is a pathogenic entity restricted to a classic root rot center, or can it routinely be found outside such a center in an epiphytic or saprophytic mode? Is a center the result of the presence of a fungus entity or of a host condition, or of a combination of both? Even if an entity such as Armillaria ostoyea appears to be a primary pathogen, its pathogenicity must be proven, since the genus usually functions as a scavenger. The latter possibility must be clearly eliminated in the case of all suspected primary pathogens. Armillaria fruiting is erratic at best; therefore, characterization of the populations must proceed from subterranean samples. Our course seems clear. Clones must be delineated over extensive geographic areas both inside and outside centers of infection and from all possible kinds of hosts. The biologic and taxonomic affiliation of these clones must be determined, and the variety of their life situations catalogued. Progeny testing can then complete the picture but only after techniques have evolved to simultaneously obtain quantitative measurement of host vigor and fungus pathogenicity.

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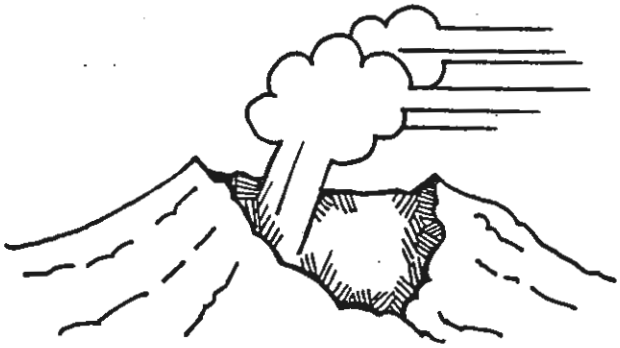

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## SILVICULTURE AS PREVENTATIVE MEDICINE

David A. Perry

### INTRODUCTION

Forest ecosystems comprise a complex network of biological interactions embedded within and shaped by the physical environment. In the healthy forest this "dance" of organisms, as Whittaker called it, acts to maintain balance and to prevent any single organism whether it be pathogen, insect pest, or weed from becoming a dominant player in the system. Silvicultural operations alter, to one degree or another, both the physical and biological environments of forests. One of the critical questions facing foresters is how such alterations may influence both short and long term resistance to pathogen outbreaks. The key to answering this question lies in inderdisciplinary, system-based research by pathologists, ecologists, and silviculturists. Payoffs may well be high for such research. A silviculturist who understands the mechanisms that maintain healthy forests has gained an important new tool. With understanding comes the ability to design operations in such a way that natural system defenses can be utilized, perhaps improved, or at the very least protected from disruption. In my opinion this ability to merge with and capitalize on the natural rythms of the forest will characterize the silviculture of the future.

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There are probably numerous ways in which silviculture effects the susceptibility of trees to pathogens. Fertilization and thinning allow residuals to increase carbohydrate reserves and hence manufacture defensive secondary chemicals that aid in resistance to diseases and pests (Waring 1983; Cromack, see these proceedings). Thinning can also negatively impact forest resistance, causing damage that provides entry courts for pathogens (Aho 1983), and, done at the wrong time of year, attracting vectors of pathogenic fungi. Other influences of silvicultural operations on the forest health are less well understood. What effect, for example, does narrowing the gene pool of tree populations have on their ability to resist pathogens? The answer to this question is very important because many see clonal forestry as the wave of the future, arguing that pathogen and pest problems can be avoided by suitable mixtures of clones. Foresters need to know whether this is true or not before irreversible decisions are made.

Another area in which silviculture may influence pathogenesis, but about which little is know, is harvest and site preparation. Clearcutting and residue treatment, particularly fire, profoundly alter both the physical and biological characteristics of forest soils. Research by my group and by others in the past several years has led me to believe that the way we treat sites during the harvest and regeneration phase does effect relationships between trees and pathogens. Evidence suggests that these effects may be either negative, increasing tree susceptibility, or positive, with the potential to significantly increase tree growth. In the remainder of the paper I will discuss ongoing research in this area. My objective is to use this particular subject as an example of how silviculturists, ecologists, and pathologists might combine their expertise to better define the way forest systems operate; and to perhaps contribute significantly to our ability to grow trees.

### HARVEST, SITE PREPARATION, AND PATHOGENESIS

Clearcutting, particularly when followed by broadcast burning, profoundly alters the soil biological community. The most striking change is a shift in the relative proportions of bacteria and fungi, induced by fire and in some cases persisting for many years. Perry and Rose (1983) found that bacterial colonies per gram of soil on three sites in southwest Oregon averaged five times higher in clearcut and burned areas than in undisturbed forest. In contrast, colonies of actinomycetes were only slightly higher in burned soils, and fungal numbers were slightly lower. Mycorrhizal formation on tree seedlings is often reduced in disturbed relative to undisturbed soils (Perry et al. 1982, Harvey et al. 1980, Parke et al. 1984). Productive sites with a diverse mycorrhizal flora appear to be better bufferd against these reductions than droughty or nutrient poor sites (Schoenberger and Perry 1982, Pilz and Perry 1984).

Do alterations in the community of soil organisms influence pathogenesis? Much research is needed but there is a fair amount of evidence that the answer to this question is yes. Schroth and Hancock (1982) cited several cases in which disruption of soil microflora led to disease problems. Widden and Parkinson (1975) measured a decrease in species of Trichoderma and Penicillium following a forest fire, while the pathogen Cylindrocarpos destructans was unaffected. Because the former species are often antagonistic to pathogens, Widden and Parkinson speculated that fire would increase the incidence of root diseases. Post-fire plantations of pines in Finland are often infected by Rhizina undulata, and Jalaluddin (1968, cited in Ahlgren 1974) showed that this pathogen was stimulated by heated extracts of pine roots. Ectomycorrhizae have long been thought to protect tree roots against pathogens (see Bledsoe, these proceedings), and it is possible (though not yet demonstrated) that reductions in mycorrhizal formation that sometimes occur in clearcut soils increase seedling susceptibility to disease.

In recent years attention has been directed to the role that a certain class of iron chelators, called siderophores, play in plant resistance to root disease. Siderophores, released into the soil by various bacteria and fungi, are among the strongest known chelators of ferric iron. They are very similar to the iron-binding protein transferrin, which inhibits the growth of pathogens in mammalian bodies by binding iron so tightly as to make it unavailable to the pathogen. Kloepper et al. (1980) suggested that siderophores play a similar role in plant rhizospheres. We found that the concentration of hydroxymate siderophores (HS), produced primarily by fungi (including mycorrhizae), are frequently lower in clearcut and burned then in undisturbed forest soils (Perry et al. 1984). Might this result in greater susceptibility of seedlings to pathogens? To test this we inoculated HS-rich and HS-poor soils with Pythium sp., then grew Douglas-fir from seed in these soils. Table 1 shows seedling mortality during the first year (D. Perry, E. Hansen, P. Hann, unpublished data). Means and standard errors are based on three southwest Oregon sites, each with adjacent old-growth and broadcast burned areas. Though relatively low in all cases, seedling mortality was significantly higher in burned than in old-growth soils. Fertilization with chelated ferric iron eliminated mortality in burned soils, suggesting that iron nutrition did play a role in the reduced seedling resistance to Pythium.

Is it possible that low levels of HS in broadcast burned areas are linked to the epidemic of Phellinus weirii in young Douglas-fir plantations? Concentrations of HS are reduced in Phellinus weirii pockets. In the Woods Creek area of Marys Peak (Oregon Coast Range), HS concentrations in soil outside of root rot centers average 2.38 mg/g (SE = 0.93), while inside root rot centers then average only 0.48 mg/g (SE = 0.17). At Waldo Lake, Oregon, where there is a very large Phellinus infection, HS concentrations average 9.9 mg/g in the soil of the Mountain hemlock forests outside the Phellinus wave front, and drop to 2.3 mg/g from the wave front to 9 m into the infection. At 14 m into the infection, concentrations jump dramatically on one transect, but not on another. It is difficult to interpret the significance of these results. HS could be lower in Phellinus pockets simply because of reduced root activity, the pathogen could actively suppress production of the chelator, or some external environmental factor (e.g. fire) could lower HS levels, giving the pathogen a foothold in the system. This is the type of question that silviculturists, ecologists, and pathologists should be combining forces to answer.

There is much to learn about the influence of soil biology on tree growth. Our work, as well as that of others in the Pacific Northwest, clearly shows that soil sterilization or pasteurization can increase tree growth, sometimes dramatically. Evidence to date indicates that this is due to removal of some component of the soil biological community rather than an artifact of the sterilization process. Is there chronic pathogenesis in some forest soils that reduces growth but doesn't kill? If so, under what conditions does it occur and what can the silviculturist do about it? We find the phenomenon to be highly variable. Pasteurization may either increase tree growth, decrease it, or have no effect, depending on site and, at any one site, when soils are collected. There is some evidence that the degree to which tree growth is inhibited by soil organisms correlates positively with the biomass of soil microbes. There is also a possibiliy that in some cases hot broadcast burns may have a positive effect on tree growth through partial sterilization. At this point we are rich in observations and questions, but poor in answers. The pathologist who is willing to plunge into the murkiness of the soil ecosystem has much to offer silviculture.

Table 1--First year mortality of Douglas-fir seedlings grown in soils from (a) old growth forests and (b) adjacent clearcut and broadcast burned areas.

| | Soils without added $Fe^{3+}$ mortality (%) | | Soils with added $Fe^{3+}$ mortality (%) | |
|---|---|---|---|---|
| | x | SE | x | SE |
| Old-growth | 3.0 | 1.0 | 5.0 | 5.0 |
| Clearcut and burned | 13.0 | 6.2 | 0 | 0 |

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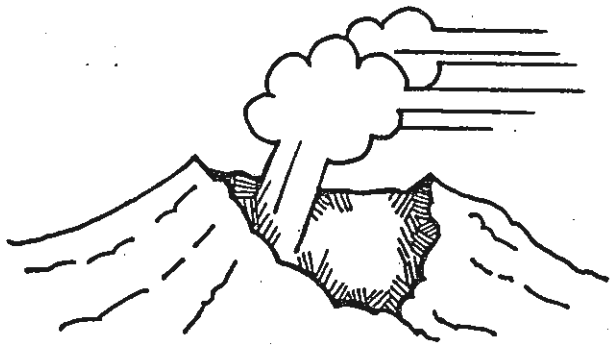

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## INTEGRATING SILVICULTURE AND PATHOLOGY

Chadwick Dearing Oliver

ABSTRACT: Forest pathology and silviculture are closely related and interdependent fields. Silvicultural problems rarely allow the luxury of starting over with a new stand; instead, silviculturists have to work with existing stands. The options open to a silviculturist when manipulating a stand depend on the existing biological (including pathological), economic, sociological, and operational circumstances. Silviculturists need help from pathologists in viewing forest diseases from the perspective of "epidemiology and public health", not that of a surgeon. Silviculturists and pathologists need to anticipate and avoid pathological problems, as well as respond to current ones.

### INTRODUCTION

It is very appropriate that the integration of silviculture and pathology be addressed frequently, since silvicultural practices are very often determined by pathological considerations. Forest pathology and silviculture are, of course, not synonomous since the practice of forest pathology often is concerned with more in-depth microbiology than the minimum necessary for common silvicultural prescriptions. Silviculturists, of course, need to understand enough pathology to make relatively common decisions and to know when to call in a pathology expert. At the same time, silviculture encompasses more than pathological considerations since just because a forest is healthy and disease-free does not necessarily mean that it has the appropriate species mixture, stand structure, and growth rate to meet the landowner's objectives. There are many good pathologists who are also good silviculturists, and many good silviculturists who are also good pathologists--but there are some who are one or the other but not both.

Silviculturists have to be the "jack-of-all-trades" of stand manipulations, and as such need to keep abreast of many diverse fields from pathology and entomology, soils, and micrometeorology to logging engineering, road building, product innovations and projections, and economics. Panels such as this one are appropriate in reminding silviculturists of the importance of pathology, since silviculturists--being human and limited in time--often respond to the "squeaking wheel" in the adage: "The squeaking wheel gets the grease." As a caution, pathologists sometimes finds diseases so frequently in forests that the silviculturist gets the impression that the forests will all die within the next few years. When this does not happen, the pathologist's credibility is reduced, and the "squeaking wheel" is regarded as "the boy who cried wolf." To avoid such losses of credibility, it would help if pathologists could express their observations in more of a silviculturist's perspective--just as it would help if silviculturists would listen with more of a pathologist's perspective.

### TIME PERSPECTIVE IN STAND MANAGEMENT

Attitudes in forest practices and research in both pathology and silviculture have been strongly influenced by agriculture. In most agriculture, the emphasis is on short plant-harvest cycles--generally less than one year; high value inputs and outputs; quick returns on investments; and an ability to change crops and management strategies quickly--generally with each new year. Very often forestry is regarded as having these attributes. Forestry research is strongly biased toward the establishment of replicated, permanent plots which will yield agriculture-like information when the plots are mature--generally less than a year in agriculture and often several decades in forestry.

A more appropriate perspective of forestry is somewhere between that of agriculture, described above, and petroleum geology. Although petroleum geology is a very valuable and scientifically based enterprise, the long time scale between when the "dinosaur" (or other organic material) is buried and when it becomes oil makes practitioners of this field much more willing to accept the resource as it exists--not as it "should" be. In addition, the long "maturity" horizon gives relatively limited ways of correcting the developing resource if anything goes wrong. Much research progress has also been made in petroleum geology, although no experiment has ever buried a "dinosaur" (especially not in statistical replication) and waited for it to turn to oil--using a typical agricultural experimental technique. In the same way, much

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research in silviculture and forest pathology may be more timely if more of it were done using inferences and reconstruction of the past history of existing forest conditions, rather than establishing new plots--which may mature many years after the perceived concern has been resolved for the worse.

Silviculture is more like petroleum geology than foresters first realize. This is especially true under the present economic practice of putting geometrically increasing values on time through compound interest. Like the "buried dinosaur," once a stand of trees is established the forester is usually stuck with it for several decades (and frequently beyond the professional lifespan of the forester). In all parts of North America most stands are from natural origin (not planted or seeded) and it is unlikely that extensive areas of naturally established, immature forests will be converted to more desirable plantations--this conversion usually occurs at the time of commercial harvest of the previous stand. Most silvicultural manipulations are in existing stands and foresters are expected to manipulate them, including considering pathological concerns, before they are harvested. Much of the information and research useful to them, therefore, is of an inferred nature; they often can not wait for permanent plots to mature.

## FACTORS LIMITING STAND MANIPULATIONS

The manner in which a silviculturist responds to a disease problem depends in large part on what stage of development the forest is in. As a simplistic example, single-generation (even-age) forests can be divided into four "phases' for pathological management considerations: the pre-regeneration phase; the precommercial, established stand; the early commercial stand; and the mature, commercial stand. In most of these phases, the role of forest pathology is more like one of "epidemiology and public health," rather than similar to s medical surgeon's role. The silviculturist is dealing with the health of populations, rather than the health of individual trees.

When considering each stand, the silviculturist goes through a subconcious decision-making process similar to one laid out in a "dichotomous decision-tree." Many of the component considerations of this process have already been developed and the process needs to be made explicit and incorporated into silvicultural training. The silviculturalist considers the impact of each potential biological, engineering, and socio-economic factor which may affect the stand. Forest pathology is part of the biological factor, and the control of the disease becomes incorporated into the engineering and socio-economic factors as well. There are other considerations than pathology in the biological factor as well, however. We now know enough about stand development patterns (stand dynamics) to realize that each stand develops its own structure based on its history and site factors so that the future options for manipulation are limited. As a simplistic example, if a stand is evenly spaced at a twelve foot spacing, it can not be respaced to a fourteen foot, regular spacing; it can be respaced to approximately a seventeen foot spacing (thinning on the diagonal) or to a twenty-four foot spacing. Similarly in each phase, the amount a stand manager can invest in controlling his stand depends on such factors as how long before he will realize a return from the investment and how much of a return he will realize.

The silviculturist's considerations of pathology will be different for each stand. As a rough example, the considerations in each of the "phases" of an even-aged stand described above would be somewhat as follows:

In the pre-regeneration phase, the forester has much flexibility. Within the limits of site and economics, species can be chosen and stand spscings and other measures of structure prescribed which will help prevent anticipated disease problems.

In the precommercial, established stand, the forester probably has the least flexibility. Here, too much time and effort has already been invested in the stand for the forester to invest very much more money to solve a disease problem; and the time before the investment can be realized through a commercial harvest is so long that further investment is even more discouraging.

In the early commercial phase, the stand can be manipulated commercially--by thinning or clearcutting to resolve a disease problem; and the choice is to treat the stand to obtain perhaps a more valuable product later, or a low value one now.

In the mature stand phase, the trees can be harvested for money, and many disease treatment options can be considered to keep the stand alive during the relatively short periods needed for it to increase even more in value. Decisions here to avoid diseases by harvest or to treat diseases depend on the individual landowner's objectives and management constraints.

The above phases are further complicated by the realization that the stands we are managing now will not be like the ones we managed before. In fact, forests are constantly changing and at practically no time and in no region is a stand like the one previously occupying the site.

In the coastal Douglas-fir region in Oregon, Washington, and British Columbia, the largest acreages are in 0 to 20 year old stands--approximately 2.4 million acres--many of which are plantations. Most silviculturists and pathologists practicing today will grow old with these stands. We are beginning to become concerned that the much more regular spacing and even age distribution may not allow these stands to differentiate as well as the older, natural second-growth stands of 20 to 90 years old. It may be necessary to thin these stands at small diameters to keep them from becoming over crowded and unvigorous. There is a strong need for

pathological work to determine the risks and disease consequences, if any, of not thinning these stands. The problem of too many trees of small diameters in dense stands seems to be a national one, caused by a merging of stand development patterns occurring at different rates in different regions. It does not mean that a timber surplus will perpetuate forever; however, for the next few decades there will be such an abundance of small diameter trees that the demand will decline and commercial thinning will become less necessary to obtain wood. In these cases, the pathological consequences of retaining dense stands needs to be assessed.

In light of the above discussion, silviculturists need answers to pathological questions of four types:

1. What is a pathological problem and what is a natural part of stand development? We know diseases are not extraneous to the forest, but are a natural part of it. At what point is a disease beginning to affect the commercially valuable component of the stand and when is it simply removing the weakened trees which would die soon, such as from suppression, anyway?

2. What will be the impact of a particular disease on a stand? Included in the answer to this question must be the impact of the disease under different possible treatments--including both doing no control and cutting down the stand immediately.

3. How can the disease be recognized? Pathologists are generally very good at providing answers to this question.

4. What are the options to prevent, detain, or cure the disease? In this area, knowledge, creativity, and cooperation on the part of the silviculturist and pathologist are needed. The knowledge and creativity are needed to recognize the subtle weak "links" in the life cycle of the pathogen and the cooperation is needed to plan appropriate treatments accordingly.

## FUTURE POSSIBLE PROBLEMS IN SILVICULTURE

Pathologists and silviculturists need to anticipate and therefore avoid future problems as well as respond to current ones--especially in a field such as forestry where it takes many years for the resource to mature. Several possible areas where the silviculturists and forest pathologists may consider cooperative work are:

1. Rotation of forest crops. Crop rotation is known to be beneficial in agriculture. In certain forest conditions there is some suggestion that, after a particular species has occupied the site for a rotation, it is less able to compete successfully for the next rotation. Is there some form of weakening of the species—perhaps by a buildup of disease-causing pathogens--so that changing of the species on the site would avoid problems?

2. There is some evidence that fire prevention and/or selective cutting has led to the weakening of trees and the buildup of pathogens, so that losses caused by diseases will be much greater than occurred naturally in certain forest types. Is this true? And, are there other practices foresters are doing which, although sincere in intent, are leading to increased incidences of forest diseases?

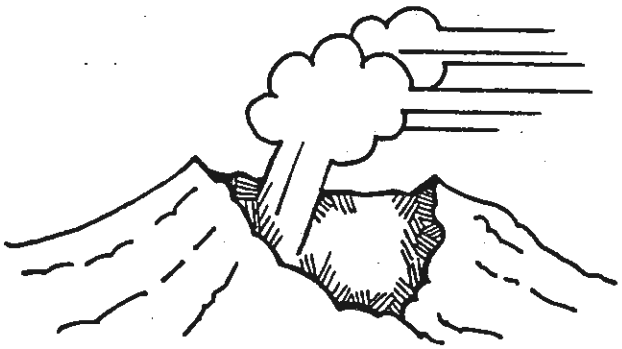
3. Forest pathologists are very good at noting the presence of a disease. It would help in management decisions if a silviculturist could assess what the impact of the disease would be on end products of the forest (e.g., loss of value caused by downward change of grade of the wood).

4. Rather than forest pathology studies being done separately from silvicultural and economic studies, the efficiency of obtaining useful results in disease control could be increased if economic analyses were done to determine what "critical value" of control a certain practice would have to obtain before it would be economically practical. The pathologist could then develop research to answer the "yes/no" qnestion of whether the control measure could obtain this critical value.

5. Future forests will be different because of natural climate change and possibly because of "acid rain" problems and "pollution-induced" climatic changes. It would help the silviculturists to know what kinds and ranges of pathological problems one might expect from these changes.

6. It is very possible that pruning of plantation-grown Douglas-fir will become important in the future. It would help if the silviculturist knew what kinds of pathological problems should be looked for by this practice.

7. Similarly, proper selective cutting--as opposed to "high grading" as done in many mixed species stands--may be done under certain circumstances. Again, the silviculture of these stands would greatly benefit from a knowledge of what kinds of pathological problems might be expected.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## INTEGRATION OF PATHOLOGY AND SILVICULTURE--

## OPINIONS OF A DIRT FOREST PATHOLOGIST

James S. Hadfield
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"Forest pathology is the branch of botanical science that deals with diseases of forest trees for the purpose of preventing or controlling such diseases."

"The forest pathologist must not only have a knowledge of the methods employed by the plant pathologist in investigating and controlling diseases of agricultural crops; he must also thoroughly understand the methods and economics of producing forest crops in order that he may develop economically applicable procedures for the prevention and control of forest tree diseases."
--John S. Boyce

Silviculture is the science and art of producing and tending a forest--Society of American Foresters, Forestry Terminology.

Forest pathology and silviculture have the same goal. Healthy forests. Forest pathologists would do well to occasionally remind themselves of this goal. We must not forget that our ultimate concern is with forest trees, not with all the interesting pathogens that interfere with tree health.

"Forest pathology deals with diseases of forest trees for the purpose of preventing or controlling such diseases." How are most forest tree diseases prevented or controlled? Certainly not with pesticides. Practically all forest diseases are controlled, prevented, manipulated, or managed by cultural treatments of forest trees. Who prescribes and implements these cultural treatments? In the USDA-Forest Service, it certainly is not done by forest pathologists. It is done by silviculturists. We forest pathologists accomplish virtually no disease control. We are not cutting mistletoe-infected trees, or favoring less root disease-susceptible species during reforestation, or pruning rust-infected branches. Yet, these treatments are being carried out on thousands of acres because silviculturists are prescribing and overseeing disease management treatments. Forest pathologists recommend forest disease control; silviculturists do it.

To be successful, salespeople must know their customers. Who are the customers of forest pathologists? First, and foremost, are silviculturists. Forest pathologists have one product to sell--advice on forest disease control. If we want to sell our services, we have to be able to communicate on a professional level with our customers. Forest pathologists who cannot communicate with silviculturists are unlikely to be effective. We need to understand what is meant by terms such as "group selection," "two-stage removal," and "stand exams."

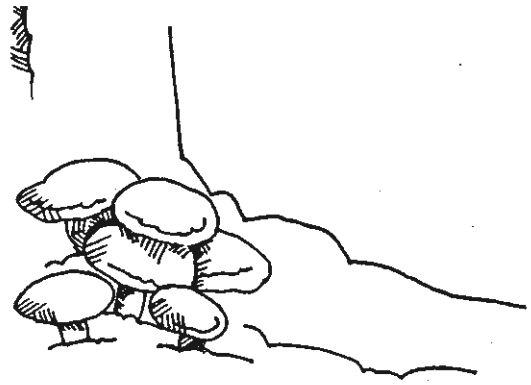
Silviculturists need forest pathologists. Silviculturists who do not recognize diseases affecting forest stands or who do not understand how to prevent or control diseases, or who fail to control diseases when losses are economically significant, are incapable of meeting management objectives. How can silviculturists properly produce and tend a forest if they don't have an understanding of forest pathology? They cannot. In my part of the world, there probably are no pathogen-free stands. Forest diseases are part of day-to-day reality for silviculturists. Silviculturists must be able to recognize major disease problems occurring in their area. They must be familiar with treatment options and the consequences of treatments to prepare prescriptions. Advice should be sought from forest pathologists.

The question is not: Should forest pathology and silviculture be integrated? That is a necessity. The question is, How do we improve integration?

Forest pathologists do not have to be certified silviculturists. They should have completed at least one class in silviculture. It is highly desirable for pathologists to participate in the numerous training opportunities, especially short courses and tours, available to silviculturists. Forest Service pathologists should be encouraged to participate in silvicultural certification programs. Go to coffee breaks and lunch with silviculturists. Read silviculture literature. We must understand the language and needs of silviculturists.

Forest pathologists have an obligation to improve the skills of silviculturists. We must train silviculturists and their staffs how to recognize and manage diseases that could be damaging in their areas. We need to conduct interesting and informative training sessions that silviculturists will want to attend. Produce books and

slide tapes and establish disease demonstration sites. We know how to control all kinds of forest tree diseases, but pathologists don't control them. We need to get this information to the people who need to control diseases. Ask to make presentations at silviculturists' meetings. When doing biological evaluations, make sure you know what information the silviculturists need for their prescriptions and give it to them. Ask the silviculturists and their staffs to participate in evaluations. Have headquarter silviculturists review reports before sending them to field silviculturists. We forest pathologists need to make ourselves visible to silviculturists and we need to provide them the service they need.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## SPECIES DIFFERENTIATION IN ARMILLARIA

Duncan J. Morrison

### BACKGROUND

A recent review article by Watling, Kile and Gregory (1982) describes the taxonomic and nomenclatural confusion and problems surrounding the genus Armillaria (typonym Armillariella). They suggest that this confusion has hindered pathological study of the genus; there is no doubt that it has. Armillaria mellea was assumed to be a very variable or polymorphic species with a world-wide distribution. In spite of taxonomic studies (Singer 1956, Stevenson 1964, Romagnesi 1970, 1973; Watling 1976) indicating that the genus could be divided into a number of species, plant pathologists continued to use A. mellea because there was no quick, reliable way to determine the group/species they were working with. This is particularly true for North America. Development of genetic methods to define intersterility groups or biological species has changed the situation.

Hintikka (1973) observed that single spore cultures from a basidiocarp of Armillaria had abundant, white, aerial mycelium, whereas cultures from basidiocarps, rhizomorphs and some pairings of single spore cultures were dark, crustose and usually without aerial mycelium. He also found that the pairing reaction of single spore isolates followed a tetrapolar pattern and suggested that the nuclei of crustose mycelia were diploid.

Korhonen (1978) in Finland and Anderson and Ullrich (1979) in North America confirmed these observations and developed methods for determining biological species or intersterility groups of Armillaria. The methods are: 1) pairing of mating types (single spore testers) from sporophores of known biological species with single spores from an unknown sporophore. (The paired cultures belong to the same biological species if crustose mycelium results). 2) pairing of single spore testers of a known biological species with unknown diploid cultures. (The paired cultures belong to the same biological species if the tester becomes crustose.)

To date, all of the studied Armillaria species are bifactorially heterothallic, that is, two unlinked genes determine compatibility of monosporous isolates. For mating to occur, alleles must be different at each locus (table 1). To determine the mating types (testers) for a sporophore collection, a number, usually 10-12, of monosporous cultures are paired in all combinations. Based on the reactions, the mating types are identified. By pairing testers from a number of sporophore collections, they may be separated into intersterile groups. Korhonen (1978) found five such groups in European study material and Anderson and Ullrich (1979) found 10 groups among North American collections. Subsequently, the methods were used by Guillaumin and Berthelay (1981) in France and Rishbeth (1982) in Britain to determine their biological species. Anderson, Korhonen and Ullrich (1980) found that certain species from Europe were interfertile with certain species from North America.

There appears to be a relationship between rhizomorph growth habit (branching pattern) and pathogenicity of the various species or groups of Armillaria. During studies on rhizomorph characteristics of about 20 British isolates, Morrison (1982) observed that branching pattern in mineral soil was either monopodial or dichotomous. The dichotomous group could be divided into two groups based on branching frequency and toughness. Rishbeth (1982) reported that the monopodially-branched isolates were A. bulbosa; tough, high frequency, dichotomously-branched isolates were A. ostoyae; and fragile, low-frequency, dichotomously-branched isolates were A. mellea (Fig. 1). Experiments by Redfern (1975) Rishbeth (1982) and Morrison (1982) showed that the pathogenicity of the dichotomous group is significantly greater than that of the monopodial group. Within the dichotomous group A. mellea is more pathogenic than A. ostoyae. The relationship holds true among the North American intersterility groups that I have examined.

### A Case History

Based on rhizomorph growth habit and marked

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Table 1--Possible Mating Interactions Between Testers Derived from different fruiting bodies of Armillaria (from Anderson and Ullrich 1979)

| | Members of one intersterility group | | | | | | | | Members of a different intersterility group | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Testers from one fruiting body | | | | Testers from a different fruiting body | | | | Testers | | | |
| | $A_1B_1$ | $A_2B_2$ | $A_1B_2$ | $A_2B_1$ | $A_xB_x$[b] | $A_yB_y$ | $A_xB_y$ | $A_yB_x$ | $A_1B_1$ | $A_2B_2$ | $A_1B_2$ | $A_2B_1$ |
| $A_1B_1$ | -- | + | -- | -- | + | + | + | + | -- | -- | -- | -- |
| $A_2B_2$ | + | -- | -- | -- | + | + | + | + | -- | -- | -- | -- |
| $A_1B_2$ | -- | -- | -- | + | + | + | + | + | -- | -- | -- | -- |
| $A_2B_1$ | -- | -- | + | -- | + | + | + | + | -- | -- | -- | -- |

[a] + = compatible, - = incompatible. [b] Where $x \neq 1, 2$ and $y \neq 1, 2$

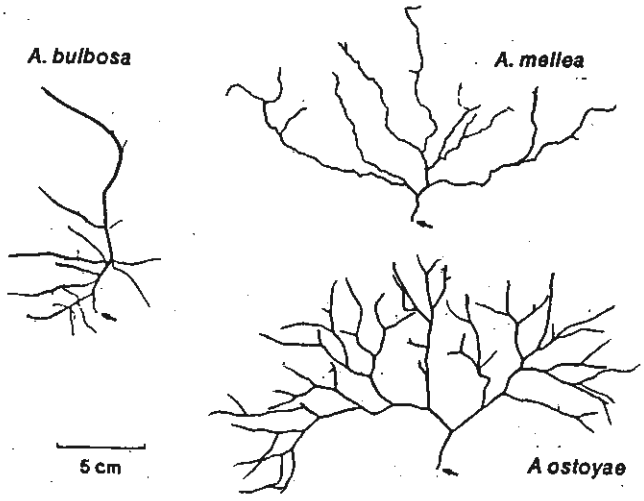


Fig. 1. Rhizomorph growth habits for A. mellea, A. bulbosa and A. ostoyae. Rhizomorphs were produced in sandy soil containing 1-2% organic matter (arrows indicate point of attachment to food base).

variation in hosts and damage among regions, we knew ten years ago that there was more than one Armillaria species in B.C. However, methods were lacking to identify isolates quickly. The genetic methods described above remedied the situation. Over a four year period, we found six intersterility groups and determined their host preference and distributions in B.C. The procedure was as follows. In the first season, hasidiocarps were collected from 37 locations. Basidiospores were discharged onto water agar in petri dishes; after 36-48 hrs, 15 germinated spores of each collection were transferred to mait slants. The mating types (testers) among single spore isolates from each collection were determined by pairing 12 isolates in all combinations. The testers from three to five collections from a limited geographical area were paired with those from other geographical areas until the number of intersterile groups was determined. Five were found in the first year. In the second, third, and fourth seasons, two monosporous cultures from each collection were paired with the testers of the intersterility groups identified above. The sixth group was found among second season collections.

To relate results from B.C. to those from other regions, testers of B.C. intersterility groups were paired with testers of Anderson's North American biological species and A. borealis, A. cepistipes, A. mellea, A. bulbosa and A. ostoyae from Europe. Five of the B.C. groups were compatible with groups I, V, VII, IX and X of Anderson and two with A. ostoyae and A. bulbosa from Europe. The sixth B.C. group is a new record and is partially interfertile with A. cepistipes (table 2). The relationship among North American and European groups was identical with those reported by Anderson et al. (1980) except that N.A. group X was not compatible with A. cepistipes.

After season one, the study objectives were to determine the distribution and hosts of each group (tabie 2). Armillaria bulbosa (VII) and group IX were collected on living and dead broadleaved hosts in southwestern B.C. Group V was found province-wide from 49° to 57° (to 58.5° in coastal Alaska). Group XI (new record) occurred on broadleaved hosts at two widely separated locations, Hope and Stewart. Group X was collected on coniferous hosts primarily, in southeastern B.C. The only other record of this group is from Idaho, directly south of our collections. Armillaria ostoyae (I) was found province-wide from 49° to 53°N, primarily on conifers; broadleaved species occurring within disease centers were attacked and killed.

The intersterility groups occurring in a region may be determined more quickly than above by a) pairing testers of known groups with 2 or 3 monosporous isolates from a sporophore or b) pairing testers of known groups with diploid isolates.

## SUMMARY

Division of Armillaria mellea sensu lato into species or intersterility groups has answered many of the questions about these fungi. For example, why was there damage to conifers on only one of two infested sites. Much work remains to be done, including detailed distribution studies in many regions, site/habitat preference studies and pathogenicity tests.

How should I refer to Armillaria? Continued use of Armillaria mellea complex or Armillaria mellea (Vahl:Fr.) Kummer (except for the European A. mellea) perpetuates the confusion surrounding the genus and consigns your results to the circular file. Until the unnamed North American species are described, Anderson's Roman numerals should be used to identify intersterility groups.

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Table 2--Host material from which sporophores of the Armillaria groups occurring in B.C. were collected.

| Group/Species | | Conifer[1] | | | Broadleaved[2] | | | Other[3] |
|---|---|---|---|---|---|---|---|---|
| B.C. letter | N.A./Europe | living | dead | stump | living | dead | stump | |
| D | I/A. ostoyae | 25 | 77 | 4 | 4 | 8 | 3 | |
| B | VII/A. bulbosa | | | | 8 | 3 | 2 | 7 |
| A | V | | 1 | 1 | 3 | 19 | 11 | 4 |
| C | IX | | | | 3 | 5 | 4 | 1 |
| E | X | | 2 | 1 | | 1 | | |
| F | XI/Korhonen B[4] | | | | | 1 | 1 | |

[1] Pseudotsuga menziesii (Mirb.) Franco, Thuja plicata Donn, Picea glauca (Moench) Voss, P. engelmannii Parry, Pinus contorta Dougl., P. monticola Dougl., Tsuga heterophylla (Raf.) Sarg. and Abies lasiocarpa (Hook.) Nutt.

[2] Populus trichocarpa Torr. and Gray, P. tremuloides Michx., Prunus emarginata Dougl., Betula papyrifera Marsh., Acer glabrum var. Douglasii (Hook.) Dipp., A. macrophyllum Pursh., Alnus rubra Bong., A. sinuata (Reg.) Rydb., Salix spp. and Crataegus sp.

[3] buried wood, host not identified.

[4] partially compatible.

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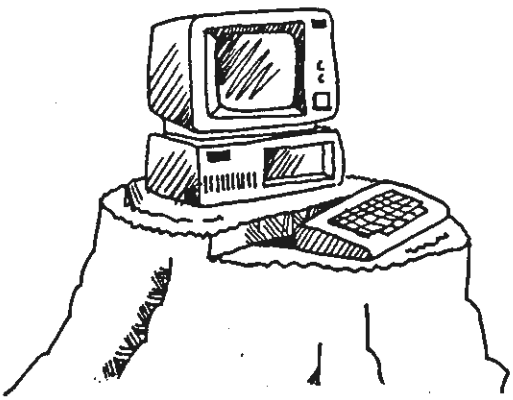

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## DEVELOPMENT OF A ROOT DISEASE SUBROUTINE FOR USE WITH STAND GROWTH MODELS OF WESTERN FORESTS

Charles G. Shaw III, Albert R. Stage, and Timothy M. Webb

### Introduction

Last year at WIFDWC I [Shaw] briefly discussed the modeling effort that the Forest Service is sponsoring on root diseases in western forests. Because of the briefness of that presentation, my rather cartoon-like pictures, or the incipient nature of the project, many of you may be rather confused about this endeavour. Hopefully this presentation will clarify why we decided to develop the model, how it is being constructed, what it does, and how it might be used in management of forest lands affected by root disease. Additional information on the purpose, construction, and use of this model appears in the August 1985 issue of Forest Research West (Brookes 1985).

### History and development of the model

This modeling effort was initiated because of the pervasiveness of root diseases in western coniferous forests and their economic impact. Current estimates place the average annual loss of timber to root diseases in western forests at nearly 240 million bd. ft. (Smith 1984), with some effects being reported from all western regions.

The main objectives of the project have been to develop a computer simulation model of root disease dynamics for inclusion in existing stand growth and yield models of western coniferous forests (hopefully to be used in silvicultural planning and management of diseased areas), and to identify inadequacies and uncertainties in our current knowledge of root disease dynamics and their responses to management treatments. Thus, from its inception the project has had two goals--to provide a useful tool for management and to define high priority research needs.

The project was initiated by a special appropriation from the Head Office of the USDA Forest Service, Forest Insect and Disease Research (FIDR). These funds were directed to Al Stage's research project in the Intermountain Station on modeling forest growth and yield (Noble 1982, Stage 1978). Additional support from FIDR and Forest Pest Management in the Head Office and the Rocky Mountain, Intermountain, and Pacific Northwest Research Stations of the Forest Service have provided enough funds to allow us to plan for necessary refinements in the model and for its transfer to the Forest Service computer system.

To avoid unnecessary duplication of effort, we decided that this model would be designed to interface with existing stand growth models for western forests, such as PROGNOSIS, DFSIM, and RMYIELD. Because Al has a rather fatherly attachment to PROGNOSIS, because it operates on a tree basis rather than a stand basis, and because several versions of it are available for various forest types in the western United States, we chose to adapt the root disease subroutine to PROGNOSIS. We plan, however, to ensure that the root disease subroutine is flexible enough so that it will also adapt to use with stand oriented growth and yield models, such as DFSIM and RMYIELD.

The model is structured around the behavior of Armillaria because of the importance of this fungus as a cause of root disease in the West (Wargo and Shaw 1985), and the amount of existing information on it. This decision in no way implies that root diseases caused by other organisms, such as Phellinus weirii--"the West's worst disease" (Thies 1984), are of any lesser importance; however, we felt that it was easier to modify assumptions made in the model about the behavior of Armillaria to fit that of Phellinus rather than vice versa. In fact, all actions in the model that are dictated by disease behavior can be adapted to Phellinus and we are developing a routine to deal with both of these diseases in the same stand. Further adaptation of the model, however, to include root diseases that may spread through dispersal of air borne propagules, such as occurs with Fomes annosus, are beyond the scope of the present project.

To start the modeling effort we followed the protocols of Adaptive Environmental Assessment, as outlined by Holling (1978). In this procedure, a series of workshops are helo where various experts

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in disease recognition, biology, and management, as well as potential users of the model, meet together. Through the direction and assistance of outside coordinators they develop a conceptual model of the problem and possible management actions. The outside coordinator is then responsible for converting this conceptual model into a working model that is further refined at later workshops through additional input from various experts and potential users. The process itself is actually not new, but rather serves as a creative extension of the scientific method from the individual investigator to a sort of corporate surrogate (Campbell 1980).

Because of their expertise and experience in modeling forestry related problems through this technique, Environmental and Social Systems Analysists (ESSA) of Vancouver, B.C. was selected as the outside coordinator for this project. In September 1984, four of their staff, including Tim Webb, met with a core team of research scientists and pest management specialists to develop a structure for the model, select workshop participants, and decide on locations for the workshops.

The first workshop was held in November 1984. Participants, including managers, professors, administrators, planners, and researchers from industry, State and Federal agencies, and universities throughout the West, were divided into four subgroups (stand, management, root disease, and other agents) to prepare various components of the conceptual model. The last day was spent examining these various components to see which portions could be supported by available data and which portions were based on our best assumptions. The latter turned out to be far more common than the former, emphasizing the need for additional research on various aspects of root disease.

A second workshop was held in Feburary 1985. In the intervening months, ESSA staff had developed a computer model to represent the behavior of root diseases, as developed in the conceptual model. At the second workshop this computer model was put through several working demonstrations to show workshop participants how well it represented actual processes. Modifications were made to the model as deemed necessary by workshop participants. This process generated a rather long list of research needs as many assumptions in the model were supported more by consensus of workshop participants, rather than hard data.

After this second workshop, ESSA staff continued to check and refine model behavior. The core team met with ESSA staff in August 1985 and decided that four main objectives remained to be accomplished: 1) refine and document the model; 2) transfer it to the Forest Service computer system; 3) design appropriate inventory procedures; and 4) test sensitivity of the model to alternate stands, control actions, and uncertainties in current knowledge about root disease spread and impact.

Since additional funding has been obtained, the core team and ESSA consider that these tasks can be accomplished within the next year. This will necessitate holding another workshop, presenting the model to potential users, and developing an operators' guide. If all goes well, a working version of the model should be available on the Forest Service computer system at Fort Collins by October 1986.

## Form and Function of the Root Disease Subroutine

This section's intent is to provide an overview of how the root disease subroutine works and an understanding of the major assumptions that have been made in its construction. In addition, results from a few runs of the subroutine attached to PROGNOSIS are presented to demonstrate the types of output that are available. The subroutine is currently being revised and improved in a number of areas; where appropriate we indicate what these improvements will be and why they are important. Further details about subroutine structure and function appear in McNamee et al. (1985).

The approach used in this project involved construction of a simulation model based on the current "best understanding" of root disease dynamics. This approach necessitates documenting the current knowledge and structuring it into a conceptual model. This process of structuring current knowledge is a powerful method of detecting data gaps and areas of poor understanding and, thus, can be very useful in generating research priorities.

Model structure The model consists of three main components: the root disease subroutine, an "other agents" subroutine, and a stand interface subroutine. The root disease subroutine considers the status and spread of root disease, as described in considerably more detail below. The other agents subroutine, at present, models the effects of windthrow and three types of bark beetle behavior. This subroutine is important as it provides a structure for considering the interactions between root diseases and other damaging agents. The stand interface subroutine provides the interaction between the stand growth model, currently PROGNOSIS, and the other two components. This structure allows the root disease subroutine to be isolated from the stand growth model, a feature that allows it to be adaptable to other stand growth models with a minimum of disruption.

Managers participating in the first workshop identified two treatments that they wanted to be represented in the model: stumps removed after harvest, and change of species through planting or variation in regeneration methods. Indicators which they wished to consider included the usual inventory volumes and yields, augmented by disease-specific indicators such as proportion of stand affected, spatial patterns of mortality, and number of infected stumps by species and size.

The root disease subroutine This subroutine provides a dynamic representation of the spacial and temporal epidemiology of root diseases. The subroutine assumes that the distribution of root disease within a stand can be characterized by a number of spreading root disease centers, each of which contains infected and noninfected trees and

other inoculum sources (i.e., stumps). The disease centers are defined by their locations in the stand (coordinates) and their size (radii).

There are three important characteristics of root disease centers that are addressed: 1) the dynamics of infection and inoculum within root disease centers; 2) the expansion rate of spreading centers; and 3) the "carry over" of root disease from one stand after a clearcut to a new stand. These components are all complex functions of the sizes, distributions, and species of trees, and the sizes and distribution of inocula--all of which vary through time. Because of this complexity, the subroutine simulates small portions of the stand in explicit detail, noting exact positions of a number of trees and the spacial relationships of their roots. Results from these small scale, detailed simulations are then expanded to represent effects of root disease in the stand as a whole.

To characterize spread of root disease centers through a stand, it is first necessary to describe disease spread through the roots of individual trees. Figure 1 depicts how live root systems become infected, how trees are killed, and how infection spreads in roots. In the subroutine, the quantity of inoculum is measured as area occupied by infected roots since this is directly related to the probability of root contact.

A major assumption in need of verification is that neither P. weirii nor pathogenic strains of Armillaria attack and colonize totally uninfected, dead root systems. These fungi only attack live roots systems and, with Armillaria, even a small lateral root infection will be sufficient to colonize the entire root system after tree death. On the other hand, P. weirii is assumed to be a relatively weak saprophyte that is unable to further colonize infected root systems after tree death.

The pattern shown in figure 1 for the progress of infection and decay after tree death specifically relates to Armillaria. There are two major differences for P. weirii: 1) the maximum portion of the root system which becomes infected is that portion which is already colonized when the tree dies; and 2) the minimum length of time that inoculum survives is 20 years. The shape of the various portions of this relationship (Figure 1) are functions of the size, species, and origin (planted vs seeded) of the tree in question.

The time necessary to kill a Douglas-fir tree on Douglas-fir habitat in the interior region of the western United States is defined by the relationship shown in figure 2. This relationship is modified for other species, pathogens, and habitat types, as shown in the figure, but assumes that all trees react to infection in a similar way until their d.b.h exceeds 4 in. In the current subroutine, variations between habitat types are not included, nor is the effect of planting.

The average portion of a root system that is colonized when a tree dies is a function of the pathogen and tree species (table 1). Following tree death, the progress of disease depends on the pathogen; Armillaria colonizes the entire root system within 5 years. For P. weirii, the proportion of infected roots does not increase after tree death. For both pathogens, inoculum is assumed to deteriorate rather rapidly after its maximum buildup.

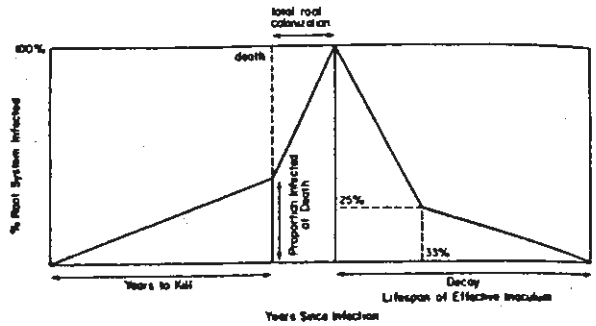


Figure 1--Pattern of pathogen spread and inoculum buildup and decline in a single root system.

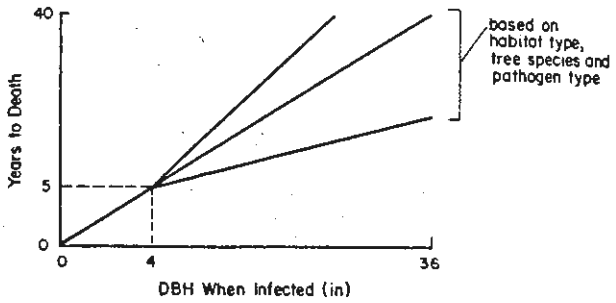


Figure 2--Time required from infection by Armillaria to tree death for Douglas-fir on a Douglas-fir habitat type.

Table 1--Average percentage of root systems assumed to be infected at the time a tree is killed by root disease.

| Tree Species | Fungal Species | |
|---|---|---|
| | Armillaria | P. weirii |
| | (% root system infected) | |
| Douglas-fir | 80 | 60 |
| Pines | 30 | 85 |
| True fir | 80 | 60 |
| Hemlock | 80 | 80 |
| Spruce | 75 | 65 |
| Larch | 85 | 75 |
| Cedar | 75 | 85 |

The maximum lifespan of effective inoculum is a function of stump size and tree species (Figure 3). Tree species are grouped into heartwood and non-heartwood types. Species with heartwood include Douglas-fir, pines, western redcedar, and western larch; non-heartwood species are true firs, hemlocks, and spruce.

Inoculum is assumed to decay at a rate that reduces the radial extent of infected root systems by 75% during the first 1/3 of the lifespan. Remaining infected roots are assumed to decay at a steady rate over the remaining 2/3 of their lifespan.

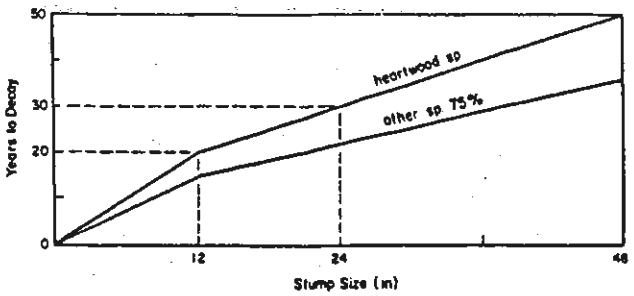


Figure 3--Lifespan of inoculum for various tree species infected with Armillaria; see text for description.

Simulation of root disease dynamics The simulation for enlargement of infection centers has three main components: an estimation of the average rate of enlargement, the translation of that rate into an area of new stand encompassed by root disease, and translation of that area into the number of new trees infected. Spread rate is estimated by simulating a small portion of the stand for a number of years and calculating the length of time it takes the disease to cross that area. This spread rate is then converted to an increase in the radius of each disease center during the time step of the main model (10 years for PROGNOSIS). These increased radii are then converted into an increase in diseased area, taking account of overlaps between two or more disease centers. Given the increased area inside infected zones, the tree list from the main model is processed and the number of new trees now inside the centers is estimated. The assumption is that 90% of all new trees encompassed by the spreading center become infected as the center expands.

How root disease centers are affected by clearcutting and regeneration of a new stand is poorly understood. We consider three different scenarios: 1) root disease centers from the former stand cease to exist after clearcutting, and root disease in the new stand arises in a small number of new centers located within the previously infected area; 2) root disease centers from the former stand retain their integrity, and, as the new stand matures, these centers enlarge, starting at their old boundaries; and 3) after a clearcut and regeneration, root disease centers form around certain individual pieces of inoculum throughout the area affected in the former stand and these centers gradually expand and coalesce.

These three scenarios actually form a continuum that is dependent on the density of inoculum and the probability of a piece of inoculum initiating a new center capable of expanding. These processes are poorly addressed in the current model, but will be considered in detail during forthcoming revisions.

Model demonstration Output presented here comes from a subroutine that is currently undergoing major revisions. These results are intended to provide only a flavor of the types of output that can be generated.

These demonstration runs are based on stand data obtained from Jim Byler. The stand is in Region 1, it is about 100 years old, and is dominated by western hemlock and grand fir. The site is at 3800 feet with no slope and the habitat type is Tsuga heterophylla/Clintonia uniflora. The stand actually expresses moderate levels of root disease with a mixture of Armillaria and P. weirii; however, for this demonstration, the model has been initiated with various and different levels of Armillaria.

Results of four different scenarios are presented. In all cases the 100-acre stand is cut in year 10 of the main model (stand age 110) and is replanted with Douglas-fir at 600 stems per acre; some natural regeneration is also assumed to occur. The four scenarios are: 1) no root disease; 2) a single twenty acre root disease center; 3) twenty, one-acre root disease centers; and 4) scenario 2 with a stump removal operation that is assumed to be 90% efficient in destroying inoculum.

Figures 4 and 5 show comparisons between these scenarios for volume of wood in board feet per acre and the total stand area occupied by root disease centers. Line "a" in figure 4 depicts the stand with no root disease. Volume is initially high, drops to zero at the time of cutting, and then gradually increases over the next 90 years. Line "c" in figure 4 represents what happens to that portion of the new stand that is within one of the original root disease centers. Volume remains low after the cut because of mortality caused by root disease. Line "b" represents what happens within the infected area if stumps are removed after the cut. Volume increases are markedly higher than those in the non-treated root disease center, but remain lower than those in the non-infected stand because some inoculum persists.

Line "a" of figure 5 represents what happens to the area occupied by root disease if the stand has a single, 20-acre root disease center. At the time of cutting the center stops spreading; after about 20 years it gradually continues to expand outward from the boundary present in the previous stand.[1/] Remember, however, that even though this center expands only slowly, little merchantable volume develops within it (line "c" fig. 4).

Line "b" in figure 5 represents what happens when the root disease occurs in 20 approximately one-acre centers. Because of the geometry of expansion, the same rate of radial enlargement results in more area in root disease centers than for one, 20-acre center. Line "c" in figure 5 depicts the effects of stump removal at 90% efficiency. The area in root disease centers is

1/A refinement is being made here. After clearfelling disease centers should expand outward from a region slightly beyond their observable boundaries in the previous stand. This happens with Armillaria because many trees at the edge of a center have infected roots, but no crown symptoms. These trees become colonized after cutting--a process that enlarges the area occupied by inoculum to the outer edges of these trees' root systems.

initially reduced to near zero, but, because some inoculum remains, root disease starts to spread outward from a number of separate locations within the area infested with root disease in the previous stand. Because root disease develops from a number of discrete centers, the total area infested expands rather rapidly.

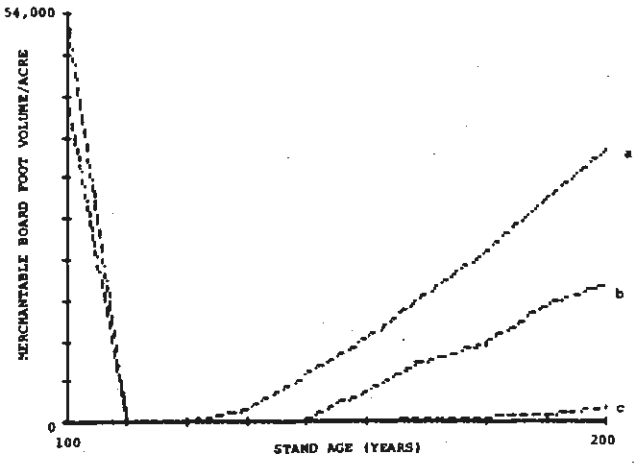


Figure 4. Output from the root disease subroutine linked to PROGNOSIS showing differences in stand volume under various management scenarios; see text for description.

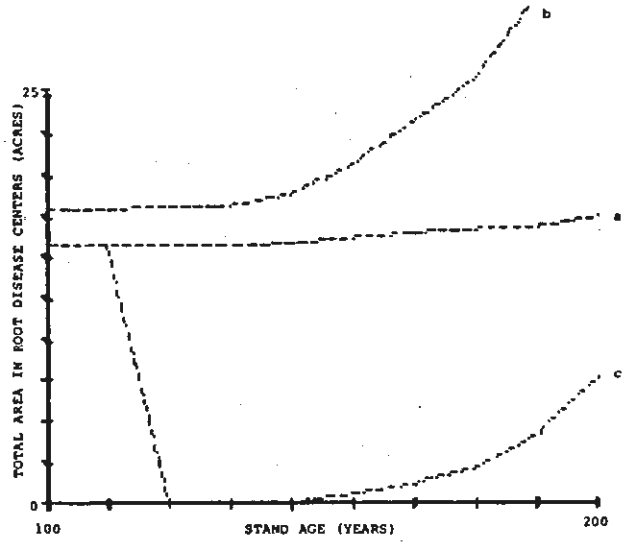


Figure 5. Output from the root disease subroutine linked to PROGNOSIS showing differences in stand area infested with root disease under various management scenarios; see text for description.

This output indicates how a forest planner or manager might use the model to evaluate various silvicultural alternatives in stands affected by root disease; a series of "what if" questions can be asked and estimated results of implementing these alternatives evaluated by examining differences in model output.

Similarly, a research scientist can evaluate how sensitive the model is to various assumptions made during its development; the assumptions are changed systematically and the model run to see what differences in output result from the modifications. The degree of change that results from the modification indicates how sensitive the model is to that particular assumption. Assumptions that are sensitive to modification indicate areas of uncertainty most in need of clarification to ensure reliability in model behavior. Using the model in this manner can assist scientists in establishing priorities for future research on root diseases.

The last section of this paper provides information on stand growth models in general, how PROGNOSIS works, and how the root disease subroutine is linked to it. In addition, inventory procedures necessary to provide input data for the root disease subroutine are discussed.

## PROGNOSIS--A Fortune Teller for Forest Stands 2/

Choosing a schedule of treatments for forest stands requires the manager to look far into the future to evaluate consequences. Treatments that are to be scheduled or anticipated--thinning, pest reduction, fertilization, regeneration harvests, etc.--have complex interactions that affect the future utility of the stand for meeting management goals. Diverse fields of knowledge must be integrated by the manager if the selected schedule of activities is to be effective. Prognosis models provide consistent systematic procedures for integrating the knowledge of many specialists to predict the consequences of treating forest stands.

A model does not stand alone as a source of information about stand management. It is just one of five segments in a decision-support system for assisting managers to schedule stand treatments. Because the model must interact with the other segments, a brief over-view of its role should help one understand the stand PROGNOSIS model. The five segments are procedures for: 1) choosing the scope of potential treatments and their range of intensity; 2) inventorying the stand and the ecosystem of which it is a part; 3) predicting the consequences of applying the various treatments; 4) choosing the schedule of treatments having consequences that most closely accomplish the goals for management; and 5) monitoring results of treatments.

The first and fourth segments are the prerogative of the manager, who must specify the kinds of treatments he is considering, and the criteria by which alternatives will be evaluated. These decisions set the bounds within which the prediction segment and the inventory segment must function. Because the inventory segment must provide the initial conditions for the prediction segment, designs of these two parts should be carefully coordinated with each other as well as with the remaining segments.

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2/ Based in part on a similar report in the 1978 SAF Proceedings (Stage 1978).

The stand PROGNOSIS model that is linked to initial versions of the root disease subroutine predicts future development of stands through displays of long-range values of tree diameters, heights, crown ratios, tree-species composition, and understory shrub composition and coverage. The model reflects effects of thinning, fertilization, regeneration, and harvests; through interaction with pest outbreaks, it also models the effects of treating with chemicals or biological control agents.

After the basic root disease subroutine has been developed and evaluated using PROGNOSIS to represent stand dynamics, two additional yield models will be linked to the root disease subroutine. These two, DFSIM and RMYLD, will require modification to represent spatial attributes in the root disease subroutine. At this time, the major changes which are needed are the ability to carry separate densities and related stand parameters for two portions of the stand--areas inside root disease centers and areas outside these centers.

Users of the root disease subroutine must realize, however, that management actions which may be evaluated using these other growth and yield models will be limited by the species diversity of the stands these models can represent.

Components of the PROGNOSIS model The overall model represents tree growth through a collection of submodels representing growth of trees at different stages of their life-cycle. These stages are: 1) regeneration establishment that follows seedlings through their first 10 years; 2) regeneration development that represents growth of established seedlings and saplings up to the time they reach 5.0 inches d.b.h.; and 3) poles and larger trees.

The regeneration establishment submodel predicts the stocking characteristics of small plots of 1/300 acre (Stage 1974; Ferguson and Crookston 1984). Factors influencing stocking rate include habitat type, slope, aspect, elevation, topographic position, time since disturbance, site preparation method, overstory composition and density, planting, and distance from seed-source.

The regeneration development submodel predicts height and diameter increments of trees less than 5 inches d.b.h. Height increment varies with species, habitat type, slope, aspect, elevation, overstory density, conifer and shrub competition, and height of subject tree. Diameter increment is a function of species, height, and predicted height increment.

Growth of poles and larger trees is represented by equations for each species that predict diameter increment from values of diameter, crown ratio, crown competition factor (Krajicek et al. 1961), basal area in trees larger than the subject tree, slope, aspect, elevation, habitat type, and geographic region. Height increment of poles and larger trees of each species is dependent on predicted diameter increment, height, diameter, and habitat type (Stage 1975).

Mortality is represented by reducing the trees-per-acre variable associated with each sample tree. At the start of PROGNOSIS, this variable is established by the sampling design of the inventory. At each successive time step in the PROGNOSIS calculations, endemic levels of mortality are estimated from a probability function that depends on d.b.h. (Hamilton and Edwards 1976).

Each of the models described above has been calibrated using data from previous stand inventories in Northern Rocky Mountain Forests. Where existing data were inadequate, research studies have been designed to fill the gaps (Stage 1974). Most of these data used to calibrate the growth and mortality submodels represent pest losses at low level of pest populations. However, if additional periods of growth, and other geographic areas are to be added to the model, pest damage should be given careful scrutiny to avoid double-counting of losses when the model is to be coupled with explicit pest damage models such as the root disease subroutine.

Inventory Procedures There are presently no standardized inventory procedures for describing levels and spatial distributions of root disease in stands. The following information is needed to characterize root disease in the model stand: 1) number of root disease centers, their location, and diameter; 2) a list of dead trees and stumps with all their attributes required by the root disease subroutine (McNamee et al. 1985); 3) a list of infected trees with all their attributes required by the root disease subroutine (McNamee et al. 1985); and 4) a list of uninfected trees with all their attributes required by the stand growth simulator (Wykoff et al. 1982).

Currently, initial conditions for the number, size, and location of root disease centers can be set by the user or set randomly by the initialization model. If set randomly, all centers are assumed to be the same size and the location of each center in the stand is determined randomly. This structure can be used to represent a number of qualitatively different situations: 1) a stand with a series of discrete centers of infection which may or may not overlap; 2) a stand with scattered mortality throughout and no well-defined root disease centers (this can be considered as one large infection zone with a certain level of infected and uninfected trees and stumps/snags); and 3) a young stand with a large amount of inoculum from disease centers in the previous stand (this will give rise to a number of new infection centers in the region of previous infection).

The stand condition inside the infected areas is strictly a function of the stand condition defined in the normal stand inventory. The number of infected and uninfected trees of each tree record inside the infected areas is set by the user to fixed proportions of the tree density in each record. The proportion of root systems colonized in the infected trees is also defined by the user. The dead tree/stump list is made by using one minus the above proportions as multipliers on the tree density calculated from the normal stand inventory.

This method of defining initial root disease conditions in the stand does not allow users to utilize current root disease conditions defined as part of a normal stand inventory procedure to initialize root disease conditions in this model. However, the current initialization method is extremely useful for being able to quickly redefine and examine model behavior under alternate initial root disease conditions.

Further improvements in inventory specifications are considered critical for enhancing the utility of this subroutine. Such refinements are being made during current revisions in the root disease subroutine and we are open to any suggestions you care to make.

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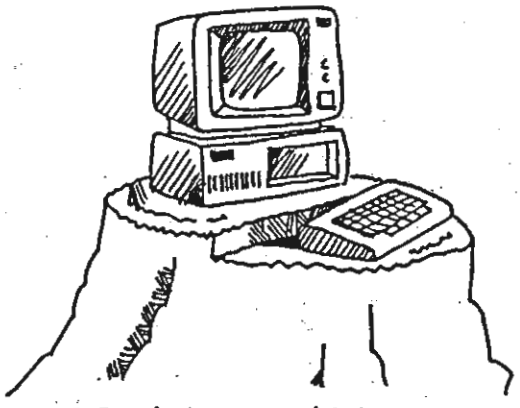

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## Decision Making and Disease Management

Kenelm Russell[1] and John E. Browning[2]

### INTRODUCTION

"Justifying the forest management decision!" That's the way I led off the 1981 talk in the WIFDWC "Root Diaease Control Strategies—Are They Worth It?" panel in Vernon, BC. Damn right they're worth it! Let's look further. In that talk I presented you with the Present Net Worth method of justifying forest management expenditures using root disease as the pest.

Now I want to show you how to do your own Present Net Worth analyses on your own personal computers. Also, if you want your own program, send me a standard 5.25 inch diskette and I will return it copied as the program is public domain. I am using standard economic methods tailored to the needs of the Washington Department of Natural Resources. The method is easily adapted to any organization and can be used for any forest expenditure, pest caused or not. The program is written in BASIC LANGUAGE specifically for the IBM Personal Computer XT (Chambers and Smego 1984).

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### PEST IMPACT

Since much of this discussion centers around timber production, I will stay with that theme, realizing there are other ways of valuing the forest. I will not be talking about regional pest losses here, but individual acre or stand losses. The easiest way to describe pest impact in a stand is in terms of its production over a rotation.

Pest Impact is the difference between the stand's healthy state and what is actually there after the pest has ravaged it. I like to express the "shrinkage" as percent of expected healthy production for a rotation. Think of shrinkage either by the acre, or by the stand. While individual acre shrinkage might be in the 30-50 percent of normal range, stand shrinkage will be in the 65-90 percent of normal due to the strong influence of high production performance on healthy acres.

Remember that we can inject ourselves into the loss at any point in the stand rotation. Thus, loss timing can be better defined by breaking the rotation into decades which are very convenient forest management time units. We could be in an actual "Looking backward; What is it at some mid point? or What will it be at the end of the next rotation?" condition.

For example, let's examine two nearly identical 100 acre Western Washington Douglas-fir stands; "A", healthy with normal rotation mortality and "B" with 25 acres of severe root rot, an "abnormal" condition. We are at the end of the rotation looking back on the devastation. Stand "A" produced 50,000 board feet on each of its 100 acres in 60 years, while "B" produced only 15,000 board feet on each of its 25 diseased acres in the same time span.

Healthy stand "A" cut out at 5.0 million board feet while diseased stand "B" cut out 4.125 million board feet, a difference of 875M board feet or 82.5 percent of normal. Can we do something about expected root rot mortality next time around? We know that the 25 acre root rot infection is going to enlarge in the next rotation. The tough question is how much? The good news is that we now have an impact model that takes some of the guesswork away. It is described elsewhere in this proceedings.

The rest of my discussion is based on the description of impact above. I have assumed that we know a good deal about the future disease impact and can either use the root rot model to help arrive at meaningful shrinkage values or make good estimates.

### MAKING THE ANALYSIS

There are several parts to the pest management decision. These include economic, biological, environmental, social and sometimes political aspects which must be skillfully merged for the final decision. This discussion will cover only the economic portion dealing with the Present Net Worth Method.

How The System Works. You need basic understanding of the Present Net Worth method, knowledge of the Forest Management Regime, Yield of the Stand and the Impact of the Pest before proceeding.

Present Net Worth is defined as discounted revenues minus discounted costs expressed in dollars per acre. The internal rate of return is the annual, real (inflation removed) interest rate that an investment returns. It is calculated as the interest rate in the PNW discounting formula where discounted costs just equal discounted revenues. When PNW equals zero at a certain rate of return, the investment has earned that rate and any revenue above it is gravy (Russell 1981).

The Management Regime states what will be done over the rotation. It includes timing of management activities and costs for site preparation, planting, unwanted vegetation management, spacing, fertilization, intermediate commercial thinning(s), rotation age, and harvest method. It is most educational to make many PNW runs on the PC by changing rotation age, species, method of treatment, and the above variables. Every alternative can be examined and argued until the right solution is found.

Your own organization policy dictates interest rate, taxes, cost and price increases, stumpage costs, inflation, etc. It is most important in making these analyses that costs and other prices be taken from moving averages developed by your own organization. (DNR uses a ten year moving average.)

Stand yields are available from many sources (Chambers and Smego 1984). You as the skilled Forest Pathologist or Forest Manager supply the pest impact through surveys and evaluation.

Case Histories. A 90 acre (36 ha) Department of Natural Resources west slope Douglas-fir timber sale called "Easy Picking" and an eastern Washington mixed conifer stand will be used as examples in the PNW comparisons. Easy Picking has 22 acres (9 ha) of laminated root rot and the eastside stand has scattered pockets of Armillaria root rot. In healthy condition assuming only normal stand mortality, Easy Picking is capable of producing about 53,000 board feet per acre in 60 years and the eastside unit about 27,500 board feet per acre in 75 years.

"Easy Picking" was a 120 year old stand of coastal Douglas-fir located just west of Chehalis, Washington. It was the site WIFDWC visited on the field trip. Soil is a productive clay loam and the terrain is relatively flat with excellent road access - a prime forest management site. The sale was clearcut in summer, 1985 and the stumps in root rot infection centers pushed to minimize root disease in the new Douglas-fir stand.

CREATING YOUR OWN DATA FILE

The following information was taken from the DNR manual prepared by Chambers and Smego (1984). I have streamlined it here and there or otherwise used it verbatim. You should be able to run the program without the manual or you can request it from me.

After all the input data has been gathered, the next step is to create the DATA FILE with your own management information for the computer. It describes your special management regime for your problem stand. The DATA FILE is made up of a column of line numbers and seven columns of management information. For convenience, line numbers are the same as stand age numbers. A comma must follow each column entry except the last one on each line. Data within each entry is written without commas or decimals (ex. 53000, etc.).

Management information in DATA FILE columns opposite line numbers is as follows: (1) stand age or years until activity occurs, (2) clearcut volume in board feet per acre (3) commercial thinning volume, (4) reforestation (planting or natural) and site preparation such as STUMP PUSHING, (5) precommercial thinning, (6) fertilization and (7) vegetation control.

Columns 2 and 3 state total volume in board feet per acre. Columns 4-7 are entered as either 1 or 0, where 1 means activity occurs and 0 means it does not. Table 1 summarizes the DATA FILE format.

Table 1--Program DNRPNW DATA FILE format

| Column | Data Element | Value |
|---|---|---|
| 1 | Line number | years |
| 2 | Time until activity occurs | years |
| 3 | Clearcut volume | bd. ft. |
| 4 | Commercial thinning volume | bd. ft. |
| 5 | Reforestation, stump pushing | 1 or 0* |
| 6 | Precommercial thinning | 1 or 0* |
| 7 | Fertilization | 1 or 0* |
| 8 | Vegetation control | 1 or 0* |

* 1 indicates an activity occurs
* 0 indicates an activity does not occur

Table 2 is a blank DATA FILE worksheet you can copy and use when creating your own PNW runs.

Table 3 illustrates the correct DATA FILE format. The example is the healthy condition Easy Picking Sale and shows planting at age zero (now), vegetation control at age 7, precommercial thinning and fertililization at age 15, commercial thinning at age 40 and final harvest at age 60. Remember that you can add line numbers for other or repeated activities and change rotations to fit your own needs. You can show other events such as more thinning or vegetation control, etc. The possible combinations are numerous.

Table 2-- DATA FILE worksheet for DNRPNW program

| TITLE: | | | | REGIME NAME: | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| | | | | | | | |

Table 3-- DATA FILE for the westside healthy condition, Easy Picking Sale formatted for entry into DNRPNW program.

| TITLE: EASY PICKING HEALTHY | | | | REGIME NAME: EPICHEA | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 7 | 7, | 0, | 0, | 0, | 0, | 0, | 1 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 40, | 40 | 0, | 5426, | 0, | 0, | 0, | 0 |
| 60, | 60 | 47670, | 0, | 0, | 0, | 0, | 0 |

INPUTTING DATA FILE INFORMATION

After your DATA FILE worksheet has been assembled and checked for accuracy, it is time to enter it into the computer. Check carefully -- those numbers and commas have a way of getting messed up.

I'm assuming here that you have the DNRPNW program on a floppy disk in the computer.

Sign on and enter BASIC LANGUAGE SYSTEM.

Type NEW. (Computer responds "Ok")

Enter each line of data as written, with commas following each value except the last. Press RETURN after each line and at the end of the file.

When worksheet data is entered, press the SAVE [F4] key and type A:FILENAME.DAT",A and RETURN to safely store your file. FILENAMES can use up to eight characters. Check to make sure it is saved and in correct format by pressing LIST [F1] and RETURN keys.

To call up a DATA FILE that is not currently loaded, press LOAD [F3] and type A:FILENAME.DAT and RETURN. Then press LIST [F1] and RETURN to view the file. The ",A is only needed when saving.

CORRECTING DATA FILE ERRORS

There are three ways to correct errors in a DATA FILE before the file is saved. First, move the cursor to the error and type the new character. Second, delete the line by pressing ESCAPE [Esc] and retype the new line. Third, press RETURN and re-enter a correct line. The computer will always read the last entry when line numbers are the same.

To modify a file that has been saved, simply type in a new line of data with an existing line number or a new line number and press RETURN. SAVE the new line A:FILENAME.DAT",A and the computer will print Ok or list error messages if there are any.

RUNNING THE PROGRAM

When you are happy with your DATA FILE, it is time to load the program.

NOTE: If you want a print of your work as you go, press the control and print screen keys [PrtSc] before loading the program. The program will print date and time before beginning.

Press LOAD [F3] key and type A:DNRPNW and press RETURN.

Press RUN [F2] key. Program will begin asking you management information questions. Separate each answer requiring more than one number with a COMMA, otherwise NONE. Strike RETURN and go on to the next question.

Q1 TITLE

?Type name of this PNW run (use no punctuation).

Q2 REGIME NAME

?Type up to 8 characters A:FILENAME

Q3 ROTATION

?Type age in years

Q4 ANNUAL COST

?Enter annual administrative overhead cost. DNR uses $2.84/acre or use your own figure.

Q5 COST INCREASE, REGENERATION LAG, SHORT FORM OR LONG FORM

?Enter cost increase in percent (use 2%), regeneration lag in years, if any and enter 1 for short form or 2 for long form.

The short form prints only the PNW table and the long form prints everything. I recommend using long form until you get familiar with the program (type 2,0,2).

Q6 THREE PRICE INCREASES AND TWO INTERVALS

?Enter the real rates of price increases. DNR uses 3% the first 40 years of investment and 1.8% thereafter. Type 3,3,1.8, 20,20 or 3% first 20 years, 3% second 20 years, and 1.8% thereafter.

Q7 STUMPAGE PRICES FOR THINNINGS 1,2,3 4,5,6 AND CLEARCUT

?Enter stumpage prices. The program allows you to enter stumpage prices for up to 6 commercial thinnings and a final harvest. If you are doing a shelterwood, treat the big harvest as a thinning. Enter all thinnings with a value, using zeros where none occur.

For example, Stumpage prices for a single thinning at 40 years and clearcut at 60 years are entered: 132,0,0,0,0,0,213.

Q8 PLANTING (STUMP PUSHING OR OTHER SITE PREP), PRECOMMERCIAL THINNINGS, FERTILIZATION AND VEGETATION CONTROL COSTS

?Enter per acre values for each specified activity. Add costs of site preparation/ stump pushing to planting costs and enter as single entry because these activities usually occur the same year. If no activity occurs, enter a zero. Enter as many cost repeats as may be necessary. I used $125 for planting, $55 for PCT, $73 for fertilization (when done) and $32 for vegetation control.

Q9 INPUT INTEREST RATE BOUNDS & INTERVALS (%)

?Enter range of interest rates to be considered from lowest to highest and the interval. I usually use rates from 5 to 10% in 1% intervals. Type 5,10,1.

The program calculates present value for your management regime. It will list discounted costs, discounted revenue and present net worth for a single rotation by each interest rate specified in a table. At the end of the run you will have the option of leaving the program with a yes/no inquiry.

DNRPNW PROGRAM EXAMPLES

The following examples are the same ones we ran in the workshops. I assumed a healthy, diseased, and treated condition for each stand and included an alder rotation in a species switch run. I also assumed we were stuck with expensive stump pushing because a cheaper species switch did not appear feasible.

Remember that I am referring to healthy acres and diseased acres only. This exercise deals with root rot and its treatment by the acre not by the stand. Our workshop time did not permit us to blow the values up to a stand basis. You now have the tools to do it.

Tables 4 and 5 give the DATA FILES we used in the workshops.

Table 4--DATA FILES for the westside Easy Picking Sale. Four alternatives show the PNW for healthy, diseased, and treated conditions and an alder rotation.

| TITLE: EASY PICKING HEALTHY | | | | REGIME NAME: EPICHEA | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 7 | 7, | 0, | 0, | 0, | 0, | 0, | 1 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 40, | 40 | 0, | 5426, | 0, | 0, | 0, | 0 |
| 60, | 60 | 47670, | 0, | 0, | 0, | 0, | 0 |

| TITLE: EASY PICKING ROOT ROT | | | | REGIME NAME: EPICROT | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 7, | 7, | 0, | 0, | 0, | 0, | 0, | 0 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 40, | 40, | 0, | 0, | 0, | 0, | 0, | 0 |
| 60, | 60, | 14201, | 0, | 0, | 0, | 0, | 0 |

| TITLE: EASY PICKING TREATED | | | | REGIME NAME: EPICTRT | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 7, | 7, | 0, | 0, | 0, | 0, | 0, | 1 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 40, | 40, | 0, | 5046, | 0, | 0, | 0, | 0 |
| 60, | 60 | 44333, | 0, | 0, | 0, | 0, | 0 |

| TITLE: EASY PICKING ALDER | | | | REGIME NAME: EPICALD | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 40, | 40, | 15323, | 0, | 0, | 0, | 0, | 0 |

Table 5--DATA FILES for the eastside mixed conifer stand. Three alternatives include healthy, diseased and treated condition. This stand is located near Colville, Washington in a Douglas-fir, grand fir, ninebark habitat type.

| TITLE: EASTSIDE HEALTHY | | | | REGIME NAME: EASTEA | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 45, | 45, | 0, | 5400, | 0, | 0, | 0, | 0 |
| 65, | 65, | 0, | 15820, | 0, | 0, | 0, | 0 |
| 75, | 75, | 6200, | 0, | 0, | 0, | 0, | 0 |

| TITLE: EASTSIDE ROOT ROT | | | | REGIME NAME: EASTROT | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 45, | 45, | 0, | 2160, | 0, | 0, | 0, | 0 |
| 65, | 65, | 0, | 6328, | 0, | 0, | 0, | 0 |
| 75, | 75, | 2480, | 0, | 0, | 0, | 0, | 0 |

| TITLE: EASTSIDE TREATED | | | | REGIME NAME: EASTTRT | | | |
|---|---|---|---|---|---|---|---|
| Line No. | Stand Age | Clear cut Vol. (bf) | Comm. Thin Vol. (bf) | Plant Push | PCT | Fert. | Veg. |
| 0, | 0, | 0, | 0, | 1, | 0, | 0, | 0 |
| 15, | 15, | 0, | 0, | 0, | 1, | 0, | 0 |
| 45, | 45, | 0, | 4860, | 0, | 0, | 0, | 0 |
| 65, | 65, | 0, | 13526, | 0, | 0, | 0, | 0 |
| 75, | 75, | 6200, | 0, | 0, | 0, | 0, | 0 |

Table 6--Computer run of Present Net Worth for HEALTHY Douglas-fir- Easy Picking Sale. Rotation 60 years, site index 130 ft (40 m) (50 years), plant, vegetation control, precommercial thin, one commercial thin, clearcut.

```
RUN
09-25-85  1506:57

TITLE:   EASY PICKING--HEALTHY

REGIME NAME
? EPICHEA
INPUT ROTATION
? 60
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 132,0,0,0,0,0,213
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($/ac)
? 125,55,0,32
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

        EASY PICKING--HEALTHY ACRES

CLEARCUT  AT 47670 BF AT 60 YEARS, AT $992.71
  PER MBF DISCOUNTED
60 YEARS (100% yield)
THINNING  AT 5426 BF AT 40 YEARS, AT $430.59
  PER MBF DISCOUNTED
40 YEARS (100% yield)
PLANTING AT $125 AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG = 0 YEARS
PCT AT $74.02 AT 15 YEARS,DISCOUNTED 15 YEARS
VEGETATION CONTROL AT $36.76 AT 7 YEARS,
  DISCOUNTED 7 YEARS

              SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
  (%)        INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)     ($/ac)

   5          2865          330        2683
   6          1662          286        1420
   7           973          256         716
   8           575          235         340
   9           343          218         124
  10           207          207           0

  END Y/N? Y
  1518:13
  OK
```

Table 7--Computer run of Present Net Worth for DISEASED portions of Easy Picking Sale. Same as healthy stand except no commercial thinning due to poor stocking from root rot. Infection centers estimated to produce only 27% of healthy stand.

```
RUN
09-25-85  1520:27

TITLE:    EASY PICKING--ROOT ROT INFECTED
          (LAMINATED ROOT ROT)

REGIME NAME
? EPICROT
INPUT ROTATION
? 60
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 0,0,0,0,0,0,213
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($/ac)
? 125,55,0,32
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1


   EASY PICKING--ROOT ROT INFECTED ACRES

CLEARCUT AT 14201 BF AT 60 YEARS, AT $992.71
  PER MBF DISCOUNTED
60 YEARS (27 % yield)
PLANTING AT $125 AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG = 0 YEARS
PCT AT $74.02 AT 15 YEARS, DISCOUNTED
  15 YEARS
VEGETATION CONTROL AT $36.76 AT 7 YEARS,
  DISCOUNTED 7 YEARS


        SINGLE ROTATION

INTEREST  DISCOUNTED    DISCOUNTED    PRESENT
  (%)       INCOME        COSTS      NET WORTH
            ($/ac)        ($/ac)      ($/ac)
   5          755           279          476
   6          427           254          174
   7          243           235            8
   8          139           221          -82
   9           80           210         -130
  10           46           201         -155

  END Y/N? Y
  1526:19
  OK
```

Table 8--Computer run of Present Net Worth after STUMPS PUSHED TO CONTROL ROOT ROT @ $250/acre in the Easy Picking Sale. Management regime same as healthy stand. Treated portions are estimated to produce at 93 percent or more of healthy stand. Stump pushing plus planting = $375/acre.

```
RUN
09-25-85  1530:12

TITLE:    EASY PICKING--ROOT ROT TREATED

REGIME NAME
? EPICTRT
INPUT ROTATION
? 60
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 132,0,0,0,0,0,213
PLANTING (+ Stump Pushing), PRECOMMERCIAL
  THINNING, FERTILIZATION, AND VEGETATION
  CONTROL ($/ac)
?**375**,55,0,32 (Planting @ $125 + stump
  pushing @ $250 = $375)
  ($250) + planting ($125) cost goes)
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1


     EASY PICKING--ROOT ROT TREATED ACRES

CLEARCUT AT 44333 BF AT 60 YEARS, AT $992.71
  PER MBF DISCOUNTED
60 YEARS  (93 % of healthy stand yield)
THINNING AT 5046 BF AT 40 YEARS,  AT $430.59
  PER MBF DISCOUNTED
40 YEARS (93%)
PLANTING AT **$375** AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG = 0 YEARS
PCT AT $74.02 AT 15 YEARS,DISCOUNTED 15 YEARS
VEGETATION CONTROL AT $36.76 AT 7 YEARS,
  DISCOUNTED 7 YEARS


              SINGLE ROTATION

INTEREST  DISCOUNTED    DISCOUNTED    PRESENT
  (%)       INCOME        COSTS      NET WORTH
            ($/ac)        ($/ac)      ($/ac)

   5         2665           576         2088
   6         1545           534         1012
   7          905           504          400
   8          535           484           51
   9          319           468         -149
  10          193           456         -264

  END Y/N? Y
  1533:37
  OK
```

Table 9--Computer run of Present Net Worth after STUMPS PUSHED TO CONTROL ROOT ROT @ $700/acre in the Easy Picking Sale. Stump pushing plus planting = $825/acre.

```
RUN
09-25-85  10:55:59

TITLE:   EASY PICKING--ROOT ROT TREATED
         --STUMPING AT $700/AC

REGIME NAME

? EPICTRT
INPUT ROTATION
? 60
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 132,0,0,0,0,0,213
PLANTING (+ Stump Pushing), PRECOMMERCIAL
  THINNING, FERTILIZATION, AND VEGETATION
  CONTROL ($/ac)
?**825**,55,0,32 (Planting @ $125 + stump pushing
  @$700 = $825
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

      EASY PICKING--ROOT ROT TREATED ACRES

CLEARCUT AT 44333 BF AT 60 YEARS, AT $992.71 PER
  MBF DISCOUNTED 60 YEARS (93% of healthy stand
  yield)
THINNING AT 5046 BF AT 40 YEARS, AT $430.59 PER
  MBF DISCOUNTED 40 YEARS (93%)
PLANTING AT **$825** AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG = 0 YEARS
PCT AT $74.02 AT 15 YEARS, DISCOUNTED 15 YEARS
VEGETATION CONTROL AT $36.76 AT 7 YEARS,
  DISCOUNTED 7 YEARS

            SINGLE ROTATION

INTEREST  DISCOUNTED    DISCOUNTED    PRESENT
  (%)       INCOME        COSTS      NET WORTH
            ($/ac)        ($/ac)      ($/ac)

   5          2665          1026         1639
   6          1545           984          562
   7           905           954          -50
   8           535           934         -399
   9           319           918         -599
  10           193           906         -716

  END Y/N? Y
  10:59:06
  OK
```

Table 10--Computer run of Present Net Worth for alternate RED ALDER ROTATION for comparison to stump pushing option in the Easy Picking Sale. Management regime includes burning following a clearcut to expose mineral soil, natural seeding and clearcutting at age 40 (Stumpage at $40/MBF).

```
RUN
09-25-85  1540:02

TITLE:  EASY PICKING--RED ALDER ALTERNATE
        SPECIES STUMPAGE $40/MBF

REGIME NAME
? EPICALD
INPUT ROTATION
? 40
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 0,0,0,0,0,0,40
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($/ac)
? 30,0,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

      EASY PICKING--RED ALDER ALTERNATE

CLEARCUT  AT 15323 BF AT 40 YEARS, AT $130.48
  PER MBF DISCOUNTED 40 YEARS
PLANTING AT $30 AT 0 YEARS, DISCOUNTED 0 YEARS
REGEN LAG = 0 YEARS

            SINGLE ROTATION

INTEREST  DISCOUNTED    DISCOUNTED    PRESENT
  (%)       INCOME        COSTS      NET WORTH
            ($/ac)        ($/ac)      ($/ac)

   5           284           117          167
   6           194           102           92
   7           134            91           43
   8            92            82           10
   9            64            75          -12
  10            44            70          -26

  END? Y/N Y
  1544:14
  OK
```

Table 11--Computer run of Present Net Worth for alternate RED ALDER ROTATION when ALDER stumpage is increased to $100/MBF. This is not a realistic stumpage for red alder

```
RUN
09-25-85  11:01:18

TITLE:  EASY PICKING--RED ALDER ALTERNATE
        SPECIES STUMPAGE $100/MBF

REGIME NAME
? EPICALD
INPUT ROTATION
? 40
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 0,0,0,0,0,0,100
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($/ac)
? 30,0,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

    EASY PICKING--RED ALDER ALTERNATE
                 STUMPAGE $100/MBF

CLEARCUT  AT 15323 BF AT 40 YEARS, AT $130.48
  PER MBF DISCOUNTED 40 YEARS
PLANTING AT $30 AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG= 0 YEARS

            SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
  (%)        INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)     ($/ac)

   5           710          117         593
   6           486          102         432
   7           334           90         264
   8           230           82         157
   9           159           75          88
  10           110           70          42

  END? Y/N Y
  11:03:48
  OK
```

Table 12--Computer run of Present Net Worth for HEALTHY Mixed Conifer East Side Stand. Rotation 75 years. Site index 130 ft (40 m) (50 years). Managed using shelterwood harvesting system, one commercial thinning with main harvest at age 65 and final cut at age 75.

```
RUN
09-25-85  11:13:33

TITLE:  EAST SIDE MIXED CONIFER STAND--
        HEALTHY

REGIME NAME
? EASTHEA
INPUT ROTATION
? 75
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 65,100,0,0,0,0,110
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($/ac)
? 0,75,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

    EAST SIDE MIXED CONIFER STAND--
    HEALTHY ACRES

CLEARCUT  AT 6200 BF AT 75 YEARS, AT $669.97
  PER MBF DISCOUNTED 75 YEARS (100% yield)
THINNING  AT 5400 BF AT 45 YEARS, AT $231.82
  PER MBF DISCOUNTED 45 YEARS (100% yield)
THINNING  AT 15820 BF AT 65 YEARS, AT $509.55
  PER MBF DISCOUNTED 65 YEARS (100% yield)
PLANTING AT $0 AT 0 YEARS, DISCOUNTED 0 YEARS
REGEN LAG = 0 YEARS
PCT AT $100.94 AT 15 YEARS, DISCOUNTED
  15 YEARS

          SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
 (%)         INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)     ($/ac)

  5            584          205         379
  6            326          152         174
  7            185          119          66
  8            106           96          10
  9             62           80         -18
 10             37           68         -31

  END Y/N? Y
  11:16:21
  OK
```

Table 13--Computer run of Present Net Worth for HEALTHY stand with increased volume (22% more than table 12 example). Same management regime.

```
RUN
09-25-85  11:13:33

TITLE:  EAST SIDE MIXED CONIFER STAND--
        HEALTHY -- INCREASED VOLUME

REGIME NAME
? EASTHEA
INPUT ROTATION
? 75
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 65,100,0,0,0,0,110
PLANTING, PRECOMMERCIAL THINNING,
  FERTILIZATION, AND VEGETATION CONTROL ($ac/)
? 0,75,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

      EAST SIDE MIXED CONIFER STAND--
      HEALTHY ACRES -- INCREASED VOLUME

CLEARCUT AT 7500 BF AT 75 YEARS, AT $669.97
  PER MBF DISCOUNTED 75 YEARS (100% yield)
THINNING AT 6000 BF AT 45 YEARS, AT $231.82
  PER MBF DISCOUNTED 45 YEARS (100% yield)
THINNING AT 20000 BF AT 65 YEARS, AT $509.55
  PER MBF DISCOUNTED 65 YEARS (100% yield)
PLANTING AT $0 AT 0 YEARS, DISCOUNTED 0 YEARS
REGEN LAG = 0 YEARS
PCT AT $100.94 AT 15 YEARS, DISCOUNTED
15 YEARS

       SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
  (%)        INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)    ($/ac)

   5           712          218        493
   6           395          160        235
   7           223          123        100
   8           128           99         29
   9            74           81         -7
  10            44           69        -25

  END Y/N? Y
  11:16:21
  OK
```

Table 14--Computer run of Present Net Worth for DISEASED mixed conifer eastside stand in Table 12. Yield is 40% of healthy stand. Same Management regime.

```
RUN
09-25-85  11:16:45

TITLE:  EAST SIDE MIXED CONIFER STAND--DISEASED

REGIME NAME
? EASTRR
INPUT ROTATION
? 75
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT FORM=1,
  COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT ($/MBF
  Stumpage)
? 65,100,0,0,0,0,110
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION,
  AND VEGETATION CONTROL ($/ac)
? 0,75,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

     EAST SIDE MIXED CONIFER STAND--
     DISEASED ACRES

CLEARCUT AT 2480 BF AT 75 YEARS, AT $669.97 PER
  MBF DISCOUNTED 75 YEARS (40% yield)
THINNING AT 2160 BF AT 45 YEARS, AT $231.82 PER
 MBF DISCOUNTED 45 YEARS (40% yield)
THINNING AT 6328 BF AT 65 YEARS, AT $509.55 PER
  MBF DISCOUNTED 65 YEARS (40% yield)
PLANTING AT $0 AT 0 YEARS, DISCOUNTED 0 YEARS
REGEN LAG = 0 YEARS
PCT AT $100.94 AT 15 YEARS, DISCOUNTED 15 YEARS

       SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
  (%)        INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)    ($/ac)

   5           234          164         70
   6           130          129          2
   7            74          105        -31
   8            43           88        -45
   9            25           75        -50
  10            15           65        -50

  END Y/N? Y
  11:19:28
  OK
```

Table 15--Computer run of Present Net Worth for TREATED mixed conifer eastside stand in Table 12. Stump pushing cost $300/ac. Same Management regime.

```
RUN
09-25-85  11:51:42

TITLE:  EAST SIDE MIXED CONIFER STAND--TREATED

REGIME NAME
? EASTTRT
INPUT ROTATION
? 75
ANNUAL COST ($/ac)
? 2.84
INPUT COST INCREASE IN %, REGEN. LAG, SHORT
  FORM=1, COMPLETE=2
? 2,0,2
INPUT 3 PRICE INCREASES (%) AND TWO INTERVALS
  (Years)
? 3,3,1.8,20,20
INPUT THINNING 1,2,3,4,5,6, AND CLEARCUT
  ($/MBF Stumpage)
? 65,100,0,0,0,0,110
PLANTING (+ Stump Pushing), PRECOMMERCIAL
  THINNING, FERTILIZATION, AND VEGETATION
  CONTROL ($/ac)
? 300,75,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,10,1

EAST SIDE MIXED CONIFER STAND--TREATED ACRES

CLEARCUT AT 6200 BF AT 75 YEARS, AT $669.97
  PER MBF DISCOUNTED 75 YEARS (90% yield)
THINNING AT 4860 BF AT 45 YEARS, AT $231.82
  PER MBF DISCOUNTED 45 YEARS (90% yield)
THINNING AT 13526 BF AT 65 YEARS, AT $509.55
  PER MBF DISCOUNTED 65 YEARS (90% yield)
PLANTING AT $300 AT 0 YEARS, DISCOUNTED
  0 YEARS
REGEN LAG = 0 YEARS
PCT AT $100.94 AT 15 YEARS, DISCOUNTED
  15 YEARS

        SINGLE ROTATION

INTEREST   DISCOUNTED   DISCOUNTED   PRESENT
  (%)        INCOME       COSTS     NET WORTH
             ($/ac)       ($/ac)     ($/ac)

   5           521          496          25
   6           291          448        -157
   7           164          416        -252
   8           953          394        -301
   9            55          379        -324
  10            33          368        -334

 END Y/N? Y
 15:53:52
 OK
```

SUMMARY

After going through this exercise, we hope you now have a feeling for the present Net Worth Process. We want to emphasize that other parts of the analysis carry equal weight such as the biological pest reduction and yield improvement of the treated stand. Many times we only look at economic return, then reject a proposal because Present Net Worth is too low. A look at all factors together helps put the financial analysis into perspective.

The financial analyses we used can be expanded from the per acre basis to stands or timber sale units with varying degrees of disease impact. You can compare the expected financial returns and play around with different options to gain a confident feeling for disease impact and treatment.

The 1981 Vernon WIFDWC presentation was a start at simplifying the financial approach to dealing with pest management. This exercise attempted to bring the system to you. The next challenge is to merge the root disease model with the financial model to do everything in one step. Ultimately, the forest manager will do the entire analysis on a small computer. "We ain't through yet!"

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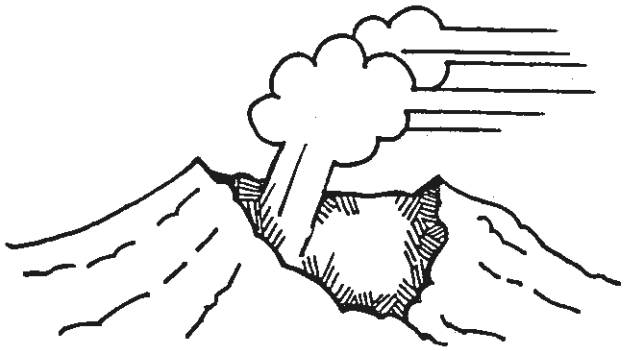

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## HERBICIDE-KILLED ROOTS AS INOCULUM SOURCES OF ARMILLARIA ROOT ROT IN ONTARIO SPRUCE

R.D. Whitney

ABSTRACT: Examination of roots of 65 young spruce (10-14 years old) in three Ontario plantations previously herbicide-treated for reduction of competing hardwoods, revealed 45% were infected with *Armillaria* sp.[1] Inoculum sources of 44% of infected trees were roots of herbicide-killed hardwoods, 18% were stumps of the previous stand and 38% were not traceable.

### INTRODUCTION

Armillaria root rot is prevalent in Ontario conifers (Whitney, 1978), and is associated with mortality in young trees (Howse, Gross and Syme, 1979). In recent years the use of herbicides for brush control and conifer release from competing hardwood vegetation (OMNR, 1982) has resulted in an abundance of potential inoculum for intensification of this disease. Pronos and Patton (1977) reported killing of 10-year old red pine (*Pinus resinosa* Ait.) by Armillaria root rot, correlated well with oak (*Quercus* sp) stumps, chemically killed 7 years earlier.

A study was designed to determine the importance of 2,4-D herbicide-sprayed hardwood species on incidence of Armillaria root rot in released white and black spruce in Northern Ontario plantations.

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### MATERIALS AND METHODS

One fifth ha. rectangular plots were located in three spruce plantations (10 to 14 years old) in which herbicide spraying had been conducted to reduce competing woody hardwood vegetation. Mortality from Armillaria (*Armillaria* sp.[1]) root rot was monitored at 2-year intervals beginning in 1981. Competing hardwoods were chiefly poplar (*Populus tremuloides* Michx.) and birch (*Betula papyrifera* Marsh.).

Within each 1/5 ha. plot, a sub-plot 10 m x 10 m, (2 on the Oly Lake plot) was established on which roots and root collar area of killed hardwoods and killed spruce, were examined in detail for mycelial fans, rhizomorphs and yellow stringy sapwood decay, indicative of Armillaria root rot. Additionally, the root collar area and basal 10-20 cm portions of main roots of all living spruce on the sub-plot were carefully exposed and any evidence on them indicative of Armillaria root rot noted. The evidence included resinosis, dead bark with mycelial fans beneath, and attached rhizomorphs. Care was taken to prevent damage to living tissues of these roots. Soil, humus and litter were replaced. It was hoped the trees would continue to grow and that future examinations could be made for root rot diagnosis. Rhizomorphs were traced from living infected spruce roots to their original food base wherever possible.

### RESULTS

All plantations had substantial mortality from Armillaria root rot in 1981 (Table 1). Additional mortality was recorded on all plots in 1983 and 1985, averaging 3.5 and 3.1 percent of stems per year on the two areas.

In 1985, 29 (45%) of 65 living trees on the 4 sub-plots were judged to have *Armillaria* sp. in their roots (Table 2). These trees were all still living and may or may not eventually be killed by the disease.

When inoculum sources were traced from these trees, 44% were apparently connected by rhizomorphs to stumps or roots of herbicide-killed hardwoods (Table 2) -- all poplars except 2 white birch. Eighteen percent of the infections were connected with stumps from the previous stand. These included poplar, birch, spruce (*Picea mariana* (Mill.) B.S.P. or *P. glauca* (Moench) Voss) and balsam fir (*Abies balsamea* (L.) Mill.). No definite source could be traced for 38% of infections in living trees.

In the 29 dead trees on the 4 sub-plots, all of which had *Armillaria* sp. in the roots, 48% of inoculum sources were apparently from the herbicide-killed hardwoods. Twenty-one percent were from stumps of the previous stand, and 31% could not be determined.

[1] Probably *A. ostoyae*

TABLE I. MORTALITY CAUSED BY ARMILLARIA ROOT ROT IN THREE NORTHERN ONTARIO SPRUCE PLANTATIONS.

| Location | Species | Year Planted | Herbicide Treatment | No. Trees* | % Mortality 1981 | 1981-1983 | 1983-1985 |
|---|---|---|---|---|---|---|---|
| Oly Lake | Black Spruce | 1970 | 2,4-D 1979 | 260 | 16.2 | 3.6 | 4.2 |
| Hillsport 1 | White Spruce | 1975 | 2,4-D 1979 | 271 | 4.4 | 9.1 | 5.3 |
| Hillsport 2 | White Spruce | 1974 | 2,4-D 1981 | 194 | 5.1 | 8.9 | 10.1 |
| Ave. | | | | | 8.8 | 7.1 | 6.2 |

*1/5 ha. plots

TABLE 2. INOCULUM SOURCES OF ARMILLARIA SP. IN LIVING SPRUCE SAPLINGS ON 4 SUB-PLOTS IN 3 PLANTATIONS IN NORTHERN ONTARIO.

| Sub-plot Location | No. Trees | Armill. Root Rot Present % | Inoculum Source: Herb.-Killed Hdwoods. % | Inoculum Source: Stumps of Previous Stand % | Inoculum Source: Could Not Be Traced % |
|---|---|---|---|---|---|
| Oly Lake 1 | 10 | 90 | 33 | 22 | 44 |
| Oly Lake 2* | 10 | 50 | 80 | 0 | 20 |
| Hillsport 1 | 21 | 29 | 17 | 34 | 50 |
| Hillsport 2 | 24 | 38 | 56 | 11 | 33 |
| Wted Ave. | | 45 | 44 | 18 | 38 |

*Two sub-plots in same plantation.

TABLE 3. INOCULUM SOURCES OF ARMILLARIA SP. IN DEAD SPRUCE SAPLINGS ON 4 SUB-PLOTS IN 3 PLANTATIONS IN NORTHERN ONTARIO.

| Sub-plot Location | No. Trees | Armill. Root Rot Present % | Inoculum Source: Herb.-Killed Hdwoods. % | Inoculum Source: Stumps of Previous Stand % | Inoculum Source: Could Not Be Traced % |
|---|---|---|---|---|---|
| Oly Lake 1 | 13 | 100 | 54 | 23 | 23 |
| Oly Lake 2* | 4 | 100 | 50 | 25 | 25 |
| Hillsport 1 | 11 | 100 | 36 | 18 | 45 |
| Hillsport 2 | 1 | 100 | 100 | 0 | 0 |
| Wted Ave. | | | 48 | 21 | 31 |

*Two sub-plots in same plantation.

## DISCUSSION AND CONCLUSIONS

In this very limited sample of spruce plantations in Northern Ontario, all of which had been sprayed with 2,4-D herbicide to control unwanted hardwood competition, almost half of the inoculum sources for Armillaria root rot were the killed roots of these hardwoods.

These plantations have relatively high proportions of trees infected with *Armillaria* sp. (ave. of 45% of living trees). The numbers apparently would have been lessened by 44%, if the herbicide-killed poplar and birch roots were not present. This is conjectural however, in the absence of control areas where young hardwoods were not sprayed.

The stocking is currently (1985) not badly interfered with on these young plantations, with about 1,300 living trees per ha. at Oly Lake (14 years old) and about 2,250 per ha. at Hillsport (10 years old). Uneven distribution of groups of the dead trees has resulted in small openings, especially in the Oly Lake plantation. If no more trees, or only a few additional trees died, the stocking would improve, and spacing of the trees would allow optimal stand development. However, with 45% of the remaining living trees infected with *Armillaria* sp. (70% at Oly Lake and 34% at Hillsport), the prognosis would be for stocking to be severely reduced in the next few decades.

In the three plantations sampled, the average annual mortality of 3.1% of stems was accompanied by the high proportion of 45% of living trees infected. This is an interesting statistic, but might not be as foreboding as it would appear, since an average of 33% of living black spruce and white spruce, 30-150 years of age, on some 150 plots in Northern Ontario were found infected by *Armillaria* sp. in a previous study (Whitney, 1978).

## RECOMMENDATIONS

1. Examine additional spruce plantations in Northern Ontario to determine more definitely the relstionship between herbicide-killed hardwoods and Armillaria root rot in the released trees.

2. Continue studies to determine the effect of Armillaria root rot on stocking in spruce plantations until harvestable ages are reached.

3. Begin studies on alternative measures for reducing unwanted competing hardwood vegetation that would not add to inoculum for spreading Armillaria root rot. Options to try could include:
   a) Kill the hardwoods at a very young age so root volumes would be small and dissipation rapid.
   b) Kill the hardwoods in such a way as to result in low carbohydrate concentration in the root cambium, nonconducive to the growth of *Armillaria* sp. mycelium.
   c) Kill the hardwoods back to ground level only, keeping roots alive so they would be less attractive to mycelium of *Armillaria* sp.

4. Determine feasibility of displacing pathogenic strains of *Armillaria* sp. with nonpathogenic strains of this species or other fungi.

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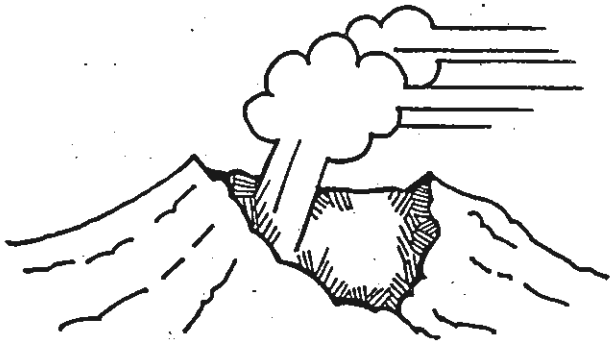

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## SPORE DISPERSAL OF LOPHODERMIUM SEDITIOSUM IN SCOTCH PINE CHRISTMAS TREE PLANTATIONS

Andrea L. Koonce and Jane E. Cummings

ABSTRACT: Scotch pine Christmas trees infected with Lophodermium seditiosum represented 5% of the crop trees in 1984 resulting in a loss of over $300,000. to the growers. To further reduce needlecast severity and limit spray applications, an index was developed to predict high spore dispersal days.

### INTRODUCTION

Christmas tree growers in Central Wisconsin are planting one and a half million Scotch pine seedlings per year. These trees are expected to gross 15 million dollars at maturity. Currently, however, a needlecast fungus, Lophodermium seditiosum, is reducing tree quality resulting in a loss to the grower because of reduced tree marketability. The fungus was introduced in plantations from infected nursery stock in the early 1970's (Nicholls 1984). Airborne inoculum now comes from surrounding plantations which have not been treated to control the disease. Once established, the needlecast builds up in focus trees which are centers of inoculum that can spread easily to the rest of the plantation when environmental conditions are favorable.

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Pine needles are infected by ascospores in late summer and early fall. Preliminary symptoms, brown bands with yellow margins, begin to appear the following spring on second and third year needles. Usually, infected needles are cast during the spring and summer, and hysterothecia are formed on the dead needles.

Needle browning and loss detract from the appearance of the crown, and may result in the tree death. Resistant varieties of Scotch pine and different micro-climates in a stand result in different levels of needlecast severity so that losses are irregular and infected trees are patchy in distribution. Unmarketable trees may be as high as 50% in some plantations, others are unaffected.

Protective fungicides, maneb and chlorothalonil, are registered for Lophodermium. The timing and number of applications vary with regional and local spore dispersion but effectiveness depends in on accurately predicting spore dispersal in advance of favorable conditions. Aerial applications of fungicides are expensive, and repeated chemical applications are environmentally hazardous. So it is essential that spray frequency be minimized and effectiveness maximized.

### OBJECTIVES

1. to determine periods of high spore dispersal
2. to relate spore dispersal to environmental conditions
3. to develop an easy index to signal high spore dispersal periods

### MATERIALS AND METHODS

#### Lophodermium Severity Survey - 1984

In 1984, a severity survey was conducted of Lophodermium infected Scotch pine Christmas trees in Waushara and Portage Counties, Central Wisconsin. Approximately 1,500 acres on 15 plantations were surveyed and one percent of the trees (14,064) were rated for severity of Lophodermium needlecast. While walking through each plantation, the surveyor randomly chose and rated sample trees.

Severity ratings were developed based on the economic loss to the grower from "downgrade" as a result of Lophodermium infection (table 1). Tree values were determined by using the average wholesale value of Christmas trees sold from Central Wisconsin. Losses in table 1 include only losses incurred if the infected trees are sold. If the trees not sold, other costs would arise such as the price of renting land to compensate for holding the infected trees, and control costs.

#### Lophodermium Severity Survey - 1985

Twenty-two Scotch pine Christmas tree plantations in Waushara and Portage Counties in Central Wisconsin were surveyed in May, 1985 for the presence of Lophodermium. A systematic strip sample was used. The starting point of the strip sample and intervals between strips were determined using a random number table. Each

Table 2--Number and percent of trees in different severity ranks, wholesale value of trees with and without downgrade, and total dollars lost in 1984.

| Severity Rating | Trees (%) | Trees (#) | Value without downgrade | VAlue with downgrade | Net loss |
|---|---|---|---|---|---|
| | | | ----------Dollars ---------- | | |
| 0 | 95.2 | 1,339,500 | 15,712,335 | 15,712,335 | 0 |
| 1 | 3.2 | 45,000 | 127,850 | 307,350 | 220 ,500 |
| 2 | 1.4 | 19,600 | 229,908 | 164,248 | 65,660 |
| 3 | 0.2 | 2,300 | 26,979 | 0 | 26,979 |
| Total | 100 | 1,406,400 | 16,497,072 | 16,183,933 | 313,139 |

Table 1. Description of Christmas tree severity ranking and associated wholesale value loss from Lophodermium

| Severity Rank | Tree Description | Wholesale Value $ Loss Per Tree |
|---|---|---|
| 0--Grade #1 tree, no needlecast, can be sold in the 5.5' - 7' category | | - $0.00 |
| 1--Defoliation from needlecast moderate, reduces grade and value of tree | | - $4.90 |
| 2--Defoliation from needlecast severe, the bottom of the tree must be cut off and the tree sold in the 4' - 5.5' category | | - $3.35 |
| 3--Defoliation from needlecast severe, tree unsaleable. | | - $11.73 |

strip contained 50 trees. The survey was initiated with 1.0 % sample but, due to a time limit, the number surveyed was changed to 0.2%.

Weather Monitoring - 1984

A weather station was installed in a plantation with severe needlecast infection belonging to Kirk Co. near Wild Rose, Central Wisconsin. The station included a recording rain gauge, a standard rain gauge, and a Belfort hygrothermograph. Weather charts were collected each week from May 25 to October 31, 1984. Daily high, low and average temperature, high, low, and average relative humidity, and precipitation were tabulated.

Spore Monitoring - 1983

A nine year old heavily infected Scotch pine plantation in Waushara County, Central Wisconsin, was chosen for monitoring ascospore release. Vaseline coated microscope slides were prepared according to methods described by Ostry and Nicholls (1982). 5 slides were mounted on wire stands placed under 5 Scotch pine Christmas trees infected with Lophodermium. The wire stands were located 1 ft. from the main stem of the Christmas tree and the slides were 1.5 ft. above the ground.

Ascospore release was monitored from September 5, 1983 to November 8, 1983. Slides were changed weekly. After collection they were kept at $4^{o}C$ until they could be examined. Lactophenol blue was used to stain the spores and the total number of ascospores under an 18 x 18 mm square cover slip were counted.

Spore Monitoring - 1984

The spore monitor was set up in the Kirk Co. plantation next to the weather station. Spores were sampled every 2-hrs. for 4-min. using a Kramer-Collins vacume spore sampler with a flow rate of 20-l./min. The spores were collected on 2 sided scotch tape. The tape was not coated with vaseline and, to reduce the likelihood of spore movement, it was not stained Spores were tabulated by 2-hr. periods for each day from June 8 to October 31, 1984.

RESULTS

Severity Survey

5%, or 66,900 trees, lost value due to downgrade from needlecast (table 2). This represents a loss of $313,139 to the growers. 3.2% of the trees' wholesale price was reduced by a loss in quality. 1.4% of the trees was reduced by a loss in height. 0.2% were unsalable.

In 1985 the average percentage of trees affected by needlecast in infected plantations was 3.1%. The percentage of infection for all trees sampled was 1.4%. The 1985 data may not be comparable to the 1984 data due to a different sampling scheme. Nevertheless, some reduction in infection is expected since the second survey was conducted 2 years after a protection spray program was begun.

Weather Data

Each day 12 points were chosen from the temperature and relative humidity data recorded on graphs by the hygrothermograph. The points were tabulated for each 2-hr. interval and were used to obtain the daily average. July high and low average daily temperatures differed by $13^{0}$ F. By September and October average daily temperatures differed by as much as $32^{0}$ F.

Average daily precipitation was calculated for a 24 hour period by choosing 12 points from the precipitation graph. The highest rainfall in a 24-hr. period, 2.1-in, occurred on September 24,

Table 3—Weather conditions and spore counts for June - October 1984

| Month | T (°F) | RH (%) | Precip. (in.) | Spores | Total Spores |
|---|---|---|---|---|---|
| | - - Average Daily Reading - - | | | | |
| June | 66 | 75 | 2.2 | 0 | 0 |
| July | 63 | 77 | 3.3 | 2 | 36 |
| August | 67 | 79 | 4.0 | 6 | 133 |
| September | 54 | 79 | 5.2 | 8 | 120 |
| October | 49 | 84 | 5.9 | 20 | 187 |

Table 4—Spore data for 1983

| Date | Number of spores on 2.8 $cm^2$ slides | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | Ave. |
| Sept 5-12 | 0 | 10 | 1 | 11 | 2 | 5 |
| Sept 13-20 | 7 | 0 | - | 27 | 4 | 10 |
| Sept 21-28 | 5 | 12 | 11 | 8 | 13 | 10 |
| Sept 29-Oct 4 | 195 | 138 | 271 | 242 | 152 | 200 |
| Oct 10-17 | 769 | 460 | 603 | 750 | 132 | 543 |
| Oct 18-25 | 18 | 17 | 58 | 24 | 22 | 28 |
| Oct 25-Nov 1 | 0 | 1 | 0 | 1 | - | 1 |
| Nov 1-8 | 2 | 2 | 6 | 11 | 5 | 5 |
| Total | | | | | | 802 |

followed by 1.9-in. on October 7. The highest and most prolonged period of humidity occured between October 7 and 17.

Spore Dispersal - 1983

Spore counts from 5 vaseline coated slides are given in table 4. The average number of spores on each slide was 5 in early September and 10 in the last 2 weeks. A significant increase in spores, 200, occurred between September 28 and October 4. The highest number, 543, was observed in the 2nd week of October after which spore dispersal reduced dramatically, 28% to 5%.

Spore Dispersal - 1984

Daily spore counts were tabulated on an hourly basis. Spores were detected first on July 10 and were counted through October 27 (fig. 1). The largest number of spores per day was 99 on October 15, during a period of high humidity and coinciding with 0.8 inches of rain. The highest spore deposition, 154 spores, fell between October 12 and the 15th. No spores were detected from September 16 to the 23, and September 26 through October 5. As could be expected, there was no rainfall from September 15 through the 23 and only 0.15 inches of rainfall fell from September 26 to October 5. During these same periods average humidities ranged from 60% to 83%. Average daily temperatures ranged from approximately 67 to 34° F.

Key factors in spore release are rainfall, moderate night-time temperatures, and high relative humidity. Rainfall, independent of the amount, seems to be the greatest stimulus to spore release. At times, high humidities can substitute for rainfall but the number of spores released is low compared to spores released with small amounts of precipitation.

Table 5 -- Peak 1984 spore dispersal days and corresponding weather conditions

| Date | Spores | Spores-5[1] | Min.T (°F) | Ave. RH (%) | 24 hr. Precip. (in) |
|---|---|---|---|---|---|
| Oct. 15 | 99 | 102 | 57 | 97 | 0.8 |
| Oct. 12 | 40 | 156 | 54 | 97 | 0.3 |
| Average | 70 | 129 | 56 | 97 | 0.5 |
| Sept. 12 | 28 | 49 | 54 | 88 | 1.5 |
| Sept. 9 | 27 | 70 | 43 | 80 | 0.3 |
| Average | 28 | 60 | 49 | 84 | 0.9 |
| Oct. 27 | 20 | 20 | 49 | 94 | 0.6 |
| Sept. 24 | 19 | 22 | 61 | 92 | 2.1 |
| Aug. 2 | 17 | 48 | 60 | 85 | 0.2 |
| Average | 19 | 30 | 57 | 91 | 1.0 |
| Average, all dates | | | 54 | 90 | 0.8 |

[1]—Cumulative spore count for 5 days starting with date in far left column.

The 5 peak spore dispersal days occurred when minimum temperatures were in the 50's relative humidity was above 90% and it was raining (table 5). The October 15 and 12 peaks of spore dispersal occurred during days of continuous 97% relative humidity. It's notable that they also occurred after frosts when the evening temperatures returned to the 50's.

Only October 15 had the environmental conditions which were associated with the peak spore dispersal. The conditions on October 12 were duplicated twice more and one of these days the spore count was less than 5, considered to be an insignificant number. The conditions associated with the next laevel of spore dospersal were repeated frequently. An average of 29 days matched the conditions of September 9 and 12 and only 35% of these had spore counts above 5. The conditions associated with the third highest spore dispersal days were infrequent, and 40% of them had spore counts greater than 5. Again, high relative humidity was a key factor in the latter dates. There was no nocturnal or diurnal pattern of spore release. The time of day that that it rained seemed to be the major factor in determining the time of spore release.

Spore Dispersal Index

Rain is usually associated with spore release, but it is not a good forcast variable as spores are not dispersed every time it rains. An index was sought that would be independant of season and would be based on easily measured parameters, such as relative humidity and temperature. The previous data suggested a wide range of acceptable temperatures for spore release. 66° was the highest minimum temperature in all spore dispersal days greater than 5. Spore release was much more sensitive to relative humidity. Periods of hugh relative humidity triggered both early and late

Figure 1--Relative humidity, minimum temperatures, precipitation, and spore release from June 8 to October 31.

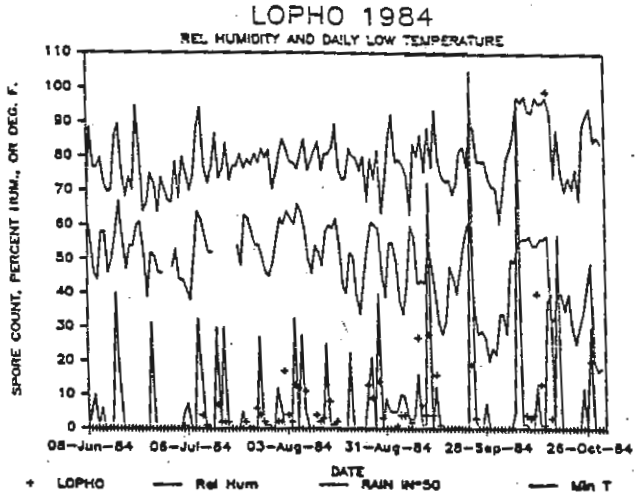
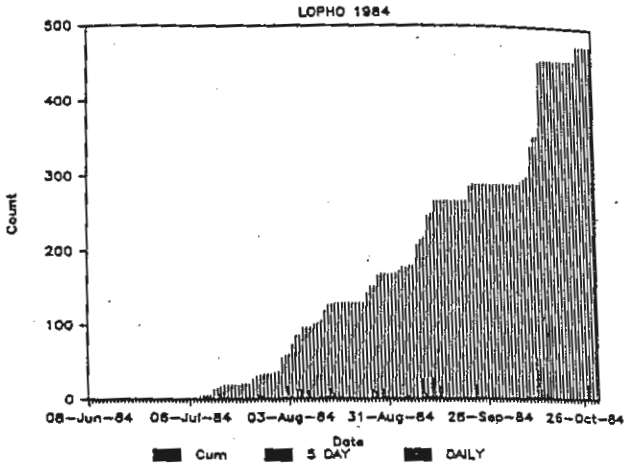



Figure 2--Total cummulative spore count, plus individual and 5-day cumulative spore counts (indicated by bars at the base of the figure), from June 8 to October 31.




spore releases. 97.3% was the relative humidity during the peak spore dispersal periods. After some trial and error, the following equation was developed to predict favorable spore dispersal conditions.

$(66^0$ - min. T)/5 + (97.3% - RH) = x
if x <10, expect high spore counts.

The equation predicts a "perfect day" to have $T=66^0$ and RH=97.3%. The further away from an index of 0, the less likely a large spore dispersal. The conditions of October 12 and 15 would have a score of 2. September 9 a score of 16, and August 2 a score of 13. The index is simple and must be interpreted by the manager. A decision to spray could incorporate use of the index but should include a consideration of weather forcasts and seasonal patterns. The index could be fine tuned each year by spore monitoring and associated weather checks.

## CONCLUSIONS

The 1985 disease severity showed a 4% decline in Lophodermium related downgrade from 1984. This indicates that fungicide applications are being effective to limit disease severity. Other factors which may influence disease severity are variable environmental conditions, and early harvest of infected trees.

Spore dispersal begins slowly in late July. Cumulative spore dispersal (fig. 2) climbs and plateaus about 3 times during periods of no precipitation. Dispersal falls off in late October or early November.

The approximate cost to spray trees is $5-8/ac. plus the cost of the chemical, another $12-15/ac. How these costs will be balanced by reduced damage in future years is not known. A 50 ac. field will loose $1500. in downgrade with 50% needlecast infection. It costs $800 per spray. If only 2 sprays are applied the growers cost is $1600., more than the loss due to downgrade. Other damages result if the stand is not cut on schedule by lengthening the rotation period and increasing demands for space. Low quality trees and incomplete orders cause loss of company reputation in the marketplace.

A carefully timed spray schedule may reduce the number of sprays applied in number of years infected stands are sprayed or number of applications per year. Based on the data presented here if only 1 spray were to be applied, early October should be considered a priority. If 2 sprays were prescribed the first spray should be targeted to days with high humidity in September. Further studies are being conducted to monitor infection periods and to relate infection to environmental conditions and spore release.

High hazard areas, indicated by severe needlecast outbreak in individual years or those with repeated infections, should be planted with Scotch pine varieties with more resistance. Since the edges of the plantations are to most likely to harbor inoculum-focus trees, buffer strips of resistant pines might be helpful. Focus trees, once identified, could be sprayed by hand. Trees that are not tightly sheared also seem to hold their grade better despite needlecast perhaps the schock is not as great to the trees, or the additional current year's foliage hides more of the bare interior branches.

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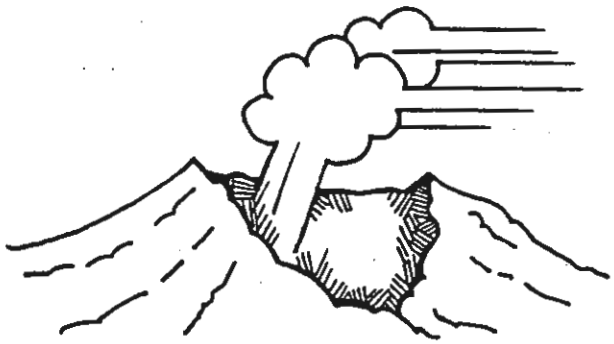

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## PEST MANAGEMENT AND THE NATIONAL FOREST PLANNING PROCESS: A CASE HISTORY

Robert E. Wood

ABSTRACT: The Lincoln National Forest developed an issue in the planning process which identified losses caused by western spruce budworm and dwarf mistletoes as preventing attainment of management objectives. Pest management principles were then applied throughout the planning process.

### INTRODUCTION

Forest insects and disease are factors which often is a process leading to National Forest Land and Resource Management Plans. Although each Forest has a unique set of pest/host/environment user relationships to consider, a similar process can be used for all Forests. Is there anyone here who doesn't believe wholeheartedly that insects and diseases must be addressed in any forest management plan? Good. I won't spend any time trying to convince you. Instead, I'll tell you how one particular National Forest incorporated pest management considerations into the planning process. I also hope to have time to discuss some of the problems and limitations we encountered, and our solutions or lack thereof.

Robert E. Wood is Land Management Planning Staff Officer, USDA Forest Service, Lincoln National Forest, Alamogordo, New Mex.

### METHOD

I find it hard to believe, but some folks in the audience may not be completely familiar with the planning effort which is now consuming so much Forest Service time, effort, and money. So, let me explain briefly the process used to produce Forest plans.

My Forest, the Lincoln, and every other National Forest in the country, is mandated by Congress to prepare a long-range Land and Resources Management Plan, which will determine the mix of goods and services offered by the Forest over a planning horizon of 50 years. That's a long time, so Congress also mandated that plans would be modified and updated as needed, but no more than every 15 years. The Lincoln, like most Forests, is planning an update every 10 years.

The process used to develop Forest Plans is controlled by the implementing regulations for the National Environmental Policy Act (NEPA). Briefly, this is the process we followed.

The first step was to determine the scope of the issues to be addressed in the plan and its draft environmental impact statement. Examples of issues are conflicts between user groups, resource limitations, undesirable conditions, or the public's needs or wants. Preliminary issues proposed by the public and by land managers were screened by the Forest's management team who decided which ones could and should be dealt with in the DEIS.

At the same time, available information on outputs of goods and services was accumulated and fed into one of two computer programs-ECOSIM for timber growth and yield, and FORPLAN for all other resources.

A range of alternatives were then formulated which provided different mixes of goods and services designed to satisfy various issues. This was done by programming the models to select the most cost-efficient combination of prescriptions which would satisfy the objectives of a particular alternative.

The Forest's management team selected the alternative which, in their opinion, best resolved certain issues which were considered more critical than others. This alternative served as the basis for the proposed plan, which contains site-specific standards and guides designed to accomplish the overall goals and objectives.

Finally, the DEIS and proposed plan went to the public and other government agencies for review and comment. When the comment period ends, in the middle of October, we will analyze them and revise the proposed plan as needed. A final plan will then be implemented. The plan is then subject to appeal, and most plans have been appealed.

Now, where can insects and diseases best fit into this process? We took a hard look at this, and decided that insects and diseases should be considered in the DEIS in development of issues, and the prescription-writing phase of alternative development. We considered them in the standards and guidelines in the proposed plan.

First, we developed an issue around western spruce budworm and dwarf mistletoes. Why just budworm and mistletoes? Three reasons. We believe that these pests are the most serious of those present on the Forest. We can predict many of their effects. And we can develop prescriptions to prevent or control losses caused by these specific pests.

According to a survey published in 1960 (Andrews and Daniels), the Lincoln has the dubious distinction of leading the region in dwarf mistletoe incidence. They found the parasite in about two thirds of our pine stands. A similar survey (Hessburg, Beatty, and Wood 1985) performed recently on another Forest in the southwest indicates that dwarf mistletoe has increased in the last 30 years. We believe these results apply to the Lincoln as well.

Western spruce budworm epidemics occur infrequently on the Lincoln, but are potentially disasterous because of the high proportion of host type relative to the total forested area, and the high value of this type for recreation. The Forest is the forested land most readily available to half of west Texas. In addition, there are about 20,000 individual parcels of private land within its boundaries. For these reasons, the way we manage, or mismanage, budworm outbreaks have the potential to effect a large number of persons.

Second, we incorporated available loss data and prescriptions designed to prevent or control those losses into our growth and yield models. Dwarf mistletoe losses were not originally part of the model we used. However, the loss coefficients from another growth and yield model, RMYLD, were borrowed and incorporated into ECOSIM. Unfortunately, budworm loss figures were not available when we ran the model.

I don't have time to go into the range of prescriptions which the Forest's silviculturist put into the model, except to say that they ranged from the very intensive to ones which called for no entry.

The keys to both budworm and mistletoe prescriptions were control of stand density, structure, and species composition. Budworm prescriptions specified a lower-than-normal stocking, in this case, a growing stock level (GSL) of 60. Normally, two or more entries are required to attain an even-aged condition on the Lincoln. Budworm prescriptions do it in one entry. The prescriptions also favor ponderosa pine and southwestern white pine over Douglas-fir and white fir. Because the pines are early successional species in many of our habitat types, and because past cutting practices high-graded them, many of our stands will still be predominantly Douglas-fir and white fir.

Although we called these budworm prescriptions, you have no doubt recognized that they satisfy most of the requirements of a dwarf mistletoe prescription.

Third, we created an alternative specifically to emphasize resolution of the insect and disease issue. The main objective of this alternative was to manage timber in the heavily-used parts of the Forest in such a way as to limit the effects of pests. Secondary emphasis was on developed recreation and wildlife habitat improvement in the same areas. In order to accomplish the objectives, the model was constrained to maximize the area managed under budworm and high intensity prescriptions in seven analysis areas, or planning units. These seven areas contain most of the Forest's developed recreation sites, and are popular for dispersed use as well.

In the first attempts at developing this alternative, we repeated a lesson learned long ago by most pathologists and land managers. Insect and disease prevention and control comes with a high price tag attached. We found that we could either construct the recreation facilities needed to satisfy demand, and then let the forest deteriorate around them, or we could protect the forest but without developing its recreation potential. So, we compromised, and did neither. We removed the prescription constraints on two of the seven analysis areas, which had the least potential for developed recreation, and we reduced the recreation budget for the five remaining areas.

In developing recreation-oriented alternatives, including the one which became the proposed plan, we used some of the logic inherent in the insect and disease alternative described earlier. We decided that it wouldn't do much good to develop recreation sites without managing the forest around them, so we again constrained the model to select prescriptions in our high-use areas, although not to the same extent as in the insect and disease alternative.

Finally, we developed standards and guidelines in the proposed plan to manage dwarf misletoes and budworm. The standards and guides translate the prescriptions into terms used by silviculturists, and specify the number of acres to be allocated to each prescription in each analysis area. They also discuss management activities specific to dwarf mistletoes, such as the use of growth and yield models, removal of infected trees, and clearcutting.

## CONCLUSIONS

Well, that's what we did and how. Looking back, I already see changes I would like to make, some of which may be incorporated into the final plan. After all, revisions suggested by management are just as valid as those requested by the public.

If we had it all to do over again, insects and diseases would still be an issue. If incidence estimates for other pests, especially root diseases, were suddenly produced, we would incorporate them into the data base and carry them through the process as was done for budworm and mistletoes.

We would still develop prescriptions designed to prevent budworm damage and control mistletoe. In fact, we would develop more prescriptions to fill in some of the gaps and give the model a little more flexibility. These prescriptions would not satisfy the purists among pest managers, but they would reduce costs significantly, and provide a degree of control high enough to achieve management objectives.

And finally, we would still develop an alternative having insect and disease management as a primary objective. It probably would not be selected as the preferred alternative, but it would serve the purpose of displaying the tradeoffs necessary to resolve the insect and disease issue, and surface, for land managers and the public, the significance of forest pests in management of the Lincoln National Forest.

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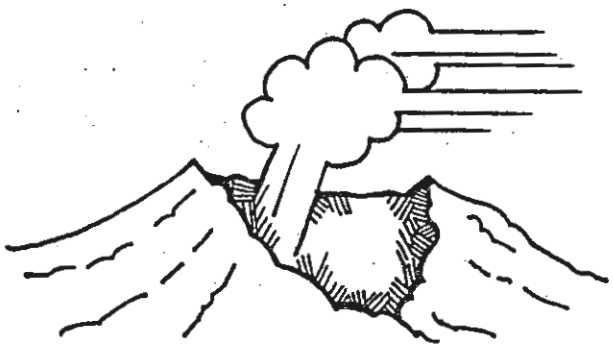

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## VARIATION IN RUST VIRULENCE AND HOST RESISTANCE OF MELAMPSORA ON BLACK COTTONWOOD

Tom Hsiang & B. J. van der Kamp

ABSTRACT: Disease severity as expressed by spore production rate was compared in a test of 14 clones of black cottonwood inoculated with ten isolates of Melampsora rust. The absence of qualitative resistance and virulence suggests that the resistance of cultivated cottonwood is unlikely to be readily overcome in genetically uniform plantations.

### INTRODUCTION

As a rule, a parasite species has a very limited range of host species on which it can survive; but sometimes a parasite species is so specialized on a host species that only certain parasite races can parasitize a particular host variety. Knowledge of this specificity or physiological specialization may be very important to the plant breeder who seeks to produce varieties with resistance to disease, and to the plant pathologist who wishes to understand the source of disease stability.

In agricultural crops, one commonly observed phenomenon is that resistance incorporated into cultivars is overcome within a few seasons through physiological specialization by the pathogen. But there are cases in which resistance has not been lost or even decreased over decades. In such cases, the loss of resistance through physiological specialization of the parasite apparently cannot or does not occur. Thus, the recognition of the type of resistance in certain varieties stems from the history of their behavior through periods of disease. With poplars, and forest trees in general, such records are mostly non-existent. This sort of data may be most quickly gathered in the laboratory through artificial inoculations in order to assess the type of disease interaction involved.

The purpose of this study was to determine the type and extent of variation in resistance of Populus trichocarpa Torr. & Gray, and virulence of Melampsora occidentalis Jacks, toward esch other, when sampled from their natural pathosystem.

### METHODS AND RESULTS

Disks were cut out from the most recently mature leaf of every clone. These fourteen 17 mm disks were all set into a petri dish and inoculated with a single rust isolate. This was repeated for each of the ten isolates, and this all was replicated in a Randomized Complete Block design with 9 blocks.

Disease severity was quantified by the spore production rate. The number of spores produced after two times the latent period (time from inoculation till spore production) was measured by taking an absorbance reading of the spores in suspension, and doing a regression of haemocytometer spore counts on absorbance readings.

The overall average spore production rate during the time from inoculation through s period equal to two times the latent period was 747 spores/disk/day. The latent period ranged from 6 to 12 days with a median of 8 days.

Analysis of Variance and of the Components of Variance were carried out on these spore production rates. The results showed that while clones and isolates contributed significantly to the variation, their interaction did not.

### DISCUSSION

The sampling was biased toward selecting specimens which had the opportunity to be physiologically specialized, since isolates were collected along with their hosts in late summer; yet this specialization was not found. The lack of qualitative resistance and virulence indicates that qualitative interactions do not play a major role in disease in this system. This finding holds the promise that cottonwood resistance will be of a durable nature and not devastatingly overcome when used in plantations. More details of this study can be found in Hsiang & van der Kamp (1985, Canadian Journal of Plant Pathology, in press).

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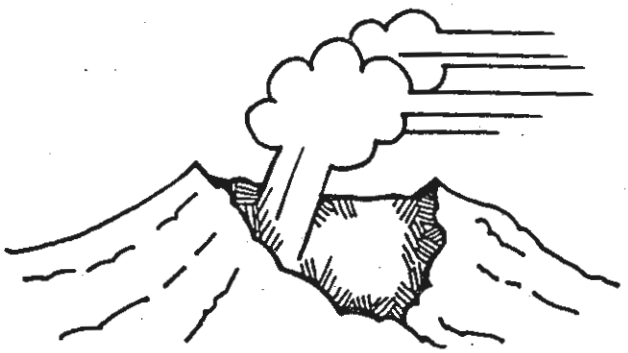

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## INCIDENCE AND SEVERITY OF DWARF MISTLETOE IN RELATION TO TREE SIZE AND STAND DMR IN IRREGULAR, UNEVENAGED PONDEROSA PINE STANDS ALONG THE COLORADO FRONT RANGE

Helen M. Maffei, Frank Hawksworth, William R. Jacobi

In order to study the distribution of dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum) among different tree sizes at various stand infection levels, 37 plots of ponderosa pine growing in irregular unevenaged stands were examined. Site indices and basal areas of plots ranged from 38- to 50 (base age 100) and from 40- to 180 sq ft/acre, respectively. There had been no management on the plots for at least 12 years. Trees on each plot were divided into 4 dbh size classes: 1-4 inches, 4.1 to 8 inches, 8.1 to 12 inches, and 12.1 inches or greater. Trees in the largest size class ranged from 12.1 to 25 inches, with a majority of the trees ranging from 12.1 to 16 inches. Plots were then divided into 4 stand DMR classes, very lightly infected (stand DMR .1-1), lightly infected (stand DMR 1.1-2), moderately infected (stand DMR 2-4) and heavily infected (stand DMR 4.1-6). Four to fourteen replications (plots) were used in each size/DMR group. LSD t-tests were used, when appropriate, to test differences in infection levels between size classes. Residuals were analyzed for normality and equal variance.

Incidence of dwarf mistletoe rarely differed significantly among different size classes. In lightly infested stands the largest diameter size class had a significantly lower ($P<.05$) incidence of dwarf mistletoe (17 percent of the size class infected) than the smaller size classes (52 percent infected). In all other stand/DMR groups there appeared to be uniform incidence of dwarf mistletoe among size classes. The very lightly-, moderately- and heavily infected, had, on average, 17, 73, and 93 percent of the total trees infected respectively.

The distribution of heavily infected trees among size classes was also of interest, primarily because of the strong correlation between heavily infected trees and mortality. For example, in the 37 plots examined, 80 percent of the trees that had died within the past 10 years had DMR's of 5 or 6. Percent of heavily infected trees significantly ($P<.05$) increased with increasing stand DMR (Table 1). The lightly infected DMR class exhibited a significant ($P<.05$) increase in the proportion of infected trees having heavy infections with increasing tree size. In heavily infected stands the situation was reversed; the percent of infected individuals having heavy infections decreased significantly ($P<.05$) with increasing tree size.

Results of the analysis indicate incidence and severity of dwarf mistletoe within, and between, different tree size classes varies with stand DMR. These differences may be summarized as follows:

1. In lightly infested stands the smaller trees are most frequently infected.
2. In all other stands there is no relationship between infection levels and tree size.
3. In lightly infested stands, the smaller trees are least severely infected.
4. In heavily infested stands the smaller trees are most severely infected.

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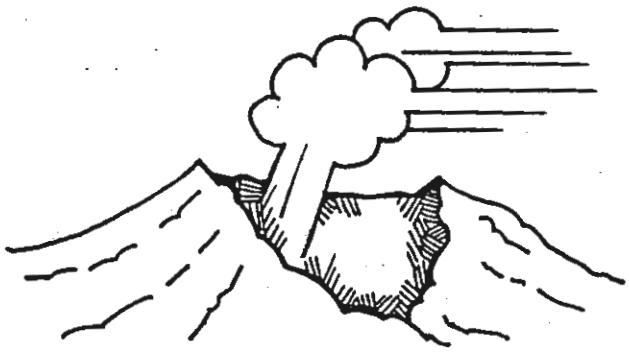
Table 1--Amount of heavily infected trees (DMR 5 or 6) and their distribution among tree size classes at various stand DMRs

| | Average ratio of heavily infected to infected trees by DBH class | | | | |
|---|---|---|---|---|---|
| | DBH class (inches) | | | | |
| Stand DMR class | 1.1-4.0 | 4.1-8.0 | 8.1-12.0 | 12.1-25.0 | total |
| very light* 0.1-1.0 | 0 | 6 | 11 | 29 | 5 |
| light 1.1-2.0 | 11 | 6 | 5 | ** | 9 |
| moderate 2.1-4.0 | 31 | 23 | 39 | 21 | 28 |
| heavy* 4.1-5.6 | 65 | 46 | 34 | 25 | 43 |

* There is a significant ($P<.05$) relationship between the ratio of heavily infected to infected trees and tree size in the DMR class.

** There were insufficient samples (<3).



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## OBSERVATIONS ON AN ARMILLARIA ROOT ROT CONTROL EXPERIMENT IN THE MOUNT COLE STATE FOREST, VICORIA, AUSTRALIA

By

Chas. H. Driver, G.A. Kile, J.D. Kellas and R.O. Squire.

Preliminary observation six years after site preparation and planting of clearcut, cut and ripped, stump pushed, and stump pushed ripping field studies indicated the following developments:

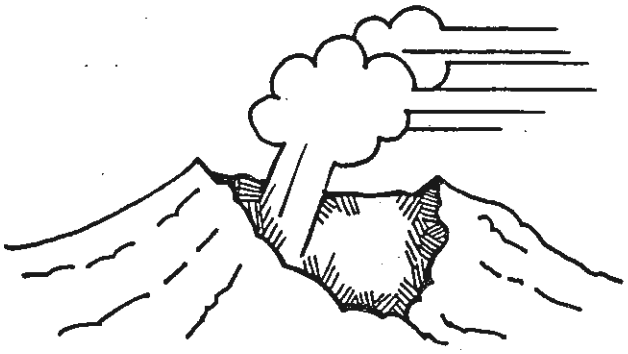
1) On sites initially exhibiting high infection potential with stump pushing treatment demonstrated high mortality within the first six year period of the study.

2) The ripping treatments, either with clear cutting only and with stump pushing, tended to result in lower mortality than stump pushing alone.

3) However, it was observed that on a high disease potential site the clear cut treatment only exhibited the lowest mortality rate.

4) Of special interest, it was observed of the two native species of Eucalyptus planted (E. obliqua and E. globulus s.sp. bicostata) E. globulus exhibited significantly lower mortality than the other species tested. However, there was a complicating factor of the original planting density in this case was lower than that of the other plots.

These preliminary observations appear to indicate that more detail study be made on the long term value of site treatments as root rot disease control measures.



33rd Annual Western International Forest Disease Work Conference
Olympia, Washington
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# LIGHT AND NUTRIENT LIMITATION IN PINUS MONTICOLA: SEEDLING SUSCEPTIBILITY TO ARMILLARIA INFECTION

James A. Entry, Neal E. Martin,
Kermit Cromack, Jr., and Susan G. Stafford

ABSTRACT: Pinus monticola Dougl. seedlings grown under full light with complete nutrient supply had significantly lower Armillaria infection rates than seedlings grown with light, nitrogen, or phosphorus limitations and had significantly greater root, shoot, and total biomass and shoot:root ratios than light- or nutrient-deficient seedlings. Root or shoot sugar or starch concentrations did not differ regardless of treatment. Creating conditions that favor tree vigor could reduce incidence of Armillaria infection, especially where light is limiting.

## INTRODUCTION

Armillaria is an opportunistic parasite whose pathogenicity and role in the decadence of the ecosystem often depend on ecosystem conditions including soil texture and compaction, nutrient balance, pH, organic matter quality, waterlogging, tree age and type, vigor and population density of the host tree, and abundance of inoculum in the form of rhizomorphs (Singh 1983). Shields and Hobbs (1979) reported that A. mellea infection of conifers in the northern Rocky Mountains was associated with soils low in nitrogen, phosphorus, and calcium. Redfern (1978) found that suppressed conifers and those experiencing reduced light intensity are more susceptible to infection than dominant trees and trees in full light. Under greenhouse conditions, a significantly greater number of coniferous seedlings died of A. mellea attack when grown in soils with low pH and nutrient deficiency (Singh 1980). However, seedlings producing more resin and callus were more resistant to fungal attack (Singh 1983).

We hypothesized that specific interactions between Armillaria of known virulence and physiological condition of a stressed host might explain some results observed in the field. To test this, we subjected Pinus monticola Dougl. seedlings to light, nitrogen, and phosphorus limitations under greenhouse conditions and examined subsequent seedling response to Armillaria infection as well as effects on seedling biomass, shoot:root ratio, carbohydrate accumulation, and nutrient concentration and uptake.

## METHODS

### Growth Conditions

Pinus monticola seeds from wind-pollinated tree #40 from the USDA Intermountain Forest and Range Experiment Station genetics program at Moscow, Idaho, were germinated and grown in periolite in 165-ml containers for 3 weeks under greenhouse conditions. Seedlings were then thinned to one per cell.

In a split-plot design, seedlings were randomly assigned treatment combinations of light or shade (main plots) and nutrients or water (subplots) as follows: (1) full light x complete Arnon's solution (LC) (Arnon and Hoagland 1943), (2) full light x complete Arnon's solution minus nitrogen (L-N), (3) full light x complete Arnon's solution minus phosphorus (L-P), (4) full light x distilled water (LW), (5) shade x complete Arnon's solution (SC), (6) shade x complete Arnon's solution minus nitrogen (S-N), (7) shade x complete Arnon's solution minus phosphorus (S-P), and (8) shade x distilled water (SW). All treatments except LC were considered stress treatments. Each experimental unit had seven seedlings, and each of the eight treatments was replicated 7 times.

Treated seedlings were grown at the USDA Intermountain Forest and Range Experiment Station greenhouse for 5 months (June-November). Two layers of shade cloth provided shade for those seedlings so designated. Greenhouse light readings taken with an ISCO model SR spectraradiometer on a cloudless July 11 from 1 to 5 pm measured average photosynthetic photon flux density of fully illuminated seedlings as 1369 uE $m^{-2}$ $s^{-1}$ and that of shaded seedlings as 377 uE $m^{-2}$ $s^{-1}$. Seedlings were watered twice weekly.

One month after treatments began, seedlings were exposed to Armillaria collected from a recently dead resin-soaked Pinus monticola at Deception

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Paper 2074, Forest Research Laboratory, Oregon State University, Corvallis. The mention of trade names or commercial products does not constitute recommendation by the authors or Oregon State University.

Table 1--Infection and biomass data for Pinus monticola seedlings subjected to eight light x nutrient treatments and infected with Armillaria mellea[1]

| Treatment[2] | Infection rate[3] | Biomass | | | Shoot:root ratio | Starch | | Sugar | |
|---|---|---|---|---|---|---|---|---|---|
| | | Root | Shoot | Total | | Shoot | Root | Shoot | Root |
| | | grams (dry wt.) | | | | milligrams per gram | | | |
| LC | 1.06 A | 0.0514 A | 0.0542 A | 0.1062 A | 1.1711 A | 34.0 A | 40.8 A | 14.73 A | 2.1 A |
| L-N | 1.78 B | 0.0458 B | 0.0438 B | 0.0900 B | 0.9534 A | 37.9 A | 36.1 AB | 15.03 A | 6.8 B |
| L-P | 1.63 BC | 0.0449 B | 0.0441 B | 0.0894 B | 0.9928 A | 34.5 A | 33.5 B | 12.40 AB | 3.3 AB |
| LW | 1.55 BC | 0.0394 C | 0.0368 CD | 0.0753 C | 0.9653 A | 49.2 B | 41.0 A | 13.63 AB | 8.7 B |
| SC | 1.43 C | 0.0191 D | 0.0325 C | 0.0518 D | 1.8672 B | 35.0 A | 37.1 B | 11.65 B | 2.6 A |
| S-N | 1.80 B | 0.0271 E | 0.0447 B | 0.0753 C | 1.7570 B | 37.2 A | 39.3 A | 14.00 A | 3.4 B |
| S-P | 1.67 BC | 0.0230 DE | 0.0413 BD | 0.0663 C | 1.8630 B | 37.4 A | 32.9 B | 19.33 C | 3.0 AB |
| SW | 1.57 BC | 0.0208 D | 0.0354 C | 0.0560 B | 1.9000 B | 38.3 B | 37.1 AB | 17.73 C | 5.2 B |

[1] In each column, values followed by the same letter are not significantly different ($P \geq 0.05$), as determined by Fisher's Protected LSD test.
[2] See text for treatment descriptions.
[3] Seedlings rated as 1 (uninfected and living), 2 (infected and living), and 3 (infected and dead).

Creek Experimental Forest near Coeur d'Alene, Idaho. Seedlings were removed from their cells and inoculated by sandwiching the primary root between two 1- x 1- x 3-cm blocks of infected P. monticola wood. One small lateral root also was severed on each seedling. A duplicate set of seedlings, to be used as controls for the nutrient analyses, was not inoculated but had one lateral root severed per seedling. Exposure and severing of lateral roots were done underwater to eliminate root damage due to desiccation. Seedlings were then replaced in their cells and treatments continued for another 4 months.

After budset, seedlings were transferred to a growth chamber (16-hour daylength, 4°C) to determine if treatments would alter starch accumulation. In the growth chamber, photosynthetic photon flux density was 185 uE $m^{-2}$ $s^{-1}$ on fully illuminated seedlings and 17 uE $m^{-2}$ $s^{-1}$ on shaded seedlings. At harvest, seedlings were removed from their cells and their root systems carefully washed with distilled water and then surface-sterilized in 0.20 kg $kg^{-1}$ clorox solution. Five sections per seedling of Armillaria-infected roots were placed on malt agar in numbered petri dishes; the treatment to which each seedling had been subjected was recorded. Infection was confirmed by growth of rhizomorphs, which characterize this species. Seedlings were rated as 1 (uninfected and living), 2 (infected and living), and 3 (infected and dead). Seedlings were then dried at 85°C for 2 days and weighed to determine root, shoot, and total biomass; root:shoot ratio; root and shoot starch; and root and shoot sugar.

### Analyses

Sugar and starch.--For each treatment, three replicates of nonstructural carbohydrates were analyzed in roots and shoots with a method similar to the one developed by Hansen and Moller (1975) and modified by Marshall (1984).

Nutrients.--For each sample, three replications of 16 entire seedlings were dried and ground to < 1 mm, and 0.5 g of subsamples was ashed at 525 ± 2°C. The ash was taken up in 6 N HCl, brought to 50 ml volume, and analyzed for Al, B, Ca, Cu, Fe, Mg, Mn, Mo, K, Na, P, Si, and Zn (Jackson 1958) with an inductively coupled plasma spectrometer. Total N was analyzed by standard microkjeldahl techniques modified for nitrate.

Statistics.--The data were normally distributed and analyzed with GLM procedures (SAS Institute 1982) for a split-plot design. Individual treatment means were compared with Fisher's protected least significant difference (LSD) test at the 5% level.

A principal component analysis (PCA), followed by a stepwise discriminant analysis, was run on these data. Standardizing transformations were unnecessary because all the data collected (except for Armillaria) were in the same units.

## RESULTS

### Infection Rates

Seedlings receiving the LC treatment had a significantly lower infection rate than those receiving stress treatments (table 1). Seedlings receiving the SC treatment had a significantly lower infection rate than those receiving the S-N treatment but not the S-P or SW treatment. Regardless of light or shade, seedlings receiving a complete nutrient supply had lower infection rates than those receiving nutrient-deficient solutions, which did not differ significantly from each other. However, seedlings receiving the water-only treatment had lower infection rates than those receiving treatments with only one nutrient deficiency.

### Biomass and Shoot:Root Ratio

Seedlings receiving the LC treatment had greater root, shoot, and total biomass than those receiving stress treatments (table 1). All light treatments produced significantly greater root biomass

Table 2—Total nutrient concentrations and nutrient uptake for Pinus monticola seedlings subjected to eight light x nutrient treatments and infected with Armillaria mellea [1]

| Treatment [2] | Al | B | Ca | Cu | Fe | K | Mg | Mn | Mo | P | Na | Si | Zn | Total N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | micrograms per gram of plant tissue | | | | | | | | | | | | | |
| | Concentration | | | | | | | | | | | | | |
| LC | 118 A | 13.2 A | 9423 A | 12.5 A | 186.7 A | 7470 A | 2798 A | 82.1 A | 3.8 A | 2659 A | 2015 A | 404 A | 75.9 A | 19264 A |
| L-N | 234 B | 14.3 B | 3908 B | 8.5 B | 175.0 A | 15741 B | 3976 B | 101.2 B | 3.4 B | 2050 B | 2378 B | 592 B | 60.2 B | 7546 B |
| L-P | 275 C | 17.5 C | 13100 C | 8.0 B | 229.2 B | 9431 C | 2969 C | 49.4 C | 1.8 C | 1025 C | 2765 C | 453 A | 121.5 C | 16133 C |
| LW | 275 C | 14.1 B | 7019 E | 7.8 B | 99.7 C | 3142 D | 2545 D | 59.7 C | 1.2 D | 1345 D | 2066 A | 346 A | 108.4 D | 8843 D |
| SC | 202 B | 13.9 B | 9273 A | 19.7 C | 316.1 D | 7548 A | 2915 E | 101.3 B | 3.2 B | 3310 E | 1980 A | 500 AB | 196.7 E | 19675 A |
| S-N | 115 A | 14.3 B | 4326 B | 10.4 BD | 229.6 B | 15486 B | 4586 F | 118.6 BC | 7.3 E | 2603 A | 2135 D | 431 A | 135.2 F | 11533 E |
| S-P | 110 A | 17.5 C | 16293 D | 11.2 AE | 247.3 B | 11966 E | 3016 G | 96.5 ABC | 1.7 C | 1647 F | 2233 AD | 531 AB | 171.7 G | 20421 F |
| SW | 140 E | 13.4 A | 7728 F | 12.1 AE | 122.5 C | 2795 F | 2827 A | 74.9 AC | 0.8 F | 2018 B | 1958 A | 332 A | 131.8 F | 13095 G |
| | Uptake | | | | | | | | | | | | | |
| LC | 108 A | 10.2 A | 9380 A | 9.4 A | 163.3 AB | 6245 A | 2271 A | 49.8 A | 3.7 A | 1259 A | 1988 ADE | 382 AC | 62.8 A | 13382 A |
| L-N | 221 B | 10.6 B | 3857 B | 4.8 B | 147.4 A | 14244 B | 3354 B | 63.3 B | 3.3 B | 398 B | 2335 B | 567 B | 44.1 B | 3667 BC |
| L-P | 262 C | 13.9 C | 13049 C | 4.1 B | 186.3 CB | 7933 C | 2343 A | 32.0 C | 1.7 C | 0 D | 2730 C | 320 AC | 105.4 C | 6670 CD |
| LW | 260 C | 9.3 D | 6958 D | 3.5 B | 66.8 D | 1361 D | 1801 C | 14.3 D | 1.1 D | 0 D | 2056 D | 315 AC | 89.2 D | 2272 B |
| SC | 181 D | 7.7 E | 9209 A | 15.3 C | 268.2 E | 4963 E | 1801 C | 35.2 C | 3.0 E | 1335 A | 1923 AE | 458 DE | 168.9 E | 9670 AD |
| S-N | 100 AE | 10.1 A | 4265 B | 4.0 B | 197.7 D | 13708 F | 3858 D | 73.1 E | 7.2 F | 627 C | 2096 F | 402 AD | 116.0 F | 5362 BC |
| S-P | 94 E | 12.7 F | 16224 E | 6.8 D | 209.9 D | 9946 C | 2262 A | 44.8 F | 1.5 G | 0 D | 2179 F | 499 BE | 150.0 G | 9416 D |
| SW | 120 A | 7.7 E | 7659 F | 6.2 D | 30.63 F | 404 H | 1847 C | 13.9 D | 0.6 H | 0 D | 1906 AE | 293 C | 113.1 CF | 2369 B |

[1] Within each subtable (concentration or uptake) and column, values followed by the same letter are not significantly different ($P \geq 0.05$) as determined by Fisher's Protected LSD test.
[2] See text for treatment descriptions.

than shade treatments; within light treatments, the water-only treatments produced significantly lower root, shoot, and total biomass than the nutrient-deficient treatments.

Seedlings in the light treatments had lower shoot:root ratios than those in the shade treatments. Regardless of light or shade, shoot:root ratios of seedlings receiving nutrient-deficient treatments were not significantly different from those receiving a complete nutrient solution (table 1).

### Carbohydrates

Light, nitrogen, and phosphorus deficiencies did not produce any biologically explainable differences in sugar, starch, or their ratios (table 1). The low light intensity in the growth chamber evidently did not cause seedlings, dormant from early October until harvest in late November, to produce enough photosynthates for us to determine the effects of N and P deficiency on carbohydrate storage.

### Nutrients

Nutrient concentrations were more balanced in seedlings given the LC treatment than in those given the stress treatments. However, seedlings given the SC treatment had higher concentrations of Al, B, Cu, Fe, Mg, Mn, Mo, P, Zn, and total N than those given the LC treatment (table 2).

Regardless of light or shade, seedlings given water-only treatments had lower nutrient concentrations than those in all other treatments, and seedlings given nutrient-deficient treatments had significantly higher concentrations of all nutrients except Al.

Within light treatments, seedling Ca concentrations were significantly lower in the nutrient-deficient than complete solutions. Potassium, Mn, and Mg concentrations seemed to depend on light treatments within nutrient treatments; shaded seedlings contained more K, Mn, and Mg. Phosphorus concentrations seemed to depend on nutrient treatments within light treatments; seedlings receiving LC and SC treatments contained more P than seedlings receiving L-N, LW, S-N, and SW treatments. Total N concentration seemed to depend on light treatments within nutrient treatments. Seedlings receiving LC and SC treatments showed no significant differences in total N concentration; however, seedlings receiving nutrient-deficient or water-only treatments contained significantly higher total N when shaded.

Nutrient uptake was similar to total nutrient concentration (table 2). Tap water, used as a base solution for all treatments, probably contained trace quantities of all elements analyzed, and seedlings also contained nutrients from seeds, even nearly 5 months after germination. However, seedlings receiving the LC treatment were able to assimilate a more balanced amount of nutrients than those receiving stress treatments, and, regardless of light or shade, seedlings receiving

Table 3--Results of the PCA on Pinus monticola seedlings subjected to eight light x nutrient treatments and infected with Armillaria mellea, where $X_i$ is the associated eigenvalue and underlined coefficients were used in developing substantive interpretation of PC's

| Variables | Principal components | | | | |
|---|---|---|---|---|---|
| **Total nutrient concentration** | | | | | |
| $X_i$ | 4.56 | 4.06 | 3.42 | 0.95 | |
| % variation | 30 | 27 | 23 | 6 | |
| Cumulative var. (%) | 30 | 57 | 80 | 86 | |
| | $PC_1$ | $PC_2$ | $PC_3$ | $PC_4$ | |
| Al | -0.2425 | -0.1066 | 0.2366 | 0.4654 | |
| B | 0.0196 | 0.1839 | 0.4813 | -0.1564 | |
| Ca | -0.0411 | 0.4245 | 0.2341 | -0.0987 | |
| ARM | 0.0473 | 0.0900 | 0.3351 | -0.4891 | |
| Fe | 0.3506 | 0.2437 | 0.1150 | 0.2272 | |
| Mg | 0.3350 | -0.3131 | 0.0903 | -0.1820 | |
| Mn | 0.4511 | -0.0912 | -0.0169 | -0.0590 | |
| Mo | 0.3696 | -0.2050 | -0.0863 | -0.1161 | |
| P | 0.3104 | 0.0401 | -0.3611 | 0.2267 | |
| Na | -0.0256 | -0.0552 | 0.4939 | 0.1506 | |
| Si | 0.2600 | -0.0190 | 0.2642 | 0.5128 | |
| Zn | 0.1421 | 0.3452 | -0.0169 | -0.2570 | |
| K | 0.3553 | -0.1959 | 0.2494 | 0.0233 | |
| SN | 0.1378 | 0.4524 | -0.0177 | 0.0177 | |
| TN | 0.1780 | 0.4377 | -0.0960 | 0.0661 | |

| **Nutrient uptake** | | | | | |
|---|---|---|---|---|---|
| $X_i$ | 4.62 | 3.03 | 2.81 | 1.07 | 1.01 |
| % variation | 33 | 22 | 20 | 8 | 7 |
| Cumulative var. (%) | 33 | 55 | 75 | 83 | 90 |
| | $PC_1$ | $PC_2$ | $PC_3$ | $PC_4$ | $PC_5$ |
| Al | -0.1259 | 0.3704 | 0.0073 | 0.5026 | 0.4087 |
| B | 0.1352 | 0.3593 | 0.3887 | -0.2419 | 0.0670 |
| Ca | -0.1117 | -0.0280 | 0.5561 | -0.2066 | -0.1217 |
| ARM | 0.0281 | 0.3416 | -0.0139 | 0.5261 | -0.3091 |
| Fe | 0.2906 | -0.1512 | 0.3564 | 0.3543 | 0.0255 |
| Mg | 0.4042 | 0.1604 | -0.1935 | -0.1038 | -0.1389 |
| Mn | 0.4580 | -0.0117 | -0.0520 | -0.1129 | -0.0116 |
| Mo | 0.3945 | -0.1192 | -0.1681 | 0.1190 | -0.0174 |
| P | 0.1926 | -0.4191 | -0.0258 | 0.2868 | 0.4340 |
| Na | 0.1080 | 0.4582 | 0.2668 | 0.0189 | 0.1926 |
| Si | 0.2946 | -0.0344 | 0.0593 | 0.0379 | -0.1010 |
| Zn | -0.0656 | -0.2516 | 0.2952 | 0.3345 | -0.5885 |
| TN | 0.0998 | -0.2789 | 0.4252 | -0.0373 | 0.3226 |
| K | 0.4355 | 0.1596 | 0.0258 | -0.0939 | -0.1081 |

a complete nutrient supply were able to assimilate more Cu and P than seedlings receiving nutrient-deficient treatments (table 2).

The PCA on total nutrient concentration and Armillaria revealed three principal components with eigenvalues > 1 and explained 80% of the total variation (table 3). A correlation matrix was used rather than a covariance matrix because the extreme range of values and relatively high values for certain nutrients caused the most abundant nutrients to mask the other variables in the covariance-based PCA. The first three PC's are associated with Mn, Ca, N [both shoot (SN) and total (TN)], B, and Na; in the fourth PC, included because of its high eigenvalue ($X_i$ = 0.95), Armillaria (ARM) appears to be inversely related to both Al and Si at about equal orders of magnitude, although it was not a major variable in the earlier PC's. The PCA on nutrient uptake (table 3), also reported for a correlation matrix, shows many of the same variables to be important. The first PC is basically a linear combination of K and Mn; in the second PC, Na and P almost balance each other out. The third PC is Ca, the fourth Al and ARM, and the fifth Zn. The absence of N is noteworthy.

The stepwise discriminant analysis, based on the three Armillaria infection rates previously described and using proportional prior probabilities to handle unequal group size, revealed that 88% of the seedlings were correctly classified for both the nutrient concentration and uptake data (table 4). The order of variables in the discriminant function for total nutrient concentration

Table 4--Percentage of seedlings correctly classified according to the three Armillaria infection rates (see text), as determined by stepwise discriminant analysis on Pinus monticola seedlings subjected to eight light x nutrient treatments and infected with Armillaria mellea

| | 1 | 2 | 3 | |
|---|---|---|---|---|
| | ------- percent ------- | | | |
| | Total nutrient concentration | | | |
| 1 | 100 | 0 | 0 | n = 6 |
| 2 | 11 | 78 | 11 | n = 9 |
| 3 | 0 | 11 | 89 | n = 9 |
| | Nutrient uptake | | | |
| 1 | 86 | 14 | 0 | n = 7 |
| 2 | 0 | 89 | 11 | n = 9 |
| 3 | 0 | 12 | 88 | n = 8 |

was SN, Fe, P, Na, and Mo; the order of variables for nutrient uptake was K, Mn, Mo, and Na. The discriminant functions for the three Armillaria infection rates are given in table 5.

Table 5--Discriminant functions for the three Armillaria infection rates of the treated Pinus monticola seedlings

| | Infection rate | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| | Total nutrient concentration | | |
| Constant | -821.41962687 | -756.00822875 | -784.22140880 |
| Al | 0.17226511 | 0.32576670 | 0.33321249 |
| B | 8.77781792 | 7.87254886 | 8.78915530 |
| Ca | 0.02902591 | 0.02431945 | 0.02398955 |
| P | -0.03501772 | -0.07925134 | -0.08004255 |
| SN | -0.02690076 | -0.02390700 | -0.02404295 |
| Mn | 19.36099049 | 20.09431557 | 20.39972376 |
| Mo | -2.15407672 | -2.37595507 | -3.84573428 |
| Na | 0.31829975 | 0.27419598 | 0.27450137 |
| Zn | -3.59346581 | -3.55440041 | -3.62859614 |
| K | -0.07086158 | -0.06969980 | -0.07038877 |
| TN | 0.02032558 | 0.02215955 | 0.02287487 |
| | Nutrient uptake | | |
| Constant | 648.92490286 | -609.89680908 | -562.11013544 |
| Zn | -0.69040418 | -0.78749169 | -0.48509831 |
| Al | -0.22899288 | -0.09184068 | -0.09711049 |
| TN | -0.05825690 | -0.06661951 | -0.04938554 |
| Na | 0.24332437 | -0.21350802 | 0.17371011 |
| B | 17.37444670 | 11.15521652 | 17.18548682 |
| P | 3.62031890 | 3.50478312 | 3.31224455 |
| Ca | 0.06010636 | 0.06372016 | 0.05347131 |
| Mg | 0.21094857 | 0.23144300 | 0.24261565 |
| Mn | 0.87226142 | 0.74928425 | 0.68417189 |
| Mo | -0.51890976 | -0.18874696 | -1.34766393 |
| K | -0.06862198 | -0.06421891 | -0.06076463 |

## DISCUSSION

Under greenhouse conditions, full light combined with a complete, balanced nutrient supply resulted in greater root biomass and lower Armillaria infection rate in P. monticola seedlings. Infection rate was higher when seedlings were stressed by lack of light or nutrients and highest when the deficient nutrient was N.

Conclusions from previous greenhouse and field studies are similar to ours. Redfern (1978) reported a higher infection rate of A. mellea with reduced light intensity on Pseudotsuga menziesii, Abies grandis, Picea sitchensis, Larix kaempferi, and Pinus sylvestris in greenhouse experiments. In a greenhouse study, Singh (1980, 1983) noted a higher infection rate of A. mellea on Picea abies, Picea sitchensis, Pinus mariana, and Pinus sylvestris associated with N, K, and Na deficiencies combined with low pH. Shields and Hobbs (1979) found that lower pH and N, P, and Ca levels were associated with A. mellea decay of Pseudotsuga menziesii and Abies grandis in northern Idaho. Although factors that determine the infection of A. mellea on host species are not completely understood, nutrient-deficient seedlings are more vulnerable to attack fungus (Singh 1983).

Our study results indicate that low vigor due to nutrient and/or light limitation under greenhouse conditions predisposes P. monticola seedlings to A. mellea infection. In many areas of the Pacific Northwest, trees are stressed by unfavorable site and soil conditions. Although conifers are generally adapted to low soil nutrient levels, many soils have growth-limiting or deficient levels of one or more of the macroelements, primarily N (Lavender and Walker 1979). Positive growth response of Tsuga heterophylla to N fertilization is most likely in soils where extractable P is high and total and mineralizable N low (Radwan and Shumway 1983). However, large areas of ash-capped soils are high in $Al(OH)_3$ from allophane (Birkland 1974); high levels of $Al^{+3}$ in soils often tie up P, rendering it unavailable to plants (Tinker 1975). Thus, the erratic response of trees to Armillaria infection after N fertilization may be explained by the lack of available P.

Creating conditions more favorable to tree vigor could reduce the incidence of Armillaria infection where that inoculum is prevalent. A fire hot enough to remove large amounts of inoculum while supplying additional available N to trees is a management practice that should be investigated in stands with heavy Armillaria infection. Establishing $N_2$-fixing plants at appropriate times during a rotation may improve tree vigor and therefore increase relative resistance to disease (Waring 1983; Matson and Waring 1984). In nitrogen- or phosphorus-limiting soil, fertilizer applications or interplanting of $N_2$-fixing species may reduce the incidence of Armillaria infection.

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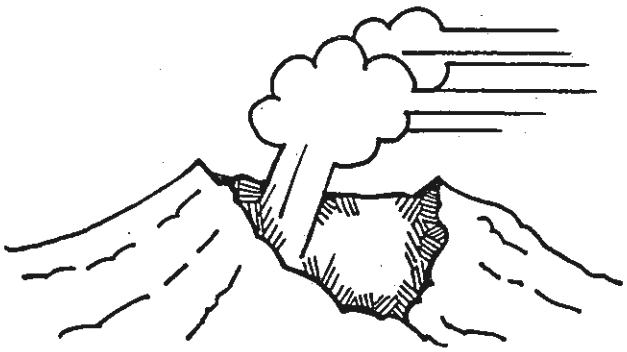

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## ROOT DISEASE ASSESSMENT ON NON-FEDERAL LANDS IN WESTERN OREGON: METHODOLOGY AND PRELIMINARY RESULTS.

ALAN KANASKIE

ABSTRACT: A method was developed to assess extent and impact of laminated root rot on timber resources of western Oregon. The procedure involves estimating the area visibly affected by disease on fixed radius plots located on a 5.5 kilometer grid. Preliminary results from Columbia and Clatsop Counties indicate that 5.3 percent of the conifer timberland is visibly affected by laminated root rot.

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### BACKGROUND/PURPOSE

Laminated root rot (caused by Phellinus weirii), is the most damaging pest of Douglas-fir west of the Cascade Mountains. As much as one million cubic meters of wood in western Oregon and Washington may be lost annually to this disease (Hadfield and Johnson 1977). However, reliable estimates of volume loss or extent of area affected by this or other root diseases are unavailable.

Few systematic large scale (regional or statewide) disease surveys have been attempted. Gedney (1981) documented occurrence of laminated root rot on non-federal lands in northwest Oregon, but did not estimate extent or impact because amount of area affected was not determined. In southwest Oregon, extent and distribution of black stain root disease in young plantations have been documented on federal lands (Goheen and others 1982, Goheen and others 1984) and certain private industrial ownerships. Root disease impact data are also available from U.S. Forest Service Pest Management biological evaluations, but these are usually intensive surveys of small management units on federal ownerships.

The purpose of this survey is to improve our understanding of the impact of root disease on non-federal timber resources in Oregon. Resource planners, forestry advisory services, and other decision-makers frequently request impact or loss estimates. Reliable and accurate estimates could be particularly important when determining allocation of limited funds for research or management programs.

This project is cooperative between the Oregon Department of Forestry and the U.S. Forest Service Pacific Northwest Forest and Range Experiment Station Forest Inventory and Analysis Work Unit (FIA).

### OBJECTIVES

The objectives of this project are:

1. To develop, within the framework of FIA field procedures, a method for estimating the area affected by root disease;

2. To estimate extent and impact of root disease on Oregon's non-federal timber resources.

### FIA INVENTORY PROCEDURE

FIA is responsible for inventorying the forest resources of all land ownerships except national forest and Bureau of Land Management. There are seven such units across the United States. In Pacific Coast states, inventories are repeated every 9 to 10 years, providing opportunity for remeasuring permanent plots.

The sample design is double sampling for stratification. In western Oregon the primary

sample consists of 23,000 permanent photo points systematically located on a 1.3 kilometer square grid. The second, or ground sample, consists of every sixteenth photo point (5.5 kilometer grid). About 1100 Timberland plots will be ground checked during the 1985-86 survey. ("Timberland" is defined as forest land that can grow continuous crops of trees to industrial roundwood size, quality, and quantity). Each photo point represents approximately 187 hectares (462 acres), and each ground point about 3,000 hectares (7,400 acres).

At each ground sample point, a cluster of five 17-meter radius plots were established in a design similar to that shown in figure 1. Plots are located within the same land class and stand condition, i.e., timber type, to ensure reasonable plot averages and an adequate assessment of stocking variability within the stand (Forest Inventory and Analysis Work Unit, 1985).

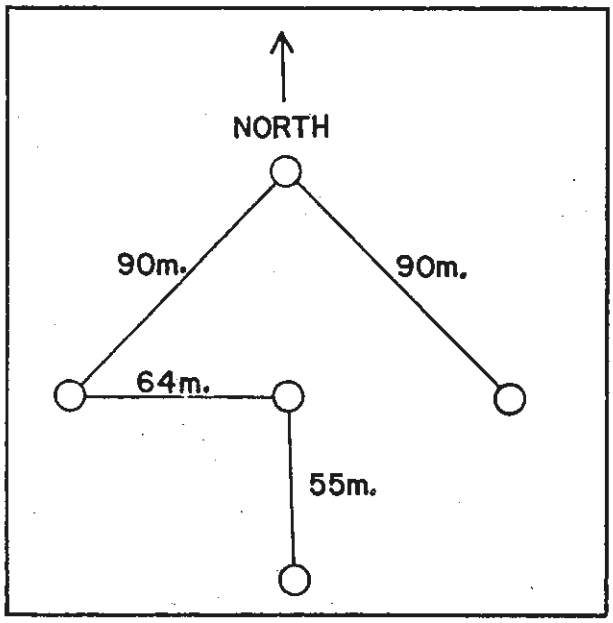


Figure 1. Plot layout for FIA Inventory points in western Oregon 1985-86. Each circle is 17-meters in diameter.

## ROOT DISEASE ASSESSMENT

The FIA procedure was not designed as a root disease survey. Our task was to integrate a root disease assessment procedure into an existing system. The major constraints were that the method had to be quick, easy, and accurate. A time-consuming procedure was unacceptable because of the already heavy workload on field crews.

We limited the scope of the survey to four major root diseases: Laminated (Phellinus) root rot, Annosus root rot, black stain root disease, and Armillaria root disease. The procedure involves mapping the affected area based on crown symptoms according to the methods of Bloomberg (1980), and estimating the percentage of plot area affected.

Only plots in conifer stands (conifer percent cover greater than or equal to 25 percent) with average stand diameter greater than or equal to 8 inches qualified for the root disease survey. We excluded regeneration stands (mean stand diameter less than 8 inches) because: (1) root disease usually is expressed poorly in these stands, and (2) difficulty in seeing through vegetation made the procedure too time consuming. Hardwood stands were eliminated because root diseases would not occur there or would be difficult to detect.

Because our sample is biased away from young stands, Armillaria and black stain will not be well represented. Laminated root rot, however, lends itself well to our method.

## FIELD PROCEDURES FOR ROOT DISEASE ASSESSMENT

The following are detailed field procedures as specified in the FIA survey manual:

On each 17-meter fixed radius plot estimate the location and dimensions of root disease areas using a compass and pacing or measuring distances. Sketch infection center boundaries on the root disease plot card, shade the infected area and label with the appropriate code. More than one disease can occur on a plot. The disease codes are as follows:

| CODE | CAUSAL FUNGUS | DISEASE |
|---|---|---|
| PW | Phellinus weirii | Laminated root rot |
| VW | Verticicladiella wageneriì | Black stain root disease |
| FA | Fomes annosus | Annosus root rot |
| AM | Armillaria mellea | Armillaria root disease |
| UK | Unknown | ------- |
| NO | None present | ------- |

If evidence of root disease is found but the disease cannot be identified, map the affected area and collect at least two samples of diseased material. Place samples in a paper bag labeled with county, plot and point numbers, tree species, and a short description of the stand from which it was collected. Enter "unknown" (UK) for the disease code.

Map and estimate percentages only for diseases that are primary causes of tree symptoms or death. Do not map secondary infections (such as Armillaria that invaded a tree killed by Phellinus). If evidence of secondary disease exists, note the situation on the disease plot card.

Define the boundary of an infection center using straight lines connecting inner faces of healthy appearing trees in the margin of the root disease center. A healthy-appearing tree is defined as follows:

1. lacks crown symptoms of root disease, reduced terminal growth increment, thin or yellow crown, distress cone crop;

2. has a root disease-infected tree as nearest neighbor on side toward infection center;

3. has a healthy-appearing tree as nearest neighbor on side away from infection center (Bloomberg 1981).

When defining the boundary, do not consider islands of healthy appearing trees inside an infected center, as those trees are likely infected. Figure 2 shows how infection center boundaries would be drawn in several situations.

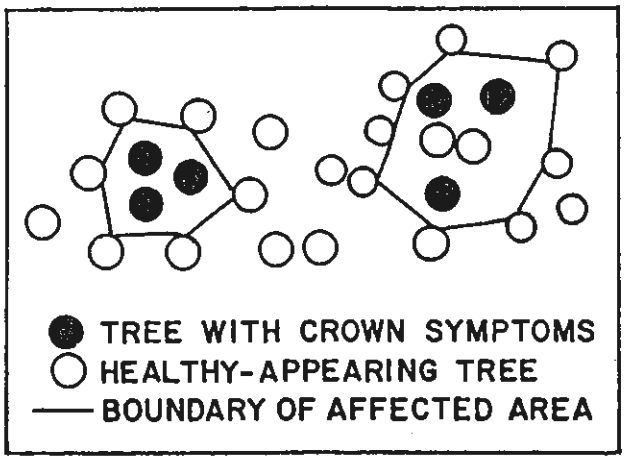


Figure 2. Definition of root disease infection center boundaries by joining faces of healthy-appearing trees.

When mapping disease centers, do not include area that is hardwood site or nonstockable (area that will not support susceptible host species). Do include areas that are conifer sites but not currently supporting conifers because of root disease. Map and label hardwood sites or nonstockable areas on root disease plot card.

Centers of laminated root rot often contain an abundance of red alder, since red alder is not affected by the disease. If the alder appears to be present because of root disease (i.e., there are symptomatic trees adjacent to the alder), include the alder patch as part of the infection center. If the alder is apparently present because the site favors alder (for example, stream margins or excessively wet sites), do not include the alder in the infected area.

An example of root disease plot card is shown figure 3.

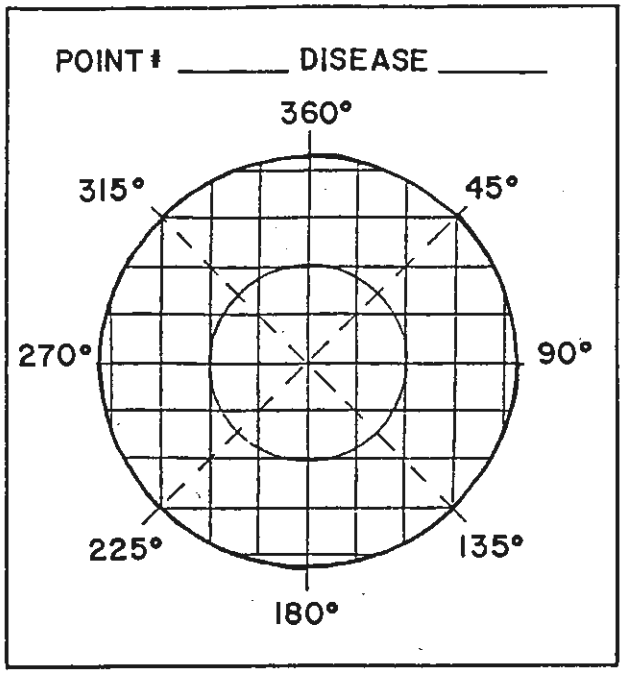


Figure 3. Plot map from root disease plot card. Each plot card contains five plot maps.

Estimating and recording percent cover of root disease. For each root disease present on the plot estimate percent of the 17-meter fixed radius plot that is infected by the particular root rot. Base the estimate on the root disease diagram. Each square of the grid (4 m X 4 m on the ground) represents 2 percent of the area of the 17-meter fixed-radius plot. A half-shaded square represents 1 percent and so forth.

## DATA ANALYSIS

The outcome criteria are (1) percentage of area visibly affected by disease at this point in time, and (2) average annual volume loss.

For each ground point we calculate the mean percentage of area visibly affected by averaging estimates for the five 17-meter radius plots. These means are then averaged within forest type strata.

Area affected by disease is a useful quantity, but expansion to volume loss is necessary to describe impact on the timber resource. Because we did not measure mortality or yield reduction, we assume that Douglas-fir yield in affected areas is reduced by 10 to 50 percent as compared to unaffected areas (Filip 1984, Bloomberg and Reynolds 1985).

Average annual yield reduction will be calculated as follows for each timber type stratum:

| | | | | |
|---|---|---|---|---|
| Annual yield reduction | = | Potential mean annual increment yield at rotation age without disease* | x | mean % of area affected by disease |

x assumed % yield reduction in affected area

*Determined from yield tables or FIA projections.

PRELIMINARY RESULTS AND DISCUSSION - LAMINATED ROOT ROT IN COLUMBIA AND CLATSOP COUNTIES.

After eliminating plots because they were non-stocked, hardwood type, or regeneration, 58 qualified for root disease assessment. Of these, 15 (26 percent) had laminated root rot.

These results are preliminary and very conservative, especially in regard to the area estimates. The area visibly affected does not account for nonsymptomatic infected trees which, if included, would expand the affected area by a factor of 1.5 (Wallis and Bloomberg 19B1). From a forest management standpoint, the expanded estimates would be more useful.

Our occurrence estimates are higher than the 12 to 13 percent reported by Gedney (1981). That survey likely understated occurrence because: (1) only plots with dead trees or openings were recorded as affected, whereas our survey included live standing trees with crown symptoms, and; (2) the sample included a higher proportion of young stands in which root disease is expressed poorly.

Yield reduction estimates will depend on the assumed percentage of yield lost within affected areas. Filip and Wiitala (1984) suggest using 50 percent reduction at the end of a rotation in affected parts of intensively managed stands of highly susceptible species, and 25 percent in poorly stocked natural stands. These figures were derived by comparing basal area in affected versus unaffected areas, which were delineated as would be done for management activities, i.e., including a buffer to capture hidden infections. Bloomberg and Reynolds (1985) suggest a much lower yield reduction in 30 to 40 year-old Douglas-fir stands on Vancouver Island; volume and basal area were reduced by 10.3 percent. Under the above assumptions, reductions in yield over the two counties could range from 0.5% to (assuming 10 percent loss in affected areas) to 2.5% (assuming 50 percent loss in affected areas). These estimates are also conservative because they have not accounted for increasing damage from laminated root rot as stand age increases.

Volume loss will be estimated more precisely when yield projections are available from FIA data. Field work for the Western Oregon Survey will be completed in 1986.

ACKNOWLEDGEMENTS:

Thanks to the FIA field crews and their supervisors for their willing cooperation.

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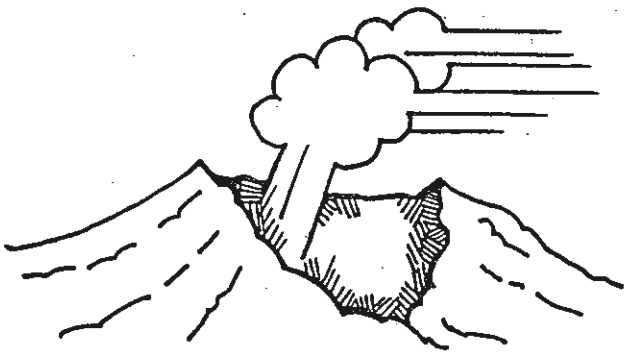

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## ARMILLARIA ROOT ROT: TEN YEARS OF CHEMICAL PROTECTION, GROWTH, AND MORTALITY IN A PONDEROSA PINE FOREST

Cregory M. Filip

ABSTRACT: Chemicals were applied once to the root collars of small diameter ponderosa pines to prevent mortality caused by Armillaria ostoyae (mellea). After 10 years, only captan at 100 g/tree significantly reduced mortality over untreated trees. Diameter growth rate of surviving trees averaged 2.5 mm/year, and fungus spread rate averaged 0.5 m/year. There were no significant differences in tree mortality rste, tree growth rate, or fungus spread rate among seven plots or from year to year.

There are two reasons why I am giving this paper. The first is that the work was done in Washington State where we are meeting this year. Also, this is sort of an introduction to the field trip to be held tomorrow. After this talk we won't need to worry about transportation for so many people. The second reason is that this information is part of my doctoral thesis that I started over ten years ago, and ten years is too long to work on any thesis!

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My study area is located at Glenwood, Washington near Mt. Adams which is about 150 miles southeast of Olympia, as the crow flies. The topography is flat to rolling, elevation is 2500 to 3500 feet, and precipitation is 25 to 35 inches per year. Plant communities range from ponderosa pine/bitter brush at the lower elevations to ponderosa pine/Douglas-fir/common strawberry at the higher elevations. Stocking of understory trees is dense ranging from 1000 to 2000 trees per acre over 1.0 in. DBH. Site index at 100 years is moderate to good ranging from 90 to 113 feet. Most of the plots are located on land owned by the St. Regis Paper Company. A few are located on Washington State land.

The root disease situation in the stands at Glenwood is notorious and has been a research subject for the past 20 years. Lew Roth's studies concentrated on inoculum identification and removal by excavation (Roth et al. 1977, 1978, 1980). We will visit two of his study areas at Glenwood, one a ten acre area used to study the effects of various levels at inoculum removal on disease incidence. The second study of 80 acres was designed to determine the effects of commercial thinning with stump removal on disease incidence.

Disease spread in the Glenwood area is by rhizomorphs or root to root contact. This information was obtained by extensive excavation work performed under the able guidance of Terry Shaw. From these and other studies, it was determined the tree mortality is a result of attack by Armillaria ostoyae at and only at the root collar: lateral root infections are not lethal (Shaw 1980). With this in mind, I felt that protection of the root collar with a chemical barrier might prevent attack at the root collar and thus reduce tree mortality.

The objective of my work was to test seven chemicals applied once to the root collar of living and presumably uninfected ponderosa pines. Chemicals were applied randomly to selected trees within each of seven plots. Most of the chemicals were water soluble and applied as a drench to the root collar. The fumigants chloropicrin and vorlex were applied within polyethylene bottles buried around the root collar. These chemicals are released slowly through the porous polyethylene. Diameters of treated trees ranged from 3 to 6 inches and as such were primarily understory trees. Adjacent inoculum levels were kept as similar as possible. Tree mortality was monitored yearly, and diameter growth was measured on surviving trees after 10 years.

Let's look at tree mortality after 10 years. Only one treatment, captan at high concentrations (100 g/tree), significantly ($p=0.05$) reduced mortality over untreated trees. Some of the treatments appeared to exacerbate tree mortality due to Armillaria root rot. Tree mortality rate ranged from 30 to 70% of the trees killed over 10 years. Although it appears that mortality rates were higher in some plots than in others, the differences were not statistically significant. Except for the first two years where infected

trees were probably selected, mortality rate was fairly constant at about 5 to 6 trees per year.

Diameter growth rate of surviving trees after 10 years averaged 2.5 mm/year. This is an extremely slow growth rate considering the site index. There were no significant differences among chemical treatments or plots.

Fungus spread rate was measured by recording annually the mortality of trees from known infection sources. Spread rates averaged 1.7 ft. (0.5 m) per year and were not significantly different among plots or from year to year.

What does it all mean? It appears that chemical protection of small diameter pines generally does not work, except possibly for captan which may have some value in protecting pines from lethal attack in high value areas such as seed orchards ornamental plantings. More promising is the use of chemicals as eradicants rather than protectants where I did show that A. ostoyae can be eliminated from small diameter stumps injected with choloropicrin, volvex, vapam, methyl bromide, or carbon disulfide (Filip and Roth 1977).

Perhaps a better method of protection may be precommercial thinning, which on certain sites does significantly reduce crop tree mortality caused by A. ostoyae (Johnson and Thompson 1975).

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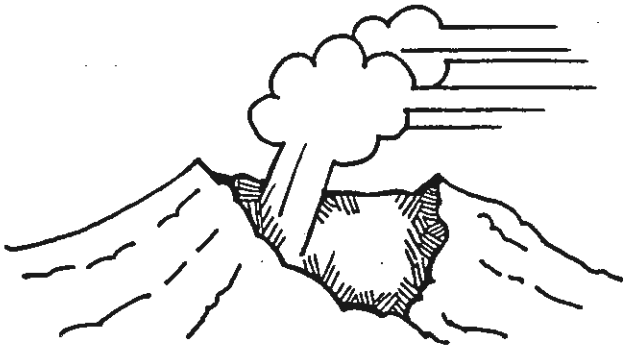

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## INFLUENCE OF SOIL ALUMINUM ON INCIDENCE OF ARMILLARIA IN DOUGLAS-FIR

J. E. Browning and R. L. Edmonds

ABSTRACT: The effect of soil Al, organic matter, and pH on the incidence of Armillaria root disease was studied for coastal and Cascade Mountain Douglas-fir sites in Washington. Armillaria disease incidence was found to decrease with increasing soil extractable Al. Soil organic matter and pH did not relate significantly to Armillaria incidence. Increasing Al was found to decrease the growth of Armillaria in culture.

### INTRODUCTION

Armillaria causes a root rot of conifers in the Pacific Northwest. It appears to be increasing in incidence as intensive forest management in the Pacific Northwest increases and it is particularly noticeable after precommercial thinning in Douglas-fir (Pseudotsuga menziesii Mirb. Franco).

The factors controlling pathogenicity of Armillaria are not well understood, particularly soil variables. The influence of pH is inconsistent. Some isolates grow well under acid conditions while others do not (Morrison 1982). Low soil pH has been found to favor disease development (Shields and Hobbs 1980).

Soil Al has been found to be toxic to some fungi. High Al levels reduced pathogenicity and growth of Phytopthora capsici from green pepper (Muchovej et al. 1980) and Verticillium albo-atrum and Whetzelinia sclerotiorum from sunflower (Orellana et al. 1975). Increasing Al concentrations also tended to reduce the growth of mycorrhizal fungi (Thompson and Medve 1984). Ko and Hora (1972) indicated that Al can act as a soil fungitoxin.

J. E. Browning is a graduate student and R. L. Edmonds is a professor of forest pathology at the College of Forest Resources, University of Washington, Seattle.

Tree species, on the other hand, tend to be tolerant to high levels of Al including Douglas-fir (Ryan 1983). It is difficult, however, to differentiate Al from pH effects since increasing Al levels are associated with decreasing pH.

This study was initiated to: (1) examine the relationships between soil pH, soil extractable Al and soil organic matter and the incidence of Armillaria root rot in a number of Douglas-fir forests in Washington, (2) determine the influence of pH and Al levels on the growth of isolates of Armillaria in culture, and (3) develop a system for delineating high hazard sites.

### METHODS

#### Disease Severity In Relation To Soil Chemical Factors

Thirteen sites where Armillaria was noted to be a problem were selected in coastal and Cascade Mountain locations in Washington. Three other sites where Armillaria did not occur were selected as "controls." Disease severity was ranked by estimating the number of diseased trees/acre. High sites had greater then 10 diseased trees/acre, medium sites had 5-10, and low sites had less than 5.

Soil samples were collected from the upper soil horizon and taken to the laboratory for analysis of extractable Al, organic C, and pH. Water extractable Al and 2N KCl extractable Al were determined on an IL 951 Atomic Absorption Spectrophotometer. Organic C soil samples were soaked in sulphurous acid then run on a Leco C analyzer. Soil pH was determined using a 1:1 soil : distilled water mix.

#### Influence of pH and Aluminum on Armillaria Growth in Culture

Soil extract medium--Isolates were grown in agar made from extract of the different soils to see if growth would vary. Soil extract agar medium with and without nutrients was used in this experiment. The nutrient medium was supplemented with 10 g of glucose and 1 g of $NaNO_3$ per liter. Petri plates were inoculated with three isolates of Armillaria and grown at room temperature for 30 days in the nutrient medium and 60 days in the un-amended medium. Five replicates plates were used. Diameter growth was measured in each plate.

Aluminum medium--Armillaria isolates were grown on 2% malt agar containing different amounts of Al to determine how Al and pH affects growth. $AlCl_3 \cdot 6H_2O$ salt was used as the Al source. Al concentrations of 0, 10, 25, 50, 100, and 200 µg/g was used in unbuffered medium. The media was inoculated with three isolates of Armillaria. Diameter growth was then measured after 30 days.

Buffered media with different concentrations of Al was made by using citric acid and trisodium citrate to buffer the media to a ph of 5.0. Al was added in the concentrations of 0, 100, 200, and 300 µg/g. KOH and HCl were used to adjust the final pH. The media was inoculated with plugs of three isolates of Armillaria. There were 10 replications of each treatment. The cultures were grown at 20°C for 30 days and diameter growth was measured.

### RESULTS

#### Relationships Between Armillaria Incidence and Soil Chemical Factors

Table 1 shows that sites with noticeable incidence of Armillaria in general had significantly lower concentrations of soil extractable Al (both 2N KCl and water) than sites with no

Table 1--pH, organic matter and extractable Al in soils from western Washington with high, medium, low, and zero incidence of Armillaria root rot in Douglas-fir.

| Site No. | Armillaria Incidence * | pH | Percent Organic Matter | 2N KCl Ext. Al (µg/g) | Water Ext. Al (µg/g) |
|---|---|---|---|---|---|
| 1 | High | 6.5 | 3.25 | 2.0 | 2.0 |
| 2 | High | 4.9 | 5.88 | 321.0 | 8.4 |
| 3 | High | 4.9 | 4.89 | 312.0 | 8.3 |
| 4 | Med. | 4.8 | NA | 15.0 | 0.5 |
| 5 | Med. | 4.7 | 4.69 | 136.0 | 11.3 |
| 6 | Med. | 5.0 | 12.55 | 577.0 | 20.1 |
| 7 | Med. | 5.8 | 6.09 | 109.0 | 28.6 |
| 8 | Med. | 4.9 | NA | 4.0 | 1.1 |
| 9 | Low | 4.5 | 6.23 | 433.0 | 31.8 |
| 10 | Low | 5.0 | 4.63 | 271.0 | 21.3 |
| 11 | Low | 4.0 | NA | 26.8 | 0.9 |
| 12 | Low | 4.8 | NA | 7.0 | 2.1 |
| 13 | Low | 4.8 | NA | 6.0 | 1.6 |
| | Average | 5.0 | 6.03 | 170.8 | 10.6 |
| | (Sd. dev.) | (0.61) | (2.81) | (192.9) | (11.2) |
| 14 | 0 | 4.3 | 11.2 | 1958.0 | 50.4 |
| 15 | 0 | 4.9 | 5.52 | 1075.0 | 37.8 |
| 16 | 0 | 4.9 | 9.4 | 632.0 | 62.6 |
| | Average | 4.7 | 8.71 | 1222.0 | 50.3 |
| | (Sd. dev.) | (0.33) | (2.90) | (675.0) | (12.4) |
| t-test significance | | NS | NS | 0.01 | 0.01 |

*High >10 infected trees/acre
Medium 5-10 infected trees/acre
Low < 5 infected trees/acre

incidence. There was no significant difference in either soil pH or organic matter between sites with and without Armillaria. A general increase in water extractable Al concentration was noted as severity of disease decreased.

Influence of Aluminum on Armillaria Growth in Culture

Average diameter growth of the three Armillaria isolates on the different un-amended soil extract agars is shown in Figure 1 along with equivalent water extractable Al concentrations. Armillaria diameter growth decreased with decreasing soil Al concentrations. Soil pH also tended to decrease as soil extractable Al increased. Armillaria growth on soil extract agar to which nutrients were added did not show a clear trend with increasing Al for any of the three isolates.

In both the non-buffered and buffered Al mediums, growth of the three Armillaria isolates decreased as Al concentrations increased. pH of the non-buffered media decreased with increasing Al concentrations.

## DISCUSSION

There appears to be a strong relationship between concentrations of soil extractable Al and incidence of Armillaria. In general, as Al levels increased disease incidence decreased. If concentrations of water and 2N KCl extractable Al were less than approximately 35 µg/g and 600 µg/g, respectively, disease was noticeable. Disease incidence was not related to pH or percent organic matter.

Unfortunately, only three sites were selected as healthy sites. It is difficult to select "control" sites since is is possible that susceptible sites might not yet be showing signs of disease because the

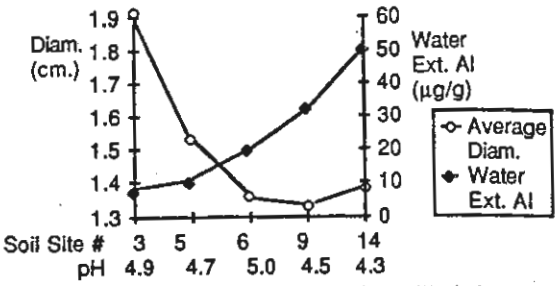


Figure 1--Average diameter growth of Armillaria in un-amended soil extract medium from 5 soils, in relation to water extractable Al and soil pH. Growth is average of 3 isolates after 60 days.

fungal inoculum is not present. Conclusions concerning disease incidence and Al levels may be spurious simply because of the selection of control sites.

Data from laboratory experiments indicate that Armillaria growth decreases with increasing Al concentrations. In both the un-amended soil extract agar and the unbuffered Al media growth decreased with decreasing pH.

Thus growth inhibition of Armillaria in culture appears to be related to increasing soil Al concentrations and decreasing pH. The data appear to support the field disease incidence data. If soil water extractable Al concentrations exceed 35 µg/g Armillaria is inhibited in its ability to attack Douglas-fir. Douglas-fir, on the other hand, can tolerate relatively high Al levels (Ryan 1983). Furthermore, the reason that hemlock appears fairly resistant to Armillaria could be because it typically occurs on soils with high extractable Al concentrations, at least in coastal Washington.

Preliminary conclusions from this study indicate that Armillaria growth is limited by high soil Al levels and that susceptible sites, i.e., those with low soil Al, can be delineated via soil analysis.

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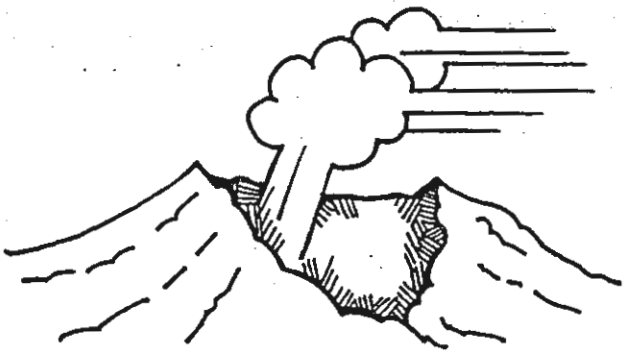

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## ISOZYME POLYMORPHISM IN FOMES ANNOSUS

William J. Otrosina

ABSTRACT: Isozymes from a total of 60 isolates of Fomes annosus obtained from pine and fir were analyzed by starch gel electrophoresis. A high degree of polymorphism was found among isolates as well as difference in allele frequencies between pine and fir, suggesting further studies employing this technique relative to host specialization in F. annosus.

### INTRODUCTION

Isozymes are an array of enzymes that attack the same substrate but are products of different gene loci. The procedure for analyzing isozymes involves electrophoresis of cellular extracts of the organism in the matrix of a gel material. These gels are usually starch or polyacrilamide. When an electrical current is applied to the gel, protein molecules (enzymes) usually migrate toward the anode and, after a given time, separate from one another according to their charge or molecular configuration. The gels are then placed in an appropriate solution containing a substrate on which the enzyme will act and a colorless dye which will precipitate as a colored product of the enzymatic reaction. These colored products are visible as bands on the gels, each appearing in characteristic positions and banding configurations according to the genes and alleles specifying them.

During the past 15-20 years there have been numerous studies involving application of isozyme techniques in the area of plant disease research. Many studies have been conducted using these techniques to attempt to delimit fungal species, forma specialis or pathological races. Often, conclusions from these studies either confirming or refuting the usefullness of this technique were based upon examination of a relatively few isolates or assay of a small number of enzyme systems (Burdon and Marshall, 1983). In the case of Fomes annosus, very few isozyme studies have been done and those which have been conducted suffer limitations mentioned above (Harris, et.al., 1974; Huttermann, et.al, 1979).

As pointed out by Burdon and Marshall, (1983), the study of population genetics of plant pathogenic fungi has been based largely on virulence studies because of a lack of suitable genetic markers. Only recently has isozyme techniques begun to be used as a tool for such studies.

Since experimental evidence based on inoculation studies exists for host specialization in F. annosus (Kuhlman, 1970; Worrall et al, 1983) studies are being conducted on the application and efficacy of isozyme techniques relative to the population structure and genetics of the fungus as they relate to host and geographic distribution. This paper presents preliminary results of isozyme studies on F. annosus designed to: 1) find suitable isozyme markers and 2) determine the nature of isozyme variability or polymorphism present in F. annosus and its efficacy for use in more detailed genetic studies relative to host and geographic distribution.

### MATERIALS AND METHODS

Fomes annosus isolates, obtained from various pine and true fir hosts in California, were grown for 2 weeks in potato dextrose agar. Plugs taken with a

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sterile cork borer from the actively growing margin of each isolate was inoculated into 250ml ehrlenmeyer flasks containing 100ml potato dextrose broth. Inoculated flasks were incubated in still culture on a laboratory bench at 22-24C for 2 1/2 to 3 weeks. Mycelium was harvested by decanting the flasks into a Buchner funnel on Whatman #1 filter paper under gentle suction and rinsed briefly with distilled water. A total of 60 isolates were assayed 38 from fir and 22 from pine. Enzyme extraction was performed by placing portions of each mycelial mat into small 0.3 $cm^3$ wells drilled into a lucite block, filling about 1/3 of the well volume with mycelium. (Otrosina, 1985). Approximately 0.1 $cm^3$ of chilled phosphate buffer was added to each well and the mycelium was then crushed with a glass rod for about 20 sec. per well. The blocks containing the mycelia in the wells were kept chilled with a cold pack during all phases of extraction. Filter paper wicks made from Whatman chromatography paper cut to 2mm x 10mm were placed in each well to absorb the extract. Wicks were gently blotted with absorbent tissue and then transferred to their appropriate tracks on starch gels. The gels were prepared prior to mycelial extraction according to methods of Conkle, et.al., (1982). Gel buffer systems Tris-citrate (pH 8.8), Tris-citrate (pH 8.3), morpholine citrate, (pH 6.1) and morpholine citrate (pH 8.1) were employed in all electrophoresis runs. The reader is referred to Conkle, et.al., (1982) for details relative to specific techniques employed in set-up of electrophoresis apparatus, and preparation of gels, buffers, and stains.

After loading, the gels were placed in a refrigerated compartment and the appropriate electrical current was applied to each gel. After 15 minutes, the current was cut off, the wicks were removed, and discarded; and the gels were replaced in the refrigerated compartment. A cold water bag was placed atop each gel to dissipate heat, current was reapplied and electrophoresis was allowed to proceed for 3 1/2 to 4 hours. The gels were then horizontally sliced and placed in the appropriate stain solutions for resolution of various enzyme systems. A total of 25 enzyme systems were assayed. Systems yielding relatively readable bands were used for scoring as individual genotypes. The genotype data were analyzed by Biosys-one,[1] and allele frequencies, heterozygosity and % polymorphic loci were determined.

## RESULTS AND DISCUSSION

Eleven loci distributed in 9 enzyme systems were found to produce clearly readable banding patterns, namely: glutamate oxaloacetate transaminase (GOT), alcohol dehydrogenase (ADH), aldolase (ALD), isocitrate dehydrogenase (IDH), malic dehydrogenase (MDH), sorbitol dehydrogenase (SRDH), aconitase (ACO), phosphoglucoisomerase (PGI), and peptidase (PEP). Two isozyme loci each were identified for MDH and PEP.

A summary of the genetic parameters calculated from allele frequencies is presented in table 1. A high percentage of loci assayed were polymorphic with an average of slightly over 3 alleles per locus. The existence of such polymorphism is essential for any additional, more detailed studies of this fungus relative to population genetics. It is interesting to note the somewhat higher percentage of loci polymorphic in pine isolates. Also, the direct count heterozygosity is greater in the pine isolates although these values are extremely low as compared to the expected values given by the Hardy-Weinberg equilibrium. These expectations, however, are based upon a number of assumptions (Wallace, 1981): 1) mating occurs at random between various genotypes, 2) dispersal of propagules to or from the population does not occur, 3) selection in the form of survival or fertility of different genotypes does not occur, 4) mutation does not take place and, 5) sampling errors resulting from finite population size do not exist. While these assumptions are unrealistic for fungi such as F. annosus, the large deviations from expected frequencies do point out that one or more assumptions are not valid and serve to identify underlying questions that need to be addressed. For example, in this study, sampling of isolates was extensive and results may have been confounded by geographic variability. Also, nothing is known about the variability of genotypes of the fungus in disease centers. Are there

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[1] Swofford, D. L. and Selander, R. B. 1981. A computer program for the analysis of allelic variation in genetics (users manual). Dept. Gen. & Dev., Univ. of Ill. Urbana.

Table 1. Summary of genetic parameters calculated from allele frequencies for pine and fir isolates of Fomes annosus

| Parameter | Isolate Origin | |
|---|---|---|
| | Pine | Fir |
| Heterozygosity (HDWB)[1] | 0.51 (0.08)[3] | 0.25 (0.07) |
| Heterozygosity (D.C.)[2] | 0.05 (0.02) | 0.02 (0.007) |
| Mean No. alleles/locus | 3.45 (0.49) | 3.09 (0.51) |
| Percentage of loci polymorphic(0.95)[4] | 81.82 -- | 63.6 -- |

[1] HDWB Expected frequency of heterozygotes according to the Hardy-Weinberg equilibrium.

[2] DC Actual frequency based on proportion of observed heterozygotes among all alleles.

[3] Numbers in parentheses represent standard errors.

[4] A locus is defined as polymorphic if the frequency of the most common allele is $\leq 0.95$.

several genotypes in a given center or one "clone"? If there are several genotypes in a disease center, how are they distributed? Do they vary in their pathogenicity? Specific studies need to be conducted regarding such questions.

In conclusion, this study does identify the existence of isozyme variability in F. annosus. Also preliminary evidence indicating interesting gene frequency differences between pine and fir isolates provides fertile ground for using this powerful technique to define possible host specialization in the fungus and to study underlying factors contributing to genetic variability.

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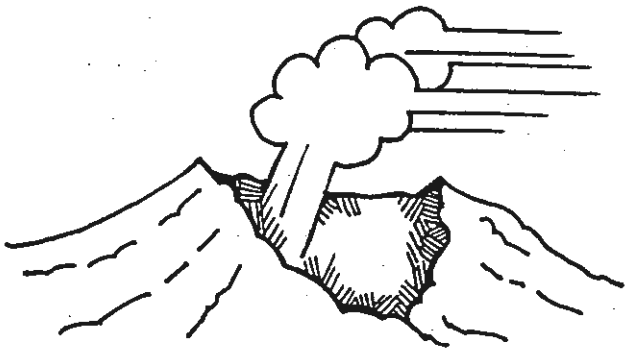

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## TRICHODERMA SPP: DISTRIBUTION IN PHELLINUS WEIRII--INFESTED STUMPS AND ROOTS AND ANTAGONISM IN VITRO

Barry Goldfarb, Earl Nelson, and Everett Hansen

ABSTRACT: Trichoderma spp. were found to be colonists of Douglas-fir stumps and root systems infested with Phellinus weirii. T. viride and T. polysporum were the most abundant species. These two species grew well in culture at 5-10° C and were efficient antagonists of P. weirii in vitro at 10° C.

### INTRODUCTION

Laminated root rot of conifers causes annual timber losses of 4.4 million cubic meters in northwestern United States and British Columbia (Nelson et al. 1981). The fungus, (Phellinus weirii (Murr.) Gilb.) kills trees while standing, or by weakening their root systems, increasing their susceptibility to windthrow. The fungus spreads between trees via root contacts (Wallis and Reynolds 1965). The disease persists on sites between rotations because the fungus can survive saprophytically in stumps of harvested trees for up to 50 years (Hansen 1979). Trees developing on infested sites become infected when their roots contact underground inoculum.

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The fungus is eventually replaced in woody residues by competing microorganisms. One strategy for breaking the disease cycle is to accelerate the replacement process by introducing an antagonistic fungus earlier than it would otherwise occur. Fungi of the genus Trichoderma Pers. are potential biocontrol organisms. Their parasitism of fungi in wood is well documented (Bliss 1951; Corke 1974; Dubos and Ricard 1974; Gibbs 1967; Komatsu 1976, 1984; Komatsu and Hashioka 1964; Munnecke et al. 1981). Trichoderma spp. frequently replaced P. weirii in naturally-infested wood blocks buried in soil (Nelson 1967). Trichoderma spp. were also frequently isolated from fumigated P. weirii-infested root systems (unpublished data). In initial trials, T. viride has been successfully established in the upper portions of P. weirii-infested Douglas-fir stumps (Nelson and Thies, in press).

In order to maximize the rate of replacement, more information was needed on the ecology and potential value of Trichoderma spp. in P. weirii-infested stumps. Specifically, we wanted to determine which (if any) species of Trichoderma are natural colonists of infested stumps, and which species have the greatest potential for replacing P. weirii in stumps and roots.

To answer these questions a three-part study was initiated.

1) A field survey was carried out to determine the species composition and distribution of Trichoderma spp. in infested stumps and roots.

2) A growth rate study was performed to determine if temperature requirements are important factors to consider in choosing species and isolates for inoculation.

3) In vitro antagonism tests were carried out to determine which species are most antagonsitic towards P. weirii.

### FIELD SURVEY

Thirty Douglas-fir stumps were selected on four sites in the western Cascades in Marion County, Oregon. Fifteen stumps were from trees harvested 11 years previously, and 15, one year previously. The four largest lateral roots on each stump were excavated with hand tools. Disks were cut with a chain saw from the stem and roots at regular intervals. Areas of wood apparently colonized by P. weirii (stain and decay) were outlined on the disks in the field.

In the laboratory ten random sampling points were chosen for each disk and the presence or absence of apparent P. weirii-colonization was recorded (decay class). Two wood chips were aseptically removed at each point. One was placed on malt agar (MA) and the other on MA plus one part per million (ppm) Benomyl (active ingredient). Organisms growing from wood chips were classified as Trichoderma spp., P. weirii, miscellaneous fungi, or bacteria.

Seventy isolates of Trichoderma spp. were obtained from 5970 sample points (1.2% recovery). From these, seven species were identified (Table 1). T. viride Pers. and T. polysporum (Link) Rifai were the most abundant species. T. viride was isolated from 36 sample points and T. polysporum from 19 sample points. No other species was isolated from more than five points.

The distribution of Trichoderma spp. in the stumps and roots differed from the distribution of the other groups of organisms. Trichoderma spp. were significantly more frequent in 11-year-old disks (1.7%) than in 1-year-old disks (0.6%) (Fig. 1). The differences in frequency of miscellaneous fungi and bacteria between the two age classes were not significant. Trichoderma spp. were also significantly more frequent in wood apparently colonized by P. weirii (1.6%) than in wood P. weirii had not colonized (0.6%) (Fig. 2). Miscellaneous fungi were significantly more frequent in wood P. weirii had not colonized, and the difference in frequency of bacteria between colonized and non-colonized wood was not significant.

The distribution of Trichoderma spp. within stumps and roots suggests a gradual invasion by these fungi (Fig. 3). In stumps, they were most abundant in disks closest to the stump top. In roots, they were most abundant in disks distal from the root collar.

GROWTH RATE STUDY

The growth rate study was undertaken to determine if growth rate at different temperatures is an important characteristic to consider when choosing biocontrol candidates. Each Trichoderma isolate collected in the field survey was tested four times at 5, 10, 15, 20, and 25° C for linear growth rate on MA. Each isolate was plotted on axes of two canonical variables created from linear combinations of the five growth rates (Fig. 4). The clear separation between species indicates a consistent characteristic growth response by each species to the temperatures tested. The species most likely to perform well in stumps and roots in similar environments are those which grow well at the lower end of the range of temperatures tested (5-10° C). When the growth rate of each species, at each temperature is

Table 1--Occurrence of Trichoderma spp. in P. weirii-infested stumps.

| Trichoderma species | No. of isolates | No. of stumps |
|---|---|---|
| T. viride | 36 | 12 |
| T. polysporum | 19 | 7 |
| T. aureoviride | 5 | 3 |
| T. harzianum | 3 | 3 |
| T. pseudokoningii | 3 | 2 |
| T. hamatum | 3 | 1 |
| T. longibrachiatum | 1 | 1 |
| Total | 70 | |

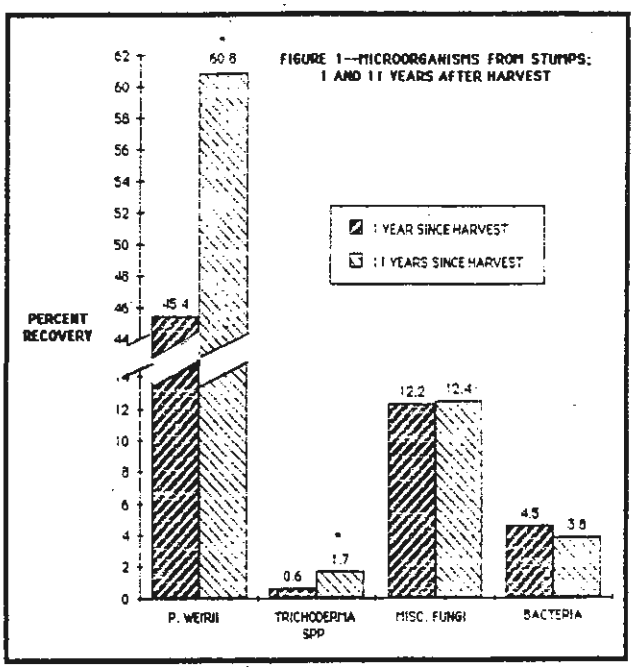


FIGURE 1--MICROORGANISMS FROM STUMPS: 1 AND 11 YEARS AFTER HARVEST

plotted against the mean of all the species at that temperature, it can be seen that T. viride and T. polysporum grew relatively well at the lower temperatures; T. harzianum and T. pseudokoningii grew best at the higher temperatures (Fig. 5).

IN VITRO ANTAGONISM STUDY

A laboratory test was needed to measure differences in the antagonistic effects of Trichoderma isolates on P. weirii. To simulate the field situation the test should measure the ability of different Trichoderma isolates to parasitize P. weirii in a previously colonized substrate.

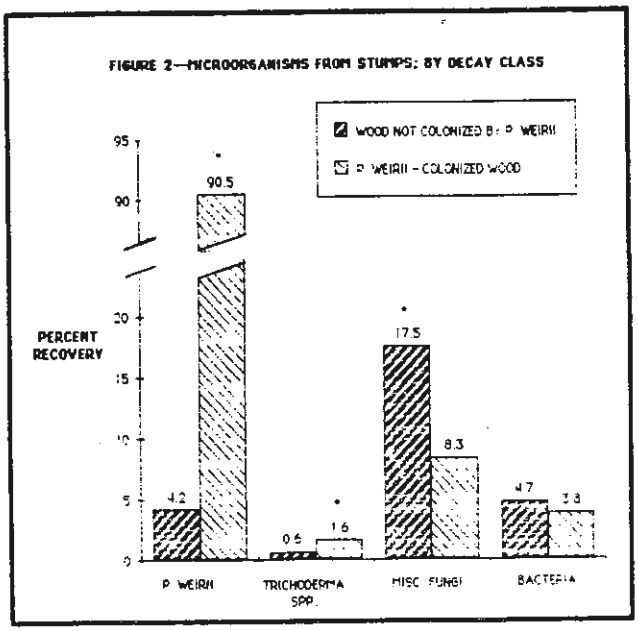
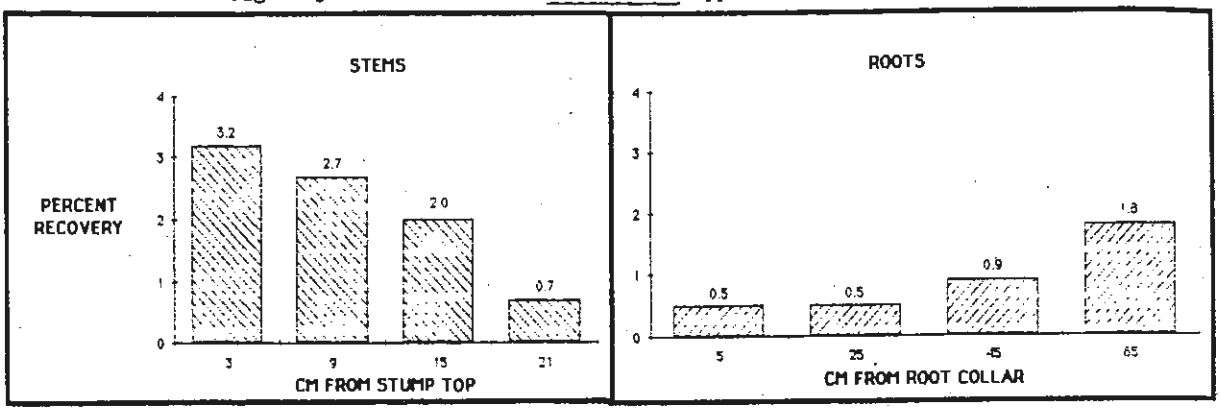
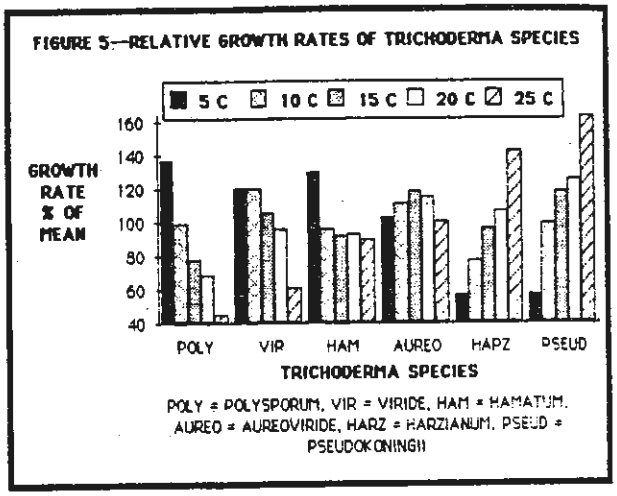


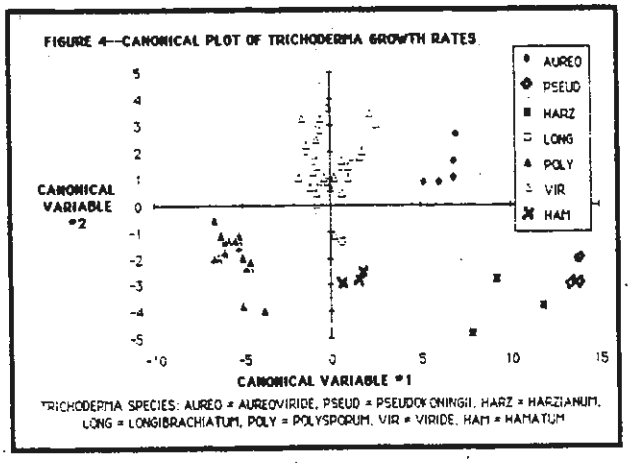
FIGURE 2--MICROORGANISMS FROM STUMPS: BY DECAY CLASS

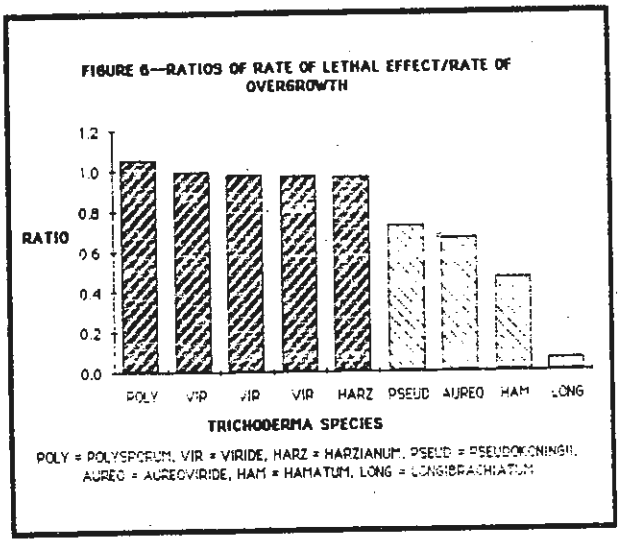
Figure 3--Distribution of Trichoderma spp. in stems and roots.




P. weirii was inoculated onto MA plates and allowed to grow until approximately 2/3 of the plate was covered. The test Trichoderma was then inoculated 10 mm from the advancing margin of the colony. After a period of interaction reisolations were attempted at fixed distances from the point of Trichoderma inoculation. At each distance paired plugs were cut with a sterile #1 cork borer and placed onto MA and onto MA plus 1.5 ppm each Benomyl, Proohloraz, and Thiabendazole (active ingredient). Preliminary tests had shown that this medium would allow for the reisolation of viable P. weirii in the presence of the faster growing Trichoderma. Paired reisolations permitted the measurement of the rate of colonization by Trichoderma, and the rate of lethal effect on P. weirii. Tests were run in triplicate at 10 and 20° C. Two isolates of P. weirii and nine isolates of Trichoderma were used. The latter included three isolates of T. viride and one each of the other species collected in the field survey.




Efficiency of antagonism was rated by comparing the ratios of the lethal effect to the rate of colonization (kill/col. ratio) (Fig. 6). Three degrees of efficiency were exhibited by the isolates tested. T. longibrachiatum was inefficient at killing P. weirii (kill/col. ratio = 0.06). T. hamatum, T. aureoviride and T. pseudokoningii were intermediate (kill/col. ratios = 0.46-0.72). T. harzianum, T. polysporum and the three isolates of T. viride were efficient antagonists. They killed P. weirii about as fast as they overgrew the colony (kill/col. ratio = 0.96-1.05).

Temperature affected the rate of lethal effect on P. weirii by Trichoderma isolates (Fig. 7). T. harzianum was the fastest killer at 20° C,

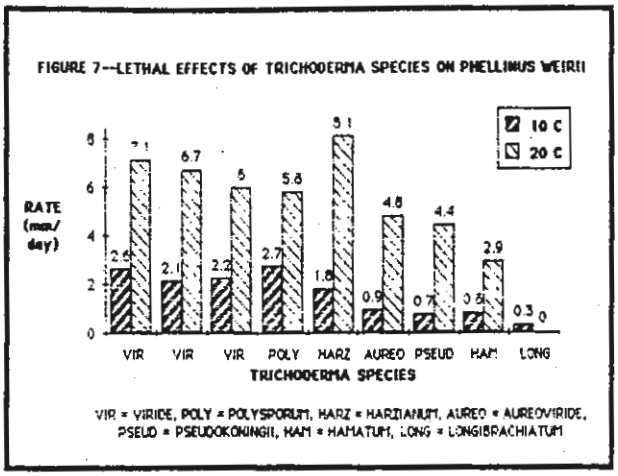


FIGURE 7--LETHAL EFFECTS OF TRICHODERMA SPECIES ON PHELLINUS WEIRII

but only the fifth fastest at 10° C. Conversely, T. polysporum was the fastest at 10° C and only the fifth fastest at 20° C. These differences were due largely to differenoe in growth rate of the fungi at the different temperatures; their ratios remained relatively constant.

## CONCLUSIONS

Trichoderma spp. are colonists of P. weirii-infested stumps and roots, but their abundance is low in the early stages of replacement. Their pattern of distribution suggests they are gradually invading, especially in P. weirii-colonized wood. Their presenoe indicates they are well adapted to the environment and therefore are likely biocontrol candidates.

T. viride and T. polysporum were the most prevalent species. This may be partly explained by their performance in growth rate and antagonism tests at lower temperatures. Isolates of these two species seem the most promising cadidates for field trials. T. harzianum could be considered for warmer sites.

Effecting biological control of P. weirii will require more study. It is hoped that this work will lay the foundation for the preliminary screening of large numbers of isolates to determine those which are the best candidates for further study, and eventually field trials.

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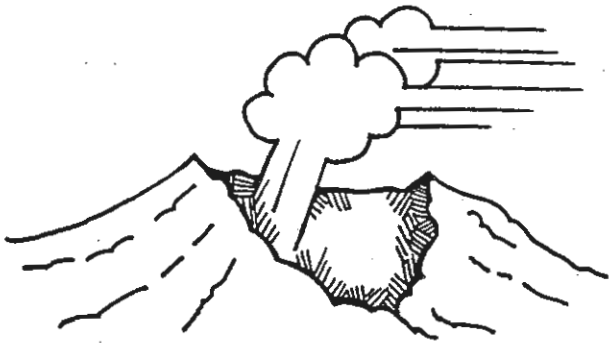

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# BULLDOZING TO CONTROL LAMINATED ROOT ROT--ANOTHER CONSIDERATION

Walter G. Thies and Everett M. Hansen

ABSTRACT: Bulldozing Phellinus weirii infested Douglas-fir stumps leaves broken infested root pieces in the soil. Longevity of the fungus in root pieces was tested by burying and later examining naturally infested roots on a site near Hoodsport, Washington. Eight years after burial the fungus could be cultured from 46% of the recovered pieces, the smallest of which was 1.3 cm in diameter. Removal of bark before burial did not cause the pathogen to be eliminated.

## INTRODUCTION

Laminated root rot is caused by a virulent root pathogen, Phellinus weirii (Murr.) Gilb, that can infect all commercially important conifer speoies in western North America. The disease, its distribution, and its impact have been discussed (Nelson et al. 1981, Thies 1984). Infection in a young stand begins when roots of developing trees contact residual infeoted stumps and roots of the preceding stand (Wallis and Reynolds 1965). Immediate replanting of an infested site with susceptible species nearly always results in continuation of the disease. A potential control being tested is the bulldozing of stumps from infested areas (Thies 1981). Bulldozing removes both the stump and much of the large root material. Bulldozing is hypothesized to reduce survival of P. weirii in residual roots by disrupting root integrity and thus allowing invasion by antagonistic soil-borne organisms.

In this paper we report our observations on the viability of P. weirii in root pieces buried as long as 8 years.

## METHODS AND MATERIALS

In the fall of 1976 P. weirii infested roots were collected from recently bulldozed fresh Douglas-fir stumps near Hoodsport, Washington. Roots were trimmed to a length of about 60 cm and were separated first by decay type and then into three classes based on midlength diameter. Decay types were (1) stain, in which stain, but not advanced decay, typical of P. weirii was visible on both ends of the piece; and (2) advanced decay, in which some degree of advanced decay typical of P. weirii was visible on both ends of the piece.

Groups of nine root pieces were designated for burial and observation in a nonorthogonal design so that the effects of burial time, root diameter, and bark protection on P. weirii survival could be examined. For each group three roots from each size class of a decay type were randomly selected. A total of 15 groups were established: 10 of stained roots and 5 of roots with advanced decay. One group each of stained roots and of roots with advanced decay were immediately assayed for viability of the fungus.

Root pieces were randomly assigned locations in parallel trenches 10 m long and 1 m apart. Root pieces were about 40 cm apart in the trenches and were buried 15 cm below the soil surface. Before burial, bark was removed from roots in two of the groups with advanced decay (18 pieces). At burial, group designation, burial location, length, and midlength diameter were recorded for each root.

A total of 117 root pieces 1.2-21 cm in diameter were buried in November 1976. In February 1979 three groups (27 pieces) were recovered: one group each in the categories stained, advanced decay with bark, and advanced decay without bark. The pieces were assayed for viable P. weirii. The remaining pieces were recovered (except six) and assayed in November 1984.

To assay for P. weirii each root was cut into sections. After the sections were split longitudinally, chips were aseptically removed from the split face, placed on 1.5% malt agar slants in culture tubes, and incubated at room temperature for 14 days. Presence of P. weirii was determined from morphological features of colonies (Nelson 1975).

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## RESULTS

P. weirii was isolated from each of the nine stained roots and the nine roots with advanced decay at burial time. Of all pieces recovered and assayed in 1984, 39 of 84 (46%) yielded P. weirii.

For individual roots, the volume of wood with viable P. weirii appeared to be nearly all or nothing. Of the 111 roots recovered and assayed in either 1979 or 1984, 58 had viable P. weirii; of these 35 roots had viable P. weirii in 100% of the sections, the remaining 23 had the fungus in 81%. Zone lines were observed in most pieces to have formed less than 1 mm below the surface of the wood with viable P. weirii adjacent to the zone line. This was true for sides as well as either cut or broken ends.

In general, the fungus survived better in large diameter roots than in small diameter roots. The mean diameter of 58 roots from which P. weirii was recovered was 7.5 cm, whereas the mean diameter of 53 roots from which P. weirii was not recovered was 5.3 cm. Of 66 roots $>5$ cm in diameter, 43 (65%) had viable P. weirii. Of 44 roots $\leq 5$ cm in diameter, 14 (32%) had viable P. weirii, the smallest being 1.3 cm in diameter.

Bark removal caused P. weirii survival to be reduced but not eliminated. Of roots with advanced decay, 17 of 18 with bark intact and 11 of 18 without bark yielded P. weirii.

Of roots without bark five of nine recovered in 1979 and six of nine recovered in 1984 yielded P. weirii.

## DISCUSSION

Many P. weirii-infested Douglas-fir roots, similar to those resulting from bulldozing of infected stumps, continued to harbor the pathogen for at least 8 years.

Bulldozing P. weirii-infested stumps leaves some infested roots in the soil. It has been generally assumed that these relatively small pieces of discontinuous food base, often with the protective bark covering disrupted, would be quickly invaded by soil borne organisms antagonistic to P. weirii, which would result in elimination of the pathogen. Our results show that although bark may aid survival of P. weirii, its removal does not necessarily result in rapid elimination of the pathogen.

We observed that in most roots in which P. weirii survived, a zone line formed about 1 mm below the wood surface and the fungus could be isolated immediately inside the zone line. Contrary to expectations, we did not detect the fungus being progressively eliminated from the root pieces starting at the cut or broken ends. Survival of P. weirii may be less a function of the size of root or presence of bark than of the physiological state of the fungus at the time of root disruption.

Long-term survival of P. weirii in roots of undisturbed stumps is well documented. Wallis and Reynolds (1965) found that 82% of roots from infected trees harbor the fungus as long as 11 years. The fungus survived in roots as small as 1.5 cm. Hansen (1979) found P. weirii alive in roots as small as 1 cm in diameter after 20 years but only in roots larger than 10 cm in diameter after 50 years. Our study confirms these earlier observations of P. weirii longevity and survival in small root pieces (as small as 1.3 cm in diameter) and extends their applicability to relatively small pieces of broken infested roots.

Although bulldozing is still probably the best direct method of reducing P. weirii inoculum on a site, it must be done with the knowledge that good technique is important. Infested roots not brought to the surface may remain as a source of inoculum for the next generation.

## ACKNOWLEDGMENTS

Our thanks go to Simpson Timber Co. of Shelton Washington for research support. We also thank Harlan Fay for technical support and Michael McWilliams and Joe McNeil for field assistance.

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**Infoman: A computer program for managing Extension Information.** Brown, R.A. and F. A. Baker. Department of Forest Resources, Utah State University, Logan, UT 83422.

The INFOMAN computer program is written in Turbo Pascal for MS-DOS and CP/M operating systems. A minimum 64 K memory and 2 disk drives are required. INFOMAN displays a series of menus from which users may view and/or print the desired graphics or text, or run other computer programs. INFOMAN records in a file each access and printing of an information packet.

Along with the INFOMAN program, the package includes an editor to create and modify menu files, a program to [convert Wordstar files for use with INFOMAN, a program to create graphics screens using the keyboard or a mouse, and a program to summarize the number of times a file has been viewed or printed. The system of programs is being field tested.

AIR POLLUTION IN THE PACIFIC NORTHWEST?

Tony Basabe and Robert L. Edmonds

ABSTRACT: Air pollution problems in forests in the U.S. have been thought to be confined to California and the Northwest. The major pollutants are the gases ozone and sulfur dioxide. Pacific Northwest forests are thought to exist in a pristine area with respect to air pollution. Ozone has been monitored at several locations along the I-5 corridor and can be similar to those in Los Angeles. Levels near the Cascade Mountains at Sumner and Lake Sammamish (160 ppb) may be higher than those in cities like Everett and Seattle. These levels are known to cause problems with trees but we know little about levels affecting Northwest tree species. The potential clearly exists for the Pacific Northwest to have air pollution problems in the future.

TONY BASABE is a research assistant and ROBERT L. EDMONDS is a professor of forest pathology, University of Washington, Seattle.

RELATIONSHIP OF INOCULUM LEVEL OF MACROPHOMINA PHASEOLINA TO DISEASE INCIDENCE IN SEEDLINGS OF THREE CONIFER SPECIES

Arthur H. McCain

Macrophomina phaseolina (Tassi) G. Gold causes charcoal rot of conifer seedlings throughout the United States. The disease is most destructive in growing areas with high summer temperatures. The fungus has a wide host range and survives in the soil as sclerotia which are resistant to drying and high temperatures. Soil solarization is not effective in controlling the fungus. Chemical fumigation with methyl bromide-chloropicrin combination is effective but mycorrhizal fungi also are destroyed. Solarization adequately controls other soil-borne pathogens such as Pythium spp., Phytophthora spp., and Fusarium oxysporum while leaving a population of mycorrhizal fungi. There likely is a level of M. phaseolina that is not harmful. Once this level is established, sampling of soil and determination of the numbers present will enable the nursery manager to decide on which treatment to employ. The purpose of this study was to determine the relationship of inoculum level of M. phaseolina to disease incidence.

Sclerotia of M. phaseolina were incorporated into field soil prior to sowing stratified seeds of Abies concolor, Pinus lambertiana and Pseudotsuga menziesii. Five inoculum levels in soil were obtained; 0, 0.1, 1.0, 10 and 100 sclerotia/gram. Disease severity was proportionate to the number of sclerotia in the soil and was greatest in A. concolor and least in P. lambertiana.

Sclerotia were produced on autoclaved, chopped alfalfa hay and concentrated by wet sieving. Sclerotia were collected from the 0.045 mm sieve. A thick suspension containing $2.2 \times 10^3$ sclerotia/ml was mixed with the top 10 cm of soil in subplots 0.13 m x 0.15 m. The high inoculum level (100 sclerotia/g) subplots received 300 ml of the sclerotial suspension and the lowest inoculum level (0.1 sclerotia/g) received 0.3 ml. Sclerotia were added to the soil on April 25, 1984. Seeds were sown on May 7 and 8, 1985. A soil sample was taken from each of the 6 replications at sowing. Stand counts and mortality were recorded periodically. Isolations from dead seedlings consistently resulted in recovery of M. phaseolina. The surviving seedlings were lifted in January 1985 and weighed.

ARTHUR H. MCCAIN is an extension plant pathologist in the Department of Plant Pathology at the University of California, Berkeley, California.

## PEST MANAGEMENT OF LODGEPOLE PINE STANDS IN BRITISH COLUMBIA

P. Humphreys, J. Muir, and P. Hall

To achieve optimal yield at the earliest rotation age, forest management must encompass pest problems occurring at various stages in the development of lodgepole pine stands.

Clearcut logging operations facilitate control of two major lodgepole pine pests: dwarf mistletoe from adjoining stands can be controlled by designing cut blocks along natural or man-made borders; and mountain pine beetle infestations can be prevented by harvesting trees before they reach their most susceptible age (80 years or over) and diameter (24.5 cm or over). Stands already infested with mountain pine beetle should be salvage logged before the next flight period to prevent expansion of infestation.

Following logging, mechanical scarification can be used both to provide a favourable seedbed and to remove dwarf mistletoe-infected residuals and advanced regeneration.

In areas with large amounts of logging debris, controlled burning can be used to destroy dwarf mistletoe-infected residuals, and in some cases to prevent the build up of secondary bark beetles such as Ips pini (Say).

Regulation of stocking density can be used to prevent or reduce pest damage. Snowshoe hares clip and girdle young saplings in areas where they find adequate cover. Thinning may be beneficial in reducing such damage. Lodgepole pine terminal weevil, Pissodes terminalis (Hopping), seems to do less well in close-spaced stands. Spacing often must be a compromise between that which promotes rapid tree growth, and that which is necessary to control an important pest problem. Other stem diseases such as western gall rust, Endocronartium harknessii (Moore), stalactiform blister rust, Cronartium coleosporioides (Arth.), and atropellis canker, Atropellis piniphila (Weir), may be reduced by selective removal in the course of juvenile spacing operations.

Careful planning and site-specific prescriptions are necessary to anticipate pest problems and prescribe effective management for the development of individual pine stands.

## TRICHODERMA VIRIDE--A POTENTIAL BIOLOGICAL CONTROL FOR LAMINATED ROOT ROT

Earl E. Nelson and Walter G. Thies

Trichoderma viride Pers. was successfully established in Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) stumps of trees harvested one year earlier by placing either spore/nutrient pellets or colonized birch (Betula) dowels in holes drilled 30 cm vertically into the stump top. One year later, stumps were dissected and sampled for Trichoderma spp. at predetermined points.

Three tested isolates of T. viride were equally effective in colonizing stumps. Pellets were significantly better inoculum than were dowels.

When noninfested, stained, and decayed stumps were inoculated with a pellet mixture of the three isolates, Trichoderma spp. were isolated from 48% of points sampled in decayed stumps, 12% in stained stumps, and 2% in noninfested stumps.

When stained stumps were inoculated with the same pellet mixture, stump colonization was best in October (29%), less in February (24%) and least in June (12%).

In all cases colonization of stumps increased with: (1) proximity to stump top, (2) proximity to the inoculum, and (3) extent of decay where the sample chip was taken.

Our conclusions are: (1) Trichoderma viride can be established in stumps infested with P. weirii; (2) colonization of stumps is more successful when advanced decay is present and when inoculations are made in late winter or early autumn rather than in late spring; (3) Stump colonization is more nearly complete in upper than in lower portions of stumps; and (4) better colonization of lower stump and major roots is requisite to successful biological control.

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## DISORDERS AND DISEASES OBSERVED DURING A SURVEY OF NOBLE FIR CHRISTMAS TREES IN WESTERN WASHINGTON AND OREGON.

Gary A Chastagner and John M. Staley

During May and October 1984, 52 plantings of Noble fir (Abies procera Rehd) in western Washington and Oregon were surveyed to determine the prevalence and distribution of diseases. Fifteen systematically selected trees, 1.5 - 2.5 m in height were examined in each planting. Yellowing of older needles during late summer and early fall, and subsequent loss of interior needles was the most common symptom observed. Approximately 80% of the trees sampled had some yellowing and loss of older needles. In most cases only the oldest needles were involved, but in a few instances all but current season needles were yellow, making the trees unmarketable. The second most common condition observed was necrosis or burning of current season needles. Symptoms varied from totally necrotic needles to needles with necrotic bands. This condition was observed on trees in all but two of the plantings. During May, 12% of the trees sampled had this symptom while 23% were symptomatic in October. Symptoms tended to be more common on current season needles in the upper portion of the trees. Isolations and histological examination of needles suggest that both the yellowing and needle necrosis were physiological in nature rather than fungus related. Two fungus related problems were also observed. Grovesiella or Grovesiella-like cankers were found in 10% of the plantations examined and approximately 2% of all trees sampled showed disease symptoms. On larger trees, branches had sunken cankers with prominent distal overgrowth. Similar cankers were found on the main stems of smaller trees. Flagging distal to the canker was the most obvious symptoms observed. The presence and abundance of apothecia associated with cankers was highly variable. In the area surveyed, Grand fir (A. grandis (Dougl.) Lindl.), Shasta (A. magnifica A. Murr) and white fir (A. concolor (Gord. & Glend.) Lindl.) were also observed to have this disease. Twig dieback was also more prevalent in plantings with Grovesiella canker and may be an early symptom of this disease. Interior needle blight was observed on trees in 10% of the plantings. Two percent of all trees sampled were symptomatic in May while 4% were symptomatic in October. Symptoms were most prominent during fall and consisted of brown older needles, most commonly on the lower branches. In most cases, trees were unmarketable. A Dothideaceous fungus was observed to be associated with symptomatic needles.

Gary A Chastagner and John M. Staley are Assoc. Plant Pathologist and Agr. Res. Tech. II, respectively, at Washington State University's Western Washington Research and Extension Center, Puyallup.

## STEM CANKERS ASSOCIATED WITH MELAMPSORA NEEDLE RUST ON DOUGLAS-FIR AND FUNGICIDE CONTROL OF NEEDLE INFECTIONS.

Gary A Chastagner, John M. Staley, and Ralph S. Byther

During June 1984, stem cankers associated with needle rust, caused by Melampsora occidentalis, severely damaged Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) Christmas trees in several plantations near Puyallup, Washington. Lesions frequently developed at the bases of heavily rusted needles, which later dropped off. In a few instances developing lesions were not associated with needle scars. Pycnia and aecia were produced on a few lesions and mycelium with conspicuous orange colored oil drops was also seen in some developing lesions which had not produced pycnfa and aecia. Aecia were not generally found on older lesions which contained mycelium lacking conspicuous oil drops. Lesion development distorted or killed entire shoots making trees unmarketable. Observations during 1984 and inoculations during 1985 indicated that under conditions favorable for infection, the development of stem lesions was dependent on distance from inoculum. Highest levels of needle infection and stem lesions developed on trees and shoots nearest to the inoculum sources. Rust resistant trees among severely cankered trees did not develop cankers. During 1985, a single application of triadimefon (0.3 mg ai/ml), triforine (0.24 mg ai/ml), ziram (1.8 mg ai/ml), ferbam (1.8 mg ai/ml), bitertanol (0.3 mg ai/ml) or propiconazol (0.16 mg ai/ml) reduced the level of diseased needles to less than 5 per shoot compared to the 43 per shoot observed on nonsprayed trees. Applications were made when there was approximately 3 cm of new shoot growth. Mancozeb (1.8 mg ai/ml), anilazine (2.4 mg ai/ml), zineb (1.8 mg ai/ml), fenarimol (0.15 mg ai/ml), oxycarboxin (0.9 mg ai/ml), and chlorothalonil (2.5 mg ai/ml) reduced the level of diseased needles to 10.5 to 15.7 per shoot and benodanil (1.2 mg ai/ml) reduced diseased needles to 26.4 per shoot. Cycloheximide (0.03 mg ai/ml) was phytotoxic, killing 8 of 9 trees. Applications of triadimefon after initial lesion development, limited further lesion development but did not provide acceptable control. Removal of infected cottonwood (Populus trichocarpa Torr. and Gray) trees adjacent to affected Douglas-fir during June 1984 controlled needle infections and subsequent lesion development in 1985.

Gary A Chastagner, John M. Staley and Ralph S. Byther are Assoc. Plant Pathologist, Agr. Res. Tech. II, and Extension Plant Pathologist, respectively, at Washington State University's Western Washington Research and Extension Center, Puyallup.

## White Pine and Blister Rust Management

Kenelm Russell

POSTER ABSTRACT. Three white pine plantations were pruned to minimize infection by blister rust. I compared rust incidence when pruning was done at ages 14 and 18 with a plantation pruned continuosly after establishment. Two plantations are located near Olympia, WA and the third in the Columbia River Gorge near Stephenson, WA. Seed source for the three plantings was Port Orchard, WA (Webster), unknown (Stephenson) and western Montana (Mima). The data below leaves little doubt that early pruning keeps blister rust away.

BLISTER RUST INCIDENCE IN PRUNED PLANTATIONS

| | No. of Trees | Age | HT (ft) | Age Pruned | % Rust | Ave canker Ht (ft) |
|---|---|---|---|---|---|---|
| Webster | 146 | 5 | 5 | 2&5 | 0 | - |
| Stephenson | 52 | 15 | 31 | 14 | 46 | 3.4 |
| Mima | 150 | 23 | 36 | 18 | 49 | <6.0 |

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Recommendations

* Know the rust hazard for the site
* Select appropriate seed source (elevation and resistance)
* Prune early to keep lower trunk free of needles. Prune to at least 6 feet in two or more prunings in the first 10 years.

## Laminated Root Rot Control With Red Alder

Kenelm Russell

POSTER ABSTRACT. Red alder was planted in a mix with Douglas-fir following logging to attempt to reduce laminated root rot in a new fir stand. Paired plots containing either an equal mix of red alder and Douglas-fir or pure fir were planted in known laminated root rot infection centers at 4x4 foot spacing. The planting was established in 1972 in the Capital Forest about ten miles southwest of Olympia.

After six years, laminated root rot mortality was 6.0 percent on the pure fir plots and only 3.7 percent on the fir-alder mix plots. After ten years, root rot mortality was nearly the same for each plot type (8.8 percent- pure fir and 8.3 percent- alder-fir).

CONCLUSIONS. It is early in the project life, but at this point it does not appear practical to plant alder - Douglas-fir mixes to reduce root rot. Better alternatives include planting and growing a short rotation of pure red alder, pushing the stumps and replanting with Douglas-fir, or leaving the stump and planting with a root rot tolerant conifer like western red cedar or western white pine.

## Thirty Years of Laminated Root Rot in a Douglas-Fir Stand

Kenelm Russell

POSTER ABSTRACT. Laminated root rot progress was followed and mapped in a second growth Douglas-fir stand since 1967. Earlier infections date prior to 1957. In 1967 the root rot occupied about 20 percent of the 1.15 acre stand in 10 small root rot centers. By 1985, the root rot had merged into five centers occupying more than 50 percent of the stand. No slowdown is anticipated and many new infections were discovered. The root rot expanded about 2.5 times over a 20 year period.

## Swiss Needle Cast Control

Kenelm Russell

POSTER ABSTRACT. Three Douglas-fir forest plantations in western Washington were helicopter sprayed with three fungicides to control Swiss needle cast. The trees were chlorotic and suffering about 30 percent growth loss expressed as a portion of leader potential. The fungicides were Manzate 200 and Dithane M45 at 3 lbs per acre plus spreader-sticker in 8 gallons of water and Bravo at 0.5 and 1 gallon per acre in 10 gallons of water.

After three years of spraying, Bravo performed best with infection generally remaining at low levels compared to the checks. It was not possible to tell if the one gallon rate was better than the half gallon rate. There was a fair amount of variability in results, probably because of the height of the trees. The uneven crowns were quite different than the uniformity of a Christmas tree plantation where more even control could be expected. Infection intensity was definitely reduced but recovery of height growth can be argued.

Careful evaluation is necessary before operational sprays are done. It is best to spray when trees are shorter which may reduce the variable results.

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Forest Pathologist. Washington State Department of Natural Resources. Olympia, WA.

# BUD DEFECTS IN WINTER-DAMAGED COLORADO SPRUCE

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Bud defects were observed on 1985 winter-damaged Colorado spruce, Picea pungens Engelm. trees of marketable size in Alberta nurseries. Colorado spruce was also damaged in Saskatchewan and Manitoba nurseries. The trees had a history of winter damage (e.g. die back and bud kill) and random epicormic bud formation. Epicormic buds varied in number, shape, and size and formed individually, in pairs, and rosettes in lateral and terminal positions and on existing nodes.

Bud dissections showed that two-out-of-three epicormic buds were winter-killed or defective in viability. Majority of the buds were defective (partially viable and non-viable). The partially viable ones had variable needle primordia and the non-viable ones had no primordia and in extreme cases no dome or bud trace. The partially viable one produced needle rosettes with little or no stem elongation, a reduced number and size of needles on spindly shoots, and deformed needlea that remain permantly enclosed by scales. The number of buds that malfunctioned and reduced rejuvenation capability of trees varied from 38 to 56 percent within a standing crop of Colorado spruce.

Defects in epicormic buds were not caused as much by winter damage as by its after-effects on growth and development. Growth and development of buds was slower, random, and late season. Buds frequently failed to develop a bud trace and a full complement of primodia and scales. Defective buds with few needle primordia were slower flushing because of their inability to cast-off scales. Growth waa stunted in leading and first order lateral shoots. Defective buds lacking needle primordia opened up without casting-off the outwardly curled scales. New epicormic buds developed and formed a rosette in the axes of the scales. Individual, paired, and rosette bud formation also occurred in the internodal areas of the shoot.

Past history of winter damage and subsequent formation of epicormic buds can be determined by examining nodal and internodal areas of living and dead shoots. Tree form and vigor can be improved by early diagnosis and corrective measures for winter damage and its after-effects.

## BUSINESS MEETING - MINUTES

The business meeting was called to order in the name of Chairman Fields Cobb, by acting chairman Walt Thies at 10:30 a.m. on September 24, 1985. A summary of pertinent points is presented here.

The 1986 meeting will be held in Juneau, Alaska September 8 - 12, at the Centenial Hall, a block of rooms has been reserved at the Prospector Hotel. Tom Laurent will coordinate finding bag space for interested graduate students. Elaine Loopstra will coordinate ferry trips.

Appreciation was expressed to Frank Hawksworth and Bob Gilbertson for putting together the list of common disease names. Copies were sent to conference members last winter but additional copies are available from Frank.

It was announced that the 5th International Congress of Plant Pathology will be in Kyoto, Japan in 1988. Suggestions for the forest pathology section should be sent to Dr. Yasu Hiratsuka.

Neil Martin made a memorable presention to Ken Russell of a "special compass" from the conference in appreciation of an extended impromptu tour of downtown Tumwater, Washington, on the way to the first field trip stop on Thursday.

Reports were given by the Interim Program Chairman and by the standing committees: Dwarf Mistletoe, Disease Control, Root Disease, and Rust. Their written reports are presented elsewhere in these proceedings.

OLD BUSINESS

The minutes and treasurer's report from the 1984 conference were approved as printed in the proceedings. It was noted with appreciation that although we elect a secretary-treasurer each year Ken Russell has, in effect, been our conference treasurer for the last 12 years. Ken stated that he is willing to continue in that role.

The following recently retired members of the conference were added to the list of Honorary Life Members: Paul Aho, Bob Bega, Tom Hinds, and Tom Laurent.

WIFDWC Name Change - At the 1984 meeting it was proposed that "International" be dropped from the conference name. The motion was tabled to allow members more time to gather facts and to evaluate the proposal. At the chairman's request, Bob Scharpf summarized the arguments for a name change while Jim Hadfield summarized the arguments against a change. The arguments for change are primarily that the current name is misleading and thus results in a hassle for U.S. Federal Employees to get permission to attend this conference. The primary arguments against change are first, tradition, and second, Federal Travel Regulations do not base approval to attend on the name of the conference, thus the current name has little final impact on approval. After considerable discussion the motion was MSA that the name not be changed. The conference will continue to be called the Western International Forest Disease Work Conference.

NEW BUSINESS

Posters were discussed. Considerable support was expressed for continuing, and expanding the poster sessions.

The practice of offering graduate students a discount on registration was discussed. There was considerable support for helping and encouraging graduate student participation in the conference. It was suggested that a fee reduction might be coupled with an advanced student registration to ease the problems of planning and projecting a budget for the conference. It was agreed not to establish firm rules but, for now, to allow the Executive Committee of each conference to decide how to best encourage graduate student participation.

Rich Hunt gave a report on the field trip and the Forest Pathology Section meeting of the APS meeting. The idea was raised by Rich and echoed by many others that we need to encourage the participation of Forest Product Pathologists in our conference.

The idea of a conference logo was raised but died for lack of discussion or audible (or visible) motion in support of same.

The use of luncheon gatherings during the conference to provide additional interaction time and time for committees to meet was discussed. A consensus developed that the luncheons were important but that separate committee sessions were somewhat less important. It was decided to let future Executive Committees experiment with format.

Meeting Location 1987 - John Laut proposed someplace in Colorado; Janna Kumi proposed Nanaimo, B.C.; Fred Baker proposed a site near Park City Utah. After some discussion Nanaimo, B.C. was selected.

Executive Committee 1986 - The nominating railroad, run this year by Bob James, arrived promptly at 11:37 to recommend Ken Russell as Chairman and Sally Cooley as Secretary-Treasurer. To spare the need for further discussion or decision making the conference unamimously accepted the recommendations. Chairman Russell subsequently appointed John Laut Program Chairman for the 1986 meeting in Juneau, Alaska.

# INTERIM PROGRAM CHAIRPERSON'S REPORT

Paul Hennon

The following are topics for panels and papers that were suggested for the 1986 WIFDWC meeting in Juneau, Alaska.

Suggested Topics for Panel Discussions:

1. Diagnosis and control of abiotic disorders of forest trees, emphasizing nutrient deficiency.
2. Roundtable discussion on the "impact" of dwarf mistletoes covering the "hemlock dwarf mistletoe controversy" and major species across geographic ranges.
3. Western hemlock diseases and management: Fomes annosus and hemlock dwarf mistletoe. Are they a problem? If so, where? Divergent views of Alaska, British Columbia, and Oregon-Washington? Reconciliation or resolution?
4. Forest products problems (e.g. wood decay); this topic would help integrate forest products workers and pathologists.
5. White pine blister rust control/management.
6. Disease resistance (genetic): e.g., white pine blister rust, Armillaria spp., and biotechnology research.
7. The control of forest diseases with silvicultural treatments.
8. Is there a future for forest nematology? (Jack Sutherland could chair this panel).
9. Panel of the "alumni" to discuss the history of a particular disease, trends in forest pathology, or any other topic.
10. Panel discussions should focus on narrow subject areas, have more interaction among panelists, and encourage subsequent audience participation.

Suggested Topics for Papers:

1. Have a session on visual aides; they have ranged from very good to lousy at our meetings. Suggest a brief workshop (with handouts) by a specialist on the preparation of slides, tables, posters, etc.
2. Special paper by a librarian on the use of libraries and the new Forest Service data base for literature.
3. Discuss disease and insect problems on the last frontier (Alaska).

Other Suggestions:

1. Have a "hospitality room" open during evenings for discussions, poster viewing, etc.
2. Reduce the registration fees for graduate students (supported, as well as unsupported? retirees?).
3. Include banquet and meal fees in the registration fees.
4. Registration fees could be paid in advance as an option.
5. Have local arrangements set up housing in private homes or youth hostel for students.
6. Pre- or post-WIFDWC field trip to view and discuss hemlock dwarf mistletoe in British Columbia and southeast Alaska.
7. "We must somehow return to discussion of work, problems, solutions, etc. as opposed to the current trend of presenting research papers. If we continue that trend, we will end up as a little A.P.S., and WIFDWC will have outlived its purpose. The program format must be innovative and encourage informal, indepth discussions (e.g., this year's Armillaria workshop)."

## ADJUSTED TREASURER'S REPORT, THIRTY-SECOND WIFDWC

NOTE: There are always some little changes after we print the proceedings. An adjusted report is the best way to "leave tracks". Changes from last year show proper recording of Harold Offord's gift and a slight reduction in cost of proceedings.

| | | |
|---|---|---|
| Balance on hand at close of thirty-first meeting: | | $553.63 |
| Interest paid July 1, 1983 through June 30, 1984 | | 54.12 |
| Sale of extra proceedings by mail from Olympia (4) | | 37.00 |
| Gift from Harold Offord (10/84) | | 20.00 |
| Binding cost for proceedings in historian's file (Duncan Morrison, Victoria) | | -43.03 |
| sub total | | 601.72 |

Thirty-second WIFDWC statement:

| | | | |
|---|---|---|---|
| Receipts: | (73 people) | 3879.00 | |
| | Interest on temporary local acct. | 15.62 | |
| | sale of old proceedings (6) | 60.00 | |
| sub total | | 3954.62 | |
| Expenses: | Meeting | 2667.34 | |
| | Printing proceedings | 665.89 | |
| | Cable cost for US $ to Canada to pay for proceedings | 20.00 | |
| sub total | | 3353.23 | |
| Balance of thirty-second expenses | | | 601.39 |
| Balance in account, close thirty-second meeting | | | 1223.11 |

As of July 1, 1984, Uncle Sam deducted ten percent of earned interest from all deposits to help repay the US debt. The new law requires deposit holders to withold such and send it to IRS. In the first quarter of our accounting year the Credit Union deducted $3.99 - our contribution to keeping the government alive.

This has required a tax number for our account (Fed. Tax No. 91-1267879). So far it is not too complicated, and eventually we will get the money back since I told them we were a nonprofit scientific organization. It will show up as returned interest on future reports.

Official signatures for withdrawing funds from WIFDWC account as of October 31, 1984 are Ken Russell, Walt Thies and Fields Cobb.

Ken Russell, October 31, 1985

# TREASURER'S REPORT, THIRTY-THIRD WIFDWC

| | | |
|---|---|---|
| Balance on hand at close of thirty-second meeting: | | $1223.11 |
| Interest paid July 1, 1984 through June 30, 1985 | | 52.06 |
| Gift from Harold Offord (10/85) | | 25.00 |
| 1984 proceedings sales @ $5.00 each + | | 105.75 |
| Common Names book sales @ $1.00 ea. (100 to PFC, 198 USFS, 17 Misc. sales) | | 315.00 |
| Advance reservation for Juneau Conference Center | | (200.00) |
| Federal withholding on interest, last quarter 1984 | | (3.71) |
| Printing 500 Common Names Handbooks ($639.11 Can) | | (472.75) |
| Shipping Common Names books | | (26.90) |
| sub total | | 1012.56 |

Thirty-third WIFDWC statement

Receipts: 100 people

Registration included travel, meals, meeting rooms, both speaker and special order mugs and computer rental.

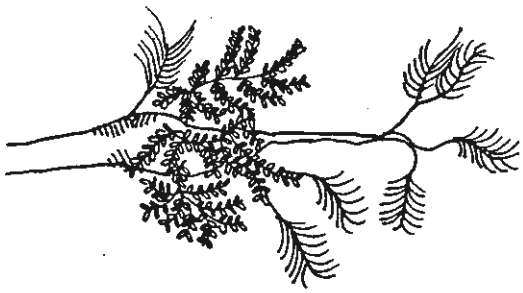
| | | |
|---|---|---|
| sub total | 6860.00 | |
| Expenses: | | |
| Hotel meals, coffee and meeting room | 3085.02 | |
| Name tags | 65.50 | |
| Computer rental | 17.80 | |
| WIFDWC mugs for speakers | 113.00 | |
| Special order mugs paid for by individuals | 220.00 | |
| Salmon barbecue | 1142.25 | |
| Field trip transport | 727.00 | |
| Field trip lunches | 511.62 | |
| Proceedings (close estimate - adjustment will be made next year) | 850.00 | |
| sub total | (6732.19) | |
| | | 127.81 |
| Balance at close of thirty-third meeting | | 1140.37 |

Continuous account No. 936258 held at:

Washington State Employees's Credit Union
P.O. Box WSECU
Olympia, WA 98507

Official signatures for withdrawing funds from WIFDWC account as of October 31, 1985 are Ken Russell, Walt Thies and Fields Cobb.

Ken Russell, October 31, 1985



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

Western International
Forest Disease Work Conference
Mistletoe Committee Report

1985 Highlights

John G. Laut, Chairman

I. Taxonomy, Hosts, and Distribution

A. In addition to finding Arceuthobium occidentale on Pinus halepensis in Southern California in 1984, we also now have found A. occidentale on P. pinea and P. thunbergiana. P. halepensis was also found infected by A. campulopodum. A manuscript has been submitted to Plant Disease. (R. F. Scharpf, PSWF & RES; F. G. Hawksworth, RMF & RES)

B. Studies of the taxonomy of the Arceuthobium campylopodum-A. occidentale complex in California. The taxonomic status of these two taxa is less clear than implied in a certain 1972 monograph. One supposed distinction between the two taxa was that Pinus sabiniana was thought to be immune to A. campylopodum, and that P. ponderosa was immune to A. occidentale. We now know that both of these host/parasite combinations occur. A. campylopodum and A. occidentale are sympatric in many areas in the Sierra Nevadas and, in these situations, the two mistletoes are (exclusively) confined to their principal hosts. However, in localities where only one species of misletoes is present, the host range may be less restrictive. Inoculation tests confirm that the host ranges of both species are broader than originally thought. There are few consistent morphological differences between the two mistletoes but flowering and seed dispersal are 7 to 8 weeks later for A. occidentale than for A. campylopodum. In the interim, until the taxonomic status of the two taxa is resolved, we recommend that their designation as species be continued. (F. G. Hawksworth, RM Station; R. F. Scharpf, PSW Station; W. R. Mark, Cal. Poly. State Univ.)

C. The 1984 annual report for the Northern Forestry Research Centre in Edmonton (Information Report NOR-X-269, by B. H. Moody and H. F. Cerezke) records jack pine dwarf mistletoe from the Fort Providence, Fort Simpson, and Fort Laird areas in the MacKenzie District. This is the first report of Arceuthobium in the Northwest Territories. (F. G. Hawksworth, RM Station)

II. Physiology and Anatomy

A. A cooperative study between the University of Utah and the Rocky Mountain Station was begun on the reproductive success in dwarf mistletoes. Populations of Arceuthobium americanum and A. douglasii were sampled to determine the number fruits that remained viable 9-12 months following pollination, and after the completion of one growing season. The data shows that two species differ markedly in this respect (A. americanum, 87%; A. douglasii 63%). While the data sets have not been analyzed statistically, there is little doubt this difference is highly significant as there is virtually no overlap between the two data sets. The reasons for these differences are not apparent, but more effective pollination in A. americanum is a possibility. This would also help to explain the higher variation in A. douglasii. Studies are continuing on these and other dwarf mistletoes. Also cytological analyses are being made of seed embryos and endosperm. (D. Wiens, Univ. of Utah)

III. Life Cycle Studies

A. Long distance dispersal of lodgepole pine dwarf mistletoe (Arceuthobium americanum) was studied on the Fraser Experimental Forest, Colorado. Twenty-one isolated satellite centers (0.4/acre) were found in an otherwise mistletoe-free 70-year-old, 45-acre stand that was surrounded by heavily infected stands. The centers ranged from 12 to 65 m from the closest potential infection source. Ages of

These plots are being developed by staff from Research and Forest Pest Management into a dwarf mistletoe demonstration area. The purpose of the demonstration area is to provide a means for forestry personnel and the general public to become familiar with the recognition, biology, impact, and control options for hemlock dwarf mistletoe in southeast Alaska. (Terry Shaw, PNW Station, Juneau, AK; and Paul Hennon, FPM, R-10, Juneau, AK.)

C. In cooperation with the Manitoba Natural Resources, we are moving jack pine mistletoe further from Minnesota, Wisconsin and Michigan. Over 50 plots have been established to determine rate of mortality, rate of spread and the value of various treatments to reduce the impact of the pathogen. Manitoba Natural Resources have a major effort underway to reduce spread and mortality in their extensive stands of jack pine.

Studies are continuing dwarf mistletoe of black spruce in Minnesota. (D. French and others, Univ. of Minn.)

V. Effects on Host

A. Manuscript in preparation: "Growth reduction of Douglas-fir attributed to Arceuthobium douglasii". (R. Halsey, J. Hoffman, A. Partridge; R-4 Idaho)

B. Studies are continuing on the effects of mistletoe infestation on the growth of irregular, uneven-aged ponderosa pine stands along the Colorado Front Range. Additional field data were collected to fill gaps in the 1973 and 1984 data sets. Infected plots were paired with healthy plots. A wide range of stand basal area (50 to 190 sq. ft/acre) and stand DMR (0 to 5.5) was collected for site indices of 38 to 48. Stand structures ranged from essentially two-aged with a narrow range of diameters, to all-aged with a broad range of diameters. A size class approach will be used to model the effects of mistletoe on diameter growth. What we call a "potential growth" curve will be developed using dominant, co-dominant, and open-grown healthy trees. The effects of competition and dwarf mistletoe on growth of each size class will be described as a reduction from the potential yield. A mortality function will be developed in much the same way. The distribution of dwarf mistletoe among size classes at different stand DMRs and within different stand size class structures is also being studied. (Helen Maffei, Colo. State Univ.; Frank Hawksworth, RM Station; W. Jacobi, Colo. State Univ.)

C. The growth impact, spread, and intensification plots in Montana have been analyzed.

In the Douglas-fir study, the effect of DMR's less than 3 was not significant, but DMR's equal to or greater than 3 had an effect that was significant only at the 85 percent level. The multiplier is 0.79, or a reduction in diameter growth of about 21 percent. Effect on height growth was not significant. Within crown intensification has been about 1 DMR class in 13 years. Number of infected trees has tripled in 13 years.

In the lodgepole pine study, the effect of dwarf mistletoe on both diameter and height growth was not significant. Within crown intensification has been about 1 DMR class in 13 years. Number of infected trees has more than quadrupled in 13 years. (Oscar Dooling, Region 1)

D. Cooperative studies between Northern Arizona University and the Rocky Mountain Station will begin next summer to quantify the rates of spread and intensification of Douglas-fir dwarf mistletoe in mixed conifer stands in Arizona and New Mexico. This information is needed to complete a growth and yield simulation model for this forest type. (R. L. Mathiasen, N.A.U., and F. G. Hawksworth, RM Station)

VI. Ecology

No reports submitted.

VII. Control - Chemical

A. Chemical control tests for A. vaginatum on ponderosa pine were continued near Estes Park, Colorado. In 1984, 27 chemicals were tested on 471 trees. Most chemicals were applied as sprays but a few were applied through bark slits or as injections (Mauget injectors). None of the chemicals or concentrations tested to date killed the mistletoe endophytic system, but all were effective in killing shoots. The chemical sprays that were most effective (90% + shoot kill) were: Butrac-ester (Union Carbide); Dacamine (Diamond Chem.); Glyposphate (Monsanto); D-40 (Dow); Dow-3724 (Dow); RP2,4-D (Rhone Poulene), and Chevron pruning paint. None of the injections or slit tests gave 90% +

shoot kill. Tests were continued in 1985 but the results are not available. (A. Moinat, Estes Park, Colorado)

B. Ethephon, a plant growth regulator, releases ethylene that promotes abscission of mistletoe shoots. The study that was begun in 1983 to test plant growth regulators as a control for dwarf mistletoe (Arceuthobium americanum) on lodgepole pine in Colorado was expanded in 1985. Approximately 233 trees in an Arapaho National Forest campground were sprayed with ethephon at 2500 ppm with a surfactant using a hydraulic jet hand-sprayer. One hundred and ten mistletoe infections were rated according to size. Twenty overstory and 15 understory trees were rated with the 6-Class Mistletoe Rating System. A replication of the study was set up in the Fraser Experimental Forest with 50 mistletoe infections and 11 overstory and 9 understory trees. Mistletoe seed traps were placed in the sprayed and non-sprayed areas to compare the amount of seed dispersal between treatments. Ethephon was also applied to 41 A. vaginatum infections on 11 Ponderosa pine using a hand-sprayer. All areas will be rated again in 1985 and annually thereafter for 4-6 years after treatment to determine the duration of control. Eighty-nine to one hundred percent of the mistletoe shoots treated with ethephon in 1983 and 1984 abscised within 5-7 weeks after treatment. Ethephon did not kill the endophytic system and a few immature shoots appeared the following year. Based upon the results so far, it is estimated that significant new seed production on treated trees will not occur until 4-6 years after treatment and perhaps even longer. (T. Nicholls and L. Egeland, North Central For. Exp. Sta.; F. G. Hawksworth, RM Station; W. H. Livingston, Univ. of Minnesota; and Dave Johnson, FPM, R-2)

C. Final results of plant growth substance analysis of black spruce tissue infected with dwarf mistletoe indicate abscisic acid had significantly lower concentrations in infected tissue. The results of this study and other suggest that alterations in ABA concentrations are important in controlling nutrient partitioning in trees infected with dwarf mistletoe.

Additional tests using ethylene releasing agents to stimulate abscission of dwarf mistletoe shoots indicate ethephon is the most effective compound, late August is the best time for treatment, and use of a surfactant can improve the effectiveness of ethephon to when concentrations of 1250 to 2500 ppm ethephon can result in nearly complete abscission of dwarf mistletoe shoots. Efforts are now underway to initiate pilot studies to evaluate the efectiveness of ethephon in preventing spread of dwarf mistletoe within and between trees. (D. French and others, Univ. of Minn.)

VIII. Control - Biological

A. The reports for 1984 of brown felt blight colonizing shoots of Arceuthobium abilitinum and of grasshoppers eating the shoots, flowers and fruit of A. Campylopodum have been written up and submitted to Plant Disease and Canadian Journal of Forestry Research respectively. (R.F. Scharpf, PSWF & RES)

B. The twig beetle (Pityogenes carinulatus) was very common on mistletoe-infested ponderosa pine in the Roosevelt National Forest, Colorado. The beetle killed the mistletoe trees up to about 6 inches d.b.h. and infected branches on larger trees. (F. G. Hawksworth, RM Station)

C. As part of a study to determine ages of infection on dwarf mistletoe in lodgepole pine in Colorado, infections were stored in a cold chamber (at ca 35° F) for about 2 months. When the infections were dissected, we noted that about two-thirds of them had a black stain in the wood. We consistently isolated a fungus from the stain that Al Funk identified as Sclerophoma pithyophila (Cords) Hoehn. The fungus is widely known as a weak parasite on pines and has been associated with a stain on Pinus contorta in England. The pathological significance of the fungus in relation to lodgepole pine dwarf mistletoe has not been determined. (F. G. Hawksworth and John Coppola, RM Station)

IX. Control - Silvicultural

A. Dwarf mistletoe suppression projects were conducted on 2,744 acres on seven national forests in southern Idaho during 1985. Two-thirds of the suppression efforts occurred in lodgepole pine stands. (J. Hoffman, R-4, Boise)

B. Four plots, mostly in ponderosa pine, established at Bryce Canyon National Park, Utah in 1952 were remeasured in

1985. A fifth plot was abandoned because it now supports several Park Service residences. The four plots (2 treated, and 2 checks) were established in connection with a mistletoe control project of pruning of lightly-infected trees, and removal of heavily-infected trees. The area was treated in 1952 and 1955, but not since. The plot data have not yet been analyzed. (F. G. Hawksworth, B. Geils, and John Coppola, RM Station)

C. Long-term ponderosa pine dwarf mistletoe control plots in Colorado (Boulder and Manitou Experimental Forest), and Arizona (Grand Canyon and Fort Valley Experimental Forest) were re-examined in 1985. Data from these plots will be used to evaluate and update the dwarf mistletoe relationships in the growth and yield simulation model RMYLD. (F. G. Hawksworth, B. Geils, and John Coppola, RM Station)

D. Silvicultural control was accomplished on about 1,000 acres on the Bitterroot, Flathead, Gallatin, and Lolo National Forests in Montana. (Oscar Dooling, Region 1)

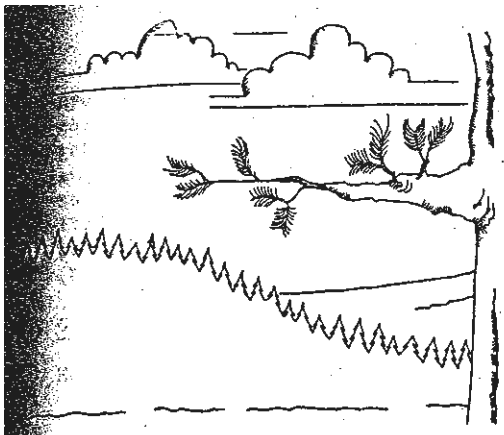
X. Surveys

A. The first disease survey was made in the Henry Mountains, Garfield County, in south central Utah. Arceuthobium douglasii was found for the first time in this range, and is by far the most serious tree disease agent encountered. It is very common on Douglas-fir, and rare on associated subalpine fir. Arceuthobium divaricatum on pinyon was the only other dwarf mistletoe found. (F. G. Hawksworth, B. Geils, and John Coppola, RM Station)

XI. Miscellaneous

A. Proceedings from the symposium on biology of dwarf mistletoes held at the 1984 AIBS meeting in Fort Collins are available as USDA Forest Service General Technical Report RM-111, 131 p., 1984, Fort Collins. The proceedings contain 16 papers on various aspects of Arceuthobium biology. (F. G. Hawksworth, RM Station, and R. F. Scharpf, PSW Station)

B. A new foliage disease was found in Himalayan blue pine in Pakistan. Shoots of the dwarf mistletoe Arceuthobium minutissimum were found emerging from pine needles, as well as from host twigs. Shoots consistently emerged from 2 to 3 mm above the base of the needles. (F. G. Hawksworth, RM Station)



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

DISEASE CONTROL COMMITTEE
1985 INVESTIGATIONS

Kenelm Russell, Chairman

Last year I tried an approach in this column called "Sounding Off" to bring out new or buried thinking on disease concepts which would be valuable to WIFDWC members. I took the familiar Fusarium problem which plagues our trees around the West and tried to explain some practical things I've learned locally about dealing with the Fusarium complex.

Many of you responded in conversation with additional ideas about this widespread problem. One nursery changed their watering schedules to fit my recommendations and not only saw less disease but saved a bundle of kilowatts.

The idea of discussing these "disease stories with emphasis on practical prevention" in this space is good but it needs a little improvement. You brought out at the Olympia luncheon that we shouldn't wait a whole year for a chance to comment or argue. The column should be current.

To solve this, when I solicit you for projects next summer, I will pick a subject area and ask any who wish, or specifically selcted person(s), to comment prior to the meeting. Their written short "essay(s)" would be available by meeting time and could provide further discussion. A consensus or verbatim commentary would show up here in the current proceedings. These mini articles should not be formal papers but more like "letters to the editor."

I know we have lots of "hidden" stuff lying around in our experience base on subjects like the nursery Fusarium and others complex. For example, do you know the details of the Fusarium complex ecology throughout the life of a nursery seedling? Did you know that they have been named Type 1, 2, 3, and 4 diseases? They are called Hypocotyl Rot, Upper Stem Canker, Lower Stem Canker, and Phomopsis/Botrytis canker. Each type has its own season and condition for attack. One uses soil collars and abrasion as the entry court. Well, guess what the topic is for Juneau. You'll find it here.

The western Forest Pathologists have been meeting informally for a day and a half in February to discuss mutual disease problems. In 1986 we meet in Olympia at which time I will find contributors for the Juneau proceedings. This column will also be a good place to record some general conclusions from this nursery disease mini meeting.

Other stories we can discuss in "Sounding Off" are: Fusarium/Phoma complex, cover crops in nurseries and disease build up, cone and seed problems, white pine and pruning, and others. Join in and help us develop connected ideas through our proceedings. Should be fun!

The spin-off from all of this discussion is to bring the information together for you the scientists, then redo it in non-technical language for nursery managers.

Listed below are your disease control reports. Also included is the missing page from the 1984 report. I forgot to mail it to Rich Hunt last year. Sorry!

SEEDLING DISEASES - NURSERIES

1. Damping-off, Root Rot, Root Destruction
   Host: Bareroot Nursery Stock
   Causal Organism: Fusarium, Pythium, Phytophthora, Nematodes, Weeds
   Control: Chemical
   Development Stage: Pilot Operational

   Basamid-Granular has been successfully used as a preplant soil-sterilant to control soil-borne fungi, nematodes and weeds, and reduce damping-off in bareroot conifer nursery stock.
   (Fred D. McElroy, Peninsu-Lab)

2. Damping-Off, Stunting
   Host: Lodgepole pine seedlings
   Causal Organisms: Fusarium spp., Pythium spp. Pratylenchus penetrans and other phytoparasitic nematodes and weeds.
   Control: Biological, Solar Heating
   Development Stage: Field Trial

   Soil solar heating at the Bessey Nursery, Nebraska resulted in significant reductions in species of Pythium and weeds. Fumigation (Methyl bromide-chloropicrin) did not result in better control (in samples taken immediately after treatment) than solar heating for species of Pythium, Fusarium, weeds or phytoparasitic nematode genera. No significant effects on survival of lodgepole pine seedlings resulted from either soalr heating or fumigation.
   (Diane M. Hildebrand, FPM-Rocky Mt. Region)

3. Fusarium
Host: Douglas-fir Seed
Causal Organism: Fusarium
Control: Biological
Development Stage: In Vitro

Douglas-fir seeds from one lot were washed in water and placed on Komada's medium. Seeds were not surface sterilized. Half of the sample had been stratified, the other half was unstratified. Results from three reps of 20 seeds each are as follows: Fusarium roseum grew from 95 to 100 percent of stratified seeds, and from 15 to 30 percent of unstratified seeds. These data suggest that Fusarium could spread during stratification.
(Alan Kanaskie, Oregon Dept. of Forestry)

4. Top Blight
Host: Douglas-fir
Causal Organism: Fusarium and Phoma
Control: Chemical
Development Stage: Field Trial

The objective is to evaluate timing and frequency of fungicide applications for reducing losses to each of four top blight disease types. Seven nurseries in Oregon and Washington are cooperating. Results from first evaluation will be available at the Disease Control Committee Meeting. The study will continue through Fall of 1986.
(Alan Kanaskie and Sally Cooley, OSDF and FPM-PNW Region)

5. Top Blight
Host: Douglas-fir
Causal Organism: Phoma spp., Fusarium spp., and others.
Control: Chemical
Development Stage: Field Trial

Fungicide Screening: Successful treatment of disease types 1 and 2 with all fungicides in summer and fall 1984. Type 3 not controlled by fungicides. Incidence of type 4 very low in 1985.

Fungicide Frequency: Plots just established.
(S. Cooley and A. Kanaskie)

6. Phytophthora Root Rot
Host: Douglas-fir 2-1 transplants
Causal Organism: Phytophthora spp.
Control: Chemical
Development Stage: Field Trial

Application of Subdue 2E$^{R}$, Subdue 56$^{R}$ (granular), Subdue Slow-Release (granular), Aliette, Truban 56 (granular), + Banol prior to or shortly after transplanting at 2 Oregon nurseries. Evaluation of mortality and root rot in winter 1985-86.
(S. Cooley, P. Hamm, W. Littke, FPM-PNW Region, OSU, Weyerhaeuser)

7. Soil-borne Seedling Diseases
Host: All PNW conifers
Causal Organisms: Fusarium spp., Pythium spp., etc.
Control: Chemical
Development Stage: Field Trial

A test comparing Metam-sodium (Soil-Prep$^{R}$) and Dazomet (Basamid Granular$^{R}$) to methylbromide-chloropicrin soil treatments will be set up at J. Herbert Stone Nursery and Bend Nursery, Fall 1985. Weed and disease control evaluated 1986.
(S. Cooley, FPM-PNW Region)

8. Phomopsis Blight
Host: Douglas-fir
Causal Organism: Phomopsis occulta
Control: Chemical
Development Stage: In Vitro

Measurements of spore germination of Phomopsis on fungicide-amended media indicated that 6 of 16 fungicides tested inhibited or reduced germination. The same 6 fungicides prevented (benomyl, imazolil, prochloraz, XE-779) or significantly reduced (chlorothalonil, mancozeb) mycelial growth at 1 ppm.
(Kliejunas, McCain, FPM-PSW Region)

9. Sirococcus Tip Blight
Host: Jeffrey Pine
Causal Organism: Sirococcus strobilinus
Control: Chemical
Development Stage: Field Trial

Tilt 3.6 EC and a wettable powder formulation of the same chemical (CGA-71818 W) applied at 8 week intervals were more efficacious (4% and 6% infection, respectively) than Bayleton 50 WP (8%) and no treatment (22%).
(Kliejunas, McCain, Allison, FPM-PSW Region)

10. Mycorrhizae Recovery and Disease Development
Host: Douglas-fir
Causal Organisms: Mycorhizal fungi and Pythium and Fusarium spp.
Control: Soil fumigation
Development Stage: Field Trial

Results are preliminary. MC33 at up to double normal rates and Basomid were applied to two nurseries (Mima and Webster near Olympia) to test speed of recovery of mycorrhizae. At same time Pythium and Fusarium assays were made approximately every other month for almost a year. Disease assays were consistent giving excellent results (low propagule numbers) in treated areas and high values in untreated areas time after time. We gained great confidence in the consistent blind data evaluation system.

Mycorrhizal fungi are making an excellent comeback in the nursery soils in fumigated soils. Trees are visually bigger and much better in fumigated or treated soils. This trial will be completed by 1986 press time and I can give much better results.
(Ken Russell, WDNR, Olympia)

11. Grey Mould

Host: Psuedotsuga menziesii Douglas-fir
Picea glauca White spruce
Picea sitchensis Sitka spruce
Thuja plicata Western redcedar
Tsuga heterophylla Western hemlock
Causal Organism: Botrytis cinerea
Control: Chemical
Materials Tested: Botran 75W (dichloran)
Rovral 50WP (iprodione)
Thiram 75W (thiram)
Pyrene 50W (anilazine)
Phaltan 50W (folpet)
Captan 50W (captan)

Development Stage: Greenhouse

This trial was designed to test the phytotoxicity and gather efficacy data on the above fungicides for Botrytis control. To date the chemicals have been applied three times and the fungus has also been applied three times. The Rovral 50WP appears to be providing the best control. The Pyrene 50W appears to have some phytotoxic effects on the Sitka and white spruces.
(J. Southerland and M. Glover, CFS-Victoria)

RUSTS

1. White Pine Blister Rust
Host: Western white pine
Occurrence: Plantation
Causal Organism: Cronartium ribicola
Control: Silvicultural
Development Stage: Pilot Operational

Pruned white pine plantation reported in 1984 is now five years old. Rust incidence is zero. Average height is about five feet. Trees were pruned with two whorls remaining until cleared boles are at least six feet long.
(K. Russell, WDNR, Olympia, WA)

2. Needle Rust
Host: Pseudotsuga menziesii
Causal Organism: Melampsora occidentalis
Control: Chemical
Development Stage: Field Trial

Bayleton (triadimefon) Banner (propiconazole) and XE-779 provided complete control. Systhane, Plantrox (oxycarboxin), Funginex (triforine), and Benodanil provided partial control (1.5-4.6%). Thirty percent of the needles on control trees were infected.
(A.H. McCain, UC-Berkeley)

FOLIAGE DISEASES

1. Needlecast
Host: Scotch pine
Causal Organism: Lophodermium and Cyclaneusma
Occurrence: Christmas tree plantation
Control: Chemical
Development Stage: Field Trial

Fungicides were applied to determine timing for best control. Results in 1986 report.
(A. Koonce, U. of Wisconsin-Stevens Point)

2. Swiss Needlecast
Host: Douglas-fir
Causal Organism: Phaeocrytopus gaumannii
Occurrence: Forest plantation
Control: Chemical
Development Stage: Pilot-Operational

This is the third year of a helicopter fungicide application reported last year to control needlecast on 20-foot tall forest grown Douglas-fir.

One gallon and one-half gallon chlorothalonil per acre gave equally good results but sometimes spotty due to uneveness of crowns. Dithane M45 and Manzate 200 gave irregular results. Chlorothalonil is an acceptable needlecast control using either rate but decision to control under forest conditions must be carefully evaluated. Problem is to get evenness of control possible in Christmas trees. It is not apparent that reduced height growth prior to spraying returned to normal.
(K. Russell, WDNR, Olympia, WA)

ROOT DISEASES

1. Armillaria Root Rot
Host: Red pine
Causal Organism: Armillaria spp.
Occurrence: Young plantations
Developmental Stage: Field Trial

Working with red pine on oak-jack pine conversion sites.
(A. Koonce, U. of Wisconsin-Stevens Point)

3. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Occurrence: Natural stands and plantations
Control: Biological - Silvicultural
Development Stage: Full Operational

Stumps were pushed on 23 acres of a 93 acre clearcut. Financial analysis showed positive gain from pushing. Stumps were pushed as a condition of the sale of the 120 year old stand with no additional cost to DNR. Sale price was same as if no stump pushing was required.
(K. Russell, WDNR, Olympia, WA)

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be evaluated (% mortality, % infected, % with >25% root system infected) just prior to lifting (December 1984 - March 1985) (S. Cooley, A. Kanaskie).

FOLIAGE DISEASES

1. Lirula Needlecast
Host: Picea glauca & P. pungens
Causal Organism: Lirula microspora
Control: Chemical
Development Stage: Pilot Operational

The disease has a two year life cycle, infecting second-year needles and sporulating on fourth year needles. Sporulation, associated with rainfall began in 1984 when new shoots were 5-8 cm long about June 1 and continued through mid-August. Chlorothalonil is being used in control tests. There appears to be wide variation in susceptibility within both species of spruce (J. Walla).

2. Swiss Needlecast
Host: Douglas-fir
Causal Organism: Phaeocrytopus gaumannii
Control: Chemical
Development Stage: Pilot-Operational

This is the second year of a helicopter fungicide application reported last year to control needlecast on 20-foot tall forest grown Douglas-fir.

One gallon chlorothalonil per acre gave equally good results but sometimes spotty due to unevenness of crowns. Half gallon rates are almost as good. This can now be an acceptable needlecast control, but decision to control under forest conditions must be carefully evaluated (Russell).

ROOT DISEASES

1. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Control: Biological/Silvicultural
Development Stage: Field Trial

In order to restrict the spread of Phellinus, 40 year-old healthy Douglas-firs, in strategic positions on the periphery of 15 infection centers were felled in 1983. Rapid colonization by the dead roots by soil-borne organisms should restrict Phellinus spread. In stands of this age, this method of felling only those trees on the periphery of infection centers deemed likely to become infected through root contact, minimizes wood volume losses relative to swathing, and should provide a good measure of control. These centers will be monitored over the next 10-15 years (G. Reynolds).

2. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Control: Biological/Silvicultural
Development Stage: Field Trial

In order to restrict the spread of Phellinus, a 4 meter-wide swath was cut around the periphery of 10 infection centers in a 20 year old stand of Douglas-fir in 1982. Rapid colonization of the roots by soil-borne organisms should restrict Phellinus spread (G. Reynolds).

3. Black Stain Root Disease
Host: Douglas-fir
Causal Organism: Verticicladiella wageneri
Control: Chemical
Development Stage: Field Trial

Two part project: 1) Investigating effects of chemical thinning on insect vectors of black stain (testing MSMA, Garlon 3A, and Roundup vs. saw thinning). 2) Evaluating effects of insecticide treatments (Dursban and Sevimal) of thinning stumps on vector activity (A. Kanaskie).

4. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Control: Chemical/Silvicultural
Development Stage: Field Trial

Bulldozing - Douglas-fir seedlings are dying from Laminated Root Rot 3-5 years after planting in non-bulldozed areas.

Fumigation of stumps - Phellinus weirii has been killed in all but a small percentage of the original inoculum.

Fumigation of live trees - the trees have survived; in trees examined so far, most of the Phellinus weirii has been killed (W. Thies).

5. Root Disease
Host: Douglas-fir, Western Hemlock
Causal Organism: Phellinus weirii (also Armillaria ostoyae, Fomes annosus, Verticicladiella wageneri

Control: Disease Assessment
Development Stage: Pilot Operational

The Vancouver Region-wide root disease survey was completed in 1984. A total 5700 ha was surveyed in 20 ha replicates in the two most productive coastal ecological regions. In Douglas-fir types at 80 years stand age, 100% of the replicates had root disease with average incidence (% land area by intersection length survey) of 13.6% for good, 11.6% for medium and 4.1% for poor sites. For Douglas-fir-hemlock type group, incidence was 10.1% for good, 6.0% medium and 4.7% for poor sites.

Further analyses planned in cooperation with W. Bloomberg, CFS, Victoria (J. Beale, P. Wood).

# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

ROOT DISEASE COMMITTEE
HIGHLIGHTS OF THE 1985 MEETING
GREG FILIP, CHAIRMAN

Because of the occurrance of several meetings concerning root diseases (a black-stain workshop in August, an annosus meeting in December, and a root disease modeling workshop in February), it was decided to postpone the proposed root disease workshop to an undetermined date. The following reports were submitted for inclusion in the proceedings:

ROOT DISEASE COMMITTEE
REGION 1, USFS
MISSOULA, MT 59807

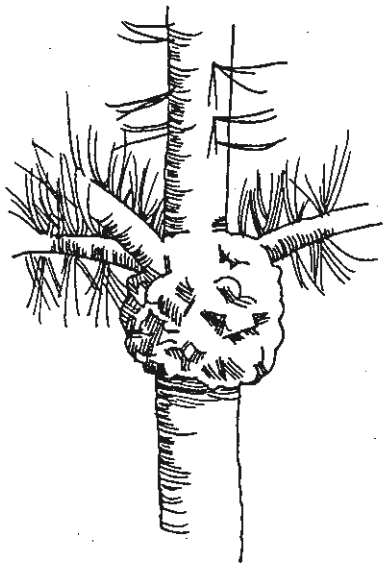
Last year's proceedings reported that we found Fomes annosus at a number of new locations in Region 1. This year we confirmed the presence of the fungus in many more stands in all National Forests west of the Continental Divide. These findings provide additional evidence for the hypotheses that:

1. Annosus root disease is widespread in Region 1.

2. F. annosus is sometimes present in what we have called Armillaria centers.

3. Douglas-fir is often affected by F. annosus.

F. annosus is much more difficult to diagnose than Armillaria sp. when both are present. We attribute the increased detections to a more thorough field examination of problem stands (including the uprooting of small trees), and to laboratory culturing and incubation of root and stem samples.



RUST COMMITTEE REPORT - Rich Hunt

Meetings of interest to the group are:

1. Fifth Internation Congress of Plant Pathology to be held in Kyoto Japan in August 1988. Eight half-day forest pathology sessions will be held with Yasu Hiratsuka being the North American contact person. He desires suggestions on sub-topics and/or willingness to participate or organize a session.

2. IUFRO "Rusts of hard pines" working group meeting will be held in Alberta, probably in 1989. Yasu Hiratsuka is the contact person.

3. XVI Pacific Science Congress will be held Aug. 10-20, 1987, in Seoul. If a session on Cronartia is held Rich Hunt will be the contact person.

At the 33rd WIFDWC it was decided that professors who may be interested in forming a pine stem rust Regional Project would be contacted to see if there was interest in getting such a project off the ground. The project would be similar to the Fusiform Rust Regional Project. Other members of the rust sub-committee would be supportive if such a project were initiated. Any professor not contacted to date, who may be interested in such a project should contact Rich Hunt.

Reports received are as follows:

1. Yasu Hiratsuka of CFS Edmonton together with Paul Maruyama (senior technician) and Eric Allen (Ph.D. student, University of Alberta)have been conducting western gall rust investigations in conjunction with genetic improvement programs of lodgepole and jack pines.

2. Yasu has been engaged in taxonomical, morphological and life history work on pine stem rusts in the world. He is especially interested in species and forms in Asia and central America.

3. Epidemiological studies of western gall rust have been started by Peter Bleniss of the University of Alberta with a graduate student (Kan-Fa Chang).

4. The western white pine resistant tree program received a boost in British Columbia with the provincial forest service paying for candidate tree selection in 1985. Concurrently the Canadian Forestry Service and C.I.P. Forest Products are establishing a Ribes garden which will produce inoculum for screening seedling of candidate trees.

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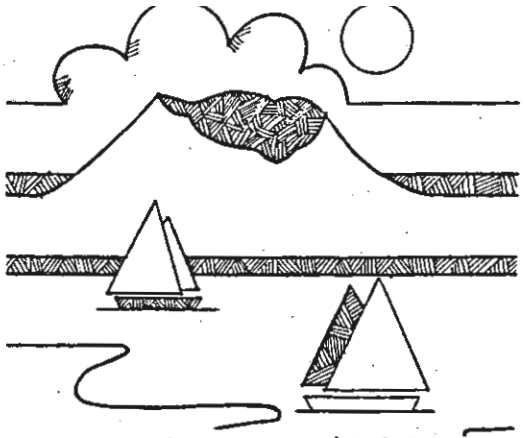
Richard S. Hunt is chairperson of the WIFDWC rust subcommittee, at Pacific Forestry Centre, 506 West Burnside Road, Victoria, B.C., Canada, V8Z 1M5.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

Preconference Sailing Trip

September 20-23

It started at the Taos meeting. Some of us decided we should have a little R&R before our Conference. We had so much fun at Chaco Canyon that 12 took up my offer of a sailing cruise on Puget Sound.

The weather forecast was excellent-well almost. Final details were not so excellent. At 1000 the morning before, I "lost" one sailboat due to skipper illness. What am I going to do? Where do I put 12 people? All I had was the "Rushwind." By noon I arranged to charter the 25-foot "Olympia Gold" and my gracious neighbor loaned us his "Legacy" a 26-footer. At last, the cruise vessels were ready and we had adequate sleeping and spread out room for everyone.

After assembling in the late hours of Friday at Percival Landing, we dispersed into nearby Bayview Market for a whirlwind food shopping spree with each group responsible for a meal or two. Since the two extra boats wouldn't be ready until Saturday AM, some slept on the Rushwind and the rest used up all the extra beds and floor at the Russells on Big Fishtrap.

Saturday AM was rainy but the prospects looked better for PM. We departed Olympia's historic Percival Landing draped in raingear and headed some ten miles north to Big Fishtrap to pick up the "Legacy." On the way, we made a stop at the Boston Harbor Marina to buy some freshly caught silver salmon for the low price of $1.75 per pound. Supper was beginning to look scrumptious.

Our destination that night was tiny McMicken Island, a state marine park not much bigger than a large ship. McMicken is a special Rushwind favorite with beautiful beaches containing clams, oysters and mussels and the upland is covered with a unique old growth climax forest with some interesting fire history.

In Dana Passage there was enough wind for the flotilla to hoist sails and as we did an eagle flew by, screeching loudly at a couple of gulls who were dive bombing him. Everyone set to, trying their hand at sailing the vessels. The weather turned warm and lazy, typical for this time of year. The fickle winds, also normal for the time, soon departed and we drifted and motored slowly into McMicken.

The crews dinghyed ashore to explore and others began to prepare the evening repast to be served on the beach. Carol Nelson concocted the salad and Stephie Axse made a fresh fruit dessert. The tide was too high for clam and oyster digging. "Wonder Woman" Ed Wood, with his blue shorts and bright yellow sailing boots, Fred Baker and Borys Tkacz saw to the salmon barbecuing.

Preparations ashore and aboard were kept clean and sterile in true pathological fashion by the use of specially purchased liquids. The vessels rose significantly in the water as the precious liquid stored in their cold below waterline lockers was consumed. It seemed to take a lot of liquid to keep everything sterile. The salmon was out of this world. The bonfire on the beach provided light to eat by and the night was warm and quiet. We tended to get very relaxed and sleeeepy. Sparkling bioluminescense danced in the black water under us as we dinghyed back to the boats anchored in the quiet bay.

Predawn (0530) coincided with low tide and the seafood gathering parties roused up and rowed ashore for mussels and clams. I like my warm sleeping bag on foggy mornings but I couldn't resist and soon rowed another party across the small bay to pick up oysters. Shucking oysters is a trick and by the time we had gathered 55 or so Fred and Stephie were pretty good at it.

It was cold and foggy and the warm cabin with fireplace fire was a delight. The hungry clam and mussel crew returned with a five gallon bucket full to the brim. I didn't think we could ever est them all.

Anderson Island was our destination on Sunday. The weather gradually warmed as we sailed and drifted in the light wind with lots of heckling amongst the boats. A single piling 200 feet offshore marked the little cove and spit, another favorite Rushwind anchorage. The shore parties departed and Earl rigged up for a little fishing off Rushwind's stern. It wasn't long before a small sculpin came aboard followed shortly by two very nice five lb or so flounders. Next, Bob Harvey hauled up a huge skate which looked like some prehistoric bird. The skate went back to the deep, but the flounders were saved for breakfast. Of course, all this was done with adequate supplies of aseptic fluids.

Ed proceeded to make a delicious clam linguini and Carol, Steph and I experimented with different ways to fix oysters. Rushwind's spice locker had all sorts of goodies including a fresh garlic clove. Margarine, clove, a little wine and herbs did those oysters up to the most discerning gourmet's taste. Littleneck clams and mussels were steamed and salads and fruit dishes prepared. Hard rolls warmed in the oven. I think we ate for three hours.

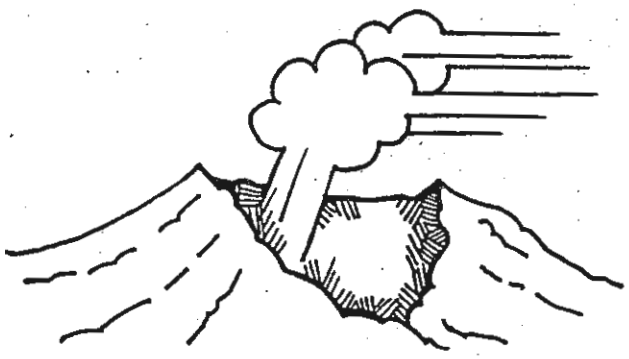
I have to admit that I had never had a hangtown fry (oysters and eggs) for breakfast. Earl's flounders were rubbed with salt, margarine, and herbs and baked in the oven. Were we obsessed with food? You bet! When you are on the water, it is a challenge to make the mealtime exciting and a treat to the palate. This crew gets a five star rating!

Next morning, we gathered up beach campers Mark and Theresa, and continued our circumnavigation of Anderson Island with Rushwind dallying a while at Lysle Point to see if a salmon would bite. None seemed to be in the vicinity. It was a warm sunny morning as only the South Sound can produce. Soon, the morning breeze picked up and the crews had some fine sailing on flat water. Earl and Everett helmed like old salts and Linda and Carol found they could do it too.

The boats stepped out at hull speed and soon rounded the north end of Anderson Island where two previous Rushwinds have spent hours in many wind deficient Toliva Shoals Races trying to get around. Since the Rushwind crew had the lunch food, we rafted the two boats (Legacy returned home earlier) and motored along while passing food back and forth. We weren't yet ready to work our way back to Olympia and Percival Landing but WIFDWC folks were beginning to arrive and someone had to register them.

This little interlude didn't have much to do with pathology but it sure set us up for the rigors of a busy conference. There is something about being on the water that cleanses the mind and renews the body. During the week, many others were able to experience short evening cruises of the Olympia Harbor aboard Rushwind. Ask me or Everett sometime about Ed's boot in the rigging and my opportunity to climb the mast in my suit and tie to rescue it.

Ken Russell, Rushwind



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

## Mt ST Helens Field Trip

Ken Russell

The weather? Well, it was just as perfect as a fall day can be in western Washington. After a little game of seeing how many we could squeeze in six vans and a few extra vehicles loaned at the last minute, followed by a brief direction finding tour of urban Tumwater, about 100 WIFDWC'rs headed south to the Stearns Creek Root Rot Control project. (I am most grateful for the "compass" given during the dignified ceremony at the business meeting to avoid future disorientation. I haven't been lost at all since.)

The Stearns Creek site is about 10 miles southwest of Chehalis. In 1977 the 120 year old Douglas-fir stand (SI 120, 50 year base) was logged. The exceptionally large stumps were pushed out with a D-8 mounted with a splitter at $160/acre.

Four 1 acre plots with stumps pushed and four plots not pushed were planted in spring, 1978 with Douglas-fir, western hemlock and a small number of white pine. More than half of the pushed area and about 85 percent of the unpushed area stumps were infected with laminated root rot.

A sample count of root rot killed trees showed 17 in one pushed plot and 26 in one unpushed plot.

After eight growing seasons there was no growth difference between planted Douglas-fir on either plots. Soil compaction does not seem to be an adverse factor.

In 1985 the adjoining 93 acre "Easy Picking" unit was logged (same unit we did the financial analysis on in the decision making workshop). Twenty-two acres of root rot area were located with aerial photos prior to logging and marked on the ground for stump pushing. The timber sold for $205/MBF with the stump pushing within the marked infection centers a requirement of the contract. The logs were exported at top prices. This was the first state timber sale where stump pushing was required as a condition of the sale. The timber sold for about the same as if there had been no stump pushing required.

The root rot centers had also attracted Douglas-fir bark beetles which were spreading into green timber prior to its being cut.

Heading south to Toledo we hooked into the Spirit Lake Highway and traveled along the mudflow that came down the North Fork of the Toutle River. The valley at this point was flooded about 12 feet above the highway. We could see the faint mud line on the cliffs along the road. The striking feature of this stretch of road was the dense red alder that seeded in and is now about 15 feet tall.

Just after the mountain erupted, everyone had a concern about revegetating the valley. Where seed source was available, the alder seeded in extremely well. We had thought that cottonwood was the better species for the river flats. The red alder has proved to be far superior as it quickly overtopped the planted cottonwoods that foresters thought would succeed.

Dick Ford, regeneration forester for Weyerhaeuser Company, briefed us on forest management for the 455,000 acre St Helens Tree Farm. The mills at Longview, downstream, are among the largest wood handling facilities in the world. We found that forest management is very intense from planting and site preparation date to final target some 50 or 60 years later.

About 14 percent of the Tree Farm was impacted by the blast and flooding from the May 18 eruption.

We continued east up the valley, passing the remains of the demolished Camp Baker and the breached debris flow dam. The dam was designed to catch sediment but the winter flooding proved too much and sent waters cascading right through it. Picture taking was at its best in the near cloudless sky.

The grassy "Badlands" type landscape of the debris flow provided a pleasant stretch in a unique area. Here, the debris flow was about 40 to 50 feet thick and about a mile wide. We could see how poorly the various tree species that were planted faired in the face of the adverse sandy site and feeding pressure from as many as 200 head of elk. Many trees were still hanging on even after four years of heavy browse.

The tree of the event is still the red alder. In the absence of seed source the planted red alder can stand the nutrient poor site and feeding pressure better than any other

species. Even the heavy grasshopper outbreak had failed to kill them. The debris flow abounds in wildlife with the populations of mice, coyotes, hawks, and elk still not in equilibrium. The power of the debris flow churning down the valley like wet cement down a concrete truck's trough could be felt here. My friend Wimpy Clark who flew overhead in a helicopter the day of the flood, said the whole valley floor was in motion.

After a pleasant lunch in the warm sun, we made our way up the Hoffstadt Creek Valley around the north side of Elk Rock. Stunning vistas of the immensity of the 150 square mile treeless blast zone opened up. We steadily climbed from the 1600 feet of the Toutle Valley floor to about 5000 feet.

Along the way, we stopped to see the plight of planted noble fir in the deeper ash. The trees were doing fairly well despite being partially buried by the water moved ash. Some winter injury was evident, but the plantation showed every indication of becoming quite normal as soon as the trees have enough bulk to truly influence the site.

Higher still, we observed where Weyerhaeuser had planted lodgepole pine on the windy ridges. The pine is a foreigner to these ridges, but grew well around timberline on the Mountain's flank just a few miles away. The pine will do well here and serve as a nurse crop for the noble fir planted a little lower and sometimes in mix with the pine.

As we rounded a final bend on tha northeast flank of Elk Rock, the Mountain and its spilled out innards occupied the entire view. The power of the debris avalanche and the sharp line between killed trees and green ones brought home the fact that this blast was stronger than the Hiroshima bomb several times over.

We could see the numerous new lakes and ponds that had formed and where the avalanche had gone right over the top of a nearby ridge and slopped down the other side, damming the Coldwater River and making that portion of the stream into a large lake.

Kodak stock rose that day with all the film being exposed. The air was perfect for pictures. I have gone to the Mountain so many times and found it hidden in the clouds.

There was a little flexibility built into the trip and I had to cut short the run down into the bowels of the debris flow to Coldwater Lake. There would have been opportunity to see the rawness of the deeper ash compared to the rather good regrowth of areas further from the mountain that we had just traveled through.

The prime plants in this area are horsetails and a few scraggly Sitka willows. The willow roots survived the blast even though the tops were completely blown off. They will serve as pioneer plants until the conifers slowly struggle back.

The little ponds formed in the flow are multicolored depending on the particular algae in them. It is a stark but exciting landscape.

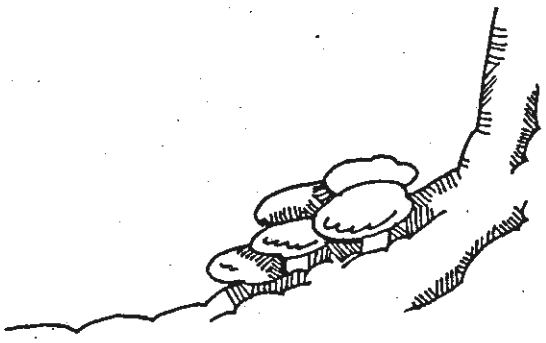
Since Joe Dupuis' salmon were waiting, I had to turn the caravan back and begin the hair raising descent down the west side of Elk Rock. We looked like a convoy of red Tonka Trucks on a sandpile as we slowly jounced down the long bumpy grade. I could smell hot brakes and radio reports from the other vans indicated same. As we neared the bottom a sign read Blondie's Corner where poor Blondie and his log truck went over the side.

This side of Elk Rock is dedicated to the root rot specialists as all the stumps with trees attached were blown right out of the ground. This was probably the biggest root rot control project ever undertaken by Mother Nature.

I was quite relieved when all of the vehicles were safely down that steep grade. It was time to leave and head for the visitor center. The dramatic and very real film of the eruption and all of the events surrounding it put the whole trip into perspective.

At Millersylvania Park, colorful Joe Dupuis was readying his smoked salmon and warm Indian fry bread. Fresh cider from the Country Cider Mill made a tasty native food meal. The early Indians carried the fry bread with them for trail food.

Ed Wood's home brew and Bob's wine added that WIFDWC special to the meal. The park rangers forgot to tell me we needed to be out by dark. With a little encouragement we made it. Thanks to all the drivers who brought us safely back. It was an adventure. It was also an adventure for me to shepherd 100 curious pathologists around the Mountain. You all proved it could be done.



# 33rd Annual Western International Forest Disease Work Conference Olympia, Washington September 24-27, 1985

Post WIFDWC Field Trip to View Armillaira ostoyae at Glenwood, Washington

Apparently several WIFDWC'ers did not receive a large enough dose of root rot at Olympia as 25 of us treked across the Cascade Mts., via a twisting, dusty, back-country road laden with logging trucks, but also graced with magnificant scenery, to view the famous Armillaria epiphytotic near Glenwood. The main body of troops arrived Friday evening to a full moon over the Flying L Ranch--a peaceful farm nestled into the southern slopes of Mt. Adams.

The Friday evening was spent in the Flying L cookhouse enjoying each others' company, examining historic paraphanalia of the area, scanning through publications that described the root disease situation in the surrounding pine forests, scrutinizing various compatible/incompatible reactions in numerous diploid (?) cultures of Armillaria sp., and sampling apple wine and cases and cases of hoppy brews too. Saturday dawned cool and crisp. A 6 AM wake-up on the cook house dinner bell brought the leader little respect; however, a hearty breakfast at the local cafe, proved a good start to a rather full day.

Len Rolph, chief forester for the St. Regis (Champion) Paper Company, briefed us on the history of the forest, the companies' general management philosophy, and their commitment to controlling root disease on their highly productive forest lands. The first field stop was at Terry's favorite disease center where participants were able to view the spatial and temporal dynamics of spreading root rot! Neil Martin and Geral McDonal immediately began digging away at a dying tree on the edge of the expanding disease center, while Brian Geils found some ripe female mistletoe plant and attempted to infect us all via flying seeds.

After finally retrieving Geral and Neil, a common operation throughout the day, we headed on down the road to where St. Regis was currently removing stumps from some 60 acres of land that was thoroughly infested with Armillaria. Len explained how he justifies the costs, some $15,000 for this particular operation: at current rates the stumping operation costs the equivalent of 5 years annual increment, but, without the operation root disease will most likely keep the otherwise productive land from yielding another crop of commercial timber. The freshly piled stumps provided ample samples of pitch encrusted lesions, mycelial fans, and rhizomorphs for the collector to take.

The next stop found us viewing a similar stump removal operation that was performed 3 years earlier. Burning and planting had been completed and the area currently expressed little root disease and the pumice-laden soil seemed to have suffered little damage from the heavy machinery.

The rest of the day was spent within the "saddle area" where many of Lew Roth's studies are locatec and much of the early experimental work by Greg Filip and Terry Shaw was performed. Participants viewed areas where Lew's marking guidelines to control Armillaria had been implemented, saw the long term control experiment that Lew established in 1971, saw plantings of larch and other species, examined stumps removed by the Vibro-stump puller, and ate lunch in a red rock pit.

The last stop of the day was at one of Greg's chemical control plots. This time it was Ken Russell and Roy Whitney who started digging away, tracing spread of Armillaria along a root from a dying tree to a root of an adjacent, outwardly healthy tree. This major excavation was halted ir time to reshuffle passengers and vehicles. Some cars went east into the settling dust and others went west, down the beautiful gorge of the Columbia River, to catch evening flights from the Portland airport.

All-in-all, the trip seemed to be educational and enjoyable to all; even Greg and I had fun![1]

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[1]Trip report submitted by Terry Shaw.

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## NEW AND MODIFIED PROJECTS

### A. *Forest Disease Surveys--General*

71-A-4 Appraisal of damage caused by forest pests in British Columbia (R. Alfaro, G. Van Sickle).

71-A-5 Forest insect and disease survey (G. Van Sickle).

71-A-7 Forest insect and disease survey in the prairie Provinces, and Northwest Territories (Y. Hiratsuka, H. Wong, H. Cerezke, B. Moody).

73-A-4 Forest disease: diagnostic and taxonomic services and research (J. Hopkins).

74-A-1 Disease (and insect) detection surveys in Colorado forests (J. Laut, M. Schomaker).

79-A-1 DISACC: a computerized acoess and analysis system for forest tree problems (A. Partridge).

80-A-1 Standard damage estimating procedures for major disease and insect problems in the inland Northwest (A. Partridge).

81-A-6 Mortality of Chamaecyparis nootkatensis in southeast Alaska (T. Shaw, P. Hennon).

82-A-3 Disease and insect impact on young-growth, mixed conifer stands in California (J. Pronos, L. Dolph).

84-A-1 Pest Impact Assessment Methodology-Fomes annosus (Parmeter, Slaughter, Otrosina).

84-A-2 Causes of mortality in thinned and unthinned Douglas-fir plantations on the Gasquet Ranger District, Six Rivers National Forest (G. DeNitto).

85-A-1 Evaluation of seed tree mortality on the Powell Ranger District, Clearwater National Forest, Idaho (C. Stewart).

85-A-2 Disease sampling in Douglas-fir plantations (W. J. Bloomberg).

85-A-3 Top-damage in Douglas-fir plantations on the west side of the Olympic Peninsula (G. Filip, E. Michaels-Goheen, FPM, R-6).

85-A-4 Pathological aspects in the management of Alaska-cedar for timber production (T. Shaw).

85-A-5 Survey to describe the extent and impact of major root diseases on non-federal timberlands in Oregon (A. Kanaskie).

85-A-6 Estimating incidence of black stain root disease on the Elliot State Forest in Southwest Oregon (A. Kanaskie).

### B. *Non-Infectious Diseases*

80-B-2 Trend of ozone injury to conifers in the southern Sierra Nevada (J. Pronos, D. Vogler).

### C. *Cone, Seed, and Seedling Diseases*

76-C-1 Diseases and seeds of cones PC-54-07 (J. Sutherland).

79-C-1 Chemical and biological control of soil-borne fungi on several conifer species at the Institute of Forest Genetics nursery (R. Bega, A. McCain).

80-C-8 Effect of sowing date on root disease and seedling growth in sugar pine (R. Bega, A. McCain, J. Jenkinson).

81-C-15 Pathogenicities and modes of infection of some fungi isolated from seeds and symptomatic seedlings of conifers (A. Partridge, S. Minggao).

83-C-1 Needle cast of western larch seedlings at the Coeur d'Alene Nursery (R. James).

83-C-2 Assessment of new chemicals to control Botrytis blight in nurseries (R. James).

83-C-3 Fungi assooiated with pine seedlings tip blight in Northern Rocky Mountain nurseries (R. James).

83-C-4 Fusarium root disease of western white pine seedlings at the Coeur d'Alene Nursery (R. James).

83-C-7 Western gall rust, Endocronartium harknessii, inoculation trials on jack pine seedlings to select resistance (Y. Beaubien, K. Knowles, S. Segaran, D. Gillis, G. Falk).

84-C-1 The effect of inoculum density of Macrophomina phaseolina on conifer nursery production (A. McCain).

84-C-3 Studies of Fusarium-associated diseases of conifer seedlings at northern Rocky Mountain nurseries (James and Gilligan).

84-C-4 Characteristics and identification of Phoma spp. associated with conifer seedling diseases (James).

84-C-5 Evaluation of conifer seedling mortality caused by Diplodia pinea in northern Rocky Mountain nurseries (James).

85-C-1 Control of Phomopsis blight of Douglas-fir and western hemlock at Humboldt Nursery (J. Kliejunas, J. Allison, A. McCain).

85-C-2 Evaluation of metam-solution, dazomet, and methyl-bromide-chloropicrin soil treatments for disease and weed control (S. Cooley).

85-C-3 Evaluation of various fungicides for control of Phytophthora root rot in transplanted Douglas-fir (S. Cooley, P. Hamm, W. Littke).

85-C-4 Evaluation of various fungicides for top-blight disease control at five nurseries (S. Cooley).

85-C-5 Evaluation of frequency of fungicide application for top-blight disease control (A. Kanaskie, S. Cooley).

85-C-6 Pathogenicity of seed-borne Fusarium isolates on sugar pine seedlings (S. Cooley).

85-C-7 Pathogenicity of five Phytophthora species on 12 conifer seedling hosts (S. Cooley, P. Hamm).

85-C-8 Biological and chemical control of soil borne fungi in forest tree nurseries (R. Blanchette).

85-C-9 Antagonism of thermophilic microorganisms found in solar heated soil to species of Fusarium pathogenic to lodgepole pine seedlings (D. Hildebrand).

85-C-10 Evaluating frequency and timing of fungicide applications to reduce losses from top-blight in bare root Douglas-fir seedlings (A. Kanaskie, S. Cooley).

85-C-11 Characterizing a Fusarium caused root disease of 2+0 bareroot Douglas-fir seedlings (P. Morgan, P. Hamm, S. Cooley, A. Kanaskie).

*D. Root and Soil Diseases or Relationships (Including Mycorrhizae)*

71-D-3 Relative species susceptibility to Phellinus weirii infection (E. Nelson).

71-D-2 Phellinus weirii root rot: epidemiology and control (W. J. Bloomberg).

71-D-3 Fomes annosus root and butt rot: epidemiology and control (D. Morrison).

71-D-4 Effects of nitrogen fertilization and interplanting red alder on root disease development in a thinned Douglas-fir plantation (E. Nelson).

72-D-2 Armillaria root disease: epidemiology and development and testing of stand management guidelines (D. Morrison).

73-D-1 Testing native conifer plantings for resistance to Phellinus weirii (K. Russell).

73-D-2 Testing red alder plantings to reduce Phellinus weirii development (K. Russell).

73-D-3 Alnus rubra as a biological control agent for Phellinus weirii (E. Hansen, E. Nelson).

75-D-1 Stump pushing in eastern Washington to control Phellinus weirii and subsequent performance of six planted conifers (K. Russell).

75-D-2 Red alder as a control for Phellinus weirii root rot of Douglas-fir: mixed stands (E. Hansen, E. Nelson).

76-D-4 Simulation of root rot impact in second-growth coastal Douglas-fir stands (W. Bloomberg).

76-D-5 Fertilization and root disruption to control laminated root rot of Douglas-fir (W. Thies, E. Nelson).

77-D-15 Stump pushing in western Washington to control Phellinus weirii and subsequent performance of planted Douglas-fir and western hemlock (K. Russell).

78-D-5 Survival of Phellinus weirii in residual roots following stump removal and nitrogen fertilization (W. Thies).

78-D-6 Occurrence of Phellinus weirii beyond visible limits of infection (W. Thies).

78-D-7 Growth loss of Douglas-fir infected by Phellinus weirii (W. Thies).

78-D-8 Chemical control of Armillaria root rot near Glenwood, Washington (K. Russell).

79-D-1 Surveys of root diseases in managed conifer stands in R-2 (D. Johnson, E. Sharon).

79-D-3 Verticicladiella wageneri on pinyon at Mesa Verde National Park: disease spread characteristics and vector relationships (D. Johnson, K. Lister, E. Sharon).

79-D-5 Spread of Armillaria mellea disease centers in managed pine stands (D. Johnson, E. Sharon).

79-D-9 Evaluation of effects of precommercial thinning in 10- to 20-year-old Douglas-fir plantations infected with Armillaria root rot in Oregon and Washington (G. Filip).

79-D-15 Infection of Sitka spruce and western hemlock thinning stumps by root disease fungi in southeast Alaska (T. Shaw).

79-D-16 Relative abundance of conidia and basidiospores of Fomes annosus in airborne inoculum (T. Shaw, E. Florance).

79-D-17 Evaluation of the incidence and impact of Fomes annosus in California fir stands (G. Slaughter, J. Parmeter).

79-D-18 Evaluation of borax stump treatment for control of Fomes annosus in California fir stands (M. Shultz, G. Slaughter, J. Parmeter).

79-D-23 Susceptibility of Pacific Northwest conifers to laminated root rot (W. Thies, E. Nelson).

79-D-24 Conifer culture with roots in nutrient mist (N. Martin).

79-D-25 Spatial relations of tree species in root disease areas (N. Martin).

79-D-26 Fungi and insects associated with and causing black stain root disease in Idaho (A. Partridge, C. Bertagnole).

79-D-29 Evaluation of selected mycorrhizal fungi for improving the survival and growth of container-grown Sitka spruce in southeast Alaska (T. Shaw).

80-D-2 Epidemiology and management of black stain root disease of western North America conifers (F. Cobb).

80-D-3 Distribution and activity of conifer mycorrhizae in Rocky Mountain forest ecosystems: impacts of disturbance, species, and age (A. Harvey).

80-D-4 Effects of fire management and intensive forest utilization on soil nitrogen status in northern Rocky Mountain timber types (M. Jurgensen, A. Harvey).

80-D-5 Evaluation of effects of precommercial thinning in 10- to 20-year-old red fir plantations infected with Armillaria root rot in southern Oregon (G. Filip).

80-D-9 Biology and management of Phellinus weirii (E. Hansen).

80-D-11 Insect-fungus interactions in the development of black stain root disease in Douglas-fir (E. Hansen, T. Schowalter).

80-D-13 Systems of organisms causing black stain in pine roots (A. Partridge).

81-D-4 Monitoring root diseases in northern Idaho forests (J. Schwandt).

81-D-10 Effects of selected silvicultural treatments on root disease development in the Northern Region (S. Hagle, and others).

81-D-12 Hylurgops porosus as a possible carrier of Verticicladiella spp. (C. Bertagnole, A. Partridge).

81-D-15 Insect attractants produced by some Verticicladiella spp. and pine hosts (C. Bertagnole, A. Partridge).

81-D-16 Root disease agents associated with subalpine fir mortality in central and southern Utah (B. Tkacz).

81-D-17 Identification of root pathogens and development of root disease management strategies in southern Utah spruce forests (B. Tkacz).

81-D-20 Infection, development, and survival of Fomes annosus in large hemlock stumps created by clearcutting (B. Van der Kamp).

81-D-21 Role of mycorrhizae in plant succession in the Mount St. Helens devastation zone (J. Trappe).

82-D-1 The application of chloropicrin and/or methyl isothiocyanate to live trees to control laminated root rot (caused by Phellinus weirii) (W. Thies).

82-D-2 The application of chloropicrin or Vorlex to infected stumps to eradicate Phellinus weirii (W. Thies, E. Nelson).

82-D-3 Endemic ectomycorrhizal fungi of ponderosa pine in central Great Plains plantings: identification of fungi and synthesis of ectomycorrhizae (J. W. Riffle).

82-D-4 Demonstration of Armillaria root disease control methods (S. Hagle, R. Becker).

82-D-5 Assessment of root disease development in young managed stands and plantations (J. Byler, R. James).

82-D-6 Development of Armillaria root disease in commercially thinned natural stands (S. Hagle).

82-D-7 Armillaria root rot of young intensively managed lodgepole pine stands of Alberta (Y. Hiratsuka, P. Blenis).

82-D-8 Resistanoe screening of Port-Orford cedar to Phytophthora lateralis root rot (E. Hansen, P. Hamm, L. Roth).

82-D-9 Effect of precommercial thinning on development of black stain root disease (E. Hansen, T. Schowalter, D. J. Goheen).

83-D-3 Evaluation of sivicultural, chemical and mechanical barriers to limit spread of black stain root disease centers in pinyon (D. Johnson, E. Sharon).

83-D-5 Intensificaton of mortality from Armillaria following sanitation/salvage (S. Hagle, R. Becker).

83-D-7 Longevity and spread of annosus root disease in ponderosa pine plantations (J. Marshall).

83-D-9 Volume losses in Gold Creek root disease center (J. Byler, C. Stewart).

83-D-10 Root disease impact on precommercially thinned stands (J. Byler, C. Stewart).

83-D-12 Ecology of mycorrhizae in Douglas-fir: uptake of nitrogen, particularly organic forms (Bledsoe, Zasoski, R. Edmonds).

83-D-18 Spread of Armillaria mellea in pine plantations (K. Knowles, Y. Beaubien).

83-D-19 Mycorrhizal fungi associated with decayed logs in old-growth and young forests (J. Trappe).

84-D-1 A case history of root disease development in unmanaged and commercially thinned stands on the Fernan Ranger District (Hagle and others).

84-D-2 Trichoderma species associated with Douglas-fir roots colonized by Phellinus weirii (E. Nelson, B. Goldfarb, W. Thies).

84-D-3 Occurrence and incidence of Fomes annosus spread from true fir stumps to surrounding pine seedlings and saplings (J. Kliejunas).

84-D-4 Mycorrhizae and soil borne pathogens recover after fumigation of nursery soils (K. Russell, Y. Tanaka, Weyerhaeuser Co.).

84-D-5 Natural occurrence of Trichoderma species on roots of recent and 10-year-old stumps of Douglas-fir infested with Phellinus weirii (B. Goldfarb, E. Nelson, E. Hansen).

85-D-1 Evaluation of the association between endemic mountain pine beetle populations and Armillaria root disease of lodgepole pine in Utah and Wyoming (B. Tkacz, R. Schmitz).

85-D-2 Evaluation of root disease--bark beetle associations in spruce stands in Utah and Wyoming (B. Tkacz).

85-D-3 Incidence of Fomes annosus spread from true fir stumps to adjacent plant pines in the Sierra Nevada (J. Kliejunas).

85-D-4 Development of a method for rating stands of Blue and Engelmann spruce in susceptibility to losses caused by Inonotus tomentosus root disease (F. Baker, B. Tkacz).

85-D-5 Incompatability reactions, cytology, and population biology of Phellinus weirii and Phytophthora species (E. Hansen).

85-D-6 Interactions between cover crops, fumigation, nitrogen availability, and populations of soil borne pathogens in nursery soils (E. Hansen).

85-D-7 Epidemiology and management of Fomes annosus (Heterobasidion annosum in western forests (F. Cobb).

85-D-8 Effects on windthrow of thinning in root disease centers (R. Harvey).

85-D-9 Ecological implications of Armillaria occurrence and damage in inland forests of the Pacific Northwest (G. I. McDonald, N. Martin).

85-D-10 Distribution of Armillaria genotypes in Pacific Northwest inland forests (N. Martin, G. I. McDonald).

85-D-11 Pathogenicity of Armillaria genotypes on native conifers of the Pacific Northwest inland forests (M. Larson, N. Martin).

85-D-12 Effects of site preparation on mycorrhization and growth of planted north Idaho conifers (A. Harvey, M. Jurgensen, R. Graham).

85-D-13 Effect of natural soil fumigation on microbial populations and growth of planted north Idaho conifers (A. Harvey, R. Graham, M. Jurgensen).

85-D-14 Genetic variability and host specificity in Fomes annosus (W. Otrosina).

85-D-15 Root distribution and infection by Fomes annosus in young mixed conifer and true fir stands (J. Parmeter, W. Otrosina, G. Slaughter).

85-D-16 Host specificity of P. tomentosus of central British Columbia conifers (B. J. Van der Kamp, J. Schulting).

85-D-17 Armillaria root rot spread plots (M. Sharon, D. Johnson).

85-D-18 Blackstain root disease-chemical and mechanical treatments (M. Sharon, D. Johnson).

85-D-19 Effects of fumigating natural forest soils on regeneration (A. Harvey, M. Jurgensen, R. Graham).

85-D-20 Determination of structural differences between conidiospores and basidiospores of Fomes annosus (T. Shaw).

85-D-21 Development of Fomes annosus root and butt rot after thinning young-growth stands of Sitka spruce and western hemlock in southeast Alaska (T. Shaw).

85-D-22 Susceptibility of conifers (Grand fir, Englemann spruce, Douglas-fir, Western larch, and Ponderosa pine) to laminated root rot (A. Kanaskie).

85-D-23 Effects of microsite microbes and organic matter manipulation on regeneration (A. Harvey, M. Jurgenson, R. Graham).

85-D-24 Incidence of root pathogens in residual trees and stumps in thinned mixed conifer stands attacked by insects (G. Filip).

85-D-25 Fire and root rot (A. Partridge, L. Nuenschwander).

85-D-26 Identification and characterization of Phellinus genotypes in north Idaho forests (M. Larson, N. Martin).

85-D-27 Phellinus weirii epidemiology and control (W. Bloomberg).

86-D-28 Carbohydrate reserves and maintenance respirations: controls of myoorrhizal turnover in ponderosa pine (R. Molina, J. Trappe).

85-D-29 Nodule-mycorrhizal interactions in Alnus rubra with special reference to nitrogen fixation and cycling in Douglas-fir forests (R. Molina, J. Trappe, S. Miller).

85-D-30 The role of ericaceous plants in maintaining diversity of conifer mycorrhizal fungi (R. Molina, J. Amaranthus, D. Perry).

85-D-31 The ability of different conifer species to share mycorrhizal fungi via fungus connections (R. Molina, M. Castellano).

85-D-32 Fall fumigation combined with spring benomyl to control antagonists against inoculated mycorrhizal fungi (R. Crawford).

85-D-33 Hypogeous fungi of southwestern Oregon and northern California compared with those of Spain for nursery inoculation (J. Trappe).

85-D-34 Effects of stump treatment on mortality caused by Armillaria root rot in a mixed-conifer forest (W. Thies, G. Filip).

85-D-35 Role of soil aluminum in Armillaria disease incidence (R. Edmonds).

85-D-36 Development of Armillaria in shelterwood cut of 50-year-old white pine (G. McDonald, N. Martin).

85-D-37 Occurrence and characterization of biologic species of Armillaria complex in western National Forests (G. McDonald, N. Martin, A. Harvey).

85-D-38 Stress, adaptational ecophysiology and susceptibility of Pacific Northwest conifers to the Armillaria complex (G. McDonald, G. Rehfeldt, A. Harvey).

### *E. Foliage Diseases*

74-E-1 Inheritance of resistantce to Rhabdocline pseudotsugae in Douglas-fir (G. McDonald, G. Rehfeldt).

77-E-1 Dothistroma pini resistance in ponderosa pine (G. Peterson).

77-E-2 Inheritance of resistance to Dothistroma pini in Austrian pine (G. Peterson, D. Van Haverbeke).

77-E-4 Resistance to Phomopsis juniperovora in geographic sources of Juniperus virginiana and J. scopulorum (G. Peterson).

81-E-7 Growth of germ tubes positively directed toward stomates--is this a common phenomenon of fungi infecting plant foliage? (G. Peterson).

82-E-1 Helicopter fungicide applictions to control Swiss needle cast in 8-12 year-old Douglas-fir forest plantings (K. Russell).

82-E-3 Dothistroma pini of ponderosa pine in northern Idaho (R. James).

83-E-3 Swiss needle cast ecology and impact in northern Montana Christmas trees (S. Hagle).

85-E-1 Biology of the needlecast fungi Hendersonia pinicola and Dothistroma septospora (J. Rogers, S. Stahl).

### *F. Stem Diseases, Malformations, Witches-Brooms, Dwarf Mistletoes, etc.*

62-F-1 Life tables for lodgepole pine and ponderosa pine dwarf mistletoe (F. Hawksworth).

62-F-2 Ecology of lodgepole and ponderosa pine dwarf mistletoes (F. Hawksworth).

62-F-4 Taxonomy, hosts, and distribution of Arceuthobium (F. Hawksworth, D. Wiens).

-F-5 Silvicultural control of ponderosa pine dwarf mistletoe in the Southwest (F. Hawksworth).

-F-1 Spread and intensification of dwarf mistletoe in ponderosa and Jeffrey pines in California (R. Scharpf, J. Parmeter).

-F-1 Effectiveness of dwarf mistletoe control following special DM-precommercial thinnings in pondersoa pine and Douglas-fir (K. Russell).

-F-1 Growth impact, associated mortality, and spread and intensification of dwarf mistletoe in stands of Douglas-fir, and lodgepole pine (O. Dooling).

-F-1 Simulation of the effects of dwarf mistletoe in ponderosa pine and lodgepole pine stands (F. Hawksworth, C. Edminster).

-F-4 Inoculation studies to determine the host ranges of Arceuthobium campylopodium and A. occidentale in California (W. Mark, R. Scharpf, F. Hawksworth).

8-F-2 Control of dwarf mistletoe-caused losses in young true fir stands by thinning (R. Smith, R. Scharpf, D. Vogler).

8-F-3 Population dynamics of dwarf mistletoe on true firs in California (R. Scharpf, J. Parmeter).

8-F-4 The effect of dwarf mistletoe on mortality and volume loss in released true fir stands (R. Scharpf).

8-F-5 Reduction of dwarf mistletoe-caused mortality of Jeffrey pines by broom pruning (R. Smith, R. Scharpf).

9-F-4 Dwarf mistletoe infection in inoculated young-growth western hemlock (T. Shaw).

79-F-7 Growth loss in managed, even-aged, dwarf mistletoe-infested stands of ponderosa pine in the Pacific Northwest (E. Nelson, R. Harvey).

81-F-1 Resistance of Jeffrey pine to dwarf mistletoe, Arceuthobium campylopodium (R. Scharpf, B. Kinlock, J. Jenkinson).

81-F-3 Interactions of dwarf mistletoe and fire in lodgepole pine forests of the central Rocky Mountains (T. Zimmerman, F. Hawksworth).

81-F-4 Development of hemlock dwarf mistletoe following precommerical thinning of infected young stands in southeast Alaska (T. Shaw, P. Hennon).

82-F-2 Development of a yield simulation model in uneven-aged, mistletoe infected ponderosa pine stands (H. Maffei, W. Jacobi, F. Hawksworth).

82-F-4 Dwarf mistletoe-related mortality of ponderosa and Jeffrey pines in campgrounds in California (D. Vogler, R. Scharpf).

83-F-1 Thinning demonstration of dwarf mistletoe-infected lodgepole pine on the Targhee National Forest, Idaho (J. Hoffman).

83-F-4 Rate of spread, volume loss and management strategies for Arceuthobium americanum on jack pine and Arceuthobium pusilum and white spruce (K. Knowles, Y. Beaubien, D. French, F. Baker).

83-F-5 Effect of N-fertilization on growth and development of dwarf mistletoe on red fir (R.F. Scharpf).

84-F-1 Parasitism of dwarf mistletoe on red fir by brown felt blight (R. F. Scharpf).

84-F-2 Field testing of dwarf mistletoe resistant Jeffrey pine seedlings (R. F. Scharpf, R. S. Smith).

85-F-1 The response of infected lodgepole pine to variations in available soil water (L. Kirkpatrick).

85-F-2 The effect of dwarf mistletoe on the response of Douglas-fir to thinning (B. Tinnin, D. Knutson).

85-F-3 The effects of dwarf mistletoe on the response of young Douglas-fir to thinning (B. Tinnin).

85-F-4 The effects of dwarf mistletoe on seed production and population dynamics of lodgepole pine (J. Wanner).

85-F-5 Silvicultural control of dwarf mistletoe in young lodgepole pine stands (D. Johnson, F. Hawksworth).

85-F-6 Dwarf mistletoe infection by seeds placed on western hemlock regeneration in coastal Alaska (T. Shaw).

85-F-7 Impact of Arceuthobium americanum in jack pine stands (F. Baker, D. French, K. Knowles).

85-F-8 Incidence of attack by dwarf mistletoe and western spruce budworm on Douglas-fir (G. Filip).

### *G. Stem Diseases: Stains and Decays*

73-G-1 Decay associated with logging-damaged conifers in Oregon and Washington (P. Aho).

73-G-2 Tests of wound dressings on artificial injuries on western hemlock and Sitka spruce (P. Aho).

73-G-3 Decay hazard in advanced regeneration of tolerant conifers in Oregon and Washington (P. Aho).

82-G-1 Bioactive metabolites of forest tree pathogens--Germmeniella abientina, blue stain fungi associated with mountain pine beetle, Condrostererum purpureum Verticicladiella spp. (Y. Hiratsuka, W. Ayer).

85-G-1 Deterioration of mountain pine beetle killed lodgepole pine in northeastern Oregon (R. Harvey).

85-G-2 Evaluation of aspen cankers and stem rots in relation to timber harvesting in Colorado and New Mexico (D. Johnson, J. Beatty, T. Hinds).

85-G-3 Evaluation of diseases associated with sprout damage and mortality in clearcut aspen stands (T. Hinds, D. Johnson).

85-G-4 Sexuality, genetics, and biology of Echinodontium tinctorium (J. Rogers D. Wilson, O. C. Maloy).

85-G-5 Effects of thnning on tree wound response in western conifers attacked by insects (G. Filip).

79-G-5 Decays and cavity nesting birds in the Pacific Northwest (A. Partridge, E. Bull).

*H. Stem Diseases: Rusts and Cankers*

66-H-1 Comparative physiology of varieties of western white pine with respect to their reaction to the blister rust fungus (R. Hoff).

67-H-2 Field level of blister rust infection in early generation, partially resistant, western white pine stock (R. Hoff).

69-H-1 Thinning and pruning western white pine to control the blister rust disease (J. Byler, N. Martin).

71-H-3 Forest tree rusts of western North America (Y. Hiratsuka).

74-H-1 Rust fungi of Cupressaceae and Taxaceae: taxonomy and life histories (R. Peterson).

74-H-6 Seed production areas for obtaining western white pine that is genetically improved for resistance to blister rust (R. Hoff, G. McDonald).

77-H-2 White pine blister rust pathology (R. Hunt).

79-H-1 Diplodia tip blight in the Black Hills of the South Dakota (G. Peterson, D. Johnson).

79-H-5 Expansion of stalactiform blister rust cankers on lodgepole pine (T. Beard, B. Geils, N. Martin).

79-H-6 Association of stalactiform blister rust with other diseases and insects of lodgepole pine (T. Beard, N. Martin).

80-H-1 Evaluation of aspen harvesting practices in Colorado and New Mexico (D. Johnson, J. Beatty).

80-H-4 Genetic variation of gall frequency in lodgepole and ponderosa pine seedlings inoculated with western gall rust (R. Hoff).

80-H-5 Inheritance of horizontal resistance mechanisms in western white pine to blister rust (R. Hoff).

80-H-7 Pruning white pine for blister rust control (K. Russell).

80-H-8 Growth of Cronartium coleosporoides in tissue of Pinus contorta (T. Beard, N. Martin).

81-H-1 Biology, cytology, and systematics of Xylaria (J. Rogers, B. Callan).

81-H-3 The etiology of Thyronectria canker on Colorado honeylocusts (W. Jacobi).

81-H-5 Biology and control of stem rusts of hard pines (R. Blanchette, D. French).

81-H-6 Wood deterioration by canker-rot fungi (R. Blanchette).

82-H-2 Canker diseases of honeylocust: etiology, infection, and disease development (J. W. Riffle, G. W. Peterson).

82-H-3 Guidelines for management of western white pine in the Northern Region (S. Hagle, G. McDonald, G. Norby).

82-H-4 Western gall rust studies in relation to the genetic improvement program of lodgepole pine (Y. Hiratsuka, P. Blenis).

83-H-1 Hazard rating and ecology of comandra blister rust in the Rocky Mountain Region (W. Jacobi).

83-H-4 Management of lodgepole pine infected by comandra blister rust in the Rocky Mountains (B. Geils, W. Jacobi, F. Hawksworth, D. Johnson).

83-H-8 Distribution and parentage association of western gall rust infection in four ponderosa pine seed orchards (J. Hoffman, J. Marshall).

85-H-1 Epidemiology and management of western conifer rusts (especially western gall rust and white pine blister rust) (F. Cobb).

85-H-2 Tuberculina maxima inoculation as an aid to biological control of white pine blister rust (R. Harvey).

85-H-3 Canker diseases of cottonwood: etiology and damage to select cultivars (J. W. Riffle, G. W. Peterson).

85-H-4 Aspen and willow cankers--cause, biology, and control (D. French, J. Juzwik).

85-H-5 Inheritance of resistance of lodgepole pine to western gall rust (B. J. Van der Kamp, M. Curran, H. O. Kojwong).

85-H-6 Evaluation of damage and recommendations for control of comandra rust in lodgepole pine (B. Giles, D. Johnson, F. Hawksworth).

85-H-7 Rating the severity of limb rust in ponderosa pine stands (F. Baker, B. Tkacz).

85-H-8 Biology of limb rust on Ponderosa Pine (F. Baker).

85-H-9 Epidemiology of western gull rust (P. Blenis, Y. Hiratsuka).

85-H-10 Pathogenicity of Cytospora sp. on thin-leaf alder, cottonwood, and willow in eastern Oregon riparian zones (G. Filip).

85-H-11 Definition of mechanisms of resistance to Cronartium ribicola in Pinus lambertiana (G. McDonald).

85-H-12 Progress and speed of natural selection in blister rust infected western white pine (G. McDonald, R. Hoff).

85-H-13 Evaluation of uniform-spore-distribution chambers for inoculating Ribes and Pinus with Cronartium ribicola aeciospores and basidiospores (G. McDonald).

85-H-14 Field level of blister rust infection in early-generation, partially resistant western white pine stock (G. McDonald, R. Hoff).

85-H-15 Seed production areas for obtaining western white pine that is genetically improved for resistance to blister rust (R. Hoff, G. McDonald).

85-H-16 Geographic variation of Cronartium ribicola on Ribes and western white pine (G. McDonald).

85-H-17 Modeling mortality of blister rust infected with pine (G. McDonald, N. Martin, R. Hungerford, W. Wykoff).

85-H-18 Development of a predictive blister rust epidemic model (G. McDonald).

85-H-19 Inheritance of horizontal resistance mechanism (G. McDonald).

85-H-20 Isozyme characterization of Champion Mine strain of Cronartium ribicola (G. McDonald).

85-H-21 Resistance of lodgepole pine to western gall rust (R. Hoff).
85-H-22 Resistance of ponderosa pine to western gall rust (R. Hoff).

*I. Wilt and Blight Disease*

71-I-1 Dutch elm disease detection surveys in all municipalities in Colorado (J. Laut, M. Schomaker).
77-I-1 Distribution of Dutch elm disease and its principal vector, the smaller European elm bark beetle, in Montana urban areas (O. Dooling, S. Kohler).
77-I-3 Diplodia pinea tip blight on pines: etiology and stem infections (G. Peterson).
79-I-2 Resistance to Cercospora sequoia var. juniperi in geographic souroes of Juniperus viginiana and J. scopulorum (G. Peterson).
85-I-1 Oak wilt--control strategies (D. French).
85-I-2 Dutch elm disease--control strategies (D. French).

*J. Defects and Decays of Forest Products*

58-J-1 Deterioration of beetle-killed Englemann spruce in Colorado (T. Hinds).
76-J-1 Microdistribution and efficacy of preservatives in treated wood and their effects on microorganisms (W. Wilcox).
79-J-1 Diagnosis of wood decay (W. Wilcox).
85-J-1 Role of heartwood mioroflora in the breakdown of thujaplicin in western red cedar heartwood (B. Van der Kamp).

*K. Miscellaneous Studies*

58-K-1 Taxonomic studies of forest fungi (A. Funk).
73-K-3 Fungi of Washington State (J. Rogers).
78-K-1 Effect of thinnings on the incidenoe and impact of Cystospora canker, fir engraver beetle, and Fomes annosus in white fir stands on the east-side Sierra Nevada (G. Ferrell, R. Scharpf, J. Parmeter).
79-K-1 Use of the Shigometer for assessment of tree vigor and growth in 25- to 100-year-old Sitka spruce and western hemlock (T. Shaw).
79-K-2 Mortality of Douglas-fir: biotic systems and impacts (A. Partridge).
79-K-3 Management alternatives in forests with Douglas-fir mortality centers (A. Partridge).
80-K-1 Evaluation of hazardous trees in developed forested recreation sites (E. Sharon, Hubbard).
80-K-3 Interactions among the pine wood nematode, fungi, and bark beetles in the Midwest (P. Bedker, R. Blanchette).
80-K-6 Computer programs to analyze street tree inventory data in urban areas of Idaho (J. Schwandt).
81-K-1 Comparative roles for saprophytic and pathogenic decays in Rocky Mountain forest soils: impacts of disturbance on regeneration and growth (A. Harvey, M. Larsen).
81-K-2 Life histories and anamorphs of lignicolous Pyrenomycetes (J. Rogers).
81-K-4 Reestablishment of vegetation on Mount St. Helens-created debris flow: an unusual "pathological" event (K. Russell).
82-K-1 Comprehensive pest management policies for Washington State (within DNR's Forest Land Management Plan) (K. Russell).
83-K-1 Evaluation of aspen harvesting practices in Colorado and New Mexico (T. Hinds, D. Johnson, J. Beatty).
83-K-2 Tree diseases and their effects in reoreational areas (T. Hinds, E. Sharon).
83-K-4 Mistletoe and root disease control demonstration areas (J. Muir).
83-K-5 Vegetative management plan for Lewis and Clark Campground, Lolo National Forest (C. Stewart, R. Yates, V. Applegate).
83-K-7 Ponderosa pine logging residue decomposition on the east side of the Washington Cascades (C. Driver).
84-K-1 Evaluation of pests associated with underburning mixed conifer stands for fuel reduction (J. Pronos).
85-K-1 Use of remote sensing techniques for the detection, survey, and damage appraisal of root diseases (J. Y. Lee, W. J. Bloomberg).
85-K-2 Potential of Beauveria bassiana for direct control of bark beetles (H. S. Whitney).
85-K-3 Interactions among forest tree diseases, insects, hosts, and humans (F. Cobb).
85-K-4 Effects of decomposition of wood on regeneration of eastern cascade slope sites (C. Driver).
85-K-5 Isolation and characterization of selective lignin-degrading fungi with potential industrial application (R. Blanchette).
85-K-6 Ultrastructure of wood decompostion by Basidiomycetes (R. Blanchette).
85-K-7 Survey of condition and vigor of recovering Rocky Mountain aspen stands (T. Hinds, W. O. Shepperd, G. L. Crouch).
85-K-8 Occurrence, anatomy, cause and early detection of fluted hemlock in southeast Alaska (T. Shaw).
85-K-9 Computer Programs for dissemination of pest information (F. Baker).
85-K-10 Nutrient dynamics in decomposing Douglas-fir and red alder logging residue (K. Vogt, R. Edmonds).