

PROCEEDINGS OF THE 34th ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

**Juneau, Alaska
September 1986**



Proceedings of the 34th Annual Western International Forest Disease Work Conference

**Juneau, Alaska
September 1986**

**Compiled by:
Sally J. Cooley
USDA Forest Service
Forest Pest Management
Portland, Oregon**

This scan has not been edited or customized. The quality of the reproduction is based on the condition of the original source.

Compiled by Sally J. Cooley
TABLE OF CONTENTS

Page		
6	Chairman's Welcome	Kenelm Russell
8	Opening Remarks: Welcome to the Alaska Region	Michael A. Barton
PANEL: "PESTS OF ALASKA"		
12	Major Forest Insects in Southeast Alaska	Andris Eglitis
13	Noteworthy Forest Diseases in Alaska	Paul E. Hennon and Charles G. "Terry" Shaw III
PANEL: "RUSTS AND RELATED DISEASES"		
22	Rating the Severity of Limb Rust in Ponderosa Pine Stands	F. A. Baker, D. Rabin, Wang Chengguo and B. M. Tkacz
24	Status and Direction of Studies on Comandra Blister Rust in the Rocky Mountains	Brian W. Geils
27	Pruning White Pine to Control Blister Rust in British Columbia	R. S. Hunt
29	Commandra Rust Damage and Risk Rating Research	W. R. Jacobi, J. E. Boyd and W. R. Zentz
31	Whitebark Pine and the 4 B's: Blister Rust, Bark Beetles, Burning, and Bears	Richard G. Krebill
PANEL: "DWARF MISTLETOES"		
34	Introduction to the Dwarf Mistletoe Discussion Session	John A. Muir
35	Comparison of Dwarf Mistletoe Effects on Hemlock in Alaska, British Columbia and the Pacific Northwest	W. J. Bloomberg
41	Mensurational and Statistical Problems in Determining the Impact of Dwarf Mistletoe on Volume Growth	Donald J. DeMars
45	Taxonomy of Hemlock Dwarf Mistletoe	Frank G. Hawksworth
47	The Effect of Dwarf Mistletoe Infection on Growth and Mortality Rates of Ponderosa Pine Growing in Unevenaged Irregular Stands in Colorado	H. M. Maffei and W. R. Jacobi
48	Dynamics of Dwarf Mistletoe Infected, Immature Western Hemlock Stands	Bart J. van der Kamp
PANEL: "ROOT DISEASES"		
52	Opportunities to Evaluate Root Disease Incidence and Damage Using Forest Inventory and Permanent Growth Plots	James W. Byler, Michael A. Marsden and Susan K. Hagle
57	Root Pathogen Impact- How Do We Measure It?	Greg Filip, Al Kanaskie and Phil Hamm
59	Effects of Management Activities and Dominant Species Type on Root Disease-Caused Mortality in Two Oregon Forests	Don Goheen, Craig Schmitt, Ellen Michaels Goheen and Susan Frankel
61	Resistance to Laminated Root Rot by Western Conifers Outplanted on Infested Sites	Earl E. Nelson
64	Controlling Laminated Root Rot with Fumigation	Walter G. Thies and Earl E. Nelson
68	Pears, Bears and Phytophthora in S.E. Alaska (or the Indication that <i>P. drechsleri</i> is Endemic to S.E. Alaska)	Phillip B. Hamm, Everett M. Hansen, Paul E. Hennon and C.G. Terry Shaw III
72	Forest Pathology Trivia Pursuit	F. G. Hawksworth, C. G. Shaw III and J. S. Beatty

74	Uncovering the Cause of Fluting in Western Hemlock in Southeast Alaska	Kent Reinhold Julin
78	Control of Dwarf Mistletoe with Ethephon	
	Thomas H. Nicholls, Leanne Egeland, Frank G. Hawksworth and David W. Johnson	
86	Forest Decline in Europe	P. Schutt
89	A Visual Ain't a Visual If You Can't See it	Delbert E. Thompson
96	Animal Vectors of <i>Arceuthobium americanum</i> on Lodgepole Pine	
	Thomas H. Nicholls, Frank G. Hawksworth and Leanne Egeland	
96	Disease Cycle of <i>Lirula abietis-concoloris</i> on White Firs in California	Robert F. Scharpf

BUSINESS AND COMMITTEE REPORTS

98	Field Trip
101	Business Meeting Minutes and Treasurer's Report
103	Mistletoe Committee Report
107	Disease Control Committee Report
111	Projects

CHAIRMAN'S WELCOME

Kenelm Russell

Welcome to all!

It only took us 17 years. We actually began this trip in 1969 and at nearly every WIFDWC since. I hope each of you have discovered something special about Alaska. It was special for the 23 of us who left Friday evening in a spectacular Seattle sunset aboard Alaska Ferry's M.V. Columbia. After waking up at the entrance to Seymore Narrows near Campbell River and running in thick fog north of Johnstone Strait, we thought we might be in the fog the rest of the way. That was not to be....

The fog thinned and gradually lifted and we were treated to sparkling days (Northwest style) and starry nights for the rest of the trip. At Ketchikan a funny bus ride, a look at a jam-packed salmon run and the Indian story of fox woman and

At Wrangell we had to wait for the tide to rise enough to allow the Columbia through Wrangell Narrows. We hiked to a beach near the mouth of the Stikine River and made rice paper rubbings of Indian petroglyphs using fern leaves. The low afternoon northern sun on the beach made us want to stay permanently, or at least until it started raining.

The midnight run through 21 mile long Wrangell Narrows at 16.5 knots with close in (15 feet at times) rock piles and bottom a scant two or three feet beneath our hull held us spellbound. The 73 flashing red and green nav lights looked like a preview of Christmas on a big city street. At the narrowest part a meteorite so bright it left a contrail streaked ahead as if to light the way and the aurora borealis made such a special presentation that even the locals were excited.

Such a show! Who wanted to go to bed?

Early Monday morning found us rounding the end of Douglas Island and approaching the snout of Mendenhall Glacier and Juneau. The air was crisp and after seeing that glacier many could not resist a flight over the expansive Juneau Ice Fields, tumbling glaciers and milky fjords.

REFLECTIONS

There have been rumblings that Forest Pathology is on the downswing. I checked our old proceedings at five year intervals to see if there were any clues to such a change.

1965. Kelowna, my first WIFDWC. Fresh from Upper Michigan, I thought Poria was in Illinois. Jack Bier advised us that we younger members would do well to listen to the talent and experience and take advantage of it. I sure needed that because I had to get Poria in perspective.

1970. At Harrison Hot Springs we learned that Willis Wagner one of our Conference founders died after 44 years of service and a lot of pioneering in our field. Chairman (It was ok then to be a chairman.) Bob Scharpf stressed informality and openness. Bob said "Do not be afraid to put yourself in harm's way."

1975. Stu Whitney told us in Missoula, "let others look at our ideas. Disseminate our words. Don't keep to ourselves." By now I had my Poria straight and then they changed the dang name.

1980. At Pingree Park under Bob Gilbertson we had some indepth talk about "Public Perceptions, Who Cares? (about Forest Pathology). Terry Shaw listened and had Sam Frear write the popular article in American Forests magazine about cedar dieback in Alaska.

Ken Russell was heard to utter the words, Keep your "ear" to the grindstone and listen to the wind. Now how could I listen to the wind if I ground my ear off?

1985. A record crowd of 100 came to Olympia and heard chair Fields Cobb (in absentia through Walt Thies) express concern about reductions in Forest Pathology... How can that be? We did some new things at Olympia: used a computer for group input pest management decision making; separated good old *Armillaria* into several species and explored the workings of the new root rot model. Might not pathology awareness be growing?

1986. We have moved out of "control" into pest prevention. We now have aggressive ways to deal with root rots and the dwarf mistletoes. Managers are into stump pushing and silvicultural management of root rot and dwarf mistletoe infested forests. Forest Pathologists are looking ahead to preventing root diseases in stumps with other organisms and fumigants. We can use computers to look at future economic and biological productivity of our forests with various levels of simulated pests. Pest management has a solid footing in the Forest Service Silviculture Institute Program.

Business is booming for those of us in pest management technology transfer. Landowners and managers have besieged us with requests for help in pest management. There seems to be an increased desire to do something about forest pests today.

We may be looking at a time lag. We did succeed in waking the land managers. They are aware of pest management. If the academic pathology base is truly shrinking can we keep up with technology transfer increases? I do not see Forest Pathology shrinking on the side of the manager. I'm really up on Forest Pest Management and the Decision Making Process. If there is a problem on the academic side I would like to see us try some innovative ways of doing the job better even if it means doing it with less money. Let's hear your thoughts.

John Laut said it aptly about coming to Juneau. "We just came up to break the ice."



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

WELCOME TO THE ALASKA REGION

Michael A. Barton

Good morning! Welcome to Alaska! After 33 annual meetings held throughout western Canada and the United States, it is high time that the Western International Forest Disease Work Conference comes to Alaska.

As you will see during your short stay in Juneau, Alaska is well-endowed with natural resources. The two National Forests in Alaska encompass some 23 million acres. You may be aware that the Tongass and the Chugach National Forests are the largest in the National Forest System. The Tongass National Forest occupies the "panhandle" or Southeast portion of the State and is approximately 500 miles long and 100 miles wide. The 17-million acres cover an area about the size of Indiana. The Chugach National Forest, headquartered in Anchorage, is about 210 miles wide and 120 miles deep. The six-million acre forest extends south and east of Anchorage along the Southcentral Alaskan coast, and encompasses most of the Prince William Sound area.

The Chugach National Forest, besides supplying timber to a limited local economy, serves as an outdoor playground to over one-half of the state's population. Maintaining a quality recreational experience, including exceptional fishing and hunting opportunities, is a prime management objective on many portions of the forest.

Michael A. Barton is the Regional Forester, Alaska Region, USDA Forest Service, Juneau, Alaska.

Development of the fisheries resource is also a top priority. In terms of multiple use, the area also supports the world's largest epidemic of spruce beetle, more of which I am sure you will hear about at this conference.

The Tongass National Forest, located here in southeast Alaska, is the largest single land unit administered by the Forest Service. Because of its immense size, some 17-million acres, the Tongass is divided into three administrative areas. Forest Supervisors and their staffs are located in Sitka, Petersburg, and Ketchikan.

The 23,000,000 acres of National Forests in Alaska are managed for multiple use purposes. The work force for the Alaska Region, including temporary employees, numbers slightly more than 800 full-time equivalents (FTE's). The important overall objective that guides our combined efforts is performing wise management of the resources -- recreation, water, wildlife and fisheries habitat, and minerals, as well as timber.

Besides containing vast quantities of commercial timber, spawning grounds for millions of commercially caught salmon, and critical wildlife habitat, these forests include fourteen wilderness areas and two national monuments. The latter provide some unique management responsibilities because of overlapping and somewhat conflicting, but mandated, management objectives, such as mining and maintaining quality wilderness.

Both National Forests present unique recreational opportunities: 190 public cabins for recreation and emergency use, 31 campgrounds, 1 major winter ski area, and 3 major visitor centers. In 1984, the Alaska Region received approximately five million Recreation Visitor Days Use.

Tourism is an important industry to the state of Alaska and opportunities for recreation abound. Here on the Tongass they range from attractions such as the Forest Service's Visitor Information Centers, one located across the lobby here in Centennial Hall, and another at nearby Mendenhall Glacier, to incomparable fishing, hunting, and hiking adventures in remote, pristine portions of Southeast Alaska.

Fishing, both commercial and recreational, continues to be a mainstay of Alaska's economy. Approximately 100 million pounds of salmon are produced annually on the National Forests. The full potential fish production from Southeast streams has not yet been met. Since 1962 the Forest Service has been cooperating with the Alaska Department of Fish and Game and the Regional Aquaculture Associations in a fish habitat improvement program. So far, over 250 fish habitat enhancement projects have been completed.

The Alaska National Interest Lands Conservation Act (ANILCA), enacted in 1980, required the Forest Service to offer roughly 450 million board feet of timber per year over a ten-year period to maintain local economies dependent on the industry. It also enabled continuance of the average annual

allowable sale quantity for timber-producing lands after acreages were deducted for classification as Wilderness areas and national monuments. Of the 17 million acres on the Tongass, about 10 percent will be harvested over the 100 year rotation.

As timber markets have declined, local industry has raised strong protests about Forest Service funding and standards for preloading, precommercial thinning, advanced logging technology, and facilities development. The industry desires the funds to be spent in a manner more directly supportive of their activities. Several policy changes have been implemented over the past few years to improve the economic viability of timber sales in Alaska, including enlarging the size of clearcuts, raising the volume of timber harvested per mile of road constructed, reducing acreages planned for harvest in low volume stands, and adjusting re-entry schedules to use existing roads wherever possible.

Mining has always been a part of the scenery on the National Forests in Alaska. Of recent interest are two mining developments; one near Juneau at Green's Creek on Admiralty Island and the other at Quartz Hill in the Misty Fiord Monument near Ketchikan. The former will provide employment for 300 people for 15-17 years while the Quartz Hill project will provide employment for about 800 people for 50-70 years. Other mining activities are scattered on the two National Forests.

To summarize, three major industries (fishing, tourism, and timber) are dependent, at least in part, upon the resources of the National Forest here in Southeast Alaska. During the first four years of the 1980's, these industries contributed roughly 11,000 jobs. The direct earnings for the fishing industry were \$90 million; the tourism industry \$60 million; and the timber industry \$120 million.

This is a brief look at the Region and hopefully helped orient you. I hope you have an opportunity while you are here to take advantage of some of the sights in the Juneau area. I wish you well in this conference. Keep up the good work. In my opinion, you are unsung heroes. You labor is virtually ignored by many of us until there is a problem. Then we turn and ask, "How could that have happened?", forgetting the many times you had tried to bring the emerging problem to a manager's attention. At any rate, I'm glad to be able to welcome you today and repay in a small way the many times I haven't paid enough attention, including, Terry Shaw -- Hemlock fluting.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

MAJOR FOREST INSECTS IN SOUTHEAST ALASKA

Andris Eglitis

ABSTRACT: There are relatively few forest insect pests in Southeast Alaska. Defoliators of western hemlock are the most conspicuous of these insects, periodically affecting vast acreages of old-growth forest. Other key pests include the striped ambrosia beetle which attacks primary forest products, and the spruce bark beetle, a localized pest found in Glacier Bay National Park.

INTRODUCTION: Due to simpler ecosystems than we find further south, there are relatively few forest insect pests in Southeast Alaska. Certain key pests such as the Sitka spruce weevil are not found in our coastal forests. Two defoliators of western hemlock are the most common insects we encounter, and although they are currently at low levels, both have periodically produced large-scale damage throughout the panhandle. Outbreaks by these insects usually develop and decline very suddenly, are of short duration, and often affect vast acreages.

WESTERN BLACK-HEADED BUDWORM

This insect is a close relative of the western spruce budworm which causes considerable damage to coniferous forests throughout the western states. The black-headed budworm feeds predominantly on the current year's foliage of western hemlock and rarely attacks Sitka spruce. Budworm populations

Andris Eglitis is an entomologist with State & Private Forestry, Alaska Region, Juneau, Alaska.

are presently at low levels in Southeast Alaska although in the late 1960's an outbreak covered several million acres throughout the panhandle. The budworm occasionally produces top-kill in hemlock and radial growth loss in affected trees.

HEMLOCK SAWFLY

In 1983 the hemlock sawfly produced visible defoliation of western hemlock on about 100,000 acres, reaching its highest levels in 15 years. Populations are currently declining, but the outbreak in 1983 produced considerable top-kill and whole-tree mortality on nearly 8000 acres in Southeast Alaska. The sawfly feeds on the older foliage of hemlock and produces its greatest affect on the host when it occurs together on the same trees with the black-headed budworm. Each year we monitor the larval populations of the sawfly and other defoliators by sampling at 60-90 remote beach locations throughout Southeast Alaska. This sampling system has been relatively effective in detecting annual changes in population levels.

STRIPED AMBROSIA BEETLE

The ambrosia beetle is by far the most important forest insect pest in Southeast Alaska from an economic standpoint. The beetle constructs galleries in the sapwood of freshly cut spruce and hemlock logs producing considerable degrade of the affected material. Since much of the material harvested in Southeast Alaska is destined for the export market, the degrade produced by the beetles has meant a substantial dollar loss to companies exporting infested material. Ambrosia beetle populations and damage have been high over the past five years throughout Southeast Alaska.

SPRUCE BEETLE

The spruce bark beetle is far more important in southcentral and interior Alaska than in the southeastern panhandle. In Southeast Alaska, the only active infestation is found in Glacier Bay National Park, but is of particular interest due to the unique vegetation in the Park and the special conditions surrounding the development of the forest. The Park was covered by a thick layer of glacial ice as recently as 200 years ago. Following a very rapid glacial recession, the exposed land was quickly colonized by pioneer plants and eventually a dense forest of Sitka spruce. That spruce forest is now around 140 years old, is fairly even-aged, and growth of individual trees has been extremely slow in recent years. The spruce beetle gained a foothold in the area following extensive blowdown in 1977 and has been at outbreak levels since 1979. Currently, about 14,000 acres of spruce forest have been infested, with mortality exceeding 70% of the stand in some areas. We have been monitoring the infestation at the request of the National Park Service and have taken the opportunity to learn how the beetle behaves and develops in the Sitka spruce host type.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

NOTEWORTHY FOREST DISEASES IN ALASKA

Paul E. Hennon and Charles G. "Terry" Shaw III

ABSTRACT: Forests in Alaska consist primarily of virgin, old-growth trees. The most important diseases of such forests in southeast Alaska are hemlock dwarf mistletoe, wood decays, and decline of Alaska-yellow cedar. Foliage, twig, and stem pathogens attack the commercially important western hemlock, Sitka spruce, Alaska-yellow cedar, and western redcedar, but none currently cause appreciable damage. The significance of some diseases (i.e., root rots, and dwarf mistletoe) in young stands that develop after the old-growth is harvested and management of the young-growth intensifies, is a topic of current study. In interior Alaska, canker diseases are particularly destructive on birch, aspen, and other hardwoods. Decays of conifers and hardwoods are common in south-central and interior Alaska; however, even general knowledge of the pathological condition of most forests in these areas is lacking. Damage to forest trees by animals (e.g., porcupines and bears) is common throughout Alaska.

PAUL E. HENNON is a Plant Pathologist, USDA Forest Service, Forest Pest Management, Juneau, Alaska; CHARLES G. "TERRY" SHAW III is a former Research Plant Pathologist, USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, Juneau, Alaska; currently Research Plant Pathologist & Project Leader, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

INTRODUCTION

To some, forest pathology in Alaska may appear to be a throwback in time. We are still studying problems of old-growth trees (primarily decays), we are still cataloging new diseases, and we openly admit that we have many more questions than answers. For example, until this summer, we did not know the fungi associated with the two most common root and butt rots of spruce in south-central Alaska.

Nevertheless, our recent work, and contributions by many others (including, but not limited to: Tom Laurent, Dow Baxter, James Kimmey, Reed Miller, Dave French, Tommy Hinds, Frank Hawksworth, Keith Shea, Jim Stewart, Ed Wicker, and Susan Tait) have allowed us to build a foundation of information on diseases in Alaskan forests. A synopsis of current information on pests in Alaskan forests appears in the recently revised book, "Insects and Diseases of Alaskan Forests" (Holsten et al. 1986). Because we share similar forest types and pathogens with British Columbia and The Yukon Territory, we also utilize information obtained by our colleagues in Canada.

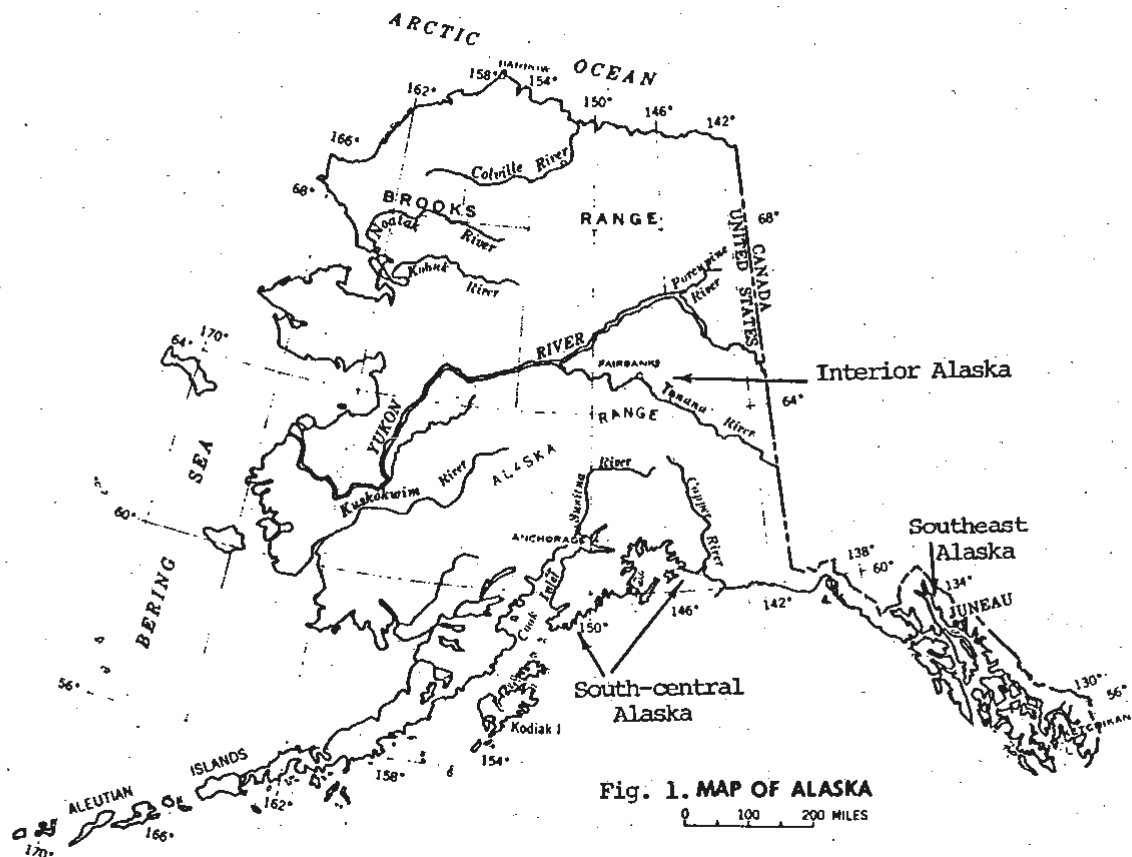
For ease of presentation, we will discuss diseases by geographic regions: 1) southeast Alaska (essentially the Tongass National Forest); 2) south-central Alaska (primarily the Chugach National Forest); and 3) the remaining, interior forests (Fig. 1). The predominantly western hemlock-Sitka spruce forests of southeast Alaska (Fig. 2) are, commercially, the most important -- which is why most of the pathological research has been conducted in these forests.

Southeast Alaska

Western hemlock and Sitka spruce comprise about 92% (64% & 28%, respectively) of the volume in the forests of southeast Alaska; Alaska-yellow cedar and western redcedar account for 4% and 3%, respectively, (Hutchison and LaBau 1975). Western redcedar is only an important component in the southern portion of southeast Alaska; it grows only as far north as Mitkof and Kupreanof Islands. Mountain hemlock (partially combined with volume of western hemlock) and shore pine are noncommercial because they grow primarily on muskegs or at higher elevations.

Clearcutting is the primary method of harvest in these forests, following which natural reproduction of both western hemlock and Sitka spruce is generally dense and thrifty (less than 10% of the clear-cut lands require planting). Because of this abundant natural regeneration, diseases of seedlings are silviculturally unimportant. Young, overstocked stands are pre-commercially thinned at age 15 to 20, which generally increases the proportion of Sitka spruce as it is favored over hemlock during thinning.

Extensive logging began with the start-up of the first pulp mill in the mid 1950's. Thus, the number and distribution of young stands that are older than 30 years is rather limited. Miller (1962) and, more recently, Tait et al. (1985)



surveyed diseases in the early stages of these young-growth forests. Several diseases occur, but none are devastatingly serious.

The role of diseases in more mature stands of young-growth, such as the second half of the planned 90-120 year rotation, is, however, poorly understood. Commercial thinning could severely scar these thin barked species and provide infection courts for decay fungi and stem pathogens. Since 40 years or more may elapse between commercial thinning and final harvest, wood decay fungi may have ample time to cause significant losses. If such damage is going to occur, and if it will result in any measurable losses by the end of the rotation, requires investigation.

South-Central and Interior Alaska

We have a preliminary study on decays of white spruce and hardwoods (French 1957) and good information on aspen cankers (Hinds and Laurent 1978) in the interior of Alaska. Similar studies are now needed on other poplars and birch as these species are severely attacked by a number of canker and stem fungi.

Disease information, let alone general data on silvicultural techniques, is desperately needed to manage forests in south-central and interior

Alaska. For example, *Dendroctonus rufipennis* (spruce bark beetle) currently infests several hundred thousand acres of spruce forests at several locations in south-central and interior Alaska (USDA Forest Service 1986). We need data on the role that pathogens play in triggering this beetle epidemic, on how long the standing-dead spruce are suitable for salvage, and how the abundance of dead wood may influence the inoculum level of pathogenic fungi in the newly developing forest.

A brief outline of current knowledge on some noteworthy diseases, decays, animal damage, and problems of unknown cause in Alaskan forests follows.

DISEASES

Hemlock Dwarf Mistletoe, *Arceuthobium tsugense* (Rosendhal) G.N. Jones

Hemlock dwarf mistletoe infects western hemlock in old-growth forests throughout southeast Alaska. Although western hemlock is the principle host in the region, *A. tsugense* also infects, albeit rarely, Sitka spruce (Laurent 1966) and mountain hemlock (Shaw 1982). To date, however, it has not been found on either Pacific silver fir or shore pine, two known host in British Columbia (Hawksworth and Weins 1972).

Fig. 2. Map of Southeast Alaska



True clear-cut logging could eliminate this disease as a management concern in young-growth stands. Infected, but non-merchantable hemlock trees are, however, frequently not cut during harvest of the old-growth. Spread of dwarf mistletoe from these infected residuals is the principle form of infestation in young hemlock stands.

Recent research indicates, however, that in southeast Alaska the levels of infection by *A. tsugense* on young hemlocks near infected residuals are much lower than occur in Washington, Oregon, and British Columbia (Shaw 1982, Bloomberg, these Proceedings). Also, most infected, young hemlocks have less than three infections per tree, and these are concentrated in the lower third of the crown--a location that limits their ability to spread the disease. These factors, together with the removal or killing of infected residuals during precommercial thinning, the height growth response of crop trees to thinning, and the common interspersions of resistant Sitka spruce, should prevent hemlock dwarf mistletoe from reaching damaging disease levels within the planned 90-120 year rotation. Reasons for the lower incidence of disease in young stands in southeast Alaska are unknown, but may relate to differences in stand composition, weather conditions, and mistletoe seed production.

A demonstration area has been installed near Thorne Bay on Prince of Wales Island (Fig. 1) to provide foresters and the general public with information on the recognition, biology, impact, and silvicultural control of hemlock dwarf mistletoe in young-growth stands (Hennon and Shaw 1986).

Root Diseases -- *Armillaria* spp., *Heterobasidion annosum* (Fr.) Bref., etc.

Armillaria spp. and *Heterobasidion annosum* are common decay organisms in old-growth forests throughout southeast Alaska where they are estimated to cause 45% of the cull volume in old-growth western hemlock and 6% in Sitka spruce (Kimmy 1956). Since both fungi continue to survive in stumps, the possibility exists for root rots to damage the developing young stands. Recent research indicates, however, that although these fungi persist in young stands, they are not causing any noticeable damage, even after precommercial thinning (Shaw 1981, 1985). While *Armillaria* spp. frequently invades thinning stumps, the biological species that appear to be most common (V & IX, Shaw and Loopstra 1986) have limited pathogenic capabilities (Wargo and Shaw 1985, Morrison et al. 1985).

In contrast, colonization of stumps by *H. annosum* is uncommon, even after inoculation (Shaw 1981, 1985). This result seems to be independent of stump diameter (Shaw unpublished), but certainly requires further clarification to determine if larger stumps, like those that will remain after a commercial thinning operation, will become inoculum sources for *H. annosum*. At present, I [Shaw] hypothesize that *H. annosum* will be of little concern throughout the rotation because it has limited abilities as a decay organism at relatively low temperatures and high moisture--the environmental conditions common to stumps in southeast Alaska. Data from the United Kingdom support this hypothesis in that *H. annosum* causes substantially less damage in plantations of Sitka spruce established in wetter areas (Redfern, 1982).

Sirococcus Shoot Blight, *Sirococcus strobilinus* Pruess.

The fungus that causes this disease is indigenous to southeast Alaska. It infects and kills shoots on western hemlock and, to a lesser degree, those on mountain hemlock and Sitka spruce. Shoot dieback is most common in young-growth stands; however, understory hemlocks and mature Sitka spruce in old-growth forests are also infected. The disease is most severe in dense, unthinned stands of young-growth where cool, moist air can stagnate; a condition that probably favors sporulation and infection by the fungus. Shoot infection can occur throughout the growing season.

Hemlocks in thinned stands have fewer infections and those present are concentrated in the lower portions of the live crown where they have less effect on tree growth and do not distort the

terminal leader. Crop tree selection during thinning also favors the more resistant Sitka spruce, discriminates against hemlock severely affected by shoot blight, and increases the distance between remaining trees, which likely improves air movement. These factors indicate that foresters should thin with confidence, even if Sirococcus is present in the stand, as there should be little subsequent effect from the disease (Shaw et al. 1981).

Shoot Blight of Alaska-yellow cedar, Apostrasseria sp.

This disease is caused by a recently discovered, but yet undescribed, fungus (Hennon unpublished) that is common in southeast Alaska on regeneration of Alaska-yellow cedar (Chamaecyparis nootkatensis). The unknown teleomorph is probably a Phacidium sp. (Al Funk, personal communication).

Terminal and lateral shoots on infected cedars are killed back 10 cm or so; however, growth rates are probably not affected unless trees are severely attacked. In an intensive survey of diseases of Alaska-yellow cedar (Hennon 1986), mature trees were not found to be infected by this fungus; they are probably resistant. To determine if this fungus might hinder reforestation efforts with Alaska-yellow cedar, the most valuable tree species in Alaskan forests, effects of this fungus on the growth and development of planted seedlings are being investigated in a variety of forest types (Hennon, unpublished).

Spruce Needle Rust, Chrysomyxa ledicola Lagerh.

This fungus attacks Sitka, white, and black spruce. Because the alternate host, Labrador-tea (Ledum spp.), grows primarily in muskegs or other boggy sites, only spruces in and near these locations are heavily infected (Hennon 1986). Epidemics of spruce needle rust have, at times, covered over one hundred thousands acres of white spruce in interior Alaska (USDA Forest Service 1981). In southeast Alaska, Sitka spruce trees in muskegs are sometimes heavily infected, but those growing in the commercially important stands of young-growth are, at most, only lightly infected.

Spruce trees are rarely killed by this rust because only current-year needles are attacked. The annual incidence of this disease also fluctuates dramatically--perhaps due to differences in weather conditions. Thus, spruce trees are not generally denuded of foliage because they are not attacked severely during several consecutive years.

Spruce Broom Rust, Chrysomyxa arctostaphyli Diet.

Unlike spruce needle rust, C. arctostaphyli invades woody tissues on spruce and causes perennial infections that develop into large witches-brooms. Whether infection impairs tree height or radial growth is not known. Incidence of this disease on spruce corresponds with the

range of the alternate host, bearberry (Arctostaphylos uva-ursi). Broom rust is thus more prevalent on white spruce in interior Alaska, where bearberry is common, than on Sitka spruce in southeast Alaska, where bearberry is rare. An exception to this generalization occurs in Glacier Bay (Fig. 2), where bearberry is present and broom rust is common on Sitka spruce.

Spruce Needle Cast, Lirula macrospora (Hartig) Danker

Lirula causes a needle cast on all three species of spruce in Alaska. The fungus likely infects current-year needles, but symptoms do not appear until these needles are one year old. The fungus only sporulates on dead needles that are at least two years old. Timing of sporulation is being monitored to determine when best to protect ornamental spruces, and perhaps forest trees, from infection.

Hemlock Needle Rust, Pucciniastrum vaccinii (Rab.) Joerst.

This rust attacks needles of western hemlock in southeast Alaska. Epidemics are rare, however, even though the alternate hosts, Vaccinium spp., are dominant shrubs in this part of Alaska. Factors that keep this fungus at endemic levels are not understood. I [Hennon] plan to monitor this disease closely because Kimmy and Stevenson (1957) indicated that it can, at times, severely defoliate trees, as occurred at Thomas Bay in 1977 (Shaw unpublished).

Western Gall Rust, Endocronartium harknessii (J.P. Moore) Hirat.

This monocyclic rust causes perennial, spherical galls on shore pine throughout southeast Alaska. On occasion, Nectria macrospora attacks these galls and eventually kills distal portions of the branch. Currently, pine is not a commercially important tree species in southeast Alaska, but the disease is of some concern to homeowners.

Alaska-yellow Cedar Rust, Gymnosporangium nootkatense Arth.

This rust attacks foliage on Alaska-yellow cedar; however, epidemics have not been noted on cedar or the alternate hosts (Pacific crabapple and mountain ash). This rust fungus is of interest because it is one of the only species of Gymnosporangium to have a uredial stage (Ziller 1974).

Cedar Leaf Blight, Didymascella thujina (Durand) Maire

Didymascella attacks leaf scales of western redcedar. It generally attacks foliage in the lower crown and likely poses little threat to redcedar in southeast Alaska.

Over the past decade, a canker disease has killed numerous small hemlocks, and the lower crowns of larger ones, along portions of the road system on Prince of Wales Island (Fig. 2). This disease appears to be highly site specific. To date, we have not found it in any second-growth stands, but only in the understory and on lower branches of overstory trees that are within several hundred feet of roads.

Xenomeris abietis was isolated from resinous cankers on infected trees (Shaw unpublished) and is thought to be the primary cause of death. Nectria sp. also occurs on many dead hemlocks and may contribute to tree death. Dust and other associations with roads may weaken hemlocks, or otherwise allow these fungi to infect. Studies on this disease continue with emphasis on determining general etiology and the possibility of damage occurring in the commercially important stands of young-growth.

Alaska-yellow Cedar Decline

Decline and mortality of Alaska-yellow cedar persists as one of the most spectacular and important forest diseases in southeast Alaska. Over 200,000 acres of forest are affected by this decline. More Alaska-yellow cedars died during 1986 than in the preceding several years, but trees have died throughout southeast Alaska every year since the onset of the problem about 100 years ago. Mortality began on muskeg sites and has since spread onto better drained, more productive sites. Spread from site-to-site, however, has not occurred, which suggests that a contagious organism is not the cause. Over 50 species of fungi have been isolated or collected from dying trees, but none possesses the pathogenic ability to cause such extensive mortality. Patterns of tree death and the apparent absence of a pathogen as the primary incitant, suggest that some form of environmental stress may cause the problem (Hennon 1986).

We have data on how long cedars, in various states of deterioration, have been dead. Current work should determine the feasibility of salvaging these trees, and how best to regenerate Alaska-yellow cedar in stands suffering from extensive mortality.

Hemlock Fluting

The boles of western hemlock trees in southeast Alaska frequently have deeply incised fissures and folds that extend from the ground to high in the crown--a condition known locally as "fluting." Elsewhere in these proceedings, Kent Julin reports on the causes and management implications of this abnormality.

Heartrot fungi decay substantial volumes of wood in the old-growth forests of Alaska. The problem is particularly acute because the fungi have ample time to decay the long-lived, slow growing trees. Two major decay studies have been conducted in southeast Alaska (Kimmy 1956, Farr et al. 1976), but little information on decays exists for forests in south-central or interior Alaska.

Pathologists familiar with heartrots in the Pacific Northwest, should recognize the common decay fungi in southeast Alaska, as listed below:

Sitka spruce-

Fomitopsis pinicola (Schwartz:Fr.) Karst.
Phellinus pini (Thore:Fr.) Pilat
Armillaria sp.
Phaeolus schweinitzii (Fr.) Pat.
Laetiporus sulphureus (Bull. ex Fr.)
Bond. et Sing.

Western hemlock-

Fomitopsis pinicola
Armillaria sp.
Heterobasidion annosum (Fr.) Bref.
Laetiporus sulphureus
Phaeolus schweinitzii
Phellinus robustus (Karst.) Bourd & Galz.
Phellinus pini
Echinodontium tinctorium (Ell. & Ev.)

Western redcedar-

Poria albipellucida Baxt.
Phellinus weirii (Murr.) Gilbn.

Even though these fungi are the same species common to forests in the Pacific Northwest, their behavior differs. For example, in Oregon and Washington Fomitopsis pinicola principally decomposes woody slash; in Alaska, it is the principal cause of heartrot in living Sitka spruce (Kimmy and Stevenson 1957) and sometimes produces conks on apparently unscarred trees.

Another example of geographic differences in fungal behavior is Phellinus pini, a predominant heartrotter of Sitka spruce and western hemlock in the Pacific Northwest. In southeast Alaska, P. pini causes a relatively small proportion of the heartrot in these tree species, particularly western hemlock (Kimmy 1956); however, it is the major causes of heartrot in living white spruce and mountain hemlock in south-central Alaska.

Echinodontium tinctorium occurs primarily on mountain hemlock in disjunct stands from Haines and Skagway, across Prince William Sound, to the Kenai Peninsula. It appears to be absent throughout most of southeast Alaska.

An unknown heartrot is also common on live white and Lutz spruce (a hybrid of Sitka and white spruce) on the Kenai Peninsula in south-central Alaska. This year Hennon (unpublished) began a study to determine which fungi cause this decay, how and where they enter trees, and how much volume is lost. To date, An unidentified fungus,

Inonotus tomentosus, Fomitopsis pinicola, and Phellinus pini appear to be the most important causes of decay. In addition, Inonotus tomentosus causes a white pocket rot in the roots and butts and appears to cause root death of Lutz spruce trees.

ANIMAL DAMAGE

Porcupines, Erethizon dorsatum, damage trees in Alaska. In southeast Alaska, damage is particularly severe in young stands of Sitka spruce and western hemlock where up to 10% of the crop trees may be girdled and killed just one year after precommercial thinning (Eglitis and Hennon 1986). Survey transects have been established in recently thinned stands on Mitkof island (Fig. 1) to determine the extent of damage and to assess population trends of the animals.

Porcupines damage trees by either girdling the main stem, which eventually kills tree parts above the girdle, scarring a portion of the bole, or by clipping branches. Scars on the main stem provide infections courts for decay fungi; if substantial decay will develop from this activity by rotation age is unknown. Long-term plots have been established to study decay and to determine if porcupines will continue to damage trees as young stands mature.

Fortunately, porcupines are not found everywhere in southeast Alaska. Porcupines, occur on the mainland, Mitkof, Kupreanof, Kuiu, Wrangell, and Zarembo Islands; but they do not occur on many other islands, such as Prince of Wales, Baranof and Chichagof.

Brown bears, Ursus arctos, scar the bases of Alaska-yellow cedar trees on Baranof and Chichagof Islands (Hennon 1986). About one half of the Alaska-yellow cedar trees in these areas have at least one basal scar. Cedars growing on the best developed soils, where they are interspersed with western hemlock and Sitka spruce, have a noticeably high incidence of scarring. Most basal scars were produced many years ago and are now characterized by deep folds of callus tissue. Each year, however, bears scar cedar trees in the springtime by tearing bark away from the tree base with their teeth.

Reasons for this activity are unknown; no other evidence of feeding is present. Perhaps bears lick the exposed cambium for the high concentration of sugars present in spring. Wood behind and adjacent to older scars is often decayed, which may cause the otherwise valuable butt logs to be culled.

SUMMARY

Hemlock dwarf mistletoe, decay fungi, and decline of Alaska-yellow cedar are the most significant diseases of old-growth forests in Alaska. These diseases cause persistent losses with limited fluctuations from year to year. At present, root diseases and dwarf mistletoe are of little

significance in managed young stands; however, what the role of root diseases might be as these stands mature is unknown and under study. Several diseases of shoots and needles also occur in young stands (i.e., Sirococcus shoot blight, spruce needle rust, hemlock needle rust, and spruce needle cast), but none are currently damaging; their status, however, is being closely monitored. A canker disease, probably caused by Xenomeris abietis, is prevalent along roads on Prince of Wales Island and has killed small western hemlocks and the lower crown of larger hemlocks. In southeast Alaska, porcupines damage forest trees and brown bears scar the bases of Alaska-yellow cedars. Research is needed on most pathological aspects, let alone the general silviculture, of all forest tree species in south-central and interior Alaska.

LITERATURE CITED

- Baxter, D.V. 1947. Occurrence of fungi in the major forest types of Alaska. Mich. Acad. Science, Arts, and Letters 31:93-115.
- Eglitis, A. and P.E. Hennon. 1986. Porcupine damage on Mitkof Island. USDA Forest Service, Forest Pest Management R-10. Tech. Rep. R10-86-1. 19p.
- Farr, W.A., V.J. LaBau, and T.H. Laurent. 1976. Estimation of decay in old-growth western hemlock and Sitka spruce in southeast Alaska. USDA For. Serv. Res. Pap. PNW-204. Pac. NW For. and Range Exp. Sta. 24p.
- French, D.W. 1957. Tree measurement and cull factors for the interior of Alaska. Unpublished office report on file at Forestry Sciences Laboratory, Juneau, Alaska. 94p.
- Funk, A. 1972. Sirococcus shoot-blight of western hemlock in British Columbia and Alaska. Plant Dis. Rep. 56:645-647.
- Hawksworth, F.G. and D. Wiens. 1972. Biology and classification of dwarf mistletoe (Arceuthobium) U.S. Dept. Agric. Handb. 401. Washington, D.C. 234p.
- Hennon, P.E. C.G. Shaw III, and E.M. Hansen. 1984. Is a pathogen the primary cause of decline and mortality of Chamaecyparis nootkatensis in southeast Alaska? Proceedings of the 32nd Western International Forest Disease Work Conference: 15-23.
- Hennon, P.E. 1986. Pathological and ecological aspects of decline and mortality of Chamaecyparis nootkatensis in southeast Alaska. Ph.D. Thesis. Dep't of Botany and Plant Pathology, Oregon State University. 279p.
- Hennon, P.E. 1986. Spruce needle rust. USDA For. Serv. Pest Leaflet R10-TP4. (In press).

- Hennon, P.E., G.B. Newcomb, C.G. Shaw III, and E.M. Hansen. 1985. Nematodes associated with dying Chamaecyparis nootkatensis in southeast Alaska. *Plant Disease* 70:352.
- Hennon, P.E. and C.G. Shaw III. 1985. A Management Strategy for Stands Suffering from Alaska-Cedar Decline. Proceedings of the 36th Alaska Science Conference: 161.
- Hennon, P.E. and C.G. Shaw III. 1986. Dwarf mistletoe demonstration area (pamphlet). USDA For. Serv., Juneau, Alaska. R10-TP5 (In press).
- Hinds, T.E. and T.H. Laurent. 1978. Common aspen diseases found in Alaska. *Plant Dis. Rep.* 62:972-975.
- Holsten, E.H., P.E. Hennon, and R.A. Werner. 1985. Insects and Diseases of Alaskan Forests. USDA For. Serv. Alaska Region Rep. No. 181. 217p.
- Hutchison, O.K. and V.J. LaBau. 1975. The forest ecosystem of southeast Alaska. 9. Timber inventory, harvesting, marketing, and trends. Pacific Northwest For. and Range Exp. Sta. USDA For. Serv. Gen. Tech. Rep. PNW-34. 57p.
- Kimmy, J.W. 1956. Cull factors for Sitka spruce, western hemlock, and western redcedar in southeast Alaska. USDA For. Serv. Alaska For. Res. Center, Sta. Pap. No. 6. 31p.
- Kimmy, J.W. and J.A. Stevenson. 1957. Forest disease survey of Alaska. *Plant Dis. Rep.* 247:87-98.
- Laurent, T.H. 1966. Dwarf mistletoe on Sitka spruce--a new host record. *Plant Dis.* 50:921.
- Miller, D.R. 1971. An extensive forest disease survey of second-growth stands in southeast Alaska. Unpublished office report on file at Forestry Sciences Laboratory Library, Juneau, Alaska. 4p.
- Morrison, D.J., C. Chu. and A.L.S. Johnson. 1985. Species of Armillaria in British Columbia. *Can. J. Plant Pathol.* 7:242-246.
- Redfern, D.B. 1982. Infection of Picea sitchensis and Pinus contorta stumps by basidiospores of Heterobasidion annosum. *Eur. J. For. Path.* 12:11-251.
- Shaw, C.G. III. 1979. Hemlock dwarf mistletoe and young-growth management in southeast Alaska -- a problem or concern? Proceedings of the 27th Western International Forest Disease Work Conference: 21-29.
- Shaw C.G. III. 1981. Basidiospores of Armillaria mellea survive an Alaskan winter on tree bark. *Plant Dis.* 65:972-974.
- Shaw, C.G. III. 1981. Infection of western hemlock and Sitka spruce thinning stumps by Fomes annosus and Armillaria mellea in southeast Alaska. *Plant Dis.* 65:967-971.
- Shaw, C.G. III, T.H. Laurent, and S. Israelson. 1981. Development of Sirococcus shoot blight following thinning in western hemlock regeneration at Thomas Bay, Alaska. Pacific NW For. and Range Exp. Sta., PNW Res. Note 387. 6p.
- Shaw, C.G. III. 1982. Development of dwarf mistletoe in western hemlock regeneration in southeast Alaska. *Can. J. For. Res.* 12:482-488.
- Shaw, C.G. III. 1982. Mountain hemlock is an occasional host for hemlock dwarf mistletoe (Arceuthobium tsugense) in Alaska. *Plant Dis.* 66:852-854.
- Shaw, C.G. III. 1985. Colonization of Conifer Thinning Stumps by Root Disease Fungi in Southeast Alaska. *Phytopathology* 75:1294.
- Shaw, C.G. III, A. Eglitis, T.H. Laurent, and P.E. Hennon. 1985. Decline and mortality of Chamaecyparis nootkatensis in southeast Alaska--A problem of long duration, but unknown cause. *Plant Dis* 69:13-17.
- Shaw, C.G. III, and E.M. Loopstra. 1986. Pathogenicity and identification of some Alaskan isolates of Armillaria. *Phytopathology* 76:1081.
- Tait, S.M., C.G. Shaw III, and A. Eglitis. 1985. Occurrence of insect and disease pests on young-growth Sitka spruce and western hemlock in southeastern Alaska. Research Note PNW-433. USDA For. Serv., PNW For. and Range Exper. Station. 16 pp.
- USDA Forest Service. 1981. Forest insect and disease conditions in Alaska in 1980. USDA For. Serv., Alaska Region. 16 pp.
- USDA Forest Service. 1985. Forest insect and disease conditions in Alaska in 1984. USDA For. Serv., Alaska Region. 20 p.
- USDA Forest Service. 1986. Forest insect and disease conditions in Alaska in 1986. USDA For. Serv., Alaska Region. (In press).
- Wargo, P.M. and C.G. Shaw III. 1985. Armillaria Root Rot: The Puzzle Is Being Solved. *Plant Dis.* 69:826-832.
- Wicker, E.F., T.H. Laurent, and S. Israelson. 1978. Sirococcus shoot blight damage to western hemlock regeneration at Thomas Bay, Alaska. USDA For. Serv. Res. Pap. INT 198.
- Ziller, W.G. 1974. The tree trusts of Western Canada. Pacific Forest Research Centre, Can. For. Serv. Publ. No. 1329. 272p.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

RATING THE SEVERITY OF LIMB RUST IN PONDEROSA PINE STANDS

F. A. Baker, D. Rabin, Wang Chengguo, and B. M. Tkacz

ABSTRACT: Limb rust kills crowns of ponderosa pines. We propose a system based on the location of the rust in the tree crown, and the proportion of crown killed by the rust for rating the severity of limb rust in trees. We are analyzing data to evaluate the correlation of visual rating with diameter increment reduction.

Limb rust is a systemic disease killing the crowns of mature and overmature ponderosa pines (*Pinus ponderosa* Engelm. var *scopulorum*) and jeffrey pines (*P. jeffreyi* Grev. & Balf.) in western North America. The disease has been labelled as "the most destructive rust observed in the West" by Hedgecock in 1912, (prior to the introduction of white pine blister rust) and as "abundant and doing considerable damage" (Garrett 1921). The causal fungus, *Peridermium filamentosum* Peck, invades the stem of the tree, and kills the crown one branch at a time. Limb rust kills the crown at a rate of about 1.5 feet per year (Mielke 1952). Once trees lose 50% of their crown, diameter growth ceases. Trees die when 80 to 90% of the crown is killed (Peterson 1966). This disease has been considered a disease of overmature pine. Recently, however,

FRED BAKER is an Assistant Professor, DAN RABIN is a graduate student, and WANG CHENGGUO was a technician in the Department of Forest Resources, Utah State University, Logan, UT 84322-5215; BORYS TKACZ is a forest pathologist with Forest Pest Management, USDA Forest Service, Ogden, UT 84401.

the fungus has caused serious losses in younger stands of ponderosa pine in southern Utah.

Trees with 50% live crown were killed, apparently by bark beetles. The only recommendation for control is to remove infected trees at each entry. Ponderosa pines require 100 - 140 years to reach maturity. With 20 - 40 years between entries to manage the stand, many trees are killed or stop growing before they can be salvaged. Ponderosa pine is also a very important part of visual corridors around recreational areas including Bryce Canyon, the Grand Canyon, and Zion National Park. Resource managers need a method for rating the severity of limb rust to identify trees which will be lost, and those which even though infected, will grow and survive until the next stand entry. Our objective in this study is to develop and evaluate a risk rating system for use in ponderosa pine stands infested with limb rust. The system must be easy to use, reproducible by different observers, and relate to rust caused growth loss and ultimate mortality.

We are now analyzing the data collected for this study. Thus, this paper deals more with our philosophy and experiences in rating system development.

Limb rust kills the branches of an infected tree, reducing the crown size. Mielke's work suggests, and we hypothesize that as the crown is reduced, diameter increment decreases, until so little crown remains that the tree becomes attractive to and is killed by bark beetles. Assuming that the loss in foliar surface is correlated with increment reduction and loss of vigor, we proposed a rating system which incorporates a position value and a severity value, each ranging from 0 to 3. This yields a rating system with 7 classes similar to the 6-class rating system used for dwarf mistletoes (Hawksworth 1977). A rating system similar to the extensively used mistletoe rating system will be easier for foresters to understand and use. Uninfected trees were assigned a 0. For trees with rust, if the rust occurred in the upper third of the crown, a position value of 3 was assigned; if the rust occurred in the middle third of the crown, the position value was 2; in the lower third, the position value was 1. We arrived at this by reasoning that rust in the top of the crown had more impact than infections lower in the crown. The mid-crown infections were considered more important than lower crown infections because with similar spread rates upward and downward, mid-crown infection would kill the crown faster. For the severity value, we arbitrarily established severity values of 1, for 1 to 30% of the crown killed; 2, for 31 to 60%; and 3, for more than 61% of the crown killed. The position value and severity value are added to give a total rating for the tree. A stand rating can be computed by averaging the rust rating for all trees in the stand.

Thus enlightened, we set out in search of ponderosa pine on the Dixie National Forest, near the sites where Peterson (1966) and Mielke

Table 1--Scheme for rating severity of limb rust of crowns in ponderosa pine

Location of infection	Score	+ Percent crown killed	Score
Top of crown	3	< 30	1
Mid-crown	2	31-60	2
Base of crown	1	> 61	3
None	0		

(1952) worked. Sixteen 0.5 ha plots were located in ponderosa pine stands with most trees 60-70 years old. Trees were tagged, and volume data recorded. Each tree was examined for limb rust, and the location of the rust (height to base of canker and to top of canker) was recorded. For each rust infected tree, an uninfected tree similar in diameter and crown class was located, and the same data were taken. Increment cores were taken from each tree to determine total age, sapwood cross-sectional area, and periodic increment. Each tree was then rated according to the scheme in Table 1.

For example, a tree with a mid-crown infection which has killed 70% of the crown would be rated $2 + 3 = 5$.

With these data, the relationship of rust location, percent crown killed, and limb rust rating with radial increment will be examined. If limb rust rating is an acceptable predictor of increment, trees and stands in which serious losses will occur during the next management period can be identified. The actual locations and percent crown kill will also be analyzed to evaluate how accurately the rating system corresponds to the actual condition of the tree. If the rating system is not a good predictor, and live crown remaining is in fact correlated with diameter increment, we should be able to evaluate other rating systems using the measurements of tree height, crown base, crown top and top and base of rust caused mortality to compute percent crown remaining and/or rust position.

Trees were tagged so that the study can be followed over a period of years, providing information on the change in rust rating over time and the life expectancy of trees within an infection class.

We are measuring the increment cores, and have not yet looked at the other data. We can, however, make several observations about the process of developing a rating system. First, record all the data about the physical presence of the disease in the trees. In this study, if the proposed rating system does not work, we have the data to attempt computing another. Although we could have recorded the data in the field, and computed ratings in the office, rating trees in the field gave us some insight into the problems associated with the use of such a system. For example, where is the base of the crown? Observers often disagree where the base of the crown is. We used the lowest height at which there were live branches in three quadrants of the tree. In multi-storied stands, crown levels vary. Where several trees

are adjacent to each other, shading may kill the lower branches on one side of the crown. This by definition raises the crown base, when in reality many vigorous branches are present below the crown base. Identification of the crown base may be even more difficult when trees are infected in the lower third of the crown. Accurate determination of the crown base may not be important for severely infected trees, but could affect the rating of recently infected trees.

We also recorded the position and severity values during data collection. We can add them to get a 7-class system, or after we analyze the data, we may find a two-digit rating better indicates tree growth and longevity. Such a rating might combine a position value of 3 with a severity value of 1 for a final rating of 31. Since a rating of 4 could also be obtained by combining values of 2, a two-digit rating might be more useful because you can picture what the tree looks like. This would be an advantage when rating trees for management of visual resources.

Developing a rating system involves two tasks: determining a rating method closely correlated with the biological property of interest, and ensuring that the rating system can be easily and accurately used by and is accepted by its intended user group. Both tasks have feedback on each other. We are in the first iteration, having collected the data to examine the correlation between a hypothesized rating system and increment loss. The foresters in the field will use the rating system under their operational constraints, and will provide a much more realistic measure of the second task.

LITERATURE CITED

- Garrett, A. O. 1921. Smuts and rusts of Utah - IV. *Mycologia* 13:101-110.
- Hedgecock, G. G. 1912. Notes on some western edineae which attack forest trees. *Mycologia* 4:141-147.
- Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. USDA For. Serv. Gen. Tech. Rep. RM-48, 7p.
- Mielke, J. L. 1952. The rust fungus *Cronartium filamentosum* in Rocky Mountain ponderosa pine. *J. For.* 50:365-373.
- Peterson, R. S. 1966. Limb rust damage to pine. USDA For Serv. Res. Pap. INT-31, 10pp.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

STATUS AND DIRECTION OF STUDIES ON COMANDRA
BLISTER RUST IN THE ROCKY MOUNTAINS

Brian W. Geills

INTRODUCTION

This brief report reviews the progress of studies on comandra blister rust (*Cronartium comandrae* Pk.) conducted cooperatively by the Rocky Mt. Experiment Station, Rocky Mt. Region, and Colorado State University. The objective of these studies has been to estimate the incidence of this disease and its severity on lodgepole pine (Geills 1981; Geills 1984; Geills and Jacobi 1984). Our intent is to provide land managers with a means to assess the impacts of this rust on various resource values.

The Forest Service research unit involved in these studies (RM-4501) has recently been given a new assignment to improve the technology for assessing pest impacts in the interior West. To achieve this goal for rusts of hard pines, we need to develop rating systems that will quantify and predict effects of the rust on the host at various levels of disease intensity, relate this damage to various resource losses, and incorporate this information into growth, yield, and alternative value models. Except for the increased emphasis on resource values other than timber, this new assignment encompasses the objective of our original project, to determine the management implications of comandra blister rust.

DAMAGE AND RISK RATING

A system that quantifies damage can be used with a model that predicts yield to determine the extent to which a pest can affect forest productivity. For example, consider the damage

Brian Geills is a Research Plant Pathologist at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, CO.

which a pest causes to an individual tree as an observable injury or symptom which can be quantified as to severity. Damage in this sense is usually a partial destruction of the crown or root system, and its magnitude can be visually rated on a relative scale (Large 1966). The direct effects of damage are to alter the tree's growth, survival, or appearance. Therefore, damage severity, as measured by the rating system, ought to strongly correlate with changes in tree growth, survival, or appearance. The models that predict yield for various resources can then be employed to translate these changes in tree size, vitality, or appearance into changes in values for timber, shade, or other uses.

For rating the effects of comandra blister rust, significant damage is measured as the loss of crown and bole that results from a girdling canker (Geills 1984). This definition, albeit rather simplistic, adequately explains the major effects of this rust on the host as it allows us to quantify disease effects by specifying when losses begin (at the time of topkill), and how much injury occurs (a function of tree, crown, and canker heights). On lodgepole pine in the Rocky Mountains, comandra blister rust usually produces only one stem canker per tree; and volume losses are slight before topkill.

The risk that damage will result from an attack of comandra blister rust is the probability that a canker girdles the bole before a specific stand age is reached. This risk is composed of two factors that precede girdling--infection and canker expansion. Even though additional research is needed to predict the frequency, duration, amplitude, and location of future episodes of infestation by comandra blister rust, we can make some generalizations regarding the survival and expansion of cankers. For example, I have observed that the cankers which ultimately girdle the bole seldom develop from branch infections that originated over 20 cm from the bole, or on stems larger than 20 cm in diameter at canker height. The rate of expansion varies greatly among cankers and years. Only a small part of this variability is explained by factors which can be easily measured, such as canker location, host size, or growth rate. On average, branch cankers expand proximally at 2 to 3 cm per year; stem cankers expand around the bole by 3 to 5 cm per year for the first 15 years, and by a rapidly decreasing rate thereafter.

RUST EFFECTS

Damage from comandra blister rust, as measured by the height of girdling cankers, can be directly related to the effects of this disease on various tree attributes. I previously reported on a simple index of timber values that describes the relative growth potential of trees affected by rust (Geills 1984). This index combines the effects of comandra blister rust on tree growth, defect, and mortality into one number. Index values range from 0 for trees with no potential to produce sound

sawtimber, to 1 for desirable crop trees. To incorporate predictions of the effects that comandra blister rust will have on tree growth, survival, and defect into yield models (such as RMYLD, Edminster 1978), it is necessary to determine relationships between the damage rating (canker height) and each effect (reduced rate of diameter growth, increased rate of mortality, etc.).

The effect that comandra blister rust has on diameter increment at breast height can be represented by relative diameter growth (RDG), which is defined as the fractional decrease in growth rate that results from a portion of the crown dying. Stem analyses (Geils 1984) provided data on: (1) 10-year diameter increments for the periods immediately before the bole was cankered and after topkill occurred, (2) canker heights, and (3) initial and subsequent crown lengths. RDG was computed as the ratio of increment after topkill to increment before canker establishment. Both square and exponential transformations of canker height and of the portion of crown retained after topkill (PCR) were significant regression predictors of RDG. Because there is undoubtedly a fundamental relation between crown size and tree growth, the expression:

$$RDG = 13 + .009 \times PCR^2 \quad (R^2 = .77)$$

was chosen as the preferred function.

This equation can be used in yield models to quantify the effect that comandra blister rust has on diameter growth of lodgepole pine if damage severity is recorded as the amount of crown lost. These yield models can later be employed in an economic analysis to determine the impacts or value changes which result from various levels of disease incidence and severity. Some additional work to refine this quantification of the effect of comandra blister rust on tree growth is needed because the function relating relative diameter growth and damage rating was developed from only 26 trees. A larger sample of topkilled trees is being collected and the previous analysis will be repeated with the additional data.

Another effect that comandra blister rust may have on an affected stand is the possibility that healthy trees near diseased individuals respond to the reduced competition after topkill of their neighbors. The amount of additional growth resulting from this release depends on the number, severity, and distribution of damaged trees. Some testing of model sensitivity to between-tree competition, analysis of existing data sets, and new experiments could all be used to evaluate the effects of comandra blister rust on reducing a tree's competitive status and enhancing its neighbor's growth. The effects of a girdling canker on tree survival can vary depending on amounts of crown mortality, competition levels, and the severity of other pest damage (i.e., from bark beetles or dwarf mistletoe). If a bole canker is below the live crown, a tree will die soon after girdling is complete. If a bole canker is higher, the tree may survive as a spike-top for many years--

until it succumbs to suppression or other agents. Alternatively, if a canker is near the top of a large tree, survival may be unaffected. Our current data from 648 trees only allows us to predict the proportion of trees expected to die several years after girdling (PMORT) as a function of canker height (CNKHT). At canker heights between 2 and 12 meters, the relation is approximately:

$$PMORT = .99 - .226 \times CNKHT \quad (R^2 = .91).$$

Limited data obtained since this equation was developed support the predictions. With the original data, however, it has not been possible to determine how competition, or other pests, influence long-term survival of top-killed trees. Additional plots are being established in an array of stand conditions to monitor disease progress and tree survival.

RESOURCE MODELS

To assess the impact of infestations by comandra blister rust on the many and various resources it could influence, effects of the rust on tree growth, quality, and survival are being added to stand models such as PROGNOSIS (Wykoff et al. 1982). An expanded version of RMYLD (Edminster 1978) that incorporates the effects of comandra blister rust is available on the USDA computer at Fort Collins, Colo. In addition to serving as a tool for managers, these models provide a simple, holistic description of the behavior of comandra blister rust within the lodgepole pine system. For example, if one considers the expansion rate of cankers and the usual height of cankers on a tree, it is reasonable to conclude that most cankers that are visible on the bole, would girdle the tree within 10 years. By programming this general behavior into RMYLD, requirements for data input are simplified. Our strategy requires a forester to collect only a minimum of disease data, and yet the model will still generate an adequate prediction with the required precision.

The project with RMYLD illustrates how equations that describe effects of a pest can be incorporated into computer programs and how these programs can be used as an aid in writing stand prescriptions, and in identifying future research needs.

RMYLD is a stand average model which can accommodate a two-storied structure. For stands infested with comandra blister rust, one story includes all trees with stem cankers and the other story contains all trees without stem cankers. Data on initial stand conditions that are required for each story are: age, stocking density, mean diameter, and mean height; for the cankered story, the percent of trees already topkilled and the average canker height of all trees with bole cankers are also needed. Functions in the program account for the loss of volume in dead trees, the loss of volume above girdling cankers on live trees, and the reduction of height and diameter growth of live trees. Cutting options allow simulation of tree

removal in either story at various ages and cutting levels. RMYLD generates an empirical yield table for each story as a display of per acre values for number of trees, basal area, and volume at 10-year intervals for any harvest and for the residual stand.

A comparison among different management scenarios for a specific stand allows a forester to see how productivity is affected by the length of time damaged trees remain in the stand. With this information, the forester is more able to determine the best management alternative for that stand considering its special conditions, which include the number of damaged trees and the severity of that damage. Similarly, a researcher can examine numerous stand responses for a large array of carefully selected stand conditions. This exercise uses the model to investigate such topics as:

1. What are the thresholds of incidence and damage at which rust becomes a serious concern to management;
2. What stand attributes are useful in classifying stands for their risk of serious loss;
3. What are the optimum stocking levels in rust-threatened stands.

Although answers to these questions have immediate use, the insight gained from this work would also help design more rigorous studies to further test and, hopefully, improve the model. The pest assessment project at the Rocky Mountain Experiment Station will be involved in the development and demonstration of RMYLD and other models which relate effects of pathogens on their hosts to impacts on forest resource values.

LITERATURE CITED

- Geils, B. W. 1981. Comandra blister rust of lodgepole pine in the Rocky Mountain Region. In Proceedings of the 29th Annual Western International Forest Disease Work Conference [15-18 September 1981, Vernon, B. C., Canada]. pp. 91-92.
- Geils, B. W. 1984. Effects of comandra blister rust on growth and survival of lodgepole pine. In Proceedings of the 32nd Annual Western International Forest Disease Work Conference [24-28 September 1984, Taos, New Mexico]. pp. 24-25.
- Geils, B. W., and W. R. Jacobi. 1984. Incidence and severity of comandra blister rust on lodgepole pine in northwestern Wyoming. Plant Disease 68: 1049-1051.
- Edminister, C. B. 1978. RMYLD: Computation of yield tables for even-aged and two-storied stands. USDA For. Serv. Res. Pap. RM-199. 26 p.
- Large, E. C. 1966. Measuring plant disease. Ann. Rev. Phytopathol. 4: 9-28.

Stage, A. R., and D. A. Hamilton. 1981. Sampling and analytical methods for developing risk-rating systems for forest pests. pp. 87-92. In Hazard-rating systems in forest insect pest management, Symposium Proceedings. USDA For. Serv. Gen. Tech. Rep. WO-27.

Wykoff, W. R., N. L. Crookston, and A. R. Stage. 1982. User's guide to the stand prognosis model. USDA For. Serv. Gen. Tech. Rep. INT-133. 112 p.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

PRUNING WHITE PINE TO CONTROL BLISTER RUST IN BRITISH COLUMBIA

R.S. Hunt

INTRODUCTION

By tallying and measuring the distances to the stem and heights above ground of blister rust (*Cronartium ribicola* J.C. Fisch. ex Rab.) on western white pine (*Pinus monticola* Dougl.), Hunt (1982) concluded that the majority of cankers originate within 2.5 m of the ground and thus it seemed possible to remove lower branches of young trees to prevent bole infections. Stands on slopes (Hunt 1982, 1983a) tended to have more cankers higher into the crown, while stands on flat areas may have the majority of cankers within 1.25 m of the ground. Based on this survey data, Hunt (1983b) recommended that young growth stands should have the lower branches removed at least for the first 1.25 m (probably combined with a thinning operation), and stands on slopes should be considered for early harvesting.

The object of this study was to determine if pruning actually accrued the theoretical benefits.

METHODS AND MATERIALS

Two stands, one on the southern end of Vancouver Island and one on the northern end of Vancouver

Rich Hunt is a Research Scientist II at Pacific Forestry Centre, 506 West Burnside Road, Victoria, B. C.

Island were chosen as experimental sites. The former was an ungrading hill, or typical, site; whereas the latter was a steep site. The benefits of pruning should be greatest at the flatter site. At each site trees were stratified by diameter class as follows: prunable to 1.25 m but less than 5 cm dbh; 5-10 cm dbh; 10-15 cm dbh; 15-20 cm dbh. Only trees in the first two classes were available at the second site. Trees lacking apparent stem cankers were paired by blister rust attributes in priority as follows: distance to stem of closest canker, number of cankers within 60 cm of the stem, canker height above ground. A coin was flipped to determine which tree would be pruned and which left as a control. Pruning removed all branches as high as seemed possible to a minimum of 1.25 m and a maximum of 2.5 m. Generally, trees in the first two dbh classes were pruned 1.5-1.75 m above ground and in the last two classes to 2.5 m above ground. Preliminary results after three years indicated that several of the cankers on control trees were still alive, but had not yet reached the stem.

Data presented are after five years, when only one canker on a control tree had not yet died or reached the stem.

RESULTS

Pruning reduced the incidence of blister rust stem cankers on the "typical" site by 62% and by 29% on the steep site (table 1). Overall reduction of stem cankers and threatening cankers (those within 60 cm of the stem) was reduced by 59 and 19%, respectively (Table 1). On the "typical" site and steep site 8% and 61% of the trees <10 cm dbh had stem cankers above the pruning height, respectively. On the "typical" site, trees in the 5-10 cm dbh class tended to have fewer stem cankers (0%) below the pruning height than either the <5 cm (22%) or 10-15 cm (50%) dbh classes.

DISCUSSION

Pruning does reduce the incidence of stem cankers and threatening cankers (Table 1); however, the infection incidence was still extremely high on the steep sloped site. Pruning some small trees (<5 cm dbh) was ineffective because the cankers originated close to the stem and the stems were already infected at the time of pruning. Larger trees (5-15 cm dbh) had the cankers originate farther from the stem and when pruned early (5-10 cm dbh) there is apparently less likelihood that the stem is already infected than delaying the pruning (10-15 cm dbh). The gains from pruning are somewhat less than expected (Hunt 1982, 1983b) for typical sites because some cankers, which appear to be restricted to branches, are indeed already in the bole. The gain can be optimized by pruning young trees (<10 cm dbh). On the steep site chosen for this study pruning was not a practical control because the blister rust incidence was high and many new cankers were initiated above the pruning height.

Table 1--Western white pine trees infected with blister rust stem cankers (S), and within 60 cm of the stem (R) at a typical site (1) and a steep site (2), 5 years after pruning

	Control			Treatment		
	Sample Size	S %	R %	Sample Size	S %	R %
Site 1	49	86	94	51	24	35
Site 2	35	97	100	31	68	81

LITERATURE CITED

- Hunt, R. S. 1982. Blister rust in British Columbia I. The possibilities of control by branch removal. For. Chron. 58: 136-138.
- Hunt, R. S. 1983a. Blister rust in British Columbia II. Can stands be hazard rated? For. Chron. 59: 30-33.
- Hunt, R. S. 1983b. White pine blister rust in British Columbia. Can. For. Serv., Pac. For. Res. Cent., For. Pest leaflet 26, 7 p.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

COMMANDRA RUST DAMAGE AND RISK RATING RESEARCH

W.R. Jacobi, J.E. Boyd, and W.R. Zentz

I. Damage Rating for Trees

1. **Growth and yield predictions:** Data inputs needed for growth and yield predictions in RMYLD and Prognosis are simple and will be clarified and tested to make sure they are feasible to collect. The data items (canker height, crown height, tree height) have been described by Geils in a previous WIFDWC proceeding.
2. **Damage Rating For Timber Marking:** We are just starting to sort out the factors that should be included in an individual tree rating scheme for use in stand thinning/harvesting activities. We assume the rating scheme will be based on a simple numerical scale reflecting canker expansion, height of canker in relationship to crown height and thus mortality/growth loss on a relatively long entry rotation ie-30 years. Younger trees may require a modification of the rating system since younger trees are usually killed because the girdling cankers are lower than the crown and thus the tree doesn't survive.

William R. Jacobi is an associate professor of forest and shade tree pathology, Colorado State University. J.E. Boyd and W.R. Zentz are graduate students working with Jacobi at Colorado State University.

II. Insect Involvement:

We hope to determine what insects (beetles) are involved in the demise of comandra rust-infected trees. Two to three insect-infested and rust-infected trees will be selected for study near permanent plots located in Wyoming.

III. Risk Rating of Lodgepole Pine Stands:

Ralph Zentz is near completion of his M.S. thesis on our preliminary work on risk rating lodgepole pine stands in the Shoshone National Forest. We have learned alot about how we should do the future research to determine a practical but disease-process driven risk rating system.

Our preliminary research was aimed at determining a relationship between disease incidence and severity in lodgepole pine stands and the distance the stands were away from the alternate host. We also looked at site features related to the occurrence of the alternate host which has been reported in previous WIFDWC proceedings. The characteristics of the lodgepole pine stands were analyzed briefly to see if there were any relationships between stands and rust incidence and severity. We found only one tree parameter (average tree height) that was significantly related to the percentage of trees infected in a stand. In our future work we hope to look at stand data in more depth focusing on stand density at infection, the relationship of stand aspect and slope with wind flow from the alternate host. We have several data sets now covering wide geographic regions that should give us the opportunity to determine if stand and stand site characteristics affect rust incidence and severity.

Future Research:

We feel a major factor in predicting rust infestation is the distance the alternate host is away from the lodgepole pine. A simple distance relationship is not adequate because one has to take into account wind flow direction when conditions are appropriate for spore production, dispersal and infection of pines. The amount of alternate host is probably also important. Ralph Zentz's work has shown us the following either directly from his data or indirectly from our greater understanding of comandra rust, wind flow and spore dispersal:

1. The distance basidiospores can move is apparently more on the scale of 0-10 miles rather than 0-5 as we originally hypothesized.

2. We unfortunately found a high incidence of rust at the distant edge of the lodgepole pine type on the Wind River District. Thus we could not determine a relationship of distance from comandra populations and diminishing rust incidence.
3. We had considerable variation in number of infected trees in stands similar distances from comandra populations.
4. The importance of wind flow direction from comandra populations became all important as we tried to explain the infestation of some stands vs. others.
5. The patterns of disease on the Wind River District and other National Forests in Wyoming indicate that upslope winds associated with moist weather systems are probably the important weather conditions to key on.
6. The infestation of comandra populations appear to be important in determining high amounts of rust. For 4 years the rust has been common on comandra plants on the Shoshone. This year the rust is almost non-existent.

IV. Future Plans:

Our planned research, if we find funds, is to finish up the risk rating work utilizing three study sites. The hypothesis which we will test is that: the location and density of the rusts alternate host Comandra umbellata (L.) Nutt., in relation to the location and characteristics of lodgepole pine stands combined with the influence of weather conditions can explain disease incidence and severity in the Rocky Mountain Region.

To test this hypothesis, our proposed project has the following objectives:

1. To determine distances and patterns of comandra rust basidiospore dispersal in several mountain areas of the Rocky Mountain Region;
2. To determine effects of apparent spore loading from various population densities of the alternate host on basidiospore dispersal distances and patterns;
3. To determine effects of lodgepole pine stand characteristics and locations on the incident and severity of comandra rust.

Related objectives that will help with the overall project:

1. To determine the relationship between weather conditions and basidiospore release;
2. To determine if wind flow models can be useful in predicting spore dispersal in mountainous terrain.

To test this hypothesis we will investigate the source and deposition locations of the fungal spore that infects the pine trees. We will determine the location and amount of the alternate host and the occurrence and severity of the spore dispersal and direction between the two host plants will be studied indirectly by utilizing location, rust incidence and severity information for both infected hosts, and associated wind flow patterns predicted by a computer model (WINDS) of boundary layer flow over complex terrain. The WINDS model and CITPUFF dispersion model will be used as aids to determine the probable dispersal pattern of the rust basidiospores from the comandra populations to the lodgepole pine stands. Remote weather stations located at each study site will provide required data on wind direction and speed when weather conditions are conducive to basidiospore formation, dispersal and infection of the pine. Research areas will be located in the Beaverhead National Forest near Dillon, Montana, Medicine Bow National Forest near Laramie, Wyoming and the Shoshone National Forest Near Dubois, Wyoming. Each study area represents a different topographical condition, scale of rust distance from alternate host at 1-30, 1-7 and 1-10 miles respectively, and amount of rust infestation at 20, 10 and 50% rust incidence respectively. One major study area will be utilized on each national forest with a possibility of several other minor study areas on the Shoshone and Medicine Bow Forests. Study areas will consist of a forest and range area defined by valleys, adjacent mountain ranges or change in species.

Mapping of Comandra umbellata occurrences and distribution, their population density and degree of plant infection will be accomplished by surveying potential comandra sites. All accessible sites will be visited in a study area. Mapping and describing lodgepole pine populations and their degree of infestation will be accomplished by sampling selected stands.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

WHITEBARK PINE AND THE 4 B'S: BLISTER RUST,
BARK BEETLES, BURNING, AND BEARS

Richard G. Krell

Whitebark pine (*Pinus albicaulis* Engelm.) is beset by several problems causing severe disturbance of subalpine ecosystems in the Northern Rocky Mountains. Best known to forest pathologists is white pine blister rust (*Cronartium ribicola* J. C. Fischer ex Rabh.). In many habitats occupied by whitebark pine, alternate host ribes are rare or absent, and temperatures are frequently cooler than optimum for rust infection and development. Nevertheless, stands are apparently infected by long-distance spread of basidiospores and the rust is now common even in upper-elevation whitebark pine stands of western Montana. With its high susceptibility to blister rust, virtually all ages of whitebark pine are attacked, and losses are often dramatic, especially among smaller trees, saplings, and seedlings. Blister rust kills branches of large pines and sometimes entire trees.

RICHARD G. KREBILL is supervisory biologist at the Intermountain Research Station, USDA Forest Service, Missoula, Mont.

Larger whitebark pines are more often killed by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) than by blister rust. Although records are incomplete, it is suspected that beetle-caused mortality has increased in recent decades because of successful fire control in adjoining lodgepole pine forests. Without fire, lodgepole stands have aged and thereby become more susceptible to mountain pine beetle. Resulting outbreaks produce an abundance of beetles, many of which may spread into whitebark stands at upper elevations.

Fire ecology in whitebark pine forests is rather complex. Whitebark pine has relatively thin bark and consequently fire can easily kill trees. As judged by the occurrence of charcoal, whole stands of whitebark pine are sometimes killed by fire. But whitebark pine is also a fairly intolerant species and consequently is losing ground to climax conifers in many stands where fire has long been constrained. Fire is also critical in that it creates sites conducive to planting of seeds by Clark's nutcracker (*Nucifraga columbiana* Wilson) and to seedling establishment and growth.

Since Research has generally focused on commercial timber species, therefore little is known about the ecology of whitebark pine. But because its nuts are an important food for grizzly bears (*Ursus arctos horribilis* Ord) in the Yellowstone Ecosystem, there is now strong interest in whitebark pine. In response, our Station has initiated research on the possibility of using prescribed fire (including prescriptions for natural fire) to rejuvenate whitebark stands. Complementary research is needed on the ecology of blister rust in renewed stands in prime grizzly bear habitat.

DWARF MISTLETOE DISCUSSION SESSION

by John A. Muir

In this session, several reports were presented, including the Dwarf Mistletoe Committee Report by J. Laut, control of dwarf mistletoes with Ethephon by T. Nicholls and F. Hawksworth, impact of dwarf mistletoe in ponderosa pine in Colorado by W. Jacobi and Helen Maffei, and several papers or reports on impact and control of hemlock dwarf mistletoe by W. Bloomberg, D. Demars, B. van der Kamp and F. Hawksworth.

The discussion of hemlock dwarf mistletoe (Arceuthobium tsugense) was prompted by several conflicting opinions about the impact of the mistletoe in various areas in coastal forests. At a 1983 workshop in Burnaby, B.C., we discussed results of several impact or loss studies in coastal stands, and strategies for controlling the parasite. At the current workshop at Juneau we reviewed more recent results and variations between regions. Several substantial differences in the parasite, tree stands and environments were recognized by the discussants between the three regions of Washington-Oregon, British Columbia and Alaska. Generally the participants appears to agree that in some instances the effect of the mistletoe in young stands was negligible, but in others, substantial impact does result from infection.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

COMPARISON OF DWARF MISTLETOE EFFECTS ON HEMLOCK IN ALASKA, BRITISH COLUMBIA AND THE PACIFIC NORTHWEST

W.J. Bloomberg

ABSTRACT: Published data on infestation rate, incidence, severity and impact of hemlock dwarf mistletoe were compared for Alaska, British Columbia and Washington/Oregon. Infestation was relatively high in Alaska and British Columbia and moderate in Washington/Oregon. Incidence and severity were low in Alaska, moderate in Washington/Oregon and ranged from moderate to high in British Columbia. Reduction in volume and volume increment ranged from moderate to severe in British Columbia, but was not significant in Washington/Oregon. Possible factors contributing to differences in epidemiology of the disease among geographic areas include effect of climate on seed production and spread, stand composition and growth rate, and dwarf mistletoe biotypes.

INTRODUCTION

Since western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) first became economically important in the coastal forest resource of western North America, forest pathologists in the Pacific Northwest, British Columbia and Alaska have been concerned about the potential impact on one of its most serious diseases, dwarf mistletoe (*Arceuthobium tsugense*

WILLIAM J. BLOOMBERG, Research Scientist,
Canadian Forestry Service, Pacific Forestry
Centre, Victoria, B.C. V8Z 1M5

(Rosendahl) G.N. Jones) (Shea 1966, Smith 1969, Laurent 1980). Initially, concern was focussed on the widespread distribution of the pest in old-growth stands due for harvesting and regeneration, and as more became known about its spread dynamics, on the fear of severe infestation of second-growth stands (Shea and Stewart 1972, Baranyay and Smith 1972). Severe qualitative (Wellwood 1956) and quantitative (Smith 1969) impacts were recorded in mature, heavily infected trees (>100 years), but few measurements were made in younger stands until Baranyay conducted systematic surveys in south coastal British Columbia stands in 1970-71. These showed a wide range of infection severity depending on stand conditions (Alfaro et al 1985). Selective surveys in young hemlock stands in western Washington and Oregon showed that severity increased with age in trees within 30' of infected overstory trees (Stewart 1976).

On the assumption that incidence of dwarf mistletoe would translate into significant volume loss in immature hemlock stands, forest pathologists recommended silvicultural control of the disease by sanitizing infected stands (Hadfield & Russell 1978, Russell 1978, Van Sickle & Smith 1978). However, some forest managers resisted the introduction of sanitizing clauses into forest management regulations (J. Muir, personal communication, Shaw 1979) contending that there was insufficient evidence for economic damage by the disease and that sanitizing costs were unjustifiable. Also, results from limited spread and impact studies led forest pathologists in Alaska and the Pacific Northwest to conclude that dwarf mistletoe could have lesser economic impacts than originally believed (Hadfield 1979, Shaw 1979). However, impact studies on Vancouver Island showed significant and major growth loss (Thomson et al 1984, 1985). A workshop held in Vancouver, B.C. to resolve conflicting viewpoints pinpointed a priority need for objective data on growth impacts (Muir 1983).

The purpose of this report is to review the findings on the pathological effects of hemlock dwarf mistletoe in Alaska, British Columbia and the Pacific Northwest, to make comparisons among these regions and to try to interpret differences among them.

DEFINITIONS

Because various epidemiological measures have been used to express the pathological effects of dwarf mistletoe on western hemlock, it is important to define these parameters. Definitions used in this report are given in Table 1. They are self-explanatory with the possible exception of "severity". This is a complex, but important parameter usually expressed as a combination of incidence and ratings, as distributions of percent trees with given ratings (Hadfield et al 1979), or as mean ratings weighted by the percentage of trees in each rating class (Alfaro et al 1985).

TABLE 1--Definitions

1. Infestation - % stands infected
2. Incidence - % trees infected in infested stand
3. Rating - tree infection class
4. Severity - infested stand rating f(incidence, rating)
5. Impact - volume reduction in infested stand, relative to healthy stands

Severity is also represented as percent trees with a given number of infections (Shaw 1982) or proportions of crown length infected (Bloomberg & Smith 1982, Richardson & Van der Kamp 1972).

DETERMINING IMPACTS

Because of the strong influence of stand history, especially survival of infected residuals on infestation, and stand conditions, especially height growth, and of composition, age and stocking density on incidence and severity of dwarf mistletoe, estimation of impacts for individual stands or for larger forest units is complicated.

Two general methods have been used to determine volume impacts in immature western hemlock.

1. Direct Method

This method is plot-based and assumes that impacts measured in plots can be directly extrapolated to those in a stand, and those in turn to similar stands. The procedure is outlined as follows:

1. Select sample stands.
2. Select sample plots in stands.
3. Select sample trees in plots.
4. Rate trees for infection.
5. Measure tree volumes.
6. Classify stand severity and calculate stand volume.
7. Compare volumes of stands of varying severities with those of uninfested stands.
8. Apply volume reduction factors to stands of each severity class.

Either final volume, as obtained from volume equations, or periodic volumes obtained from stem analysis can be compared. An example of this approach is described by Hadfield et al (1979).

Sources of variation

Sources of variation in impact study results stemming from the direct method are as follows.

1. Are the sample stands, plots and samples trees representative?

stands may vary in their history, site, age, and stocking density. Those in which infected residuals were felled at harvest or destroyed by broadcast burning afterward can be expected to have low infestation rates. Older stands can, on principle, be expected to have higher incidence and severity than juvenile stands. Plots may also vary in their history, e.g., in storm-felled patches, and in their micro-sites and age-class structure. Sample trees may vary in dominance class, origin (pre-harvest or post-harvest regeneration) and age.

While it may not be practical to determine impacts for every combination of factors, it is important that comparisons be made among stands having approximately the same combinations.

2. Are incidence and rating distributions representative of trees in each stand?

Depending on infection pattern in stands, the number of infected trees and their ratings may vary widely among plots. In some cases, plots have been centered on infected residuals, thus a stand average also depends on the number of these, as well as on their infectivity, especially their size and inoculum load.

In some cases, sample trees are selected along a distance gradient from the residual. Such a sampling plan is biased in favor of the more heavily infected trees close to the infection source and is not necessarily representative of distribution of infection in the stand as a whole. In young stands, insufficient sample trees may occur in the higher rating classes to obtain a reliable estimate of their volume losses.

3. Are the severity distributions representative of stands?

If the incidence and ratings of trees are not representative of plots, it is unlikely that the severity rating derived from them will be representative of the stand. Transects based on single residual trees do not necessarily provide a true estimate of the total infected area unless seed dispersal is uniform in all directions from a point source.

4. Is the rating system consistent?

Various rating systems have been used to classify dwarf mistletoe infection in western hemlock, e.g. three-class (Bolsinger 1978), six-class (Hawksworth 1956), nine-class (Smith 1969). For translation to quantitative comparisons, classification systems must be internally consistent, i.e., a given class unambiguously represents a specific pathological condition, and externally consistent with effects on tree growth, i.e., a given

growth effect is unambiguously associated with each class.

Published results of studies on the infestation, incidence, severity and growth impact of dwarf mistletoe in immature western hemlock vary among geographical regions of coastal western North America.

2. Indirect Method

This method indirectly measures stand volume by extrapolating tree-based volume estimates to plot-based severity estimates. The procedure is outlined as follows:

Tree Volumes.

1. Select sample stands.
2. Select sample trees by rating class.
3. Measure volumes.
4. Compare volumes among rating classes.

Stand Volume

1. Select sample plots in stands.
2. Record distribution of rating classes in plots.
3. Extrapolate volume for each rating class.
4. Extrapolate plot volume to stand.
5. Calculate stand severity.
6. Compare stand volumes among severity classes.

Baranyay used a modification of this method (Thomson et al 1984).

Sources of variation

Sources of variation arising from the indirect method are:

1. Are sample stands, plots and trees representative?

Since sample tree selection for volume measurement and sample plot selection for severity are done independently, balanced and representative samples of each can be more easily obtained than in the direct method in which each plot fixes both the rating distribution and the volumes to be measured. Relatively numerous plots can be measured for rating alone, increasing the accuracy of the stand estimate, whereas time-consuming volume measurements can be restricted to a carefully chosen balanced sample of trees from the whole stand. Because volumes of a relatively small number of sample trees are applied to a much larger number of rating plot trees, any bias in the selection of the former will be magnified in the stand volume estimate. Therefore, volume sample trees must be as representative as possible with respect to microsite, origin, and age.

2. Is rating system consistent?

The same sources of variation in the direct method also apply to the indirect method, but inconsistencies between rating of volume sample and plot sample trees will have more serious effects on variation.

1. Infestation Rate

Alaska.

Whereas the disease appears to be prevalent in older stands (250+ years), less than 20% of younger stands (<44 years) examined were infected (Drummond & Hawksworth 1979).

British Columbia.

An earlier estimate of 15% infestation rate in stands (all age classes) with western hemlock predominating (Van Sickle & Smith 1978) appears to be too low in the light of 36-51% of the forest inventory plots in the Vancouver Region containing bole infections (Beale 1985).

Washington/Oregon

Overall infestation rate of western and mountain hemlock in Washington and Oregon is estimated at 21% (Bolsinger 1978). Occurrence is scattered with extensive areas entirely free of infection.

Infestation rates for different tree size classes were 10.0, 18.0 and 32.4% for seedling/sapling/pole, small sawtimber and large sawtimber, respectively.

2. Incidence

Alaska.

Based on 19 9.1 m-radius plots concentric on single infected residuals, distributed in four immature (17-43 years) western hemlock-Sitka spruce stands, incidence ranged from 5 to 17% (Shaw 1982). Incidence was higher for crop trees (12-47%) than for non-crop trees (4-9%) and higher for advanced regeneration (9-29%) than for post-harvest regeneration (2-13%).

British Columbia.

Surveys of seven 40-100+ year stands comprising 44-96% western hemlock using fixed radius plots (.004-.016 ha) at 23-37 m grid intervals were conducted in different geographical areas of south coastal British Columbia (Alfaro et al 1985). Incidence of dwarf mistletoe ranged from 17-91% of the trees. Incidence was least where the western hemlock component was lowest and was greatest in the oldest stand.

Washington/Oregon.

Percent infected trees >12.5 cm averaged 31.2% for western and mountain hemlocks as calculated from Table 5 in Bolsinger (1978), using disease incidence classes weighted by their areas. Data were from fixed radius or prism plots located on a systematic grid.

In pure hemlock stands, 10-25 years, 9.1 m transects radiating from selected infected overstory trees showed a logarithmic increase from about 6% incidence in 10 year-old stands to about 70% in 25-year-old stands (Stewart 1976).

3. Severity

Alaska.

Overall, less than 2% of immature western hemlock had >2 live infections in four stands examined. Up to 13% of crop trees had >2 live infections.

British Columbia.

Based on a 9-class severity scale, stand infection ranged from 0.3-3.8 in seven stands in south coastal British Columbia (Alfaro et al 1985). Proportions of lightly, moderately and heavily infected trees ranged from 10-54%, 7-50% and 0-25%, respectively. Mortality averaged 0.6%. Spatial distribution varied from scattered centers to generalized disease throughout stands. Ratings generally increased with increasing dbh and tree height.

In five stands, 20-40 years, average number of live infections ranged from 179-455 with 79-100% of crown length infected (Bloomberg & Smith 1982). Number of infections was highly correlated with dbh and tree height.

In immature hemlock 45 years after release by logging, average number of infections established over the last 20 years was 431 and 229 in open and dense stands, respectively, with 51 and 41% of crown length infected (Richardson & Van der Kamp 1972). Percent crown infected increased with crown size.

Washington/Oregon.

Three-class ratings of infected trees >12.5 cm averaged 1.12 for mountain hemlocks as calculated from Table 4 in Bolsinger (1978), using rating classes weighted by their areas. Using 6-class ratings, weighted averages calculated from Tables 1 and 3 in Hadfield (1979) were 1.21, 1.67 and 1.30 for plots in an unthinned 43 year-old stand and in thinned and unthinned portions of a 73-year-old stand, respectively. Percents of trees with ratings ≤ 2 were 80, 67 and 70, respectively.

4. Impact

Alaska.

No published data was available on impact of dwarf mistletoe on western hemlock.

British Columbia.

Based on a 15% infestation rate, annual growth loss for British Columbia was estimated at 1.7 million m³ (Van Sickle 1978).

In a young (22-year-old) experimental plantation, high infection level (>100 infections) was significantly associated with zero or negative 5-year change in relative height (tree height/ average height) but there was no association with dbh (Thomson & Smith 1983). Maximum negative rate of change <-.04 contrasted with maximum positive rate of >.02 in trees with low infection (0-25 infections).

In four 40-103 year-old stands on southern Vancouver Island, volume increment reduction in moderately and severely infected trees compared with healthy-lightly infected was estimated at 15 and 25%, respectively, by age 80, with relatively stable impacts thereafter (Thomson et al 1984).

In five stands on northern Vancouver Island, 45-80 years, sample trees selected for uniformity of stand conditions and tree age, showed volume reductions of 17-34% in moderately infected (6-class, 3-4) and 30-45% in severely infected (5-6) compared to healthy-lightly infected (0-2) trees (Thomson et al 1985). Volume increment trends infection classes diverged from age 20.

In mature western hemlock, 94-133 years, lightly infected trees had 41% greater volume growth and 84% greater height growth over the latest period of their growth than severely infected trees (Smith 1969). Volume loss was estimated at 4.2 m³/ha/year.

Washington/Oregon

Annual volume loss due to hemlock dwarf mistletoe has been estimated at 1.2 million m³ (Childs & Shea 1967). However, in unthinned stands 43 and 79 years old, there were no significant differences between volumes of sample trees rated 0-2 and 3-6 on the 6-class scale (Hadfield 1979). Moreover, in thinned stands, volumes of 3-6 rated trees significantly exceeded those rated 0-2. Radial and leader growth for the past 10 years did not differ significantly between the rating classes.

Although differences in methodology limit direct comparisons of published data among geographic regions with respect to infestation, incidence, severity and impact of hemlock dwarf mistletoe, relative assessments can be made. In Alaska, despite widespread distribution of infected residuals, spread into adjacent young stands is apparently slow, with very restricted intensification in infected trees and by inference, no detectable effect on tree growth. In British Columbia, infestation rate appears to be fairly high; although wide variation occurs in incidence and severity, dependent on stand conditions, spread and intensification is evidently much more rapid than in Alaska. Relatively consistent results of impact studies show significant and economically important volume losses due to the disease. In Washington and Oregon, moderate infestation rate and incidence do not appear to translate to proportionate severity and impacts in immature stands.

Suggested reasons for limitation of dwarf mistletoe damage in Alaska include, interruption of pollination in large cutover areas, a long latent period following infection, and effects of severe climate on seed retention and infection (Drummond and Hawksworth 1979). Other factors may be stunted height growth of residuals, small size of advanced regeneration at release and their minority composition in the total stand, high stand density and sufficient proportion of non-host species (Sitka spruce) to retard spread (C.G. Shaw, personal communication). The combination of these factors could result in a small seed source, limited overstory spread, low infection probability and slow intensification.

Low severity and impact levels in Washington/Oregon, compared to British Columbia may be related to much lower seed retention and infection rates in the former region (Carpenter et al 1979). Frequency of winter storms combined with heavy precipitation may account for a higher seed loss. Higher stand density and more rapid height growth in the generally more fertile sites could restrict intensification.

In all regions, the possibility of differences in biotypes of hemlock dwarf mistletoe cannot be discounted.

SUMMARY

Real epidemiological differences cannot be confidently inferred from the limited data bases available for the three geographical areas. However, there is a strong observational evidence for such differences. More extensive sampling, using standardized methodology is necessary to support this evidence. Effect of site and stand history, composition and structure must be taken into account in the design of comparative surveys.

It would be premature to make firm recommendations for the entire host range of hemlock dwarf mistletoe based on the limited information available. However, the following suggestions should be considered. In Alaska, the apparently slow spread and intensification rate of the disease may justify a different disease management policy than in other areas. Proposed felling of all hemlock at harvest, regardless of size, and removal of diseased residuals during precommercial or commercial thinning seems a reasonable management strategy (Shaw 1982). Some additional sampling would be advisable to confirm that the low spread and intensification rates found in young stands continue to prevail in older stands.

In British Columbia, the weight of evidence is that hemlock dwarf mistletoe causes significant economic impacts in second-growth managed stands; therefore disease management guidelines are justifiable. Felling all residuals during harvesting, spacing and thinning operations, sanitizing at spacing and thinning with non-host species preference in mixed stands, maintaining stand density are some available options. However, management prescriptions should be specific to site and stand-type conditions, rather than blanket procedures. Predictive modelling can be a useful tool in the absence of field data on effects of site and stand variables on the disease (Bloomberg & Smith 1982, Bloomberg et al 1980). Contrary to criticisms that model results exaggerate the effects of the disease, a wide range of scenarios is possible from negligible spread and intensification rates where residuals are sparse and small, regeneration density is high and height growth is rapid, to very high rates where the opposite conditions apply (Bloomberg, unpublished data). Management actions based on model predictions can range from none required, to modified spacing, to stringent sanitizing.

Although dwarf mistletoe appears to be important in all areas of the host range, further sampling is recommended especially on the north coast.

In Washington and Oregon, it would be premature to conclude that hemlock dwarf mistletoe is unimportant as an economically damaging disease. The major differences in severity between stands in Washington and those relatively close by on southern Vancouver Island need to be confirmed and explained if they are general. Therefore, further sampling is desirable.

REFERENCES

- Alfaro, R.I., W. J. Bloomberg, R. B. Smith & A. J. Thomson. 1985. Epidemiology of dwarf mistletoe in western hemlock stands in south coastal British Columbia. *Can. J. For. Res.* 15:909-913.

- Baranyay, J. A. & R. B. Smith. 1972. Dwarf mistletoes in British Columbia and recommendations for their control. Can. For. Serv. Rept. BC-X-72, 18p.
- Beale, J. 1985. Hemlock dwarf mistletoe in the Vancouver Forest Region. B.C. Min. For. Pest Management Progr. 4:23-24.
- Bloomberg, W. J. & R. B. Smith. 1982. Measurement and simulation of dwarf mistletoe infection of second-growth western hemlock on southern Vancouver Island. Can. J. For. Res. 12:280-291.
- Bloomberg, W. J. & R. B. Smith & A. Van der Wereld. 1980. A model of spread and intensification of dwarf mistletoe infection in young western hemlock stands. Can. J. For. Res. 10:45-82.
- Bolsinger, C. L. 1978. The extent of dwarf mistletoe in six principal softwoods in California, Oregon and Washington as determined from forest survey records. Proc. Sympos. on dwarf mistletoe control through forest management. Berkeley, CA, p. 45-50.
- Carpenter, L. R., E. E. Nelson & J. L. Stewart. 1979. Development of dwarf mistletoe infections on western hemlock in coastal Oregon. For. Sci. 25:237-243.
- Childs, T. W. & K. R. Shea. 1967. Annual losses from diseases in Pacific Northwest forests. US For. Serv. Resource Bull. PNW-20, 19p.
- Drummond, D. B. & F. G. Hawksworth. 1979. Dwarf mistletoe in western hemlock in southeastern Alaska. Meth. Applic. Grp. For. Insect and Dis. Managemt, US For. Serv., Rept. 79-6, 14p.
- Hadfield, J. S. 1979. Influence of dwarf mistletoe on 40- to 80-year-old western hemlock stands on the Washington coast. Proc. 27th West. Internatl. Dis. Work Conf., Salem, OR, p 30-37.
- Hadfield, J. S. & K. W. Russell. 1978. Dwarf mistletoe management in the Pacific Northwest. Proc. Sympos. on dwarf mistletoe control through forest management. Berkeley, CA, p 73-81.
- Hawksworth, F. G. & A. A. Lusher. 1956. Dwarf mistletoe survey and control on the Mescalero-Apache Reservation, New Mexico. J. For. 54:384-390.
- Laurent, T. H. 1980. Dwarf mistletoe on Prince of Wales Island, Ketchikan Area, Tongass National Forest, Biol. Eval. R-10-80-3, For. Insect Dis. Managemt, US For. Serv., 6p.
- Muir, J. 1983. Ed. Proc. Workshop on Management of hemlock dwarf mistletoe. B.C. Min. For. Pest Managemt Rept. 4, 58p.
- Richardson, K. S. & B. J. Van der Kamp. 1972. The rate of upward advance and intensification of dwarf mistletoe on immature western hemlock. Can. J. For. Res. 2:313-316.
- Russell, K. W. 1978. Improving extension and training programs for dwarf mistletoe control. Proc. Sympos. on dwarf mistletoe control through forest management. Berkeley, CA, p 45-50.
- Shaw, C. G. III. 1979. Hemlock dwarf mistletoe and young growth management in southeastern Alaska - a problem or concern? Proc. 27th West. Internatl. Dis. Work Conf., Salem OR, p 21-29.
- Shaw, C. G. III. 1982. Development of dwarf mistletoe in western hemlock regeneration in southeastern Alaska. Can. J. For. Res. 12:482-48.
- Shea, K. R. 1966. Dwarf mistletoe of coastal western hemlock; principles and practices for control. Weyerhaeuser Forestry Pap. No. 9, 14p.
- Shea, K. R. & J. L. Stewart. 1972. Hemlock dwarf mistletoe. US For. Serv. For. Pest Lflt. 135, 6p.
- Smith, R. B. 1969. Assessing dwarf mistletoe on western hemlock. For. Sci. 16:277-285.
- Stewart, J. L. 1976. Dwarf mistletoe infection from residual western hemlock on cutover stands. US For. Serv. Res. Note PNW-278, 3p.
- Thomson, A. J. & R. B. Smith. 1983. Growth patterns in a young western hemlock plantation infested with dwarf mistletoe. Can. J. For. Res. 13:972-978.
- Thomson, A. J., R. B. Smith & R. I. Alfaro. 1984. Growth patterns in immature and mature western hemlock stands infected with dwarf mistletoe. Can. J. For. Res. 14:518-522.
- Thomson, A. J., R. I. Alfaro, W. J. Bloomberg & R. B. Smith. 1985. Impact of dwarf mistletoe on the growth of western hemlock trees having different patterns of suppression and release. Can. J. For. Res. 15:665-668.
- Van Sickle, G. A. & R. B. Smith. 1978. Dwarf mistletoe controls in British Columbia. Proc. Sympos. on dwarf mistletoe control through forest management. Berkeley, CA, p 106-112.
- Wellwood, R. W. 1956. Some effects of dwarf mistletoe on western hemlock. For. Chron. 32:282-296.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

MENSURATIONAL AND STATISTICAL PROBLEMS IN
DETERMINING THE IMPACT OF DWARF MISTLETOE
ON VOLUME GROWTH

Donald J. DeMars

ABSTRACT: An adequate data base is critical when the impact of dwarf mistletoe on stand volume growth is estimated. It is recommended that remeasurement data from permanent plots be used to establish the needed cause-effect relationship. Autocorrelation and multicollinearity are two statistical problems that might be encountered in the cause-effect regression analysis.

INTRODUCTION

Evaluating the impact of dwarf mistletoe (*Arceuthobium* sp.) on volume growth presents many problems not usually encountered in a statistical analysis of mensurational data. The objective of most mensurational-statistical analyses is to develop a predictive equation whereby the value of some specified dependent variable is estimated given values for some set of independent variables. In a predictive equation, the contribution of an individual independent variable does not have to be separated from the contributions of other independent variables. The main criterion used to evaluate the usefulness of a predictive equation is how well the dependent variable is estimated.

DONALD J. DeMARS is a forest mensurationist at the Forestry Sciences Laboratory, Pacific Northwest Forest Research Station, USDA Forest Service, Juneau, Alaska.

Assessing the impact of dwarf mistletoe on volume growth is more difficult because it requires a cause-effect analysis. In a cause-effect analysis, the objective is to determine what portion of the estimated value of the dependent variable can be attributed to one of the independent variables in the equation. Many growth variables--some that interact with dwarf mistletoe and others that do not interact--must be examined and their combined contribution to volume growth be determined before the effect of dwarf mistletoe on volume growth can be evaluated. The enormity of this problem becomes apparent when a list of some of the most important variables is examined. In table 1, the most important variables are organized into five logical groups.

Although the variables are divided into five groups, the groups are not independent from one another. A variable from one group might be influenced not only by variables in its own group but also by variables from other groups. For example, the rate of spread of dwarf mistletoe within a stand depends on the initial spatial distribution of dwarf mistletoe within the stand, the spatial distribution of trees within the stand, the stand density, species mix in the stand, dwarf mistletoe seed dispersal distance, crown area of healthy trees, the competitive position of the infected trees, the spatial distribution of dwarf mistletoe within a tree, and any management treatments that might be applied to the stand.

STUDY OBJECTIVE

When the impact of dwarf mistletoe on volume growth is estimated, the impact on a stand of trees is the primary objective rather than the impact on individual trees because a manager usually wants to estimate impact over a large land area. And even though the impact of dwarf mistletoe on individual tree volume growth is a desirable piece of information, it is not as useful as knowing the volume-growth response of stands to dwarf mistletoe infestations. Trees in stands compete with one another for nutrients, water, and light; the growth of an individual tree depends on its position in the stand, its vigor, and the position and vigor of trees in close proximity to it. Often, competitors of a tree infected with dwarf mistletoe can take advantage of the reduced vigor of the infected tree and increase the growth of wood on their stems. Thus, while an individual tree in a stand might lose volume growth to dwarf mistletoe, the reduction in stand volume growth might be less than the growth loss in the individual tree. The growth response of a competitor to reduced competition does take time and occurs only after the dwarf mistletoe infection is great enough to reduce the growth of the infected tree and thus change the tree's relative competitive position in the stand.

STRATEGY OF THE STUDY DESIGN

The success or failure of a dwarf mistletoe volume-growth impact study ultimately depends on the data available for analysis. Several types of data bases have been used in the past to evaluate

TABLE 1--Important growth factors

Tree variables

1. Tree age
2. Tree size
 - a. Diameter
 - b. Height
3. Crown area
4. Competitive position
5. Tree form of healthy trees
6. Species
7. Microsite factors
8. Tree volume
9. Tree volume growth

Stand variables

1. Site index
2. Stand age
3. Range of tree ages
4. Stand density as measured by:
 - a. Number of trees per acre
 - b. Basal area per acre
 - c. Stand density index
 - d. Crown competition factor
5. Species mix
6. Spatial distribution of trees
7. Tree mortality
8. Stand origin
9. Stand volume
10. Stand volume growth

Dwarf mistletoe variables

1. Age of tree (stand) when infection (infestation) started
2. Dwarf mistletoe infection level
 - a. Within a tree
 - b. Within a stand
3. Spatial distribution of dwarf mistletoe
 - a. Within a tree
 - b. Within a stand
4. Rate of spread of dwarf mistletoe
 - a. Within a tree
 - b. Within a stand
5. Tree mortality in an infested stand
6. Tree form of infected trees
7. Tree volume of infected trees
8. Dwarf mistletoe seed dispersal distance

Management variables

1. Initial spacing control
2. Intermediate treatments
 - a. Thinnings
 - b. Fertilizer
3. Timing of management treatments
4. Rotation age
5. Dwarf mistletoe control measures

Other damaging factors

1. Wind damage
2. Other diseases
3. Insect damage

the impact of dwarf mistletoe. Stem analysis data, reconstructed growth data from temporary plots, forest inventory data from National Forests, and permanent plot data have all been used with limited success. After a review of the literature and several years of trying to analyze temporary plot data, I have concluded that permanent plot data collected over many years (ideally, the length of the rotation) offer the best chance to sort out the impact of dwarf mistletoe on volume growth (regardless of species).

Data collection starts with establishing permanent plots in young stands where the initial spacing of trees is controlled. Plots are remeasured at least once every 5 years.

Permanent plot data have to be collected for healthy stands as well as infested stands. If possible, a paired plot approach should be used whereby the characteristics of the healthy stand are the same as those of the infested stand at the time of the infection; the only difference between healthy and infested plots would be the infestation level of dwarf mistletoe. Enough permanent plots must be established to cover the ranges of site indices, initial tree spacings, and dwarf mistletoe infestations levels.

The number of variables, their interactions, and the complexities of stand growth dictate that management treatments not be applied during the life of a dwarf mistletoe impact study. Any intermediate management treatments make data analysis more difficult and confound the interpretation of results.

Measurement Data

All trees 4.5 feet and taller located within plot boundaries are measured for diameter at breast height, total height, and crown length. A dwarf mistletoe rating for each tree is estimated using Hawksworth's (1961) six-class rating system (or something similar). The dwarf mistletoe ratings for the top, middle, and bottom crown thirds are recorded along with the total rating for the tree. All plots are mapped for the spatial arrangement of trees, and other pertinent variables (aspect, elevation, other damaging agents, and other important variables) are measured and recorded.

Plot Statistics

Stand statistics (per-acre values) for each remeasurement of each plot must be calculated before a statistical analysis of the impact of dwarf mistletoe on stand volume growth can be done. Most stand statistics are straightforward and easily calculated; however, estimating the wood volume of stands is more difficult because a tree volume equation is usually needed. Sometimes, a tree volume equation is not available, and additional data on tree form has to be collected so that a volume equation can be developed.

In a dwarf mistletoe impact study, a separate volume equation might be needed for infected

trees. Little research has been done on the effects of dwarf mistletoe on tree form, but indications are that stem form might be different in infected trees. If this is true, tree volume of infected trees should be estimated by using a volume equation developed from infected trees; failure to do so will invalidate stand impact estimates.

DATA ANALYSIS

A consensus has not been reached on how to best analyze growth-impact data. Several methods can be used. One possible approach is presented in the following discussion, in which, it is assumed that the data set is of sufficient size and that several remeasurements have occurred on all plots. Simple variable names are used, but many variables will be transformed when equation models are developed. Also, the variables used in the discussion might or might not be part of a final equation model.

Phase 1

The objective of the first phase of the analysis is to develop one equation model for volume growth that fits data from both healthy stands and infested stands. To do this, individual equation models are built for each data set and for the pooled set of data by using stepwise regression techniques (or something similar). Independent variables for dwarf mistletoe infestation levels are to be left out when fitting these models. The equation models thus developed are the starting points in developing a common equation model that can be used in a covariance analysis of the two data sets. Some of the independent variables that might be included in a common model are given in the following equation:

Stand volume growth = $f(\text{site index, stand age, stand basal area, and quadractic mean diameter})$.

Phase 2

Using the common equation model developed in phase 1, conduct an analysis of covariance to test for a significant difference between the adjusted means of the two data sets. The test for significant difference between adjusted means is valid only if the two samples are drawn from normal populations with common variance and if the slopes of the two regression lines are parallel (that is, the regression coefficients are not significantly different).

Regardless of the outcome of the analysis of covariance of the two data sets, at least one additional analysis of covariance needs to be conducted. For this analysis, the data set of plots infested with dwarf mistletoe is divided into three groups based on the infestation level (light, medium, or heavy) of each plot at the most recent remeasurement. Using the equation model developed in phase 1, conduct an analysis of

covariance and test for significant differences among the adjusted means of the four sets of data (data from healthy stands plus the three data groups from infested stands).

Results of this analysis will indicate whether or not volume growth decreases as infestation levels increase. Also, results should give some indication of what sign (plus or minus) a regression coefficient would have if a dwarf mistletoe variable was allowed to enter the equation model.

Phase 3

Development of an equation that quantifies the cause-effect relation between dwarf mistletoe and volume growth is the last step of the analysis. Data sets for healthy stands and infested stands must be pooled for this phase. One way to build the cause-effect equation model is to start with the equation model developed in phase 1 and add independent variables that pertain to dwarf mistletoe using stepwise regression procedures (or something similar). Interactions between dwarf mistletoe variables and other independent variables should be investigated and appropriate terms added to the cause-effect equation when needed.

Two statistical problems might be encountered during the regression analysis: autocorrelation and multicollinearity. Autocorrelation occurs when the observations have a natural sequential order. Remeasurement data of forest stands from permanent plots has this characteristic. According to Chatterjee and Price (1977), "The presence of autocorrelation has several effects on the analysis. These are summarized as follows:

1. Least square estimates are unbiased but are not efficient in the sense that they no longer have minimum variance.
2. The estimate of variance and the standard errors of the regression coefficients may be seriously understated; that is, from the data the estimated standard errors would be much smaller than they actually are, giving a spurious impression of accuracy.
3. The confidence intervals and the various tests of significance commonly employed would no longer be strictly valid."

Multicollinearity occurs when independent variables are correlated with one another. Some correlation of independent variables usually exists in most regression applications but not enough to affect the analysis. A strong relation among independent variables typically makes results of regression analysis hard to interpret. Often, estimating the effects of one independent variable on the dependent variable is impossible.

The presence of multicollinearity can be hard to detect in a data set. Two indicators to look for are (1) when independent variables are so highly correlated that one variable can be substituted for another variable in a regression equation without affecting results, and (2) when an independent variable enters a regression equation with a

regression coefficient that has a sign opposite of what might be logically expected.

Some new statistical techniques have been developed to cope with multicollinearity (Chatterjee and Price 1977). Ridge regression and principal component regression are two of the new techniques that are available. These techniques are mentioned here because they might be needed in an analysis of dwarf mistletoe impact data.

LITERATURE CITED

Chatterjee, S., and B. Price. 1977. Regression analysis by example. John Wiley & Sons, Inc., New York.

Hawksworth, F. G. 1961. Dwarf mistletoe of ponderosa pine in the Southwest. U.S. Dept. Agric. Tech. Bull. No. 1246.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

Taxonomy of Hemlock Dwarf Mistletoe

Frank G. Hawksworth

For some time, we have suspected that hemlock dwarf mistletoe, Arceuthobium tsugense (Rosendahl) G. N. Jones, contains host races or pathotypes (Hawksworth and Wiens 1972, 1984). An obvious clue is its very broad host range, which not only includes Tsuga, but several species of Pinus, Abies, and Picea as well.

The best known segregate is the form on shore pine, which is found on the San Juan Islands, Washington; along the east coast of Vancouver Island, and adjacent islands and mainland; with isolated localities at Terrace (east of Prince Rupert), and at Port Clements on the Queen Charlotte Islands (Kuijt 1963; Smith 1971, 1974; Smith and Wass 1976, 1979; Wass 1976). Inoculation studies and field observations show that there is little or no cross-infection from western hemlock to shore pine, or vice versa. Wass (1976) found that dwarf mistletoe on shore pine flourishes on habitats separate from those where A. tsugense is common on western hemlock. Although these host differences were recognized (Hawksworth and Wiens 1972), both were considered to be A. tsugense because no consistent morphological differences occurred between populations on the two hosts. On their principal hosts, however, Smith and Wass (1979) found a much higher rate of infection for the shore pine race (39 to 58%) than for the hemlock race (13-20%). The number of shoots per infection, and shoot heights, were similar for both races (Smith 1971, Smith and Wass 1979).

In 1976, Don Knutson and I examined many mountain hemlock, western hemlock, and mixed stands of both hemlocks in southern Oregon. We found no cross-infection of mistletoe between the two hemlocks, which suggested that two

Frank G. Hawksworth is Arceuthobiologist and Project Leader subsp. Emeritus, at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, Colo.

races may be involved: (1) a low-elevation form that is primarily parasitic on western hemlock and associated Abies, rarely found on western white pine and mountain hemlock; and (2) a higher elevation form that is primarily parasitic on mountain hemlock and western white pine, but rare on western hemlock and Abies. As in the situation with shore pine and western hemlock, no consistent morphological differences occurred between the populations on mountain hemlock and western hemlock. Recently, Dr. Bob Mathiasen, of Northern Arizona University, Flagstaff, confirmed our observations on the existence of putative races of A. tsugense on western vs. mountain hemlocks in southern Oregon.

Hemlock dwarf mistletoe has been reported on mountain hemlock in Alaska (Shaw 1982), and in British Columbia (Fiddick and van Sickle 1979). In all cases, however, only a few infected mountain hemlocks were found, and these were always adjacent to heavily infected western hemlocks, so we presume that these are rare cross-overs of the western hemlock race.

Thus, A. tsugense probably consists of the following three host races, or pathotypes: (Figure 1).

- I. Western hemlock race. This form occurs at relatively low elevations (sea level to about 4,000 feet) from northern California to southeast Alaska. Principal hosts are Tsuga heterophylla, Abies amabilis, and A. procera; minor hosts are Tsuga mertensiana, Pinus monticola, and Picea sitchensis.
- II. Shore pine race. This form also occurs at low elevations (usually 500 to 2,500 feet) from Orcas Island, Washington, to the Queen Charlotte Islands; in coastal B. C., from Vancouver to Terrace. Pinus contorta subsp. contorta is the only principal host; rare hosts are Pinus monticola and Tsuga heterophylla.
- III. Mountain hemlock race. This form occurs at relatively high elevations (4,000 to 8,000 feet) from the central Cascades in Oregon to the Sierras in central California. Its principal host is Tsuga mertensiana, but it is also common on Pinus monticola, P. albicaulis, and Abies lasiocarpa; it is rare on Picea engelmannii and P. breweriana.

The taxonomic status of these host forms is still uncertain, but we hope electrophoretic studies currently being conducted in cooperation with Dr. Dan Nickrent of Ohio State University may clarify the relationships. Dr. Del Wiens and I plan to make parallel morphological studies. The combined results of these studies should indicate the most appropriate taxonomic status for these forms. If no consistent morphological differences are found, and the host relationships described above hold, perhaps forma speciales, such as we used for host forms of A. abietinum on white fir

and red fir (Hawksworth and Wiens 1972) would also be appropriate here. On the other hand, if morphological differences are detected, the forms might best be treated as subspecies. For now, we suggest that, if needed, these forms be referred to by the taxonomically non-committal term "race."

Stay tuned.

LITERATURE CITED

Fiddick, R. L., and G. A. van Sickle. 1979. Forest insect and disease conditions, British Columbia and Yukon/1979. Can. For. Serv., Pacific For. Res. Cent. Rep. BC-X-200. 20 p.

Hawksworth, F. G., and D. Wiens. 1972. Biology and classification of dwarf mistletoes (*Arceuthobium*). U.S. Dep. Agric., Agric. Handb. 401. 234 p.

Hawksworth, F. G., and D. Wiens. 1984. Biology and classification of *Arceuthobium*: an update. pp. 2-17. In F. G. Hawksworth and R. F. Scharpf [eds.]. Biology of dwarf mistletoes: proceedings of the symposium. USDA For. Serv. Gen. Tech. Rep. RM-111.

Kuijt, J. 1953. Distribution of dwarf mistletoes and their fungus hyperparasites in western Canada. Nat. Museum Can. Bull. 186: 134-148.

Shaw, C. G., III. 1982. Mountain hemlock is [an] occasional host for hemlock dwarf mistletoe in Alaska. Plant Dis. 66: 852-854.

Smith, R. B. 1971. Development of dwarf mistletoe (*Arceuthobium*) infections on western hemlock, shore pine, and western larch. Can. J. For. Res. 1: 35-42.

Smith R. B. 1974. Infection and development of dwarf mistletoes on plantation-grown trees in British Columbia. Can. For. Serv., Pacific For. Res. Centre Rep. BC-X-97. 21 p.

Smith, R. B., and E. F. Wass. 1976. Field evaluation of ecological differentiation of dwarf mistletoe on shore pine and western hemlock. Can. J. For. Res. 6: 225-228.

Smith, R. B., and E. F. Wass. 1979. Infection trials with three dwarf mistletoe species within and beyond their known ranges in British Columbia. Can. J. Plant Pathol. 1: 47-57.

Wass, E. F. 1976. Ecological study of shore pine stands infested with dwarf mistletoe on southeastern Vancouver Island. Can. For. Serv. Pacific For. Res. Centre Rep. BC-X-142. 33 p.

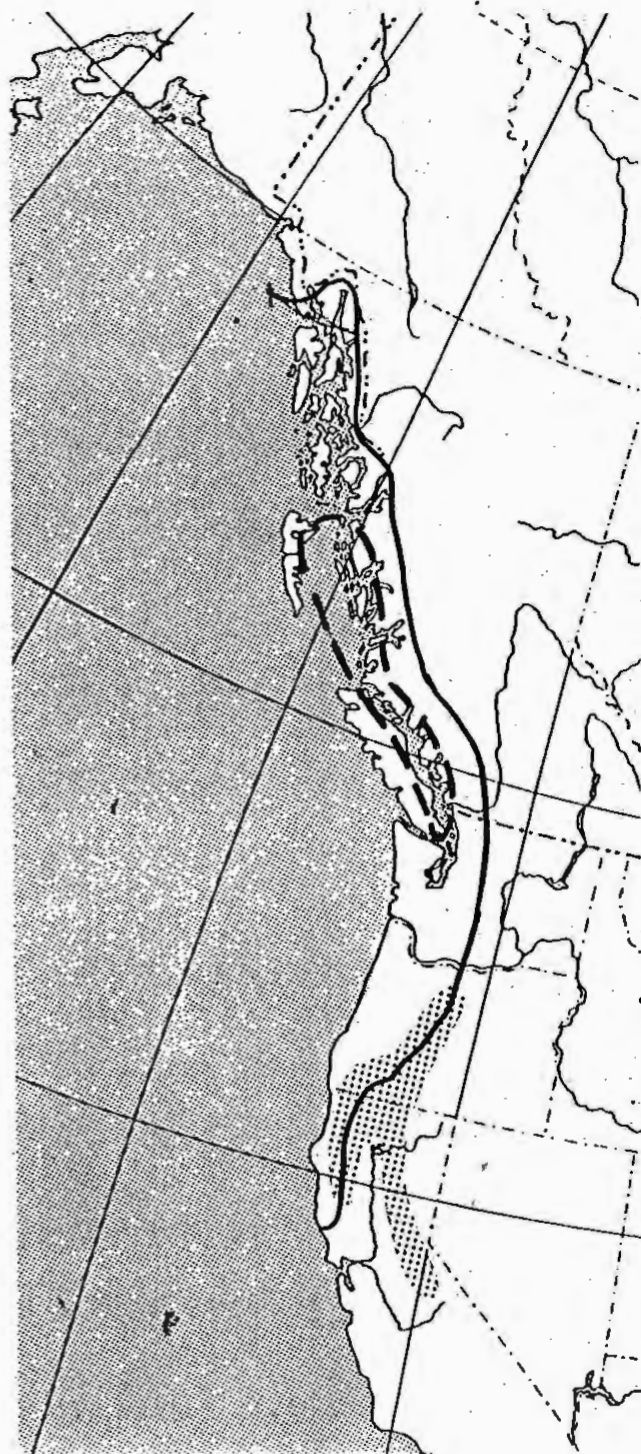


Figure 1--Distribution of hemlock dwarf mistletoe. The approximate limits of the three races are shown: western hemlock race (dark line), shore pine race (dashed line), and mountain hemlock race (stippled area).



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

THE EFFECT OF DWARF MISTLETOE INFECTION ON GROWTH AND MORTALITY RATES OF PONDEROSA PINE GROWING IN UNEVENAGED-IRREGULAR STANDS IN COLORADO

H. M. Maffei and W. R. Jacobi

A set of equations was developed for predicting 10-year diameter growth and mortality in unevenaged-irregular stands of ponderosa pine infested by *Arceuthobium vaginatum* subsp. *cryptopodum*.

Data to develop the equations were taken from 71 temporary, fixed-area plots throughout the Colorado Front Range from Fort Collins in the north to the Pikes Peak region in the south.

Plots ranged in size from .03 to 1.35 acres. The number of live ponderosa per plot, plot site index, and plot DMR, ranged from 38 to 121, 30 to 65 feet, and 0 to 5.6, respectively.

H. M. MAFFEI and W. R. JACOBI are graduate student and associate professor, respectively, Department of Plant Pathology and Weed Science, Colorado State University.

Because of the wide variety of structural types (tree size distribution) encompassed by the irregular unevenaged ponderosa pine stands of the Front Range (Peet 1981), 2-inch diameter size classes were chosen as the modeling units in order to describe competition in stands of different structures. The diameter size classes represented 2 to 100 individual trees. Basal area of the size class and larger trees (BASL) represented competition on the size class. Sixty-seven percent of the variance in the average growth of uninfected size classes, with diameters smaller than 10 inches, was explained by BASL. There was no apparent relationship between BASL and the diameter growth of size classes of trees with diameters larger than 10 inches. The lack of relationship was probably due to the small range of BASL encompassed by these size classes since they represented the largest trees in the stand.

Growth of trees within size classes of 10 inches or less decreased in response to increasingly severe dwarf mistletoe infection in the absence of competition. As much as a 50 percent growth reduction was seen as a size class became heavily infested. When overstory trees were heavily infested, their competitive effect was apparently reduced. Thus, the same BASL associated with an uninfected overstory exerted a greater competitive effect on growth than it would given a heavily infested overstory. Potential growth of trees larger than 10 inches declined steadily, beginning at an average size class DMR of 4, in response to increasingly heavy infection.

The best predictors of the percent of trees within a diameter class dying over a 10-year period were: percent of severely infested (trees with DMRS of 5 or 6) trees in each 2-inch diameter class, average diameter of the size class and BASL. As percent of size class heavily infested increased, 10-year mortality increased exponentially. This variable alone accounted for 40 percent of the total variance. Ten-year mortality rates of heavily infested large diameter trees were less than those of small diameter trees. For a given percent of the size class heavily infested, a higher level of inter-tree competition (BASL) resulted in higher mortality rates. Fifty-five percent of the total variance for trees of all sizes was explained using the three variables.

LITERATURE CITED

Peet. 1981. "Forest Vegetation of the Colorado Front Range, Composition and Dynamics." *Vegetatio* 45, 3-75.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

DYNAMICS OF DWARF MISTLETOE INFECTED, IMMATURE WESTERN HEMLOCK STANDS

By Bart J. van der Kamp
Dept. Forest Sciences, UBC

Hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendahl) G.N. Jones) is a wide-spread parasite of coastal hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The mere presence of the pathogen however, does not always mean that significant damage has occurred.

To be damaging there must be infections and brooms in the middle and upper crown. This is often observed in old-growth stands, but is less common in immature stands; and it is immature stands that should concern us most, since these are the stands that form the managed forest, and these are the stands in which we may, by various silvicultural and other interventions, influence and control the amount of mistletoe and the damage resulting from infection.

Damaging levels of dwarf mistletoe infection in immature stands arise in two main ways:

1. From tall overhead infection sources (either residuals or stand edges) which shower mistletoe seed on the new stand.
2. From infections surviving on small trees in stands in which the rate of height growth is equal to or less than the vertical rate of spread of dwarf mistletoe. Stands on very steep slopes form a special case in which infections in the lower crown shower seed from above on down-slope trees.

B.J. van der Kamp is an associate professor of forest pathology at University of British Columbia, Vancouver, B.C.

The remainder of this discussion is restricted to those instances in which tall overhead sources of infection are absent, and the dwarf mistletoe has survived on small residuals at stand renewal. This discussion also ignores damage from bole infections. In stands where such infections are common, special treatments may be required to reduce the damage.

The vertical rate of spread of dwarf mistletoe has been estimated in a number of situations. Each of these studies however has used a (sometimes radically) different definition of the height of mistletoe in the stand. The rates of spread are therefore not directly comparable. Richardson and van der Kamp (1972) estimated the vertical rate of spread in immature coastal western hemlock in southern B.C. to be 30 to 60 cm/yr; denser stands having the lower rate.

Dick Parmeter (1978) presented some diagrams showing the various possible relationships between stand height growth and the vertical spread of mistletoe. I believe at least one amendment is justified. It arises in those cases where at some stage in stand development the upper half or so of the crown is free of infection. In dense canopied stands such as those formed by western hemlock, dwarf mistletoe infections will then produce few seeds. During such a stage of mistletoe and stand development the vertical rate of spread will decrease until the stand begins to open up or the mistletoe infection advances into the upper crown. One effect of this phenomenon is a dichotomy in mistletoe development. Either (1.) Mistletoe keeps up with the tree height growth and may even reduce height growth; increment loss ensues, (fig. 1) or (2). Mistletoe falls behind and is relegated to the lower crown where reduced seed production and increased infection mortality slows spread and intensification even more (fig. 2). Significant increment losses probably do not occur in this situation. My guesstimate of the critical point dividing these two possibilities is a site index of about 40 m (125 ft.) at one hundred years.

Rates of intensification based on number of infections per tree on young trees can be misleading. The number of infections per tree established each year may increase rapidly, but such increases are in part due to increases in target size and may be matched by increases in crown volume, so that the net drain on photosynthate as a proportion of the total may not change very much. As stands grow and the crowns close, intensification rates show a dramatic decrease. This arises because shading reduces seed production while the rapid increase in crown volume, and hence target area, slows and stops. Also, infection mortality becomes more important. Infections don't last forever. Our data (Wilford, 1981) suggest a halflife of about five years for infections on secondary and tertiary branches in the lower middle crown of dense immature stands, but longer for those on main branch axes or in the upper crown. Causes of death

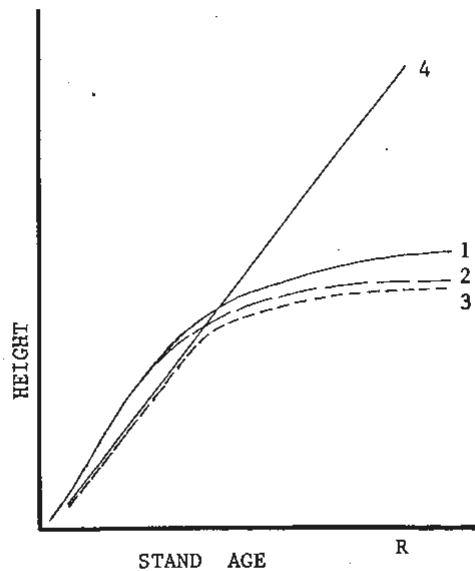


FIGURE 1. Hemlock height growth and vertical rate of spread of dwarf mistletoe on a poor site. 1 - Potential height growth; 2 - actual height growth; 3 - height of highest mistletoe infections; 4 - potential vertical rate of spread of mistletoe.

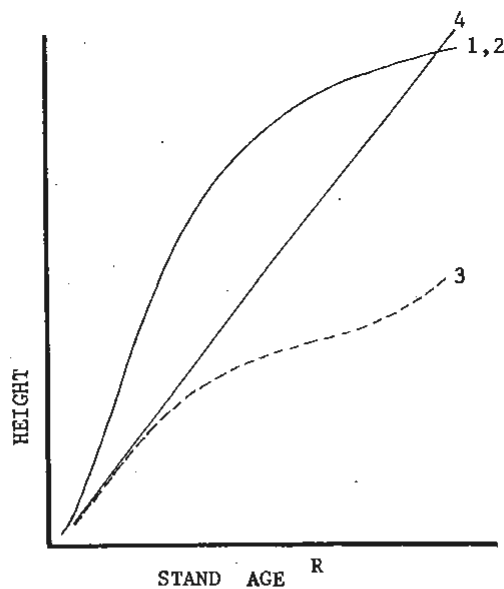


FIGURE 2. Hemlock height growth and vertical rate of spread of dwarf mistletoe on a good site. 1, 2 - host height growth: there is no reduction due to mistletoe; 3 - height of highest mistletoe infections; 4 - potential vertical rate of spread of mistletoe.

include suppression by shade, attack by secondary organisms, mechanical damage and others.

Infection rates (number of new infections per year per unit mistletoe seed source and target size) vary greatly in hemlock dwarf mistletoe. I've seen situations on southern Vancouver Island and on the Sechart Peninsula (40 miles north of Vancouver) of very high rates of infection along infected stand edges. On the other hand I've inspected 30 year old hemlock regeneration along heavily infected clearcut edges near Terrace and found hardly any infections at all. Terry Shaw has reported similar situations in Alaska. Possibly these differences are due to climate; cooler, wetter conditions being less suitable for mistletoe. Whatever the cause, it does appear that the risk of mistletoe damage may vary greatly from place to place. It may be worthwhile to try to establish a risk rating system that identifies high risk areas.

The phenomenon described above, namely that there may be a critical rate of hemlock height growth above which no serious increment loss occurs, may be helpful. The risk of loss in any area might be described as that critical rate. In low risk areas the critical site index would be low, so that most stands would escape damage. In high risk areas a significant part of the forest area might be below the critical site index. In such areas special treatment of clearcuts to remove small infected residuals might be warranted.

Intermediate cutting in infected stands is a controversial issue. On the one hand it is clear that such cutting will allow light deep into the canopy, thus reactivating older, dormant infections. The resulting increase in mistletoe seed production, as well as the reduced obstruction to seed flight, leads to higher rates of spread and intensification. On the other hand some of these immature hemlock stands will take several decades longer to reach merchantable size without an early spacing. This allows that much more time for mistletoe to build up to damaging levels. Much depends on the speed of crown closure following spacing. If crown closure occurs within a decade (i.e. all but the heaviest thinning) I believe that the advantages of thinning outweigh the disadvantages. A single treatment with ethyphion (see elsewhere in these proceedings), three to five years after thinning may prove very beneficial. Such a treatment would remove shoots and maturing seed, and effectively stop seed production during much of the critical period while the crowns are closing. It is clear to me that we need careful monitoring in several locations to decide the issue.

In summary, I've called your attention to four items. First, in dense canopied forests such as those formed by western hemlock there is a dichotomy in mistletoe development: on good sites mistletoe is relegated to the lower crown and relatively insignificant; on poor sites mistletoe keeps up with tree height growth and serious increment losses may ensue.

Second, the rapid rate of intensification often observed in very young stands declines markedly after crown closure. Third, the rate of infection appears to vary greatly over the geographic range of the parasite. An estimate of the critical site index above which serious damage will not develop (except if tall overhead infection sources are present), may be a useful way to express the risk of damage. Finally the long term effect of juvenile spacing on dwarf mistletoe damage needs to be examined and monitored.

REFERENCES

- Parameter, J.R. Jr. 1978. Forest Stand Dynamics and Ecological Factors in Relation to Dwarf Mistletoe Spread, Impact, and Control in Symposium on Dwarf Mistletoe Control through Forest Management USDA Gen. Tech. Rep. PSW-31 pp. 16-30.
- Richardson, K.S. and B.J. van der Kamp. 1972. The Rate of Upward Advance and Intensification of Dwarf Mistletoe on Immature Western Hemlock. Can. J. For. Res. 2,(3), pp. 313-316.
- Wilford, E.H. 1981. Intensification and Infection mortality of dwarf mistletoe in two stands of western hemlock. M.Sc. thesis, University of British Columbia.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

OPPORTUNITIES TO EVALUATE ROOT DISEASE INCIDENCE AND DAMAGE USING FOREST INVENTORY AND PERMANENT GROWTH PLOTS

James W. Byler, Michael A. Marsden, and
Susan K. Hagle

ABSTRACT: Experiences with the use of compartment exam and permanent growth plot data to assess incidence and damage from root diseases are discussed. Results from a Northern Region compartment exam are presented. Inventory data offers the potential to learn much about root disease damage at a reasonable cost if inventory crews are properly trained and supervised.

INTRODUCTION

We would like to discuss a successful example of the use of compartment exam data to assess root disease incidence and damage. The use of inventory plot data for disease impact evaluation has been discussed many times, but we are aware of relatively few examples of success. Problems with sampling design and the quality of the disease data collected by inadequately trained crews are common.

James Byler and Susan Hagle are plant pathologists in the Cooperative Forestry and Pest Management Staff, USDA Forest Service, Northern Region, Missoula, Mont. Michael Marsden is biometrician with the Forest Pest Management Methods Application Group, USDA Forest Service, Fort Collins, Colo.

Several forest inventory and exam plot types are established by the National Forests. Some types are:

- A. Forest Inventory
 - 1. Stand exam
 - 2. Compartment exam
 - 3. Timber inventory
- B. Permanent (remeasurement) Plots
 - 1. Monitoring (required by Forest plans)
 - 2. Growth and yield

In Region 1, forest inventory examinations are made at the stand and compartment level of sampling. The primary use of stand exams is to provide information for stand prescription writing. Compartments, usually major drainages comprising 2,000-8,000 acres, are sampled to provide information for timber sale planning. When compartment exams are completed on a substantial portion of a National Forest, they can be used at the Forest planning level. Permanent growth and yield plots are now being established throughout the Region. They are put mainly in managed young-growth stands. Most are in plantations and second-growth stands immediately following precommercial thinning.

Stand exam and permanent plot field instructions provide for the collection of disease and insect data, including root disease data (table 1). In some situations the insect and disease data is optional and left to the discretion of the Ranger Districts. The quality of the data is quite variable depending on the level of interest, training, and experience of the field crews. The goal is to collect data that is required to meet the immediate objectives; i.e., stand prescription writing and/or timber sale planning.

Our objective is to discuss some approaches we are using to evaluate root disease incidence and damage using compartment exam and permanent growth plot data. We will present results from the Crow Creek compartment that is on the Thompson Falls Ranger District, Lolo National Forest.

CROW CREEK COMPARTMENT EXAM

The compartment exam was an operational exam made by a private contractor and administered by the Forest. The purpose was to collect information to be used in timber sale planning and stand prescription writing. The exam was the first in the Northern Region to supplement stand exam data with more detailed root disease data. Supplemental funding was provided by Forest Pest Management for this purpose.

¹Field Instructions for Stand Examination. Region 1, Timber Management Data Handbook. FSH 2409.21h chapter 400.

Table 1--Northern Region stand exam root disease codes for rating individual trees.

Cause of damage/death	Severity
60 - Root disease - general	1. No symptoms, tree within 30' of root disease
61 - <i>Armillaria</i> sp.	2. Root collar signs or symptoms.
62 - <i>Phellinus weirii</i>	3. Root disease crown symptoms
63 - <i>Phaeolus schweinitzii</i>	
64 - <i>Fomes annosus</i>	
65 - <i>Verticicladiella</i> sp.	

Methods.--Seven hundred twenty-eight variable plots were established in the compartment of about 6,000 acres. Most stands were of mixed species composition, 50-100 years of age. Root disease damage was considered moderate in the compartment as a whole, but some stands were severely affected. All plot trees were coded as having root disease if symptoms or signs of root disease damage were present. Quality root disease data were obtained by writing firm requirements into the contract, providing detailed instructions to the contractor, instructing crews in root disease diagnosis in the field, and inspecting for accuracy. Cathy Stewart, on the pathology staff at the time, was a contract inspector.

All stands in the compartment were sampled. Data summary and analysis were by plot, rather than stands, so a direct calculation of area affected is not possible without taking into account stand area.

Plots were classified as diseased or nondiseased, depending on whether any plot trees were coded as diseased (severity 1, 2, or 3). The most prevalent and damaging root pathogens present in the compartment appeared to be *Armillaria ostoyae* and *Phellinus weirii*. They commonly infested the same stands and sometimes the same tree. No attempt was made in this analysis to separate effects of the two.

Habitat type.--Figure 1 relates root disease incidence to habitat type. Habitat type is a land classification system based upon potential climax vegetation (Pfister et al. 1977). We grouped habitat types by climax tree species referred to as habitat type series. Twenty-three percent of 727 plots (one was unstocked) were classified as diseased (fig. 1). Of these, 483 were in the most productive habitat type series--Douglas-fir, grand fir, and a combined cedar and hemlock series. These series had high incidence of root disease.

Cutting history.--Some stands within the compartment had been cutover in the past. The cuts were partial cuts, some made more than 20 years ago. The cutover plots had twice the incidence of root disease of uncut stands (fig. 2), a trend that held for each habitat type series. These results may suggest that the partial cutting increased root disease.

Observations to this effect have been made in a number of root-diseased stands in the past.

Figure 1.--Root Disease Incidence by Habitat Type Series

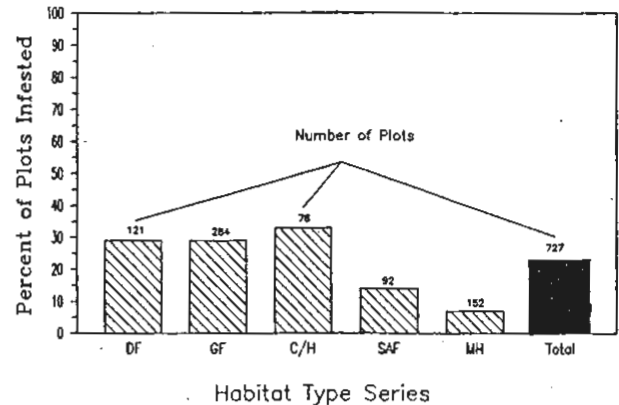
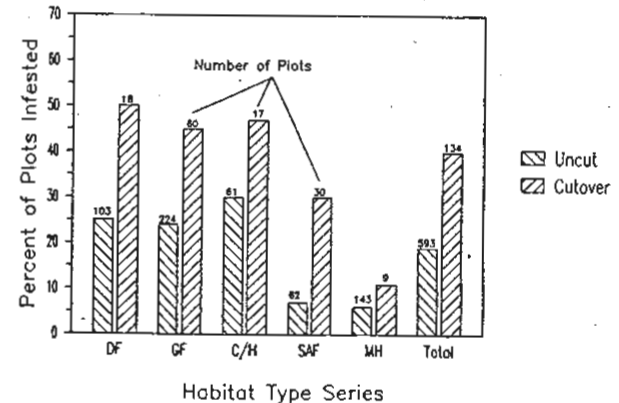


Figure 2.--Root Disease Incidence by Habitat Type Series and Cutting History



Species composition.--Root disease incidence was greatest in plots with the highest basal area of Douglas-fir, grand fir, and subalpine fir--the most affected species. It should be noted that habitat type and species composition are not independent of each other. The incidence of root disease was examined within each habitat type series.

The relationship of disease and percent host held for each habitat type series. Figure 3 shows the relationship for all habitat types combined. We interpret this to mean we can influence root disease incidence and damage by keeping the major host basal area below 40 percent of the stand total.

Volume loss.--We compared differences in volumes for diseased versus nondiseased plots. Preliminary runs indicated that volumes varied considerably by habitat type within a series and by cutting history. We stratified out this variation by summarizing volumes for uncut stands by habitat type for those types with 10 or more plots (fig. 4). Stand age and initial stocking density were not accounted for in this analysis although they also related to volume.

Figure 3.--Root Disease Incidence by Percent Host Basal Area

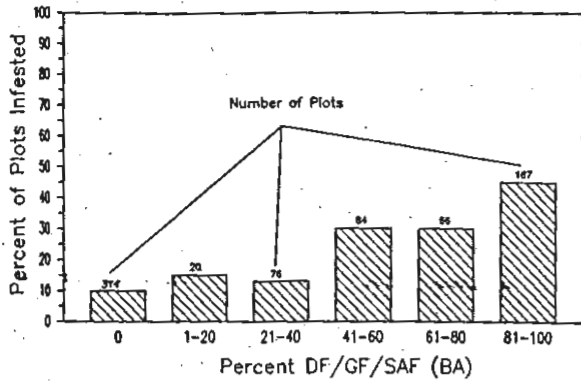
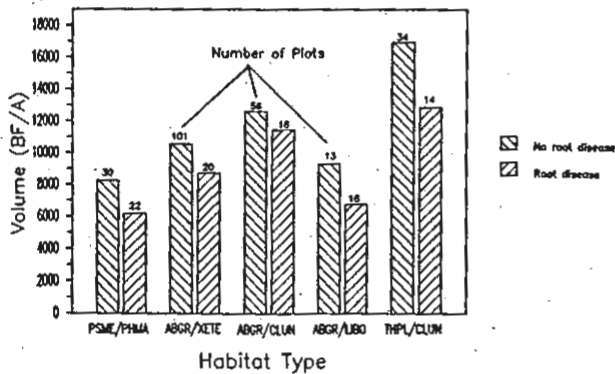


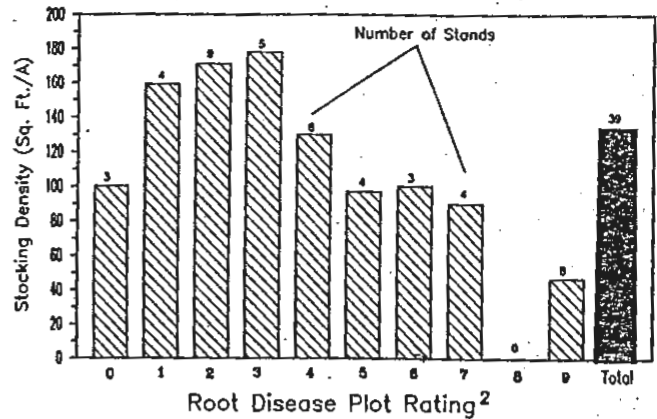
Figure 4.--Volumes for Root Diseased and Nondiseased Plots by Habitat Type (Uncult Plots in Commercial Types Only)



The diseased plots have 9-27 percent less volume than nondiseased plots. These volume differences don't appear particularly large. But keep in mind that the diseased class contains plots that have yet had little root disease damage as well as plots in which all of the major host species have been killed. We believe a more precise estimate of disease effects could be obtained by using a root disease plot rating rather than recording only disease presence or absence. Hagle (1985) used such a system and found it was correlated with stand density, even though she had relatively few plots per class and was not able to stratify by habitat type or site (fig. 5).

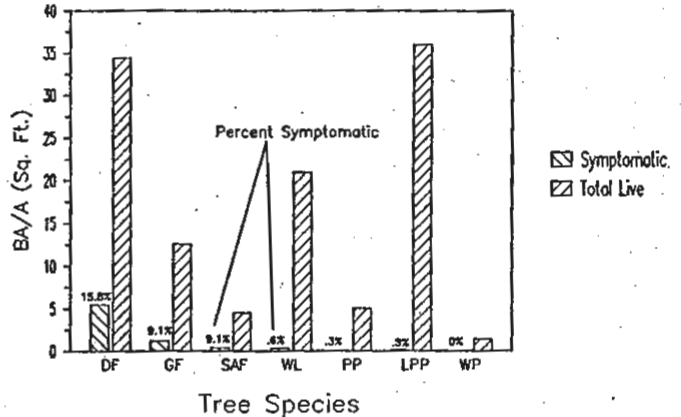
Species susceptibility.--In order to rank species susceptibility to root disease, we plotted the percentage of basal area of each species that exhibited symptoms of disease (fig. 6). Larger trees will be weighted more heavily than smaller ones when basal area is used, so absolute values given may not be correct. But rankings by species are probably correct. The disease classes include trees that had crown symptoms and/or root collar symptoms or signs (severity codes 2 and 3). As expected, more Douglas-fir, grand fir, and subalpine fir exhibited symptoms than other species.

Figure 5.--Stocking Densities in Marie Creek Compartment (Fernan RD) by Root Disease Plot Rating¹



¹0 = No root disease; 9 = Plot a disease center; no DF/GF/SAF living on plot

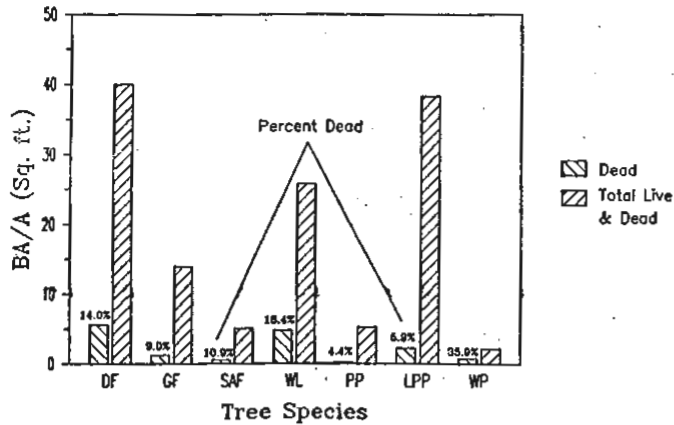
Figure 6.--Total and Symptomatic Basal Area per Acre by Tree Species



We also looked at the percent of the basal area killed by all agents (fig. 7). The proportion of dead Douglas-fir and true fir is similar to the proportion of trees exhibiting symptoms. We believe that nearly all of this mortality was due to root disease. White pine blister rust was the presumed killer of most of the western white pine. The surprise here was the high proportion of western larch that is dead. We aren't sure why, but suspect it is related to competition and dwarf mistletoe infection.

Habitat type.--When we looked at root disease by specific habitat type within the series (table 2), we found increased variation (fig. 8). The highest incidence of root disease, over 60 percent, was in the ABGR/LIBO type. Incidence was below 15 percent for several other types. GERAL McDonald (personal communication) has found variation in Armillaria incidence and associated mortality by habitat type. Root disease incidence and damage by habitat type needs further investigation.

Figure 7.--Total and Dead¹
Basal Area/Acre by Tree Species



¹Includes all causes of death

Figure 8.--Disease Incidence by Habitat Type

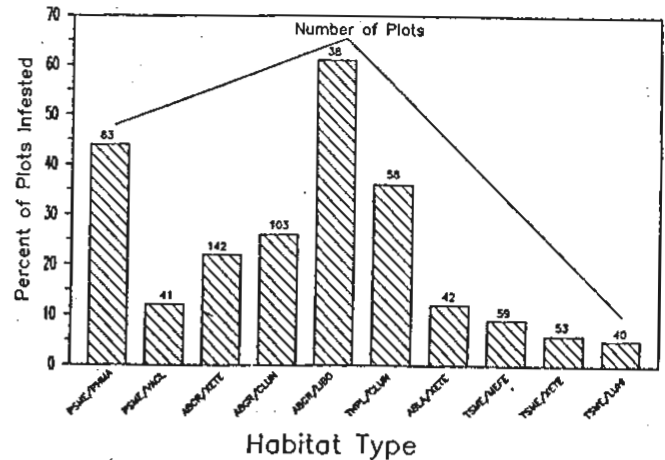


Table 2--A definition of habitat types represented by 30 or more plots in the Crow Creek compartment exam.

Series	Habitat type
Douglas-fir	PSME/PHMA = Douglas-fir/ninebark
Douglas-fir	PSME/VAGL = Douglas-fir/blue huckleberry
Grand fir	ABGR/XETE = Grand fir/beargrass
Grand fir	ABGR/CLUN = grand fir/queencup beadlilly
Grand fir	ABGR/LIBO = Grand fir/twin flower
Cedar/Hemlock	THPL/CLUN = Western redcedar/queencup headlilly
Subalpine fir	ABLA/XETE = Subalpine fir/beargrass
Mountain hemlock	TSME/MEFE = Mountain hemlock/menziesia
Mountain hemlock	TSME/XETE = Mountain hemlock/beargrass
Mountain hemlock	TSMA/LUHI = Mountain hemlock/smooth woodrush

PERMANENT GROWTH AND YIELD PLOTS

We want to briefly discuss these plots because they present an opportunity to learn much about the effects of root diseases in managed stands, rather than the unmanaged stands we are now harvesting. Plots are established in selected stands around the Region (and in other Regions) to monitor growth and yield and to obtain quantitative estimates of response to management measures such as spacing control, thinning, and fertilization. In the Northern Region, plots are established by Forest and District crews primarily in precommercially thinned stands. Three 3-plot clusters are randomly placed in a thinned portion of the stand. One cluster is placed in an unthinned portion. The one-twentieth-acre plots are scheduled for remeasurement at 5-year intervals.

Our approach has been to revisit as many of the plots as possible and examine both plots and plot trees for root disease. First priority has been given to revisiting precommercial stands that have a Douglas-fir or grand fir component in portions of the Region known to have root disease problems (northern Idaho and western Montana). If we get good baseline data on root disease, we can use Forest and District remeasurement data to calculate mortality rates on diseased and nondiseased plots. We have established supplemental plots in diseased stands to evaluate root disease (Byler et al. 1985).

We'll get our first 2- to 3-year mortality rate estimates this winter from re-exams we've just completed this summer.

DISCUSSION

Survey data has limitations. Sampling design is sometimes not appropriate to answer some questions we would like to ask. But we believe that much can be learned about root disease incidence and effects from survey data from extensive areas. Such information can be used to supplement and extend the results from relatively small-scale research experiments. Survey data from a sample of subcompartments around the Region could be available at a relatively low cost.

Permanent growth plots offer an even greater opportunity to learn about the effects of root disease in managed stands, information that will allow us to refine recommendations about planting, species composition, and precommercial thinning in managed stands of the future. They should also provide data for validating/calibrating the newly developed root disease models.

Quality inventory and permanent plot data cannot be obtained without effort. Considerable training, inspection, and coordination is required at the Regional, Forest, and District levels. But the time invested is far less than doing the survey work ourselves, a luxury we can less and less afford. And we still badly need estimates of disease impact to better focus research and action programs.

ACKNOWLEDGEMENTS

The authors wish to recognize the contributions of Cathy Stewart, Al Christopherson, and Cliff McLuskie of the Lolo National Forest, and Bob Eder of the Forest Pest Management staff in the Regional Office.

LITERATURE CITED

Byler, J. W., C. A. Stewart, and L. D. Hall. 1985. Establishment report: Permanent plots to evaluate the effects of *Armillaria* root disease in precommercially thinned stands. USDA Forest Service, Northern Region. Rept. 85-21. 12 p.

Hagle, S. K. 1985. Monitoring root disease mortality: establishment report. USDA Forest Service, Northern Region. Rept. 85-27. 13 p.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service. F.T.R. Rept. INT-34. 174 p.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

ROOT DISEASES AND RELATED PROBLEMS

Panel Moderator: Gregory M. Filip

ROOT PATHOGEN IMPACT - HOW DO WE MEASURE IT?

Greg Filip, Al Kanaskie, and Phil Hamm

I would like to begin this panel with a look at root pathogen impact and how to measure it. It is a subject that I have stumbled over for several years while I was with Forest Pest Management, and I am sure many of you have faced the same problem. It is certainly important to the forest land manager concerned with timber production. Reviewing WIFDWC proceedings for the past ten years, I found none that tackled the subject directly. At the 1979 meeting in Salem, estimates of infection vs decay were discussed in two conflicting papers during a panel entitled "Influence of diseases on the management of western hemlock." In 1980 at Pingree Park a paper was presented about the measuring of growth loss induced by *Phellinus weirii*. In 1981 at Vernon, one panel was devoted to the economics of forest root disease surveys. In that panel, a paper was presented about estimation and prediction of losses caused by *P. weirii*. To my knowledge and apart from individual reports about losses expressed as percentage of area infected/affected or wood volume loss, the subject of root pathogen impact has not been

GREG FILIP is a research plant pathologist at the Pacific Northwest Research Station, USDA Forest Service, La Grande, Oregon. AL KANASKIE is a plant pathologist at the Oregon State Forestry Department, Salem, Oregon. PHIL HAMM is a plant pathologist at Oregon State University, Corvallis, Oregon.

thoroughly explored. I believe that this is an excellent topic to begin our panel discussion.

I hope to wet your appetites by means of three short "presentations" concerning the concepts of 1) infection vs decay, 2) basal area killed vs basal area left, and 3) growth loss per tree vs growth loss per stand.

In our first presentation, Joe the land manager has just received a report hot off the press from his favorite pathologist. They seem to have a problem concerning infection vs decay in their hemlock stand.

Patho: Hi Joe, how's it going?

Joe: Pretty good, how about yourself?

Patho: What ya think about the report I sent?

Joe: Oh, you mean the one that said that my hemlock stand had 35% of the trees infected with *Fomes annosus*?

Patho: Ya.

Joe: What does it mean?

Patho: Bad news, Joe, bad news. I'd cut now before it's too late.

Joe: I don't know, my boss says we can't get anything for it now. The diameter is not there. What about decay? Do you think we have any decay?

Patho: They're probably all decayed. Cut now and start over.

Joe: But the stand is only 40 years old! We can harvest it in 10 years.

Patho: Cut it now, Joe. Bye.

In the second presentation, Joe has received another report from his pathologist. His pine stand has *Armillaria*, but the question of loss is still a question.

Patho: Hi Joe. Did you cut that hemlock stand?

Joe: Ya, I felt real bad about it.

Patho: Don't worry, pay's the same. What's up?

Joe: Well, I've been reading this other report you sent, you know the one about the *Armillaria* in my pine stand.

Patho: Right on.

Joe: Well, you say that 20% of the basal area has been killed over the past 20 years.

Patho: Right on, again.

Joe: I still have a lot of good volume. My volume table says that the stand is nearly fully stocked. Do you really think I should clearcut and start over?

Patho: By all means. That infection is just going to spread.

Joe: But I've looked at the difference in basal areas between my healthy plots and diseased plots and it's only a 5% difference.

Patho: 5% today, 10% tomorrow. Cut now!

In our last presentation, Joe has a new report concerning growth loss in his Douglas-fir stand. There seems to be a problem differentiating between growth loss per tree and growth loss per stand.

Patho: Hey Joe, how's it go.

Joe: Good.

Patho: Cut that pine stand yet?

Joe: Sure did. We didn't get much for it. Mostly firewood.

Patho: Well, you know what they say, pay me now or pay me later. What's happening?

Joe: I read your new report. You know, the one about Phellinus weirii. You said to clearcut again, but that only 3% of the trees were killed.

Patho: Ya, but another 10% are probably infected and losing about 13% of their volume growth per year.

Joe: Well, what about the pine and larch in the stand? They seem to be doing well. I looked at some increment cores the other day, and the trees next to the Phellinus centers seem to be growing faster now than 10 years ago? Even some of the firs are growing faster.

Patho: It won't last for long. Cut the stand now while most of the trees are still alive. See you later.

The End



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

EFFECTS OF MANAGEMENT ACTIVITIES AND DOMINANT
SPECIES TYPE ON ROOT DISEASE-CAUSED MORTALITY IN
TWO OREGON FORESTS

Don Goheen, Craig Schmitt, Ellen Michaels
Goheen, and Susan Frankel

Two species of true fir are very important components of East Side stands in the Pacific Northwest--White fir (*Abies concolor*) and grand fir (*Abies grandis*). These species have very similar characteristics and indeed commonly hybridize in central Oregon where their ranges overlap. White and grand fir are fast growers, release well, and are prolific seeders that establish themselves naturally on all but the driest and coldest sites. They are shade-tolerant, fire-intolerant species that have increased greatly at the expense of other trees in the last 80 years, due to fire exclusion and widespread selective harvest of more valuable ponderosa pine, western larch, and Douglas-fir. Unfortunately, white and grand fir are quite prone to damage by forest pests. Insects such as Douglas-fir tussock moth and western spruce budworm cause periodic spectacular defoliation that results in growth loss, top-kill, and some mortality. Decay fungi (especially Indian paint fungus) cause substantial losses, particularly if many trees are injured in a stand. Also, the firs are susceptible to several root diseases and associated fir engraver beetles.

DONALD J. GOHEEN AND CRAIG L. SCHMITT are plant pathologists with Forest Pest Management, USDA Forest Service, Pacific Northwest Region, Portland, Oregon. ELLEN MICHAELS GOHEEN is a Forest Technician with Forest Pest Management, USDA Forest Service, Pacific Northwest Region, Portland, Oregon. SUSAN FRANKEL is a plant pathologist at Penisulab, Kingston, WA

There has been a strong impetus to manage true firs in the Pacific Northwest. Some forest managers are reluctant to incur the costs associated with regeneration harvests and reestablishment of shade-intolerant tree species when naturally established white and grand fir understories already exist. They frequently advocate uneven-aged management schemes involving continued selective removal of overstory trees and release of white and grand fir understories.

Other managers are unhappy with this approach. They feel that a policy of favoring true firs may be very risky. They are especially concerned about pest problems in true fir stands, particularly those that are frequently entered.

Forest Pest Management, Pacific Northwest Region, is evaluating magnitude of true fir mortality and the relationship between amount of mortality and dominant species type and past management regimes in several East Side National Forests. Investigations have been completed on the Ochoco and Fremont National Forests in eastern Oregon. One hundred and ninety-eight stands were selected and surveyed in six stand composition/past management strata on these Forests. Results of the surveys showed that:

1. White and grand firs suffer considerably more mortality than do other tree species in all types of stands.

2. White and grand fir mortality is much more significant in stands that have major components (10 percent or more) of true fir in the overstory than in stands with predominantly pine overstories.

3. Magnitude of white and grand fir mortality in stands with true fir in the overstory is great indeed (averaging 13 percent of the fir in all such stands surveyed and ranging as high as 23 percent).

4. Most mortality is associated with infection by three root pathogens--*Armillaria obscura*, *Phellinus weirii*, or *Fomes annosus*--and associated infestation by fir engraver beetles. The most commonly encountered pathogen is *F. annosus*.

5. There is no evidence on the two Forests surveyed that mortality due to *P. weirii* or *A. obscura* has been increased or decreased by past harvest activities. However, *F. annosus* is significantly more damaging in entered than unentered stands and causes the most mortality in stands that have experienced multiple harvest entries.

6. In addition to currently observable mortality, overall true fir basal area (live and dead) is 40 to 50 percent less in variable radius plots that contain trees infected by *P. weirii* or *F. annosus* than in plots without infected trees (suggesting that tree killing has gone on for some time in areas affected by these root pathogens).

7. Infection and predicted volume loss due to heartwood decay fungi is great in most stands with true fir in the overstories, and decay fungi contribute to some mortality by predisposing trees to breakage.

We believe that results of our surveys suggest that decisions to manage true fir on the Forests evaluated should not be made hastily.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

RESISTANCE TO LAMINATED ROOT ROT BY WESTERN
CONIFERS OUTPLANTED ON INFESTED SITES

Earl E. Nelson

ABSTRACT: Eleven species of conifers were outplanted 3 meters from *Phellinus weirii*-infested stumps on four sites in the Siuslaw National Forest. Ten years later, patterns of host resistance, based on mortality records, are beginning to emerge. *Abies grandis* and *Pseudotsuga menziesii* appear to be the least resistant species tested. *Sequoiadendron giganteum* is reported as a new host.

INTRODUCTION

Until 1929, when *Phellinus weirii* was found causing a root disease of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) on Vancouver Island, British Columbia, western redcedar (*Thuja plicata* Donn ex D. Don) was the only known host species. Since then, this destructive root pathogen has been reported on most coniferous species within its geographic range. Only hardwood species appear immune. Some coniferous species are clearly more resistant than others to infection by *P. weirii*, some are tolerant of infection (i.e., become infected but are not often killed), and some

Earl E. Nelson is a plant pathologist at the USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, Corvallis, OR 97331.

seem nearly immune--at least to the coastal form of the fungus.^{1/}

A hierarchy of species resistance has been proposed (Hadfield 1985) based on 50 years of observations and some attempts at objective comparisons. Some additional information on species resistance has come from experimentation. Wallis and Reynolds (1965) found no difference between Douglas-fir and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), but found western redcedar is considerably more resistant when roots are inoculated and growth of ectotrophic mycelium is measured. Other attempts at inoculating roots have met with little success, and artificial methods of inoculation to determine natural resistance are open to question.

The objective of my study was to determine relative resistance of selected conifers to *P. weirii*, when planted equidistantly from identified sources of infection (infested stumps). Inoculum potential was assumed to be uniform in all directions around the stump, and differences in growth rates among species would need to be considered in data analysis (i.e., some species would likely encounter inoculum sooner than others).

METHODS AND MATERIALS

Four recently harvested sites in the Siuslaw National Forest in western Oregon (lat. 44° N., long. 124° W., elev. 200-400 m) were selected. Up to 50 stumps were chosen in each of the four areas. Area I (32 stumps) was planted in January 1972, area II (50 stumps) in December 1972, and areas III (28 stumps) and IV (31 stumps) in January 1975. Eight coniferous species were planted on each site around each stump, but species varied somewhat among sites. Species used were grand fir, *Abies grandis* (Dougl. ex D. Don) Lindl.; noble fir, *Abies procera* Rehd.; lodgepole pine, *Pinus contorta* Dougl. ex Loud.; western white pine, *Pinus monticola* Dougl. ex D. Don; ponderosa pine, *Pinus ponderosa* Dougl. ex Laws.; Sitka spruce, *Picea sitchensis* (Bong.) Carr.; Douglas-fir; redwood, *Sequoia sempervirens* (D. Don) Endl.; giant sequoia, *Sequoiadendron giganteum* (Lindl.) Buchholz; western redcedar; and western hemlock. Species were planted in random order, 3 meters from the stump center at 45° intervals around the stump, beginning at a point due north. Seedlings not surviving the first

^{1/}*Phellinus weirii* is described as *Poria weirii* by Murrill (1914) based on a 1912 collection made by Weir in Idaho from western redcedar. The collections from Douglas-fir on Vancouver Island in 1929 seemed to be *Poria weirii*, but sporophores were annual rather than perennial. After comparing western redcedar and Douglas-fir isolates, Mounce et al. (1940) decided the pathogen of Douglas-fir is the same species as described by Murrill. Literature of the era refers to coastal isolates as "annual" and inland isolates as "perennial" *Poria weirii*.

Species	Mortality by site				
	I	II	III	IV	total
<i>Abies grandis</i>		38 (8)	25 (12)	15 (13)	24 (33)
<i>Pseudotsuga menziesii</i>	6 (31)	3 (34)	23 (26)	10 (30)	10 (121)
<i>Sequoiadendron giganteum</i>	0 (9)	17 (12)			10 (21)
<i>Pinus ponderosa</i>		3 (37)	5 (19)	6 (36)	4 (92)
<i>Abies procera</i>	0 (26)	0 (5)	0 (18)	11 (27)	4 (76)
<i>Picea sitchensis</i>	0 (26)		4 (23)	0 (17)	2 (66)
<i>Tsuga heterophylla</i>	3 (31)	0 (19)	0 (10)	0 (14)	1 (74)
<i>Sequoia sempervirens</i>	0 (23)				0 (23)
<i>Thuja plicata</i>	0 (23)	0 (6)	0 (9)	0 (3)	0 (41)
<i>Pinus monticola</i>	0 (30)	0 (18)			0 (48)
<i>Pinus contorta</i>			0 (26)	0 (25)	0 (51)

1/ Mortality percentages are based on numbers of trees (given in parentheses) reaching or, for those trees killed by *P. weirii* before age 10, projected to reach an actual height of 1.3 meters in 10 years.

growing season were replanted. Each site was visited annually to trim back competing brush, measure seedling height, and observe mortality. Cause of death was recorded as *P. weirii* or other based on presence or absence of mycelia with typical setal hyphae,

RESULTS

Mortality data were summarized for each site. Only those seedlings reaching a height of 1.3 meters at 10 years or those killed by *P. weirii* previously but otherwise projected to reach 1.3 meters at age 10 were used as a base for determining the percentage of trees, by species, killed by *P. weirii*. Statistical analysis was limited to chi-square tests of grand fir vs. Douglas-fir vs. ponderosa pine on sites II, III, and IV combined (grand fir was not planted on site I). Mortality recorded for other species was zero, erratic, or the species occurred on too few plots in common with other species to be compared.

Based on mortality rates to date, grand fir seemed the most susceptible of all species tested (table 1). Nearly 25 percent of 33 grand fir were killed. Other species were less affected: Douglas-fir and giant sequoia, 10 percent; ponderosa pine and noble fir, 4 percent; Sitka spruce, 2 percent, and western hemlock 1 percent. No western redcedar, western white pine, lodgepole pine, or redwood have been killed by *P. weirii*. Chi-square analysis showed significant differences ($P=0.05$) in resistance among the three species tested: ponderosa pine appeared the most resistant, Douglas-fir intermediate, and grand fir the least resistant.

DISCUSSION

After 10 years, conifer mortality caused by *P. weirii* has only begun to point to a hierarchy

of resistance among 11 western tree species tested. This preliminary ranking of species generally fits accepted categories of resistance as established by Hadfield (1985). Three of the four species tested that experienced no mortality in this test (western redcedar, western white pine, and lodgepole pine) are considered among the most resistant species (Hadfield 1985). The fourth, redwood, is not normally considered within the geographic range of *P. weirii*. Western hemlock, Sitka spruce, and noble fir, judged as intermediate in resistance from these preliminary results, are also considered intermediate by Hadfield (1985). Giant sequoia does not occur naturally within the geographic range of *P. weirii*, but has been planted extensively as an ornamental and, to some extent, as a forest tree. These results indicate for the first time that this species is susceptible.

For this study, I assumed all species had an equal chance of contacting inoculum when initially planted. Rates of growth among species and rooting habits differ, so that in time some species might have a better chance than others to encounter inoculum. Thus, slowly growing trees might appear more resistant simply because so few encounter inoculum in their first decade of growth. Faster growing trees (especially Douglas-fir in this study) might appear more susceptible because they are more likely to encounter inoculum in the first 10 years. This possibility was considered, and the slowest growing trees were not included in these data; however, a large difference still exists in average tree size by species, and this factor deserves further consideration. A further complicating, and perhaps compensating, factor related to size and growth differences is that faster growth rates may moderate effects of symptoms even though the faster growing species are more likely to encounter inoculum.

Resistance to *P. weirii* in this study was based only on mortality data. I did not consider the possibility that some species might be readily infected but capable of tolerating that infection for many years. Trees in those species, when older, may develop root and butt rot that will weaken the tree structurally and lead to windfall but will do little harm physiologically. Lodgepole pine and western larch (*Larix occidentalis* Nutt.) (larch was not included in the study) are commonly found in this condition (Filip and Schmitt 1979); Douglas-fir, grand fir, Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) (the last two not included in the study) were much more likely to be killed.

LITERATURE CITED

- Hadfield, J. S. 1985. Laminated root rot: a guide to reducing and preventing losses in Oregon and Washington forests. USDA For. Serv., Pac. Northwest Region, For. Pest Management.
- Filip, G. M., and C. L. Schmitt. 1979. Susceptibility of native conifers to laminated root rot east of the Cascade Range in eastern Oregon and Washington. For. Sci. 25:261-265.
- Mounce, I., J. E. Bier, and M. K. Nobles. 1940. A root rot of Douglas-fir caused by *Poria weirii*. Can. J. Res. (C) 18:522-533.
- Murrill, W. A. 1914. An enemy of the western red cedar. Mycologia 6:93-94.
- Wallis, G. W., and G. Reynolds. 1965. The initiation and spread of *Poria weirii* root rot of Douglas-fir. Can J. Bot. 43:1-9.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

CONTROLLING LAMINATED ROOT ROT WITH FUMIGATION

Walter G. Thies and Earl E. Nelson

ABSTRACT: The application of fumigants to *Phellinus weirii*-infested Douglas-fir stumps will eliminate the pathogen from the stumps and most roots. Elimination of inoculum occurs directly from effects of the toxic fumigant and perhaps indirectly from effects of the fumigant on interactions of antagonistic microflora with the pathogen. Techniques are being developed that use low dosage fumigation and inoculation with fungal antagonists, specifically species of *Trichoderma*, to reduce *P. weirii* inoculum on infested sites. Current research is reviewed, and prospects for operational use are discussed.

INTRODUCTION

Phellinus weirii (Murr.) Gilb., cause of laminated root rot, infects nearly all commercially important conifer species in the northwestern United States and southwestern Canada. When diseased trees die, the fungus may remain viable in infested butts and large roots for as long as 50 years (Hansen 1979) and in relatively small diameter roots for at least 8 years (Wallis and Reynolds 1965, Thies and Hansen 1985). Infection in a young stand occurs when roots of developing trees contact residual inoculum from a preceding stand (Wallis and Reynolds 1965). Distribution and impact of the disease and options for its control have been

WALTER G. THIES and EARL E. NELSON are plant pathologists at the USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, Corvallis, OR 97331.

discussed previously (Nelson et al. 1981, Thies 1984, Hadfield 1985). Attempts at control have focused on changing species composition or reducing inoculum before a susceptible stand is regenerated.

Fumigation is one means of reducing inoculum of some root rotting fungi. *Armillaria mellea* (Vahl ex Fr.) Quel inoculum is destroyed by chloropicrin ^{1/} (Godfrey 1936), carbon disulfide (Bliss 1951), and methyl bromide (Rackham et al. 1968) when applied to soil containing infested root wood. Similarly, *Fomes annosus* (Fr.) Cke. is eradicated from roots and stumps of pines by methyl bromide or Vapam (Houston and Eno 1969).

Fumigants may be applied directly to infested wood. Fungi in the interior of Douglas-fir transmission poles are controlled by the direct injection of chloropicrin, Vapam, methyl bromide, Vorlex, or allyl alcohol (Cooper 1973, Graham 1975, Graham and Corden 1980). Direct application of methyl bromide, carbon disulfide, Vorlex, chloropicrin, or Vapam to infested stumps eliminates *A. mellea* (Filip and Roth 1977). A more complete literature review is presented by Filip (1976).

FUMIGATION TO CONTROL LAMINATED ROOT ROT

Successful fumigation of *P. weirii*-infested wood was first reported in 1975 by George Harvey. ^{2/} He found that carbon disulfide, chloropicrin, methyl bromide, Vapam, and Vorlex were all effective in eliminating *P. weirii* from 5-cm cubes of infested Douglas-fir stump wood placed in soil in plastic containers, but carbon disulfide was less effective than the others. In 1978, allyl alcohol, chloropicrin, Vapam and Vorlex were applied to stumps infested with *P. weirii*. One year later, the fungus had been eliminated from the stumps and most roots (Thies and Nelson 1982). A second study tested application techniques and dosages. The dose applied to each stump was based on estimated stump and root biomass (Thies and Nelson 1986). Either chloropicrin or Vorlex reduced the volume of roots supporting vigorous *P. weirii* to about 7% of the prefumigation volume. Neither sealing

^{1/} This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the U.S. Department of Agriculture, nor does it imply registration under The Federal Insecticide, Fungicide, and Rodenticide Act as amended. Also, mention of a commercial or proprietary product does not constitute recommendation or endorsement by the U.S. Department of Agriculture.

^{2/} Harvey, George M.: A laboratory screening test of soil fumigants for the control of *Phellinus* (*Poria*) *weirii*. Office report dated December 10, 1975, on file at the Pacific Northwest Research Station, Forestry Sciences Laboratory, Corvallis, Oregon.

stump tops with asphalt nor applying fumigant at dosages higher than the lowest dosage tested (3.3 ml/kg of biomass) resulted in lower volumes of residual inoculum.

INDIRECT EFFECTS OF FUMIGATION

Elimination of the pathogen may occur directly from toxic effects of the fumigant and indirectly through the effects of fumigants on interactions between the pathogen and other microflora, particularly *Trichoderma* spp. Naturally occurring associations of *Trichoderma* spp. with other wood-inhabiting fungi, including tree root pathogens, are not uncommon and have been summarized by Cook and Baker (1983). But in the presence of a fumigant, these associations may become more detrimental to the pathogen. Bliss (1951) has shown that if *A. mellea*-infested roots are subjected to a sublethal concentration of carbon disulfide and left in unsterilized soil, *Trichoderma* spp. replaced the pathogen. Replacement can be stimulated by many physical or chemical agents resulting in what has been termed a "stressing effect" (Munnecke et al. 1981). Filip (1976) reported an increase in *Trichoderma* spp. and a concurrent reduction in *A. mellea* in fumigated pine stumps. The increased occurrence of *Trichoderma* spp. in roots of fumigated Douglas-fir stumps was noted during the evaluation of several fumigants for the control of laminated root rot (Thies and Nelson 1982).

Our observations lead us to believe that the effect of sublethal concentrations of fumigants on *P. weirii* in wood may be similar to the effect on *A. mellea*. In a recent analysis of roots from fumigant-treated stumps, 221 sample disks were found to contain viable *P. weirii*: 99 % were confirmed by isolation whereas only 33 % were confirmed by formation of a thick felt of mycelium and setal hyphae of *P. weirii* on the surface of incubated disks (Thies and Nelson 1986). We interpret a lack of felt formation on wood containing viable *P. weirii* to mean that the fungus or the substrate was altered, resulting in less vigorous fungal growth. The cause may be analogous to the "stressing effect" fumigants have on *A. mellea*. At a sublethal concentration of fumigant, *P. weirii* may be stressed so that it can be replaced by antagonists.

The distribution pattern of residual microorganisms in a fumigated *P. weirii*-infested stump is predictable. Wood in the stump and the immediately adjacent roots is usually sterile. Distal to this is a zone of root wood where *P. weirii* is absent but other organisms are present. Further from the stump the pathogen is viable but not "vigorous." The most distal samples sometimes yield apparently normal *P. weirii*. Our results show variable movement of fumigants within Douglas-fir stumps and roots. As a result, the size of the various zones is not readily predictable. We feel that concentration of the fumigant is high enough in the second zone to kill the pathogen but low

enough to allow more resistant organisms to grow. Alternatively, the concentration of fumigant may have been higher but has diminished to a level tolerated by invading fungi. Among these fungi, eight species of *Trichoderma* have been identified (Nelson et al. 1986).

CURRENT RESEARCH

We are developing techniques that would use fumigation and fungal antagonists to reduce *P. weirii* inoculum. Isolates of fungi antagonistic to *P. weirii* are being screened for those most aggressive towards the pathogen (Goldfarb 1986) and most tolerant of fumigant. Some isolates of *Trichoderma* spp. have already been found that are more resistant to fumigant than the pathogen they antagonize. Four species of *Trichoderma* examined were shown to be approximately two times more resistant to the fumigant methyl bromide than was *A. mellea* (Ohr et al. 1973). Nelson (unpublished data) has recently shown that several species of *Trichoderma* are more resistant to Vorlex and at least two times more resistant to chloropicrin than are several isolates of *P. weirii*. *Trichoderma viride* Pers.:Fr. can be artificially established in *P. weirii*-infested stumps (Nelson and Thies 1985, 1986). We intend to treat stumps on one or more long-term field plots with lower dosages of fumigant than we have tested thus far, then inoculate the stumps with an antagonist or allow indigenous antagonists to invade and displace the weakened pathogen.

PROSPECTS FOR OPERATIONAL USE

We emphasize that none of the fumigants we are testing has been approved by the Environmental Protection Agency for treating stumps infested by *P. weirii*, and that further study may be necessary to register such use. In practice, infested stumps will most likely be treated with a low dosage of fumigant either by itself or followed later by a fungus antagonistic to *P. weirii*. In our first two studies on stump fumigation, viability of the pathogen was tested after a maximum of 20 months. Given this limited exposure time, we suspect that reduction in pathogen viability resulted mostly from the direct lethal effect of the fumigant on the pathogen. Our sampling may have interrupted the natural replacement process. Had the stumps remained in the soil, the fumigants and the antagonists may have continued to advance in the roots, perhaps eliminating the pathogen.

Cost of fumigation to control laminated root rot is an important consideration. Cost estimates of operational fumigation can be approximated based on procedures and results from our completed studies. The following assumptions apply: (1) A dosage of 1.7 ml/kg of stump and root biomass will be effective in undisturbed treated stumps; (2) mean stump diameter is 60 cm.; (3) two workers can drill and treat 100 stumps in an 8-hour day; and (4) the fumigant will be chloropicrin at \$7.50/l (\$2.05/lb). Recognizing that treated stumps will probably be

in scattered groups, the cost per treated acre (100 stumps) will be about \$480: labor \$105; fumigant \$375. Factors such as terrain, stump size, and choice of fumigant could change these costs.

We feel that fumigants will have a place in the future management of *P. weirii*-infested sites. Although fumigation currently costs more than stump removal, the difference may narrow with improvement in techniques or less expensive chemicals. If control can be achieved with longer exposure times using less fumigant, the cost of control can be drastically reduced. Otherwise, fumigation will likely find its greatest use on steep terrain, in areas of fragile soils, in the treatment of relatively small areas, or in areas where site disruption associated with stump removal is unacceptable.

LITERATURE CITED

- BLISS, D. E. 1951. The destruction of *Armillaria mellea* in citrus soils. *Phytopathology* 41: 665-683.
- COOK, R. J., and K. F. BAKER. 1983. The nature and practice of biological control of plant pathogens. *Am. Phytopath. Soc., St. Paul, Minnesota*. 593 p.
- COOPER, P. A. 1973. The movement of chloropicrin vapor in wood to control decay. MS thesis, Oregon State Univ. Corvallis, OR. 75 p.
- FILIP, G. M. 1976. Chemical applications for control of *Armillaria* root rot of ponderosa pine. Ph.D. dissertation, Oregon State Univ., Corvallis, OR., 83 p.
- FILIP, G. M., and L. F. ROTH. 1977. Stump injections with soil fumigants to eradicate *Armillariella mellea* from young growth ponderosa pine killed by root rot. *Can J For Res* 7: 226-231.
- GODFREY, G. H. 1936. Control of soil fungi by soil fumigation with chloropicrin. *Phytopathology* 25: 246-256.
- GOLDFARB, B. 1986. *Trichoderma* spp.: distribution in stumps infested with *Phellinus weirii* and growth and antagonism *in vitro*. M.S. thesis, Oregon State Univ., Corvallis, OR., 78 p.
- GRAHAM, R. D. 1975. Preventing and stopping decay of Douglas-fir poles. *Holzforshung* 27:168-173.
- GRAHAM, R. D., and M. E. CORDEN. 1980. Controlling biological deterioration of wood with volatile chemicals. *Elec. Power Res. Inst., Palo Alto, Calif. EL-1480, Proj.212-1*. 51 p.
- HADFIELD, J. S. 1985. Laminated root rot, a guide for reducing and preventing losses in Oregon and Washington forests. USDA Forest Serv. Pac Northwest Region, Portland, Oregon. 13 p.
- HANSEN, E. M. 1979. Survival of *Phellinus weirii* in Douglas-fir stumps after logging. *Can. J. For. Res* 9: 484-488.
- HOUSTON, D. R., and H. G. ENO. 1969. Use of soil fumigants to control spread of *Fomes annosus*. USDA For. Serv. Res. Pap. NE-123. Northeast. For. Exp. Stn., Broomall, PA. 22 p.
- MUNNECKE, D. E., M. J. KOLBEZEN, W. D. WILBUR, and H. D. OHR. 1981. Interactions involved in controlling *Armillaria mellea*. *Plant Dis.* 65: 384-389.
- NELSON, E. E., B. GOLDFARB, and W. G. THIES. 1986. *Trichoderma* species from fumigated Douglas-fir roots decayed by *Phellinus weirii*. *Mycologia* (in press).
- NELSON, E. E., N. E. MARTIN, and R. E. WILLIAMS. 1981. Laminated root rot of western conifers. *For. Insect and Dis. Leafl.* 159. USDA Forest Serv, Washington, DC. 6 p.
- NELSON, E. E., and W. G. THIES. 1985. Colonization of *Phellinus weirii*-infested stumps by *Trichoderma viride*: 1. Effect of isolate and inoculum base. *Eur. J. For. Path.* 15: 425-431.
- NELSON, E. E., and W. G. THIES. 1986. Colonization of *Phellinus weirii*-infested stumps by *Trichoderma viride*: 2. Effects of season of inoculation and stage of wood decay. *Eur. J. For. Path.* 16: 56-60.
- OHR, H. D., D. E. MUNNECKE, and J. L. BRICKER. 1973. The interaction of *Armillaria mellea* and *Trichoderma* spp. as modified by methyl bromide. *Phytopathology* 63: 965-973.
- RACKHAM, R. L., W. D. WILBUR, T. E. SZUSKIEWICZ, and J. HARA. 1968. Soil dessication and fumigation for *Armillaria* root rot in citrus. *Calif. Agric.* 22(1): 16-18.
- THIES, W. G. 1984. Laminated root rot: The quest for control. *J. For.* 82: 345-356.
- THIES, W. G., and E. M. HANSEN. 1985. Bulldozing to control laminated root rot--another consideration. In: *Proc. 29th Annu. West. Int. For. Dis. Work Conf.*, p.104-105. Olympia, WA.
- THIES, W. G., and E. E. NELSON. 1982. Control of *Phellinus weirii* in Douglas-fir stumps by the fumigants chloropicrin, allyl alcohol, Vapam, and Vorlex. *Can. J. For. Res.* 12: 528-532.
- THIES, W. G., and E. E. NELSON. 1986. Reduction of *Phellinus weirii* inoculum in Douglas-fir stumps by the fumigants chloropicrin, Vorlex, or methylisothiocyanate. (Submitted to *Forest Science*).
- WALLIS, G. W., G. REYNOLDS. 1965. The initiation and spread of *Poria weirii* root rot of Douglas-fir. *Can. J. Bot.* 43: 1-9.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

PEARS, BEARS AND PHYTOPHTHORA IN S.E. ALASKA (OR
THE INDICATION THAT P. DRECHSLERI IS ENDEMIC TO
S.E. ALASKA)

Philip B. Hamm, Everett M. Hansen, Paul E.
Hennon, and C.G. (Terry) Shaw, III

ABSTRACT: Phytophthora dreschleri was recovered in S.E. Alaska. Areas of recovery were remote and undisturbed, decreasing the chance of fungal introduction. This fact, plus additional information discussed, indicates that this Phytophthora is endemic to S.E. Alaska.

INTRODUCTION

Phytophthora species are well known as pathogens of many agricultural crops around the world but little is known of their behavior in native plant communities and their origins are largely speculative. Several species, including P. cinnamomi, P. palmivora and P. lateralis are destructive in native vegetation, but the susceptibility of the tree species involved, the recent origin of epidemics and the correlation with human disturbance suggest that the fungi were introduced to the areas of current damage. Whether a pathogen is native or

PHILIP B. HAMM is a Senior Research Assistant and EVERETT M. HANSEN is an Associate Professor, in the Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR P.E. HENNON is a Plant Pathologist, Forest Pest Management, Forest Service, Juneau, AK; C.G. SHAW is a Principle Plant Pathologist Rocky Mtn. Forest & Range Exp. Sta., Fort Collins, CO

introduced has practical significance to disease control programs, especially quarantine opportunities. It is also of more fundamental interest in elucidation of the evolutionary history of pathogenic fungi and the search for disease resistance (Leppik 1970).

During an investigation of the causes of dieback and mortality of Alaska yellow-cedar (Chamaecyparis nootkatensis (D. Don) Spach.) in Southeast Alaska (Shaw et al. 1985), we searched for Phytophthora as well as other potential pathogens. A heterothallic Phytophthora was recovered from very remote undisturbed site. Although we concluded that this fungus was not the primary cause of cedar dieback (Hennon 1986), its presence in this habitat is noteworthy.

MATERIALS AND METHODS

Isolation of Phytophthora was attempted from soil and streams in five areas of S.E. Alaska (Figure 1): Peril Strait, Helm Bay, Slocum Arm, Wrangell Island, and Prince of Wales Island. Collection sites, except Wrangell and Prince of Wales Islands, were in remote undisturbed areas many kilometers from any historic settlement and accessible only by boat or float plane.

Soil Sampling

In the summer of 1984 a total of 162 soil samples were collected from the 5 areas; during the summer of 1985, 77 samples were collected in the Peril Straits vicinity and 25 from the area of Slocum Arm. Most of the samples were collected from beneath trees in areas of declining cedar. The remaining samples came from beneath healthy trees away from cedar decline. Each sample was composited from 3 subsamples collected within 1/2 m of each tree. The organic fraction was separated from all samples by wet sieving (Ostrowsky et al. 1977) and a resulting 5 g (wet wgt) fraction was placed in a styrofoam drinking cup with water. The double cup baiting method (Linderman and Zeitoun 1977) with Alaska cedar foliage baits (Ostrowsky et al. 1977) was used to trap Phytophthora from the soil. Baits were floated over the organic matter for 6 days, then transferred to cornmeal agar (CMP) containing pimaricin (20 g/ml) and vancomycin (200 g/ml) in petri plates. Phytophthora colonies were subcultured for identification after 6 days.

Stream Sampling

In 1985, 8 streams draining into the Peril Straits and 2 entering Slocum Arm were also sampled for the presence of Phytophthora. Seven of the ten streams drained from bogs or muskegs with associated dead and dying cedar. Large green Danjou pears were placed individually in nylon mesh bags which were in turn anchored along the stream courses. Pears were placed at 10 m intervals in streams starting just above tidal (saltwater) influence. Each tributary was baited with two pears, one just above the mouth,

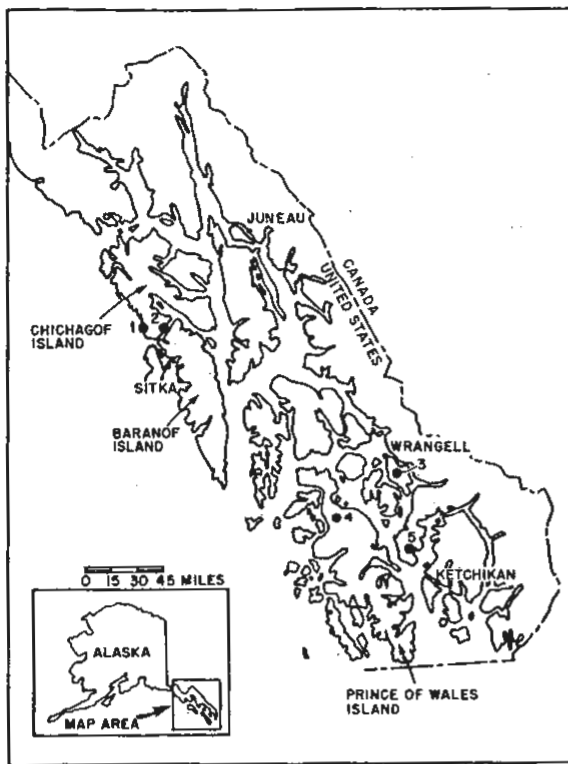


Figure 1--Areas sampled for *Phytophthora*; 1 = Slocum Arm, 2 = Peril Straits, 3 = Wrangell Island, 4 = Prince of Wales Island, 5 = Helm Bay

another 10 m above that. Between 33 and 41 pears were placed in each stream system. Pears were removed after 4-6 days and incubated outdoors for 3-7 days, until distinct brown spots appeared.

Pears were cut open and small portions of tissue were aseptically removed from the margin of seven brown areas/pear and transferred to CMP. All *Phytophthora* colonies were subcultured for identification.

Phytophthora Identification

Isolates were maintained on corn meal agar at 5C. Sporangia were induced by flooding distilled water washed colonies grown 5 days in pea broth with soil extract water. Isolates were also grown on clarified V-8 agar with or without added cedar foliage, grass leaves, or B-sitosterol, and on cedar extract agar (Trione 1974) made from Alaska yellow cedar foliage. Matings to induce oospore formation were made between Alaskan isolates and known A₁ and A₂ mating types of *P. drechsleri*, *P. cambivora* and *P. cinnamomi* on clarified V-8 agar.

Morphological characteristics were compared with those described by Waterhouse (1963) for isolate identification.

Electrophoretic protein patterns of Alaskan isolates were compared with other *Phytophthora* species found on conifers in the Northwest including: *P. drechsleri*, *P. cinnamomi*, *P.*

megasperma, *P. lateralis* and *P. pseudotsugae*. Protein was extracted using methods previously described (Hamm and Hansen 1983). Sodium dodecyl sulfate (SDS) polyacrylamide gels were used for protein separation.

RESULTS

Phytophthora was isolated infrequently in both years from the Peril Strait area. A total of 7 isolates were obtained from 5 sites. Four soil samples collected in areas of cedar mortality at 2 sites 3 km apart on either side of the Straits yielded *Phytophthora*. *Phytophthora* was not recovered from any soil samples in 1985, but was isolated from 3 pears floating in two streams entering the Peril Strait. One stream flowed through a diseased area, the other primarily through healthy forest. All pears in the two streams at Slocum Arm were eaten by bears. No further isolations were attempted in that area.

All seven *Phytophthora* isolates were identified as *P. drechsleri*. Protein patterns were indistinguishable from those of *P. drechsleri* isolates obtained from diseased Douglas-fir seedlings in Oregon and Washington nurseries, but were readily separated from other species.

DISCUSSION

This is the first report of *Phytophthora drechsleri* from Alaska, and only the second report of any *Phytophthora* species from the state (*P. infestans* was reported on potatoes in Wrangell (Cash 1934)). More significant than a range extension, however, is the habitat in which the fungus was found. *Phytophthoras* are seldom recovered outside of agricultural or disturbed forest settings, and possibly never from areas beyond historical human activity.

Phytophthora drechsleri is an important pathogen on many crops around the world (CMI map 281), but has attracted little speculation about its origin. It was regularly recovered from native vegetation in eastern Australia (Pratt and Heather 1973), prompting the suggestion that it had accompanied *P. cinnamomi* in its migration from the Pacific Islands north of Queensland (Shepherd 1975). In western North America, *P. drechsleri* causes root rot in conifer nurseries (Pratt et al. 1976) and other crops, but this is its first report as a forest inhabitant.

The evidence supports the case that *P. drechsleri* is endemic in S.E. Alaska. The places where *P. drechsleri* was found are many km from any roads, trails or permanent settlement. There has been very limited mineral prospecting, or logging activity in the area, particularly in the vicinity of our study areas. Some trees had been cut 50 years before along one stream where we recovered *Phytophthora*, but the other sites were well separated and in virgin forest. We are unaware of a *Phytophthora* report in any more remote, less disturbed location.

An endemic pathogen is expected to cause minimal damage to the plant communities in which there has been long association (Leppik 1970). While

P. drechsleri was found in areas with widespread mortality of Alaska yellow cedar, it was not a constant associate, was never isolated directly from dying cedar (Hennon 1986), and caused only limited root necrosis on AYC in pathogenicity tests. Epidemiological evidence suggests that AYC mortality is caused by complex environmental stresses (Hennon 1986). It seems likely that P. drechsleri is an inhabitant of the bogs common to this area, nibbling on rootlets of many plant species, perhaps including AYC.

P. drechsleri may, in fact, be widespread in the forests of northwestern North America as it is in eastern Australia (Pratt & Heather 1973). Geological evidence suggests a link between this disjunct distribution. The present west coast of North America has been built up from the collision beginning sometime during the Mesozoic era, of several small land masses (terranes) with the ancestral continent through the processes of microplate tectonics (Jones et al. 1982). Indeed, stratigraphic and paleontological evidence suggests that the Alexander and Wrangellia terranes that comprise much of the Peril Strait area in present day S.E. Alaska originated in the South Pacific as parts of present day eastern Australia and ancient island arcs (Gehrels and Saleeby 1984, Jones et al. 1982). Microplate tectonics provides explanation for a number of problems in biogeography of the Pacific region (Nur and Ben Avaham 1979), including perhaps, the finding of P. drechsleri in remote areas of eastern Australia and S.E. Alaska.

Electrophoresis to compare protein banding patterns has been an effective tool for confirming the identity of Phytophthora isolates (Hamm & Hansen 1982) and for the recognition of subspecies groups of isolates within P. megasperma (Hansen et al. 1986). In fact, protein similarity correlates strongly with morphological and pathological similarity (Hansen et al. 1986), and provides an important measure of relatedness (Hansen et al. 1986). The production of identical protein patterns by isolates of P. drechsleri from S.E. Alaska, Oregon, and Washington establishes their close relationship. This is expected, particularly if isolates on the Pacific Coast have a common, relatively recent origin in the South Pacific.

It is highly presumptuous to make a claim for fungal endemism based on remoteness from human disturbance in this day and age. Too much of history has passed without a written record to be sure, even in a place so far removed as S.E. Alaska. However, the geological, pathological and electrophoretic evidences indicate that P. drechsleri is indeed endemic to this area of Alaska. Better and more interesting evidence will come from genetic comparisons of these remote populations with isolates from agricultural situations. This, in turn, will further our understanding of speciation in this important genus (Hansen 1986).

LITERATURE CITED

- Cash, Edith K. 1934. Alaskan fungi. Plant Dis. Rept. 18:74-88.
- Gehrels, G.E. and J.B. Saleeby. 1984. Paleozoic geologic history of the Alexander terrane in S.E. Alaska, and comparisons with other orogenic belts. Geol. Soc. Am., Abstr. 16:516.
- Hamm, P.B. and E.M. Hansen. 1984. Improved method for isolating Phytophthora lateralis from soil. Plant Disease 68:517-519.
- Hamm, P.B. and E.M. Hansen. 1983. Phytophthora pseudotsugae, a new species causing root rot of Douglas-fir. Can. J. Bot. 61:2626-2631.
- Hansen, E.M. 1986. Speciation in Phytophthora: Evidence from the P. megasperma complex. In: Evolutionary Biology of the Fungi. Brit. Mycol. Soc. In Press.
- Hansen, E.M., P.B. Hamm, A.J. Julis, and L.F. Roth. 1979. Isolation, incidence, and management of Phytophthora in forest tree nurseries in the Pacific Northwest. Plant Dis. Rep. 63:607-611.
- Hennon, P.E. 1986. Pathological and ecological aspects of decline and mortality of Chamaecyparis nootkatensis in southeast Alaska. PhD Thesis, Oregon State University. 279 p.
- Jones, D.L., A. Cox, P. Coney, and M. Beck. 1982. The Growth of Western North America. Scientific American 247:70-84.
- Leppik, E.E. 1970. Gene centers of plants as sources of disease resistance. Ann Rev. Phytopath. 8:323-344.
- Linderman, R.G., and F. Zeitoun. 1977. Phytophthora cinnamomi causing root rot and wilt of nursery-grown native western azalea and salal. Plant Dis. Rep. 61:1045-1048.
- Nur, A. and Z. Ben-Avaham. 1979. Speculations on mountain building and the lost Pacifica Continent. J. of Physics of the Earth. 26:21-21.
- Ostrofsky, W.D., R.G. Pratt and L.F. Roth. 1977. Detection of Phytophthora lateralis in soil organic matter and factors that effect its survival. Phytopathology 67:79-84.
- Pratt, B.H., and W.A. Heather. 1973. Recovery of potentially pathogenic Phytophthora and Pythium spp. from native vegetation in Australia. Aust. J. Biol. Sci. 26:575-582.
- Pratt, R.G., L.F. Roth, E.M. Hansen, and W.D. Ostrofsky. 1976. Identity and pathogenicity of species of Phytophthora causing root rot of Douglas-fir in the Pacific Northwest. Phytopathology 66:710-714.

Shaw, C.S. III, A. Eglitis, T.H. Laurent, and P.E. Hennon. 1985. Decline and mortality of Chamaecyparis nootkatensis in Southeast Alaska, a problem of long duration but unknown cause. *Plant Disease* 69:13-17.

Shard, C.J. 1975. Phytophthora cinnamomi - an ancient immigrant to Australia. *Search* :484-490.

Trione, E.J. 1974. Sporulation and Germination of Phytophthora lateralis. *Phytopathology* 64:1531-1533.

Waterhouse, G.M. 1963. Key to the species of Phytophthora de Bary. *Commonw. Mycol. Inst. Mycol. Pap. No 92*.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

FOREST PATHOLOGY TRIVIA PURSUIT

F. G. Hawksworth, C. G. Shaw, III,
and J. S. Beatty

This trivia quiz was presented at the WIFDWC banquet in Juneau. Due to popular request, we have included some possible answers, many of which were offered at the banquet. Some younger members ("The Baby Boomers") thought that many of the questions relating to Old Timers were unfair, and promised to come up with some more recent and contemporary forest pathology trivia (pre-nostalgia?) for next year. Good luck to all future Triviologists.

1. What common tree decay fungus doesn't occur at the locale from where the type specimen was collected? (Echinodontium tinctorium was described from a log that drifted onto a beach on Admiralty Island, Alaska, in the early 1890's. The fungus hasn't been found on Admiralty Island since).
2. What states, provinces, or territories have no mistletoes? (U.S.; North Dakota, South Dakota, Nebraska, Iowa. Canada; Yukon, Northwest Territories).
3. By what name is Cunnighamella meineckella better known? (Fomes annosus, Heterobasidion annosum).
4. Who were the first non-spousal women at a WIFDWC? (Trudy Pentland and Robena

F. G. Hawksworth and C. G. Shaw, III, are Research Plant Pathologists at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins Colorado. J. S. Beatty is a Pathologist with Forest Pest Management, Southwestern Region, USDA Forest Service, Albuquerque, New Mexico.

Robinson, graduate students at University of British Columbia, attended the 6th WIFDWC at Vancouver, B. C., in 1958. Apparently the first American woman to attend was Mary Ann Strand of Oregon State University, at the 17th (1969) meeting in Olympia, Wash.

5. What U.S. tree is parasitized by both Arceuthobium and Phoradendron? (White fir in California and Arizona).
6. Does the red belt fungus cause red belt disease? (Probably not).
7. What western forest pathologist has a campground named for him? (Doc Long Picnic Ground in the Sandia Mountains, New Mexico, was named for W. H. Long; also there is a Charles Waters Memorial near Stevensville, Bitterroot N.F., Montana).
8. In what state and/or province have the most WIFDWC's been held? (British Columbia (7); Oregon (5), Washington (5)).
9. Which western states, provinces, or territories have not hosted a WIFDWC? (U.S.; Utah (but planned for 1988), Nevada, Hawaii. Canada; Yukon and Northwest Territories).
10. Which forest pathologist is also an accomplished Sasquatch scatologist? (Dr. Don Knutson).
11. What is the deepest isolation of a root rot fungus? (Armillaria sp. from mine timbers).
12. Which forest pathologists became Station Directors, Regional Foresters, or USFS Chiefs? (Station Directors - J.S. Boyce, E. Ross, J. Ohman; Regional Foresters - ?, USFS Chief - R. McArdle)
13. Which western forest pathologist claims to work on insignificant diseases of unimportant plants? (Dr. R. L. Gilbertson, of the University of Arizona).
14. What noted forest pathologist once claimed reimbursement of 5¢ for use of a pay toilet and the claim went all the way to the Secretary of Agriculture for settlement? (Dr. G. G. Hedgcock).
15. What common western fungus was first described in a San Francisco newspaper? (The western gall rust fungus, Peridermium (now Endocronartium) harknessii was described in the "Weekly Alta California" in 1876).
16. What WIFDWC member, present at this meeting, first cultured white pine blister rust? (Dr. Al Harvey, Intermountain Station, Moscow, Idaho).
17. What forest pathologist quit smoking when he began studying the effects of smoke on fungi? (Dr. J. R. Parmeter, Jr.).
18. Who was the first forest pathologist to become a USFS District Ranger? (We expect Ed Wood to attain the honor in the near future).

19. What forest pathologist can now be trusted to buy a used car from? (Randy Fuller, of Fuller Ford, Springerville, Arizona, has a deal for you).
20. What infamous Alaskan forest pathologist began his career as an Idaho mule skinner and Colorado ski ranger? (Tom Laurent).
21. What high-flying pathologist recently isolated Fomes pinicola from in-flight bark beetles? (Dr. C. G. Shaw, Sr., and students).
22. What western forest pathologist is capable of destroying the entire Russian wheat crop? (Dr. Walter Thies worked on wheat rust for the U.S. Army).
23. What famous "brother" team studied deterioration of fire-killed Douglas-fir in the Northwest? (Ken Wright (entomologist) and Ernie Wright (pathologist) in the early 1950's).
24. What famous western forest pathologist refuses to drive through Oregon so he won't have to pay for a 1954 traffic ticket? (Dr. J. R. Parmeter, Jr.).
25. What western forest pathologist published papers over a 55+-year span in Mycologia? (Dr. Ross Davidson, 1931-1987 (in press)).
26. What mistletoe occurs farthest north in North America? (Arceuthobium tsugense on hemlock (Haines, Alaska), and A. americanum on jack pine (north of Lake Athabaska, Alberta) both occur at about 59° 20'N latitude).
27. Who first used the pure culture method for isolation and identification of wood decay fungi? (W. H. Long, of Albuquerque, N.M., published on this topic in the J. Agric. Res. in 1918).
28. What root disease fungus has also been isolated from leaves? (Phytophthora lateralis, P. citricola, Rizoclonia solani, Macrophoma phaseoli, etc.).
29. What was the first North American Forest Pathology textbook? ("Outline of Forest Pathology," by E. E. Hubert, 1931).
30. When did the Department Minister promise to get the "deadwood" out of the Canadian Forest Service? (Proclaimed in 1969, but the axe didn't fall until 1970).
31. Who was Phellinus weirii named for? (Names suggested were J. R. Weir, Larry Weir, and Sam Phellinus).



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

UNCOVERING THE CAUSE OF FLUTING IN WESTERN HEMLOCK IN SOUTHEAST ALASKA

Kent Reinhold Julin

ABSTRACT: This paper presents a study in progress that examines fluting of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) growing in southeast Alaska. Following three years of study, observations indicate that site location and type of stand development can account for the spatial discontinuities of fluted stands in southeast Alaska. Patterns of translocation are apparently the key to the development of flutes.

INTRODUCTION

In the coastal forests of southeast Alaska, there are stands of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) that are seriously fluted. Fluted trees have irregular trunk shapes, where longitudinal ridges and grooves spiral upward. Trees that have fluted stems are less desirable from a timber production perspective, because the quality of pulp and saw logs of such trees is low (Harris and Farr 1974).

Kent Reinhold Julin is a doctoral student in silviculture, College of Forest Resources, University of Washington, Seattle, Wash.

The intent of this paper is to describe a portion of a cooperative study now being conducted by the University of Washington and the Pacific Northwest Forest and Range Experimental Station which examines the cause of fluting in western hemlock. Prior to this study, close proximity to salt water was a factor common to known fluted stands, and thus was considered associated with factors likely to be the cause of fluting.

FLUTING vs. BUTTRESSING

The development of buttresses is common in tropical trees (Richards 1966). But unlike buttressed trees where eccentric trunk flanges are confined to the tree base, fluted trees have flanges that extend from the root collar upward into the crown. Considering the similarities between buttressing and fluting, the literature on buttressing was considered a source of ideas from which a study on fluting could be initiated.

A variety of theories have been advanced to explain why trees develop buttresses (Richards 1966). These theories include: 1) the Strain, 2) the Conduction Current, 3) the Negative Geotropism, and 4) the Adaptation Theory. The first three theories account for the cause of buttressing, while the last addresses the functional significance of buttressing.

The Strain Theory proposes that buttresses form in direct response to mechanical bending caused by the wind. The Conduction Current Theory claims that restricted lateral movement of water and nutrients from roots results in differential stimulus around the tree trunk, and this results in buttressing. The Negative Geotropism Theory infers that the upper surfaces of roots are favorably affected by a negative geotropic force. The Adaptation Theory states that buttresses serve trees in a structural capacity by which they are better able to resist wind and/or gravity induced stresses (Richards 1966).

HYPOTHESES

Based upon the literature and some general observations made by Julin (1984), the following hypotheses were developed to explain the presence and formation of fluting in western hemlock:

- 1) A discrete pattern of translocation creates differential rates of cambial growth that results in fluting.

2) Fluting is a response to wind stress.

3) Fluting is associated with even-aged stand development.

TRANSLOCATION PATHWAYS

Since fluted stems are initially circular in cross-section and the cambium in the grooves is alive (Day 1964), fluting is probably the result of differential stimulation of the cambium (Bannan 1957, Coutts and Philipson 1976). The factors that are related to this stimulus of the cambium are most likely transported in the phloem and xylem. Chalk and Akpalu (1963) demonstrated that buttressing is more common among tree species with vascular systems that restrict lateral translocation. Several approaches are being used to describe translocation patterns in fluted hemlock.

Patterns of translocation in the phloem are being analyzed using branch girdling. A live, functional branch in a fully illuminated portion of 120 study trees was girdled near the branch base. The exposed xylem tissue was treated with tar so that water loss from the newly exposed surface would not occur. The girdle restricted the downward flow of photosynthates and hormones from the branch and into the stem. Thus, any reductions in stem growth associated with this treatment could be attributed to localized deficiencies of substances transported in the phloem.

Two years following implementation of the girdling treatment, branches were still living and the branches were swollen on the foliage side of the girdle, testimony for xylem continuity and phloem discontinuity. A reduction in radial growth of the stem directly beneath the point of branch insertion, indicates that a localized photosynthate and hormone deficiency had occurred. A confined pattern of flow in the phloem would account for this observation.

Injection of crystal violet dye into both the main stem and a root is one technique being used to describe patterns of flow in the xylem. This technique has been used by Rudinsky and Vite' (1959) to describe patterns of flow in several coniferous species.

A confined and winding ascent of dye is the pattern exhibited by fluted hemlock. The restricted lateral movement of water and mineral nutrients, as indicated by these results, implies that concentrations of water and nutrients in the xylem would vary around the stem, and thus could be considered as a source of differential stimulus. In addition to the dye injection experiment, individual lateral roots on 120 study trees were cut 5 to 10 cm below the root collar.

WIND STRESS

Since stands containing fluted trees are most frequently encountered near coastlines, areas of chronic onshore winds, it is possible that wind provides the stimulus for flute formation. Fluted trees have also been found on a windy ridgetop east of Naukati on Prince of Wales Island.

Methods that have been used to evaluate the influence of wind on stem form include:

- 1) observations of stem shape in relation to prevailing winds (Whitford 1906, Senn 1923, Naves 1924),
- 2) mechanical bending of seedlings (Gilchrist 1908, Turgeon and Webb 1971, Telewski and Jaffe 1981), and
- 3) guying (Jacobs 1953, Larson 1965, Neel and Harris 1971, Burton and Smith 1972, Wilson 1975, Fayle 1976).

A guying strategy is being used in this study to determine whether wind stress affects the expression of fluting. The guying method uses wire restraints to prevent trees from swaying and the growth response is compared against free-standing controls. A 20-year-old stand of relatively cylindrical western hemlock located on Sarkar Point, Prince of Wales Island was selected for the guying. A portion of the stand was uniformly thinned to increase local windspeeds.

Ten trees were assigned one of the following treatments: 1) High Guy, 2) Low Guy, and 3) No Guy (30 trees total). High Guy trees were secured at about 3/4 tree height, while Low Guy trees were secured at breast height (1.4 m). Those trees without guy wires serve as a control. Three wires radiating at 120° angles from each tree were attached to the stumps remaining after thinning.

Hose harnesses were used at the guying height to minimize damage to bark tissues. Trees were felled after two years of treatment for stem analysis.

Provided that two years is sufficient time for the treatment effects to manifest themselves, and that the wind stress hypothesis is true, one would expect the No Guy trees to exhibit more pronounced fluting than the High Guy trees. The Low Guy trees should exhibit a growth pattern below the guy wire attachments similar to that of the High Guy treatment; however, above the point of wire attachments a growth pattern similar to the No Guy treatment should be apparent.

STAND DEVELOPMENT

Stands containing non-fluted trees do exist along the coastlines of southeast Alaska. This indicates that a factor or set of factors in addition to the one associated with coastal sites (i.e., wind), appears to be regulating fluting. Both the pattern of stand development and the amount of time elapsed since disturbance are factors now being evaluated.

Fluting is most frequently encountered in even-aged stands that develop following windfall, fire and logging. Trees developing within even-aged stands are exposed to greater wind stress, develop larger, longer-lived branches and grow more quickly than trees that develop within uneven-aged stands. Through the guying study, stem analysis and stand examinations, we hope to develop reasoning for this association between fluting and the even-aged pattern of stand development.

Time is another factor that appears to influence fluting severity. Dissections of an old-growth cylindrical tree found near Hollis, revealed that it was fluted when young, but with the passing of time developed a cylindrical bole. Thus, stands that initiated following windthrow centuries ago may not exhibit fluted characteristics today.

CONCLUSION

Fluting occurs frequently in the coastal stands of southeast Alaska. It is evident that translocation patterns in the phloem and xylem may cause differential stimulus of the cambium and this results in fluting. The occurrence of fluted trees in areas of chronic winds, implies that trees

develop flutes in response to wind stress. Guying will hopefully elucidate the impacts of wind on fluting. Since fluted stands are also stands that initiated following windthrow, fire and logging, it is reasonable to suspect that the pattern of stand development may also affect fluting severity. Time elapsed since disturbance is a factor that may mask the presence of fluting in older trees.

LITERATURE CITED

- Bannan, M.W. 1957. Girth Increase in white cedar stems of irregular form. *Can. J. Bot.* 35(4):425-434.
- Burton, J.D. and D.M. Smith 1972. Guying to prevent wind sway influences. Loblolly pine growth and wood properties. USDA- For. Serv. Paper 50-80.
- Chalk, L. and J.D. Akpalu. 1963. Possible relation between the anatomy of the and buttressing. *Commonw. For. Rev.* 42:53-58.
- Coutts, M.P. and J.J. Philipson. 1976. The influence of mineral nutrition on the root development of trees. I. The growth of Sitka spruce with divided root systems. *J. Expt. Bot.* 27:1102-1111.
- Day, W.R. 1964. The development of flutes or hollows on the main stems of trees and its relation to bark splitting and strip necrosis. *Forestry* 37:145-160.
- Fayle, D.C.F. 1976. Stem sway affects ring width and compression wood formation in exposed root bases. *For. Sci.* 22:193-194.
- Gilchrist, M. 1908. Effects of swaying by the wind on the formation of mechanical tissue. *Rep. Mich. Acad. Sci.* 10-45.
- Harris, A.S. and W.A. Farr. 1974. The forest ecosystem of southeast Alaska: 7. Forest ecology and timber management. USDA For. Ser. Gen. Tech. Rpt. PNW-25. Portland, OR.
- Jacobs, M.R. 1953. The effect of wind-sway on the form and development of *Pinus radiata* D. Don. *Austral. J. Bot.* 2:35-51.
- Julin, K.R. 1984. Western hemlock fluting in southeastern Alaska I: Preliminary observations on distribution and cause. Unpub. Rpt. prepared for USDA Forest Service, Forest Pest Management, Anchorage. 28 pp.

- Larson, P.R. 1965. Stem form of young *Larix* as influenced by wind and pruning. For. Sci. 11:412-424.
- Naves, A. 1930. On the distribution of tabular roots in *Ceiba* (Bombaceae). Proc. Nat. Acad. Sci. (USA) 16:339-344.
- Neel, P.L. and R.W. Harris 1971. Motion-induced inhibition of elongation and induction of dormancy in Liquidambar. Science 173:58-59.
- Richards, P.W. 1966. Tropical Rain Forest. Cambridge University Press, London. 450 pp.
- Rudinsky, J.A. and J.P. Vite'. 1959. Certain ecological and phylogenetic aspects of the pattern of water conduction in conifers. For. Sci. 5(3):259-266.
- Senn, G. 1923. Ueber die Ursachen der Brettwurzelbildung bei der Pyramiden-Pappel. Verh. naturf. Ges. Basel 35:405-435.
- Telewski, F.W. and M.J. Jaffe. 1981. Thigomorphogenesis: changes in the morphological and chemical composition induced by mechanical perturbation in 6-month-old *Pinus taeda* seedlings. Can. J. For. Res. 11:380-387.
- Turgeon, R. and J.A. Webb. 1971. Growth inhibition by mechanical stress. Science. 174: 961-962.
- Wilson, B.F. 1975. Distribution of secondary thickening in tree root systems. p. 197-219 in J.G. Torrey and D.T. Clarkson (eds.), The development and function of roots. Academic Press, New York. 618 p.
- Whitford, H.N. 1905. The vegetation of the Lambao Forest Reserve. Phillip. J. Sci. 1:373-431, 637-682.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

CONTROL OF DWARF MISTLETOE WITH ETHEPHON

Thomas H. Nicholls, Leanne Egeland, Frank G. Hawksworth, and David W. Johnson

ABSTRACT

Dwarf mistletoe shoot abscission rates of 74 to 100 percent on individual infections of Arceuthobium americanum on Pinus contorta and A. vaginatum subsp. cryptopodum on P. ponderosa were consistently achieved with August applications of 2500 ppm ethephon plus surfactant using three methods of application. Most shoots abscised from infections within 2 to 5 weeks after ethephon treatment. Ethephon did not kill the parasite's endophytic system in the host tissue. Therefore, new shoots began developing on some infections 1 to 2 years after treatment. Based on the long life cycles of these two species of dwarf mistletoe, we predict that ethephon control can prevent or reduce spread of infection for up to 4 years and possibly even longer. Ethephon has control potential especially in high value stands, recreation areas, seed orchards, and ornamental plantings around homes, cabins, and business establishments.

THOMAS H. NICHOLLS is a Research Plant Pathologist and LEANNE EGELAND is a Forestry Technician at the North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn. 55108. FRANK G. HAWKSWORTH is a Research Plant Pathologist at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Ft. Collins, Col. 80526. DAVID W. JOHNSON is a Plant Pathologist at Region 2, Forest Pest Management, USDA Forest Service, Lakewood, Col. 80225.

Dwarf mistletoes, Arceuthobium spp., are parasitic seed plants that are regarded as one of the most damaging disease agents of conifers in the United States. An estimated 418 million cubic feet of wood fiber are lost annually to these pathogens either through growth reduction or tree mortality (Drummond 1982). These obligate parasites also lower wood quality, while reducing cone and seed production of infected trees.

Much successful research has been done on silvicultural control of dwarf mistletoes (Scharpf and Parmeter, Jr. 1978). However, supplemental controls, i.e., chemical, would be useful in areas of high value trees such as in campgrounds and home sites. Until recently, no chemical control of dwarf mistletoes had been found to be effective (Lightle and Lampi 1973, Quick 1964, Scharpf 1972). However, Livingston and Brenner (1983) and Livingston et al. (1985) tested ethephon, an ethylene-releasing plant growth regulator, at various concentrations with and without surfactants on A. pusillum Pk. on black spruce, Picea mariana (Mill.) B.P.S. August applications of 2500 ppm ethephon with a surfactant consistently resulted in a 74 to 100 percent abscission of dwarf mistletoe shoots. Most dwarf mistletoe shoots dropped off 2 to 3 weeks after application. Treatments did not significantly affect growth of black spruce or subsequent growth of dwarf mistletoe shoots. Livingston et al. (1985) predicted that abscission of aerial dwarf mistletoe shoots can prevent the spread of the disease in treated black spruce for at least 2 years.

According to DeWilde (1971), ethephon is a safe growth regulator. It is routinely used on food crops to promote abscission of leaves and fruits. As ethephon is absorbed into plant tissues, ethylene is released causing susceptible plant parts to abscise. An environmental advantage in using ethephon is that there are no toxic by-products when the compound breaks down. Ethylene also exists naturally in conifers and is presumably responsible for natural abscission of aging dwarf mistletoe shoots. Apparently, increased levels of ethylene resulting from ethephon applications stimulate premature abscission of dwarf mistletoe shoots. Based on these facts and the excellent results achieved in Livingston's eastern dwarf mistletoe study, we decided to test ethephon on two other extremely damaging dwarf mistletoe species in the western United States.

Our objective was to conduct some preliminary tests of ethephon to determine its potential as a control for A. americanum Nutt. ex Engelm. on lodgepole pine, P. contorta Dougl. and A. vaginatum subsp. cryptopodum (Engelm.) Hawksw. & Wiens on ponderosa pine, P. ponderosa Laws.

METHODS

We established six lodgepole pine study areas: five in the Fraser Experimental Forest near Fraser, Colorado, and the other in the Cutthroat

Bay Campground near Grand Lake, Colorado, both in the Arapaho National Forest. We also set up a small study in ponderosa pine near Meeker Park, Colorado, in the Roosevelt National Forest.

Ethylene releasing agents, Florel^{1/} and Ethrel[®], were applied to infected trees using three different spray methods: hand-held bottle sprayer, back pack mist blower, and truck-mounted hydraulic hand-jet sprayer. Two surfactants were used: X-77[®] or a combination of Nu-Film 17[®] and Spray-Aide[®].

Dwarf mistletoe infections were rated before and after treatment using the Dwarf Mistletoe Area Grid Rating System (DMAGR System) developed in this study. The 6-class Dwarf Mistletoe Rating System (DMR System) (Hawksworth 1977) was used for rating trees before and after treatment.

We used the DMAGR System for individual infections that were low enough to the ground to be reached and measured. We tagged individual male and female plants with metal tags that included treatment, plant number, and sex. For easy identification, strings were tied around the margins of each infection. Individual infections were measured for sq. inches of shoot area before and periodically after treatment using the horizontal-vertical grid of the DMAGR System (fig. 1). This system was used to determine the total sq. inch dwarf mistletoe shoot area for each treatment by adding together the sq. inch ratings of individual infections. For example, infections measuring 4.0, 6.0, and 3.0 sq. inches for one treatment would yield a total sq. inch area of 13.0. To determine the change in percent total shoot area present from an initial reading to a subsequent reading, the subsequent total mistletoe sq. inch area result was divided by the initial, before spray total sq. inch area. For example, if the total mistletoe area 5 weeks after a treatment was 2.0 sq. inches, and the before spray total mistletoe area was 13.0 sq. inches, the percent shoot area present 5 weeks after treatment would be 15 percent (2.0 divided by 13.0) or a total shoot area reduction of 85 percent after treatment.

Periodic measurements were made using this DMAGR System to determine if mistletoe shoots abscise, if new shoots develop, and how quickly these new shoots mature and produce seed.

We used the 6-class DMR System to rate overstory and understory trees where individual infections were not or could not be tagged. This system divides the tree crown into thirds. Each third of crown is rated separately and given either a 0, 1, or 2 (0 meaning no infection and 2 meaning over 50 percent of the branches infected). The ratings of the thirds are added together to obtain a total tree rating with 6 being the highest infection rating possible. We modified

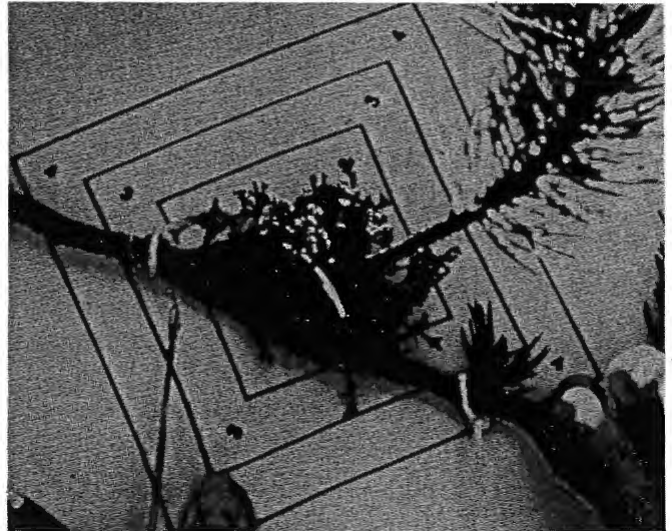


Figure 1. Dwarf Mistletoe Area Grid Rating System used to determine total sq. inch area of individual infections.

this system slightly to detect only visible dwarf mistletoe shoots so that we could document if shoot abscission occurred or not. Binoculars were used to detect shoots in tall trees.

Ethephon was applied in water at various concentrations with and without surfactant using different kinds of sprayers during the following tests from 1983 to 1985 in Colorado:

1983 Treatments

Nine different ethephon treatments were applied with a hand-held bottle sprayer to individual infections on lodgepole pine on 12 August 1983 in the Sage study area and on 15 August 1983 in the Fool study area, Fraser Experimental Forest. Some treatments included the addition of 1 ml of a surfactant and 36 ml of Dimethyl sulfoxide (DMSO) in a 1000 ml solution. For each treatment, we tried to get at least 10 male and 10 female dwarf mistletoe plants on two to four trees. The sq. inch shoot area was measured and compared using the DMAGR System before and after treatment. Infected shoots were sprayed until run-off about 2 weeks before berries were expected to disseminate seed. Weather conditions at time of spray were recorded. Temperatures in both Sage and Fool areas were in the mid to high sixties (F) with partly cloudy skies. The Sage area had some rainfall about an hour after treatment. Details of treatments follow:

^{1/} The use of trade names in this publication is for reader information only and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Treatment ^{a/}	Ethephon ppm	Surfac- tant	DMSO	No. Infections	
				Male	Female
1	500	Yes	No	10 S	10 S ^{b/}
2	500	No	No	10 S	11 S
3	1000	Yes	No	13 S	10 S
4	2500	Yes	No	11 S	10 S
				10 F	10 F
5	2500	No	No	10 S	12 S
6	2500	Yes	Yes	10 S	11 S
				16 F	4 F
7	Control	Yes	No	10 S	11 S
				10 F	9 F
8	Control	No	No	11 S	11 S
9	Control	Yes	Yes	11 S	11 S
				10 F	12 F

^{a/} Treatments 1-9 were applied at the 9,000 ft elevation in the Sage study area and treatments 4, 6, 7, and 9 were applied at the 9,400 ft elevation in the Fool study area.

^{b/} S=Sage study area, F=Fool study area

1984 Treatments

Based upon excellent 1983 results, we did a test with ethephon on 13 August 1983 using the same 2500 ppm ethephon concentration but using half the amount of surfactant, or 0.5 ml per 1000 ml of solution. In this test, we used a back pack mistblower to apply ethephon to 12 trees with 49 male and 50 female infections in the Gage study area, Fraser Experimental Forest. Whole trees were sprayed where they were small (10 to 15 ft) enough to be covered, and only lower branches were sprayed of taller trees. An application of water only to eight trees with 33 male and 33 female infections served as a control. Other methods were the same as those used in 1983. At the time of application, the temperature ranged from the low to high sixties (F) and the skies were partly cloudy.

1985 Treatments

In 1985, we set up three lodgepole pine study areas: two at the Headquarters area on the Fraser Experimental Forest and the other on the Cutthroat Bay Campground in the Arapaho National Recreation Area.

Approximately 300 high value trees in the Cutthroat Bay Campground were treated with 2500 ppm ethephon with X-77 surfactant using a truck-mounted hydraulic jet hand-sprayer on 12-13 August 1985. The tallest trees ranged from 55 to 65 ft tall. All test trees were numbered and mapped. Using the DMAGR System we measured 110 individual dwarf mistletoe infections on 17 trees. In addition, 20 infected overstory and 15 infected understory trees were rated using the 6-class DMR System. An unsprayed area of the campground served as a control. In the control area, we selected 22 trees with 113 infections for evaluation with the DMAGR System and 20 overstory and 15 understory trees for evaluation with the DMR System.

The campground was closed for 3 days and all picnic tables and grills were covered with plastic during spray operations. The spray area

was divided into compartments using string to help make sure all trees were treated. Three people were required to complete the spray: one to spray, one to make sure all trees were sprayed, and one to move the spray hose around obstacles and to be alert for safety hazards. An average of 1 gallon of solution was applied to each tree. Trees were sprayed from two different sides to achieve good coverage. The 300 trees were sprayed in 3 hours. At time of application, temperatures ranged from 40 to 70 (F) with mostly sunny skies and light to gusty winds.

To determine the effects of ethephon, if any, on surrounding vegetation, we set up photo points in treated (N=10) and control (N=10) areas. Timing of dwarf mistletoe seed dispersal and shoot abscission was monitored by placing 2 x 2 ft cloth traps on the ground under infected trees in treated (N=16) and untreated (N=15) areas. The dwarf mistletoe shoots and seeds collected on these traps were counted daily, except for weekends, from 14 August to 20 September 1985.

We established a duplicate study on the Fraser Experimental Forest, Headquarters study area. Fifty individual dwarf mistletoe infections on 11 trees and 11 infected overstory and 9 infected understory trees were treated with ethephon and rated by the two dwarf mistletoe rating systems. The tallest trees ranged from about 45 to 55 ft. These trees were sprayed on 8 August 1985 when the weather was mostly sunny with temperatures in the lower seventies (F), and light, gusty winds. For a control, we measured 53 individual infections on 13 trees and rated 10 overstory and 11 understory trees. The methods used here were the same as those used at the Cutthroat Bay Campground except that a combination of Nu-film 17 and Spray-Aide was used as a surfactant instead of X-77 and the control received a water only spray. Seven cloth seed traps were placed in the ethephon-treated area and eight were placed in the control area.

A smaller study was done along the Fraser Experimental Forest Compound Road. Twenty-five trees bordering the road were rated using the DMR System. A 2500 ppm ethephon concentration plus X-77 surfactant was applied on 13 August 1985 to trees by using the hydraulic hand-jet sprayer. Sixteen unsprayed trees served as a control. Temperature at time of application was in the low seventies F with a clear sky and light breeze.

On 19 August 1985, we applied 2500 ppm ethephon containing X-77 surfactant to 41 individual A. vaginatum infections on 11 Ponderosa pine in the Roosevelt National Forest by using a hand-held bottle sprayer. Seventeen infections on five trees sprayed with water served as a control. Methods were the same as those used in 1983 tests. Temperatures were in the mid-sixties (F) with cloudy skies and scattered thunderstorms in the area.

1983 Treatments

We tested nine different treatments in the 9,000 ft Sage study area. Treatment 4, (2500 ppm ethephon and surfactant) and treatment 6, (2500 ppm ethephon with surfactant and DMSO) were the most effective (table 1, figs. 2 & 3). Many of the dwarf mistletoe shoots and seed capsules had shriveled up and fallen off infections as soon as 2 weeks after treatment, leaving only the basal cups. Treatments 4 and 6 caused 74 to 100 percent shoot abscission by 38 days after treatment, the same abscission rate as found in the Livingston et al. (1985) eastern dwarf mistletoe study. This was in contrast to control treatments 7, 8, and 9, in which the natural rate of shoot abscission ranged from 0 to 11 percent. The 500 and 1000 ppm ethephon concentrations caused some increases in shoot abscission, but were not as effective as the 2500 ppm concentration.

In the 9,400 ft Fool study area, four different treatments were tested (table 1). Ethephon treatments 4 and 6 caused shoot abscission of 93 to 100 percent in contrast to control treatments 7 and 8 where abscission ranged from 0 to 10 percent of the shoots, 34 days after treatment.

In both Sage and Fool study areas, there was a tendency for more abscission to occur in male than female shoots and when a surfactant was used. The addition of DMSO had no major effect on shoot abscission.

Readings of test trees on 28 September 1984 and 12 August 1985 revealed that some ethephon-treated infections had some newly developing shoots, mostly at the margins of infected tissue, but that no seed had developed. In the Sage area, 54 infections had complete abscission of dwarf mistletoe shoots. Of those, 32 (59 percent) had newly developing shoots 2 years later. In the Fool area, there was complete shoot abscission of 39 infections, and 25 (64 percent) of those had some new shoots 2 years later. However, no shoots were mature enough to produce seed. We did not notice any harmful effects of ethephon on wildlife, tree foliage, buds, or surrounding vegetation. Natural abscission continued on some control infections, but many original female plants continued to produce seed.

1984 Treatments

In the Gage study area, where 2500 ppm ethephon with surfactant was applied with a back pack mist blower, the total sq. inch dwarf mistletoe area was reduced 97 percent for female shoots, from 248.0 to 6.3 sq. inches, and 99 percent for male shoots, from 274.0 to 2.5 sq. inches, by 19 days after ethephon treatment (table 1). The total sq. inch area of control shoots decreased 62 percent for female shoots, from 153.0 to 58.3 sq. inches, and 55 percent for male shoots, from 217.0 to 97.0 sq. inches, by 19 days after treatment. This unexpected loss, the greatest from our six studies, was due to fungal parasites that caused abscission of many control shoots.

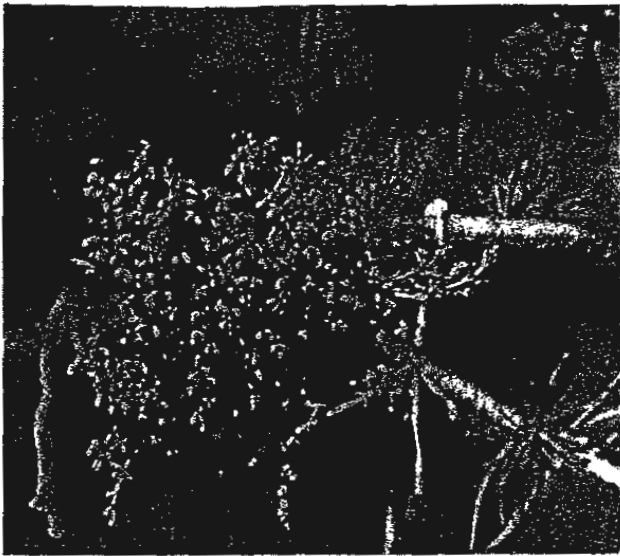


3 years after treatment



Figure 2. Ethephon control of Arceuthobium americanum on a lodgepole pine bole infection before and 3 years after an ethephon treatment was applied with a hand-held bottle sprayer, Fraser Experimental Forest, CO.

before treatment



5 weeks after treatment

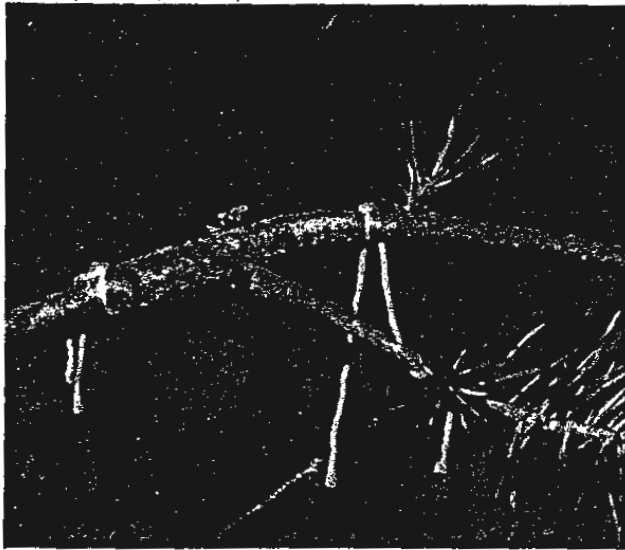


Figure 3. Ethephon control of *Arceuthobium americanum* on a lodgepole pine branch infection before and 5 weeks after an ethephon treatment was applied with a hand-held bottle sprayer, Fraser Experimental Forest, CO, 1983.

We observed no damage to lodgepole pine foliage or surrounding vegetation in August 1984. Measurements made 1 year later, on 12 August 1985, showed that new shoots were present on some infections, mostly at the margins of infected tissue. Of the 69 infections that had complete shoot abscission, 29 (42 percent) had new shoots 1 year later. However, no shoots were mature enough to produce seed.

1985 Treatments

In the Cutthroat Bay Campground, where 2500 ppm ethephon with surfactant was applied with a hydraulic hand-jet sprayer, the 6-class DMR average on ethephon-treated overstory trees dropped 30 percent from 5.3 before treatment to 3.7, by 63 days after treatment (table 2). The DMR average for understory trees dropped 81

percent from 2.6 to 0.5. The average DMR before and after for control overstory and understory trees essentially remained the same at 5.5 and 5.6, and 4.3 and 4.4, respectively.

At Cutthroat Bay, the total sq. inch dwarf mistletoe shoot area of individual infections was reduced 78 percent for female shoots, from 170.0 to 36.8 sq. inches, and 87 percent for male shoots, from 255.0 to 32.8 sq. inches, by 63 days after ethephon treatment (table 1). There was an abnormal increase in the total sq. inch area of the control dwarf mistletoe shoots from the first reading to the last reading because two different people made the readings--the only time this was done during these studies. But the result still showed that no major shoot abscission occurred in the control.

The peak dwarf mistletoe seed dispersal season began 1 week after ethephon was applied. It occurred from mid-August to the first week in September. There was no major difference in the number of mistletoe seeds trapped on seed traps between the treated (N=550) and control (N=518) area, probably because seed dispersal had already begun at the time of treatment. However, there was a major difference in the number of dwarf mistletoe shoots collected on traps: 811 in the treated area compared to 191 in the control area. Ethephon did cause some foliage damage to most of the treated lodgepole pine. It caused damage to 3-, 4-, and 5-year-old foliage but with little damage to 2-year-old foliage and no damage to 1-year-old foliage. The foliage turned brown and eventually fell off affected trees a few weeks after treatment. There was also some foliage damage to common juniper, *Juniperus communis* L. subsp. *alpina*, in the photo point plots. To date, losing foliage has not seemed to have seriously harmed affected trees. Ethephon did not appear to have an impact on wildlife or on any other vegetation in the photo point plots.

Excellent control was achieved in the Headquarters study area on the Fraser Experimental Forest using 2500 ppm ethephon with surfactant (table 2). The 6-class DMR average on overstory trees dropped 90 percent from 4.8 before treatment to 0.5, by 70 days after treatment. All shoots abscised from understory trees. On these trees the 6-class DMR average dropped from 3.3 before to 0.0 after treatment. There was little change in the control trees. The DMR average for control overstory trees was 5.1 before and 5.2 after treatment; for understory trees it was 2.1 before and 2.2 after treatment.

In the Fraser Headquarters study area, the total sq. inch dwarf mistletoe shoot area dropped 97 percent for female shoots, from 80.0 to 2.3 sq. inches, and 100 percent for male shoots, from 30.0 to 0 sq. inches, by 70 days after ethephon treatment (table 1). The total sq. inch area of control female shoots did not decrease, but the male shoots decreased 5 percent from 73.0 to 69.0 sq. inches.

As in the Cutthroat Bay Campground study area, some older ethephon-treated foliage on most lodgepole pine turned brown in the Fraser

Table 1.--Percent *Arceuthobium americanum* female and male shoot area reduction caused by ethephon treatments on Lodgepole pine, Arapaho National Forest, Colorado, 1983-1985.

STUDY AREA AND TREATMENTS		No. of female infections	No. of male infections	FEMALE SHOOTS		MALE SHOOTS		% total shoot area reduction	
				Before treatment total sq.in.area	After treatment total sq.in.area	Before treatment total sq.in.area	After treatment total sq.in.area	female	male
<u>Sage Treatments (1983)</u>									
1	500 ppm/surfactant	10	10	20	14	20	10	30	50
2	500 ppm	11	10	15	15	16	15	0	6
3	1000 ppm/surfactant	10	13	23	14	18	7	39	61
4	2500 ppm/surfactant	10	11	18	2	20	1	89	95
5	2500 ppm	12	10	18	9	22	2	50	91
6	2500 ppm/surfactant/DMSO	11	10	19	5	23	0	74	100
7	Control H ₂ O/surfactant	11	10	24	23	22	20	4	9
8	Control H ₂ O	10	11	14	13	18	16	7	11
9	Control H ₂ O/surfactant/DMSO	11	11	20	19	17	17	5	0
<u>Fool Treatments (1983)</u>									
4	2500 ppm/surfactant	11	10	14	1	10	0	93	100
6	2500 ppm/surfactant/DMSO	4	16	7	0	19	0	100	100
7	Control H ₂ O/surfactant	9	10	10	9	10	10	10	0
9	Control H ₂ O/surfactant/DMSO	12	10	12	12	10	10	0	0
<u>Gage Treatments (1984)</u>									
	2500 ppm/surfactant	50	49	248	6.3	274	2.5	97	99
	Control H ₂ O	33	33	153	58.3	217	97	62	55
<u>Headquarters (1985)</u>									
	2500 ppm/surfactant	36	14	80	2.3	30	0	97	100
	Control H ₂ O	20	33	41	41	73	69	0	5
<u>Cutthroat Bay (1985)</u>									
	2500 ppm/surfactant	51	59	170	36.8	255	32.8	78	87
	Control	62	51	122	197	111	196	0	0

Table 2.--Percent reduction of 6-class Dwarf Mistletoe Rating (DMR) caused by 2500 ppm ethephon treatments of *Arceuthobium americanum* on lodgepole pine, Arapaho National Forest, Colorado, 1985.

STUDY AREA AND TREATMENT	OVERSTORY TREES				UNDERSTORY TREES				
	No. of trees	Before treatment average DMR	After treatment average DMR	% reduction	No. of trees	Before treatment average DMR	After treatment average DMR	% reduction	
<u>Cutthroat Bay Campground</u>									
	2500 ppm/surfactant	20	5.3	3.7	30	15	2.6	.5	81
	Control	20	5.5	5.6	0	15	4.3	4.4	0
<u>Fraser Experimental Forest</u>									
<u>Headquarters</u>									
	2500 ppm/surfactant	11	4.8	.5	90	9	3.3	0	100
	Control (H ₂ O)	10	5.1	5.2	0	11	2.1	2.2	0
<u>Compound Road</u>									
	2500 ppm/surfactant	25	3.8	1.1	70	NONE TREATED			
	Control	16	3.9	4.0	0				

Headquarters study area as did some common juniper foliage. Other vegetation in the study area was not affected. As in Cutthroat Bay, there was little difference in the number of dwarf mistletoe seeds trapped between treated (N=75) and control (N=125) areas because the seed had already begun to disperse at the time of the spray. We expect a major difference between treated and control areas in the number of seeds trapped in 1986. As expected, the number of shoots collected on seed traps was much higher in the treated area (N=183) than in the control area (N=71).

The DMR of the ethephon-treated lodgepole pine along the Fraser Experimental Forest Compound Road study area dropped 70 percent by 33 days

after treatment from 3.8 to 1.1 (table 2). The DMR for the control essentially remained the same, 3.9 before and 4.0 after treatment.

In the Meeker Park study area where 2500 ppm ethephon with surfactant was applied with a bottle sprayer to ponderosa pine, the total sq. inch dwarf mistletoe area of both male and female shoots was reduced 77 percent, from 160.0 to 36.0 sq. inches, by 59 days after ethephon treatment. The total sq. inch area of control shoots increased 3 percent, from 33.0 to 34.0 sq. inches. No foliage damage was observed on ponderosa pine, although most spray was applied directly to individual infections and only drifting spray came in contact with foliage.

We achieved consistently good results by applying 2500 ppm ethephon plus surfactant in August, using three different kinds of spray equipment. Abscission rates of 74 to 100 percent of individual infections of A. americanum on lodgepole pine and A. vaginatum on ponderosa pine were achieved. Similar results were reported by Livingston et al. (1985) with A. pusillum on black spruce.

As found in all studies, subsequent growth of dwarf mistletoe shoots remained unaffected because ethephon does not kill the parasite within infected tree tissue. Based on this fact, Livingston et al. (1985) predicted that abscission of dwarf mistletoe shoots can prevent the spread of A. pusillum in black spruce for 2 years. We predict that longer control is possible with A. americanum and A. vaginatum because of their longer life cycles. The time required for fruits to mature differs greatly among dwarf mistletoes: only 5 months for A. pusillum, a year or more for other taxa (Hawksworth and Wiens 1972).

Our results show that new shoots develop on some infections 1 to 2 years after ethephon-caused abscission. It takes up to 4 years from the time first shoots develop until mature fruits are produced (Hawksworth and Wiens 1972). Therefore, with ethephon control, we expect control for at least 4 years and, perhaps even longer. Seed production and diasemination will be much reduced during the time it takes for large masses of mature shoots to redevelop on ethephon-treated infections. Also, some older treated infections may never produce as many or any mature shoots again. This is especially true of nonsystemic infections because new shoots are restricted to the original infection area. This prevention or delay in significant seed production will greatly reduce the spread and amount of infection. Even when new infections begin to occur, it will take a long time before these infections will produce seed. Hawksworth and Wiens (1972) report the minimum time from initial infection to seed production averages 6 years in A. americanum and 7 to 8 years in A. vaginatum, but the time for shoot and seed production from established endophytic systems is unknown.

As expected, natural abscission of dwarf mistletoe shoots occurred, but we never observed any massive shoot abscission in control infections as occurred in ethephon-treated infections. There have been reports that shoots die after fruits mature, but Hawksworth and Wiens (1972) report that this is certainly not normal. They observed individual shoots of A. americanum and A. vaginatum subsp. cryptopodum that produced successive crops of fruits for up to 5 years and were still living. To be able to remove such shoots with an ethephon treatment would certainly be helpful in controlling the disease by preventing the spread of the parasite within the tree or to nearby trees. Less infection will reduce nutrient drain and increase tree growth.

We had good to excellent control in high value understory and overstory trees in the

headquarters area on the Fraser Experimental Forest, and in understory trees in the Cutthroat Bay Campground. Less control was achieved in the Cutthroat Bay Campground overstory trees probably because the trees were taller than those in the Fraser study area and this made it more difficult to get good spray coverage in upper tree crowns. Prevention of dwarf mistletoe spread from overstory to understory trees would allow noninfected understory trees to become well established. This is especially important in high value recreation areas where trees help provide aesthetically pleasing landscapes or in high value stands where the understory component is important to the future stand. It is even more important where there are few, if any, good alternative species that can be planted on a given site. Planting susceptible trees under an infected overstory may be possible with ethephon control where there are no suitable non-host alternative species available. In such cases, two or three ethephon applications to infected trees over 10 to 20 years might provide sufficient control, along with recommended silvicultural controls, to prevent or reduce infection. It would also allow those trees already infected to outgrow dwarf mistletoe to the point where the parasite would not be a significant factor.

All three kinds of spray application equipment were effective. The hand-held bottle sprayer worked well for treating individual infections; the back pack mistblower worked well for treating 10 to 15 ft tall trees. The truck-mounted hydraulic hand-jet sprayer was useful in treating understory and overstory trees up to 55 ft tall. Some foliage browning and loss occurred using this equipment that was not experienced with the other two kinds of equipment. However, neither current-year growth or buds were affected on lodgepole pine. The trees did not appear to be harmed by the premature needle loss of some of the older foliage, but only additional time and observation will confirm this.

So far, we have not been able to identify the cause of the older foliage browning and casting on lodgepole pine as a result of applying 2500 ppm ethephon plus surfactant with a hydraulic hand-jet sprayer. More volume of spray was applied by this method than by the other two methods, and this may have led to accelerated abscission of needles already predisposed to needle casting. Early stages of cellular senescence must be reached before tissues become ethylene sensitive. A plant threshold must be reached before externally applied ethylene becomes effective. After the threshold is reached, leaf abscission appears to be a function of internal ethylene content and, as leaves age progressively, less ethylene is required to defoliate them (Doubt 1917).

Loss of older needles could have a positive effect in certain situations. Griffing and Ursic (1977) reported loss of 1-year-old needles of potted loblolly pine, P. taeda L., seedlings sprayed with 5000 ppm ethephon in water. Neither survival nor current-year needles were affected. Griffing and Ursic suggested that loss of foliage under field conditions could lead to a reduction

of evapotranspiration losses from southern pine forests to increase water yield. This could also conserve water for trees growing on droughty soils. Lodgepole and ponderosa pine are frequently found on droughty soils, and dwarf mistletoe infection is often more severe on such sites. Water conservation through loss of older needles and mistletoe shoots caused by ethephon treatments might benefit tree health and growth under certain conditions.

In 1984, we sprayed 80 containerized lodgepole pine seedlings with 2500 ppm ethephon with surfactant by using a hand-held bottle sprayer. Eighty seedlings served as a control. There was no noticeable difference in height growth or needle retention between treated and control trees 9.5 weeks after treatment (Authors' unpublished data).

Additional studies are needed to understand the long-term effects of ethephon treatments on dwarf mistletoes, their hosts, and surrounding vegetation. Meanwhile, direct application to individual infections using a hand-held bottle sprayer or to individual infected trees using a backpack mist blower now seems feasible once EPA registration is completed. Further research is also needed to determine the feasibility of other application methods including aerial application under forest conditions.

CONCLUSION

Dwarf mistletoes are a leading cause of growth loss and mortality on conifers in North America. Our studies have shown that ethephon will stimulate abscission of up to 100 percent of the dwarf mistletoe shoots of two dwarf mistletoe species affecting lodgepole and ponderosa pines. We feel that ethephon control will prevent or reduce spread and infection for up to 4 years and, perhaps, longer. The development of an effective, safe, and economical plant growth regulator control for dwarf mistletoes would have immediate application and would significantly reduce the impact of a major forest disease, especially in high value stands, recreational areas, seed orchards, and ornamental plantings around homes, cabins, and business establishments. It would also provide forest managers with another control option that could be used in conjunction with successful silvicultural controls currently being used.

ACKNOWLEDGEMENTS

This was a cooperative effort of the USDA Forest Service (Forest Pest Management Region 2, North Central Forest Experiment Station, Rocky Mountain Forest and Range Experiment Station, Arapaho and Roosevelt National Forests), the University of Minnesota, and Union Carbide. The authors wish to thank Bill and Ulrike Livingston, Jim Kemper, Tim Garvey, John Beckly, Robert Alexander, Laura Merrill, Wayne Shepperd, Mark and Nora Nilles, Mary Doupe, Martin Quanci, Mary Lou Nicholls, Prasad Rao, Charles Troendle, Bob Blanchette, Dave French, Mark Brenner, and Frans Schuitemaker for their help during this study.

LITERATURE CITED

- DeWilde, R. C. 1971. Practical applications of (2-chloroethyl)phosphonic acid in agricultural production. Hort. Science 6:364-370.
- Doubt, S. L. 1917. The response of plants to illuminating gas. Bot. Gaz. 63:209-224.
- Drummond, David. B. 1982. Timber loss estimates for the coniferous forests of the United States due to dwarf mistletoes. USDA Forest Service, Forest Pest Management, Methods Application Group, Fort Collins, Colorado, 24 p., Report 83-2.
- Griffing, C. G., and S. J. Ursic. 1977. Ethephon advances loblolly pine needle cast. For. Sci. 23:351-354.
- Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service Gen. Tech. Report RM-48. 7 p.
- Hawksworth, F. G., and D. Wiens. 1972. Biology and classification of dwarf mistletoes (*Arceuthobium*). USDA Forest Service Agriculture Handbook 401, 234 p. Washington D.C.
- Lightle, P. C., and E. H. Lampi. 1973. Herbicides ineffective in controlling southwestern dwarf mistletoe. USDA Forest Service Res. Note. RM-242. 3 p.
- Livingston, W. H., and M. L. Brenner. 1983. Ethephon stimulates abscission of eastern dwarf mistletoe aerial shoots on black spruce. Plant Dis. 67:909-910.
- Livingston, W. H., R. A. Blanchette, M. L. Brenner, and K. J. Zuzek. 1985. Effective use of ethylene-releasing agents to prevent spread of eastern dwarf mistletoe on black spruce. Canadian J. of For. Res. 15:872-876.
- Quick, C. R. 1964. Experimental herbicidal control of dwarf mistletoe on some California conifers. USDA Forest Service Res. Note PSW-47. 9 p.
- Scharpf, R. F. 1972. Summation of tests for chemical control of dwarf mistletoe. In Proc. West. Int. Forest Disease Work Conf., 13-17 September 1971, Medford, Oregon. pp. 80-83.
- Scharpf, R. F., and J. R. Parmeter, Jr., tech. coords. 1978. Proceedings of the symposium on dwarf mistletoe control through forest management, 11-13 April 1978, Berkeley, California, USDA Forest Service Gen. Tech. Rep. PSW-31. 190 p.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

Forest Decline in Europe

P. Schütt

Abstract

An overview is given on the peculiarities, the development and the possible causes of forest decline, a disease-syndrome which in large parts of the northern hemisphere seems to damage forests as ecosystems. Air pollution most probably belongs to the primary causes, although the classical components SO₂ and HF cannot explain the phenomenon.

Since the beginning of the eightieth forest pathologists in Central Europe became aware that a new type of disease began to spread very rapidly over old-age conifer forests of lower and medium elevation in several parts of Central and Southern Germany, of Austria, Switzerland, of Northern Italy, and Yugoslavia. Old growth of European Silver Fir (*Abies alba*) and Norway spruce (*Picea abies*) was most severely affected at first, one or two years later Scots Pine (*Pinus sylvestris*) and European Beech (*Fagus sylvatica* L.) followed, indicating that the phenomenon was not restricted to one species only but by and by was attacking the most important tree species, broadleaved ones included.

So the problem very soon beyond the economic aspects received a certain attention also by environmentalists. Toget-

her with foresters and biologists they saw a concrete danger for the continuation of natural and secondary ecosystems and therefore alarmed the public. This again led to a very engaged public debate. For years, acid rain, air pollution and forest decline were the keywords in many discussions. Newspapers, radio and television reported daily about the scenery around the suffering forests. Since industry, administrations and politicians were also involved and expressed their own (differing) ideas, opinions and hypotheses, the situation became more and more confusing. In front of this background it became almost impossible to establish a cool and objective scientific argumentation. Even now, after about six years of "Waldsterben"-experiences, it is still hard to draw a clear picture of the present situation and especially of the pros and contras on the causal effects. Almost everything is still moving and science is far away from giving a precise answer on the question what are the causes of decline and how does it develop.

1. Definitions and peculiarities of Waldsterben

Since the beginning two contrasting definitions of "Waldsterben" are given :

1. It is understood as an outbreak of a number of well-known forest diseases which by chance (or predisposed by climatic events) appear at the same time and at the same place. Consequently normal application of control techniques or of prophylactic silvicultural practices then would help to solve the problem.
2. Waldsterben has to be understood as a disease of forest ecosystems, caused by anthropogenic toxification. Not only trees are affected but also microorganisms, zoological and botanical members of the system as well as its chemistry and physics. This leads to reduced vigor of many biological components for instance of trees which will be predisposed for all kinds of abiotic and biotic attacks. Under this supposition control measures would rather harm than help.

No doubt that these two different kinds of background-philosophy necessarily must lead to different strategies of research, too.

Unrelated to these more general considerations we have to state why the peculiarities of the forest-decline-phenomenon justify to talk about a new and unique pathological event. The following characteristics may show what is meant.

1. Unknown symptoms of decline in old

spruces appeared for the first time in different localities of Southern Germany. Lower elevations were affected earlier than higher ones. Within one year, forest damages of the same type could be observed in Austria, Switzerland, Italy, Scandinavia, Poland and Yugoslavia. There was no evidence at all of a typical epidemiological pattern of disease development.

2. Since 1980 a clear progress of decline intensity is to be noted.

- Geographically : with the exception of Portugal, Albany, Bulgaria, Greece and Rumania where no Waldsterben-symptoms have been reported yet, the decline has spread all over Europe and is increasing in intensity from year to year.
- Biologically : starting with fir, spruce, pine and beech the syndrome in the meantime has reached the majority of native tree species, some introduced ones like Douglas-fir, Black Pine or Giant Sequoia, included. Shrubs and herbs begin to suffer, too.

3. In principle forest decline is not influenced by differences in geology and soil. It occurs on wet and dry, on acid and basic, on poor and fertile substrates. Regional differences in climate do not play a role, either.

4. Since the disease occurs the same way in natural reservations as well as in intensely managed even-aged forests and since it affects mixed stands as well as monocultures, silvicultural practices obviously do not influence the outbreak of "Waldsterben".

5. In a number of cases new disease-symptoms or symptom combinations occur. This is for instance true for *Picea abies*, *Fagus sylvatica*, *Betula pendula*, and *Larix decidua*.

6. With respect to the primary causes of forest decline we are far away from precisely pointing out one particular component, component-combination or chain of different compounds which without any doubt originally induce the syndrome. Instead of a convincing proof we have to argue with probabilities. So it is almost generally accepted scientific opinion that air pollution is responsible for "Waldsterben". Or as I would prefer to say : "Forest decline probably would not occur without air pollution".

So, altogether European Forestry suddenly has been confronted with an unknown pathological phenomenon which seems to affect forests as an ecosystem, which is up to now poorly understood and which has to be controlled immediately although its causes are not fully known,

yet.

How to recognize forest decline?

At first sight, symptomatology of forest decline is heterogenous and rather complicated.

Beyond a certain interspecific variation which is to be expected, there are regional and local differences in the symptoms, however, sometimes also annual changes. Moreover a pronounced increase in susceptibility against normal pathological events is obvious for several tree species. This is true for insects, fungi and abiotic influences as well. Especially a higher frequency of weak parasites is apparent.

These symptomatological variations are easier to understand if we implicate a primary pathological influence which weakens tree species (or the total forest ecosystem) and consequently acts as a predisposing influence for secondary events. These secondary events, however, imprint the actual picture of symptoms, considerably.

Apart from these sometimes confusing details a number of symptoms is jointly to be observed in most of the affected tree species investigated.

- reduction of foliage
Transparency of the crown as a result of reduced leaf numbers, and/or reduced leaf size and/or alteration of branching habits is common for all affected conifers and broadleaf-species. In addition in beech, maple, birch and ash an early autumnal discoloration and leaf fall (starting already in August) is typical for diseased trees. On the other hand, casting of green (to grayish-green) needles is characteristic for affected gymnosperms.
These symptoms often are explained as a form of early senescence. They seem to be combined with disharmonies in the level of growth hormone substances.

- destruction of the fine root system.
Numerous investigations in Norway spruce and Silver Fir indicate that the fine root system of diseased trees compared with these of healthy looking ones
 - show a much higher mortality rate
 - have a reduced reproductive ability
 - are much less intensely mycorrhized.

All these different types of root damage operate in the same direction : they reduce the rate of water- and nutrient uptake for a given size of tree crown. Thus root destruction necessarily will

lead to detrimental effects on the foliage. On the other hand a primary damage to important physiological processes in leaves (photosynthesis, enzyme-synthesis) vice versa will reduce the supply of the fine root system with primary and secondary organic plant substances.

That means that the question, whether the roots or the leaves are attacked first, has to be left open.

The cause of "Waldsterben"

As mentioned before, the primary cause of forest decline is still unknown. Five years of research activities, however, brought up a number of hypotheses which in most cases attribute "Waldsterben" to different components of air pollution. Since air pollution, however, is a very common phenomenon in Central Europe for about 120 years, since typical pollution damages in forest trees are very well described at least since 1880, the present decline syndrome must be attributed to other components than the classical air pollutants SO₂ and HF.

This consideration is at least partially accepted by the majority of hypotheses, presently under discussion:

- O₃-hypothesis (Prinz, Zoettl, Zech etc.). Photooxidants mainly O₃, cause leaching of nutrients from needles deficiency of Mg, intensified by acid mist in the higher elevations.
- Acid rain-hypothesis (Ulrich and coworkers, Bauch). Wet depositions of acidified precipitation induce exchange processes in the soil in the course of which (1) important nutrients are washed out (podsol-like processes) and (2) phototoxic Al- and Mn-Ions are concentrated in the rhizosphere.
- Stress-hypothesis (Schütt and coworkers). Permanent influence of a mixture of many air pollutants (aerosols, organic compounds, photooxidants included) reduces primary metabolic processes like photosynthesis or enzyme-synthesis (hidden symptoms) → reduced vigor of trees → reduced supply of fine root system → predisposition for pathogenic events → destabilisation of the ecosystem.

Some more or less isolated ideas which give severe winterfrost (Rehfuess) or unknown microorganisms like mycoplasma or virus (Kandler) first rank in the interaction of causal factors are not taken for very probable.

All these hypotheses do have their weak points. Furthermore in the course of time they tend to diverge that to converge. This, by the way, is not only

true for their scientific content but also true for the coordination of research.

So, at the moment between the different schools there is not much more consensus than the conviction that not one single factor is responsible for the forest decline syndrome but a combination of primary and secondary factors.

This is more than meager in view of the threat of our forests. If we are right, that "Waldsterben" is a man-made phenomenon then we have to react clearly and immediately. For the field of research this means to establish at once a convincing international strategy and this not only in Europe. American forests of the Northeast seem to suffer from a comparable event and I dare to doubt that your beautiful forests along the Pacific Coast are really as untouched as many people still believe. So, better watch the situation in Europe and join us in our research activities against forest decline.



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

A VISUAL AIN'T A VISUAL IF YOU CAN'T SEE IT

Delbert E. Thompson

No matter how sound or important your message, if your visual aids are poor, chances are you will not communicate with the audience. A picture really can be worth a thousand words. What are visual aids? The term includes slides, posters, exhibits, overheads, photographs, and drawings. When do you need visual aids? You need them when words alone do not tell the story. My objective in this paper is to suggest ways to improve your illustrations--slides, figures for publications, posters, or overheads--and to use whatever resources you have.

THE BASICS

Begin improving your visual aids by critiquing what you see. When you see something you like--or something you do not like--ask yourself why. And watch how other people react. You can learn from the success or failure of the illustrations you encounter every day. Why do you like what you see? Probably one reason you like an illustration is that you do not have to work hard to get its message. An effective visual aid does not need an explanation to get its point across. Need a picture of a tree? Show one tree--not the forest; the viewer of the whole forest may still be able to get the message, but not without extra effort. Look at what works in visual aids, and then pull the best together for your own work.

Planning good graphics--like writing a good paper or giving a good talk--requires taking time at the beginning to answer a few basic questions. Planning makes the difference between great products and indifferent ones.

Delbert E. Thompson is Art Director
for Pacific Northwest Research Station,
Portland, Oregon.

AUDIENCE

Step one is to know your audience and its needs before you ever set a pencil to paper. Who are you talking to? How much background or knowledge about your subject do they have? How big is that audience? Where is it located? What is the context--formal, folksy, or somewhere in between?

ROUGH DRAFT

Step two--no matter what your medium--is to produce a rough draft of your artwork. The rough draft lets you look at the illustration and ask yourself, what is the most important point for my audience to grasp? What is the next most important point? And so on. What logical flow do you want? What visual flow do you see for your final product?

KEEP IT SIMPLE

Art can capture attention; it can also turn people off. Too much complexity in illustrations, like long-winded prose, is likely to cost you your audience. Probably the most important guideline I can offer for any kind of visual aid is to keep it simple. Specific guidelines for how much is too much, which depends partly on the medium, will be offered as each medium is discussed.

KINDS OF VISUAL AIDS

Different media--slides, figures, posters, and overheads--can be used to provide specific and different effects. Each medium has its own special requirements to be effective, but they also have some attributes in common.

All media can communicate, whether you have a complete story to tell or only a fragment. Probably 80 percent of the effect of good illustration is psychological; you can relax an audience, command its attention, or keep its interest by being aware of the effect a balanced use of color, complexity, shape, and simplicity have on most people. If you want people to receive your message, you need to pay attention to how your illustration is likely to affect them.

SLIDES

The principal problem in keeping slides simple is the overwhelming temptation to jam too much information on a single slide. A slide should have only one message. Speakers tend to use too few slides, thinking that more slides drag out the presentation. But too much stuff on one slide--besides being dull--actually increases reading time. For example, by the time you have oriented your audience to the location of the important ultimate value of pi: "Now, if you'll just look at the third number in the fourth column here in the teensy print..." you probably could be two or three slides down the track if you had featured that important piece of information on an extra slide.

THE SLIDE GRID

Balancing the amount of information you need to get across to the audience with the amount that can be absorbed is critical. One excellent method for assuring balance is to use a slide grid, in which the field, or area, of the slide is used or enlarged into six different-sized rectangles proportional to the actual slide boundaries (fig. 1). Each of these proportional units or "fields" can be used as the boundary for your artwork. The field you use depends mostly on the effect you want. This method will help you learn how much is too much.

Fields provide a sense of proportion to your artwork. The larger the field, the smaller (proportionately) a given piece of artwork is going to look. The effect is like standing on a rock bluff in a 2-acre pasture (or "field"), looking across at a cantankerous longhorn bull in the middle of the pasture. Double the size of the pasture proportionately (4 acres, or a field of two) without changing the size of the animal, and he appears less significant. Double the field again (8 acres, or a field of three), and you have cut that critter down to a manageable size with no hassle at all.

Reverse the process, and you're back to a pretty overwhelming view. This principle ties in with all the rough-draft work you do. The important point is to use the slide grid to emphasize information or to keep it in the background. Remember that the slide grid is a tool of proportion: the visual information you put in any field--whether a field of one or a field of six--will be proportionate to that area. Using a field of six will not give you a bigger bull!

The slide grid (fig. 2) consists of rectangles at a 2:3 ratio--the ratio of a 35-mm slide. Field 1--the actual size of the slide image area--has shock power. If you use typewriter type (which you shouldn't), field 2 is the one to use. Fields 3 and 4 are the best fields to work in. Always try to keep your artwork within one or two fields. Use the smaller fields only to buy attention.

Fields 5 and 6 are usable, but proceed with caution. These are the spots where the bad guys want to put those multicolumn tables, volumes of text, and type too small to read. If you do use these fields, use fat lines and big, bold type. Keep it simple!

To take advantage of the fields concept, photocopy this grid and make your rough draft in the field you want to use. See if it will fit. Do not reduce the size of your handwriting to force it to fit; the camera will get back at you later. Do your final slide in this same field or rectangular area. When you are through, can you--at a glance--go right to the message, without having to read anything? For slides--as for the other media--a variety of techniques can help you manage visual information, but you must keep content to a workable amount!

WORKING WITH THE ART STAFF

If you have an art staff, avoid giving them too much material for any one slide. Professionally prepared slides with too much content may end up worse than slides prepared by someone with no graphics resources beyond the ability to do hand lettering but the good sense not to include too much. Here again is where rough-draft work pays off--you get the most out of your graphics resources by specifying on your roughs exactly the effect you want.

Having a competent staff or a computer to assist with your graphics helps, but you need to understand how to use the staff or computer and where to invest your dollars to help them work best for you. Special photographic effects--like superimposing titles over photo slides, computer-generated effects like neon, zooms, and spotlight spins--all make effective attention-getter slides. Special effects cost more money, but used sparingly they can jazz up your presentation. You can use spot art (a simple drawing, like a bird or tree) to enhance and communicate. For example, if you are presenting data on logs, boards, and chips, a drawing of a log that reports log data immediately orients viewers. If you lack artistic talent, watch for appropriate drawings, photocopy them, and save them for later use.

VISUAL TOOLS

Once you have identified your message, you communicate it to the audience with visual tools--lines, lettering, and colors. Lines can be varied in thickness, and type (dot, dash, solid). Lettering can be of various styles (hand-lettering, typeset), boldness (thick, thin), shape (short, tall), and size (big, little). Lines and letters can be black on white, white on black, shades of gray--or in full color.

By using these tools, you can direct viewers' eyes where you want without written words. What the eye picks up is different; use one or more of the visual tools to make your message different and thus attract attention.

For our purpose, let's assume that slides come in two general forms: color and black and white. Color slides are pictures of people and scenery; black and white are the "working" slides--titles, graphs, charts, or drawings.

Color can be added to these "black and white" slides to make a point or for emphasis. Use color to communicate, but use it sparingly. A graph with a white background, black lines, and one red dot will lead the audience right to the red dot. In a red graph with one black dot, the audience sees the black dot first because it's different.

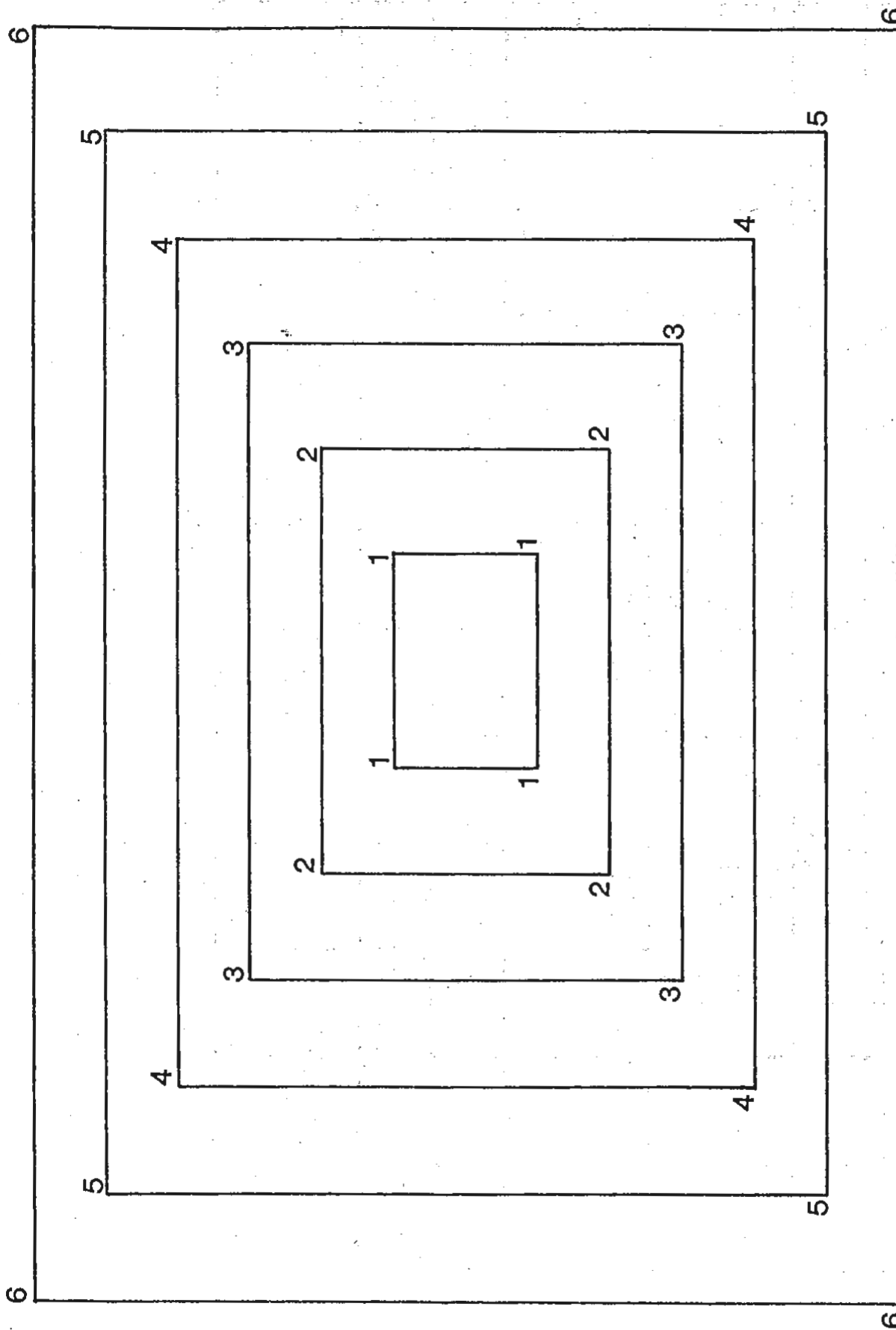


Figure 1. Each rectangle (field) represents the area of a slide: field 1 is $1 \times 1 \frac{1}{2}$ inches; field 2, 2×3 inches; field 3, $3 \times 4 \frac{1}{2}$ inches; field 4, 4×6 inches; field 5, 5×7 inches, and field 6, 6×9 inches.

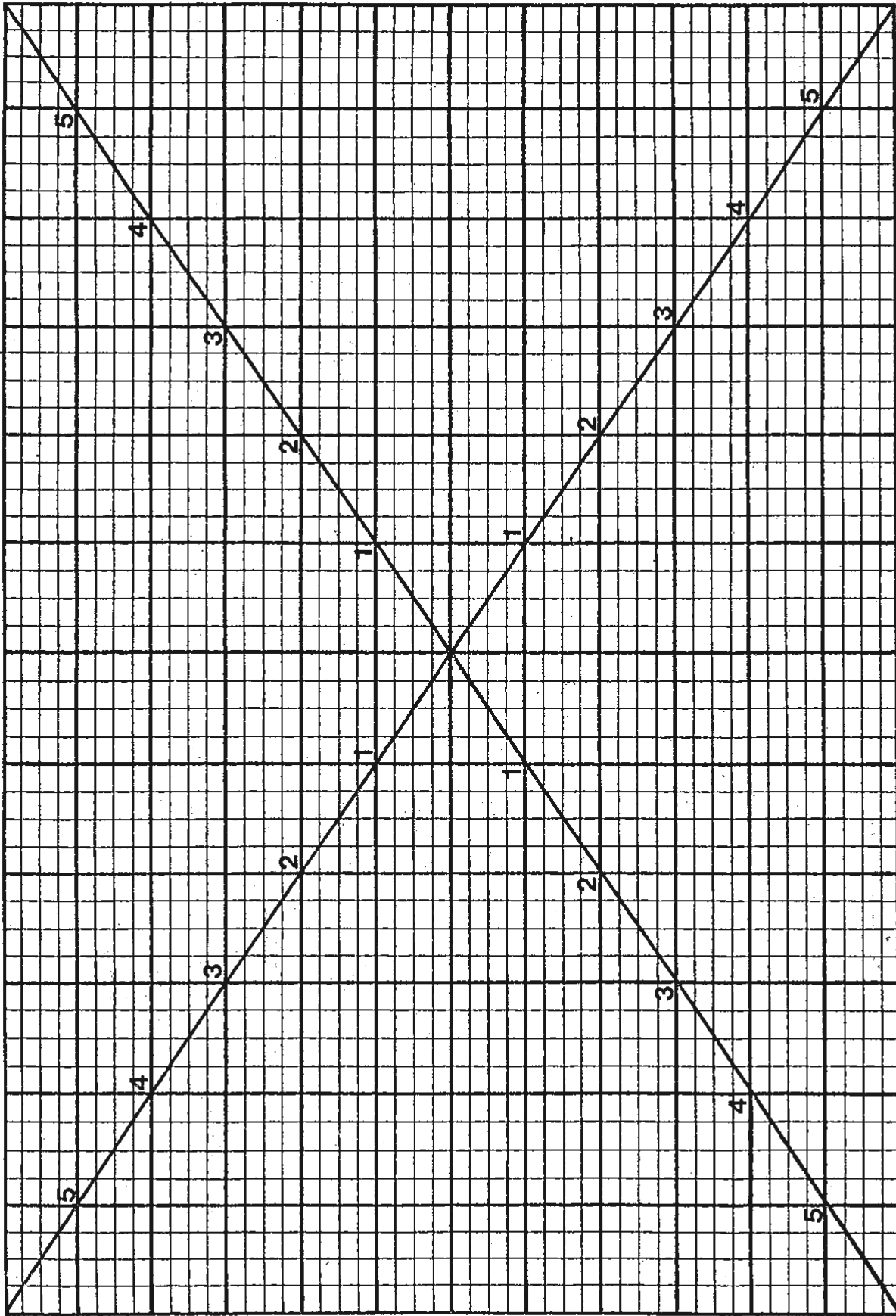


Figure 2. Layout guide (grid) for 35-mm slides.

There are three types of black and white slides--the negative slide, the positive slide, and the slide with color added to the artwork. Of these, I like the negative best; when the slide is projected, the white image on black does not have the background glare, and color can be added to highlight part or all of the slide. To add color, use a felt-tip highlighter, food color with a drop of vinegar, or slide dyes. To present progressive information (fig. 3), simply order lots of duplicates and add color to highlight information on each slide. This is the least expensive slide. It takes only 1-3 hours to process at the photolab because it takes one less step--you use the negative film as the slide. Positives (black image on white) cost more and take longer because the photo lab has an extra step to get to the positive-film stage. The art for both is handled the same; you can cut and paste or use white-out to correct mistakes, and the slide will still be good. If color is desired in positives, you or the photo lab can color the background. Highlighting with color is a problem, so use other visual tools; for instance, heavy or dotted lines, crosshatching, or bold type.

Black and white slides with color added to the artwork cost much more than the other two types. They also take longer to produce and are harder to shoot. Color artwork is less forgiving; you cannot just white-out a flaw or paste in corrections; everything shows to the camera. A 2-inch white border (using a 2:3 format) is essential around color work. Use of color can easily be overdone; and some colors just do not work together.

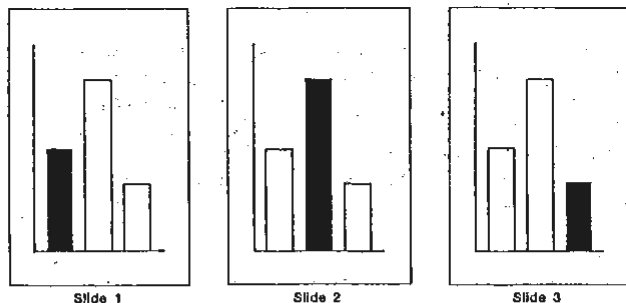


Figure 3. When information is presented progressively, color (in this illustration black is used to direct the viewer's attention).

USING COLOR

You can use color to code your presentation by providing color cues for each topic. You can take advantage of the psychological effect of color to produce the effect you want. Bright colors wake people up; some colors relax people; others irritate them. Too many colors can nullify and confuse, so be careful!

FIGURES

Figures in a publication are designed to communicate additional information beyond what is in the text. They need to be able to stand alone as a complete piece of information, and they have to be reasonably free of clutter. If they are not easy to understand, you lose the reader's attention. Figures in publications can have more information than in the other media because the audience has more time to grasp the message.

To help you get stand-alone, clutter-free figures that communicate effectively, here is another critical tip: plan and design the figure first, then write the related text copy around it. By taking advantage of the superior ability of figures to communicate certain types of information, you can save yourself the effort of describing in text what is best conveyed through figures. People remember information if they see and understand it in a picture. Tests have ranked types of illustration in the order people retain them best: photos, drawing, graphs, and tables. Very little information apparently is retained from tables.

Keep in mind that some readers look first--or only--at your figures. As for slides and other media, the best way to produce a good figure is to put together a rough draft first. By asking yourself what is the most important point, you can again pare down your figure to just essentials, keeping the content manageable and understandable.

POSTERS AND EXHIBITS

Presented posters and exhibits are important information-distributing media. Although both are often called "posters," they have different purposes. A presented poster is designed to be explained by a presenter. Text is minimal; key points are highlighted and designed to spur the viewer to ask questions. Exhibits, on the other hand, are meant to be unattended. The text will still be fairly short but needs to be self-explanatory. It is likely to be somewhat longer than for a presented poster. Sometimes you may be asked to present a poster that will also be displayed unattended; this double use requires a bit of juggling to meet both needs.

PLANNING A POSTER

Step one in planning a poster or exhibit is to find out the sponsor's requirements. How big can the poster be? How will you transport it? (A 40-foot by 60-inch display will not fit into a small airplane or car.) What kind of display space will house the exhibits? You also need to answer the following--by now familiar--questions: Who is the audience? How far away will they be? What is the context for this presentation--formal or friendly? What are the most important points? How can you use the visual flow of the design to enhance the logical flow of the content?

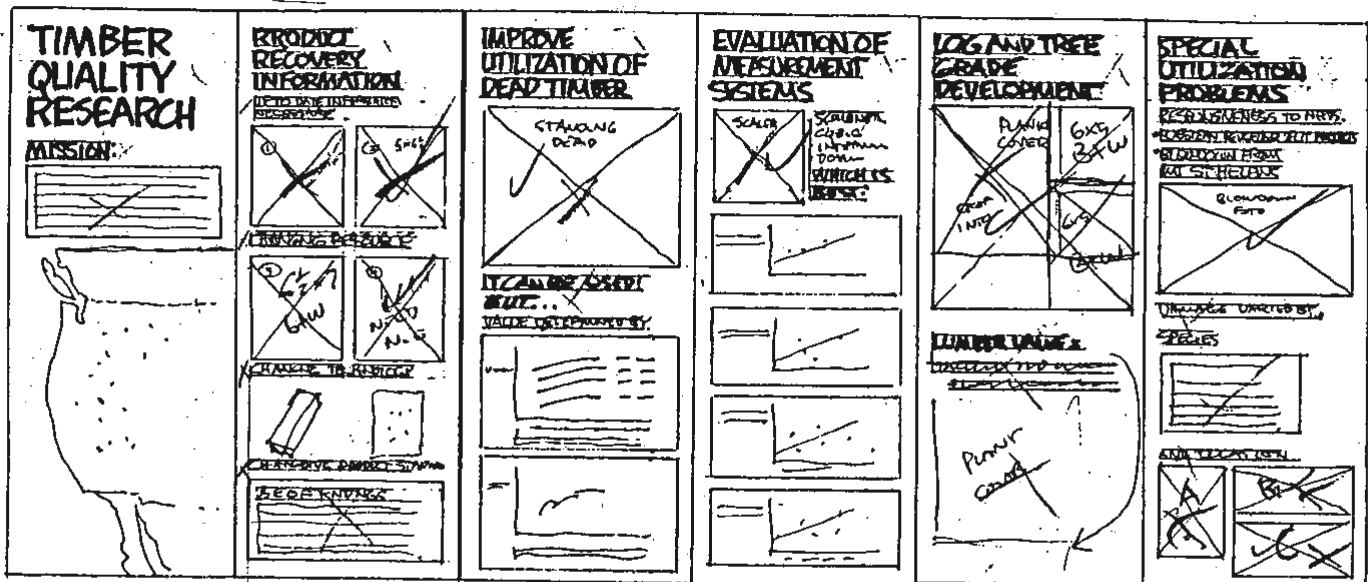


Figure 4. Rough layout for a six-paneled poster.

Rough Layout

Most posters and displays will be viewed from about 6 to 10 feet, which you need to keep in mind when you construct your rough draft. Before putting the draft together, gather clean, uncluttered photographs, artwork, graphics, and maps. Write your text around them. On a regular size piece of paper do a scaled-down version of your poster (fig. 4).

Generally, guidelines for successful posters require that you use:

- No more than seven words in the title;
- No more than 25 words in figure captions;
- No more than 50 words of text in one place;
- An attention-getter near the title. It should be the element with the most visual impact of the whole poster. The first panel should contain only the title, author information, introduction, and attention getter. What stops the passerby can be a photo, map, drawing, graph, or the title.

When doing your rough layout, look at all the illustrations carefully. Do not use one 8- by 10-inch closeup photo and the rest 8- by 10-inch far-off shots; the closeup will pull the viewer's eye to its location on the poster. The smallest type on the poster should be at least one-fourth inch tall.

Mix drawings, photos, graphs, and text to help prevent big blocks of text and to make the poster more interesting. If you have only photos and text, some spot art helps break the mechanical appearance.

Design your poster in panels or components of manageable size. Long, narrow panels (40 inches by 18-22 inches) are the the best design I have found.

Keep the subject to no more than three or four points; do not crowd the information; create logical flow. The poster should contain title, introduction, methods, results, and conclusion--but not usually so labeled.

Do not use lots of colors; use them sparingly to aid viewers or complement your poster. Do not use a bright color as background.

Making a Poster

After you have made your rough layout and the copy is written, photos have been selected and illustrations made, what's next? You need supplies. First, backing material. Poster board will work, but one-eighth-inch foam board is better and cheaper; it comes in 30-inch by 40-inch and 40-inch by 60-inch sheets.

You also need large sheets of colored (not bright colors) paper, 68-80-lb cover, enough to cover the full size of your poster. Cut the foam board into panels the sizes you need (round the corners so they do not dog-ear easy) with rubber cement or spray glue. Glue the paper to the panels.

All photographs, illustrations, and type should be mounted individually--or grouped to make a complete message--on foam core and then glued to the paper-covered panels (hot glue works best). Keep everything as large as possible. You can get type from a typesetter or use press-on sheets of type. You can buy typeset copy smaller than its final size and enlarge it on a photocopier to save money. The finished poster in figure 5 has a good balance of type, photographs, and drawings.

When you are at the poster session, learn from others' successes and failures. Was the type too small? Too much text? The color confusing? Could you see the message? Didn't get your interest? Why? Why not?

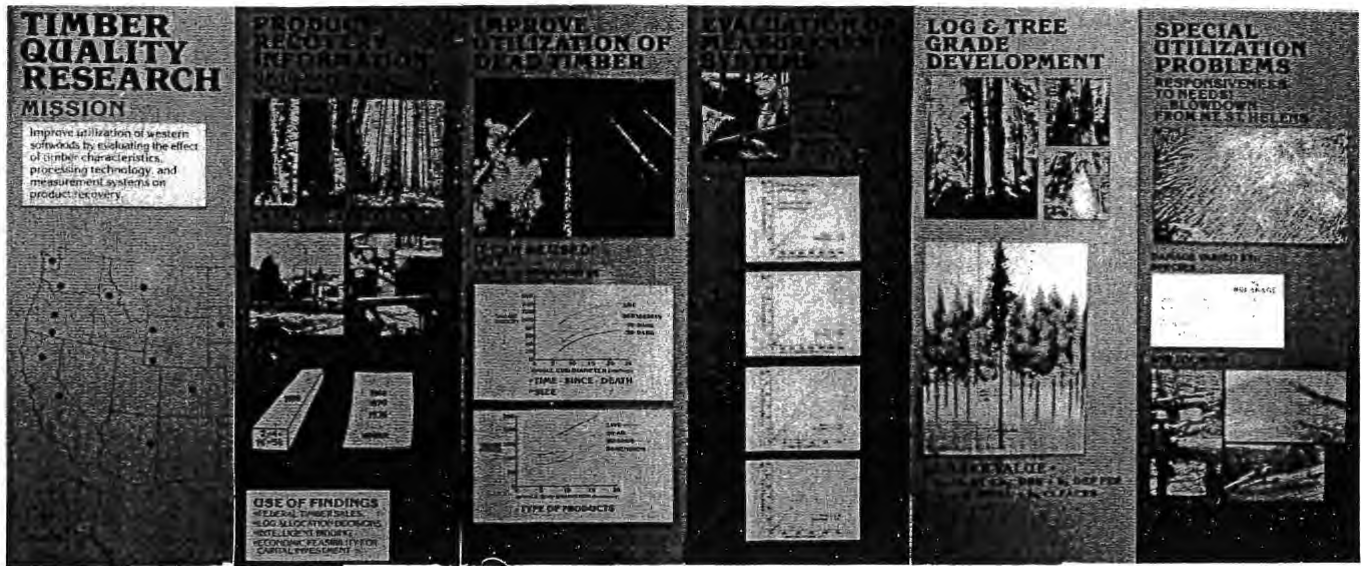


Figure 5. Finished posters based on the rough layouts in figure 4.

CONCLUSION

To get good visuals, use any of the tools I have mentioned to direct attention to your message. We all like to be entertained; visuals that work best are entertaining--which makes getting the message easy. Watch for new and better ways to capture audience interest and to entertain. And don't be afraid to use humor!

In summary, critique what you see, do a rough draft and keep it simple!

Robert F. Scharpf

Thomas H. Nicholls, Frank G. Hawksworth, and
Leanne Egeland

Dwarf mistletoe, Arceuthobium americanum, is a destructive parasitic plant on lodgepole pine. It adversely affects wood quality while reducing seed production in infected trees. Many infected trees eventually die prematurely. An understanding of how dwarf mistletoes are spread is critical to their effective control. Local seed dispersal of dwarf mistletoe via their explosive fruits has been studied in detail, but little is known of its long range dispersal. The establishment of dwarf mistletoes beyond the range of their explosive fruits suggests vector involvement. Our objective was to determine if birds and mammals are vectors of A. americanum dwarf mistletoe on lodgepole pine. The research was done from 1982 to 1986 on the Fraser Experimental Forest in Colorado.

A total of 721 birds (including retraps = IRT) of 31 species were trapped and examined for dwarf mistletoe seed. Fifty-two seeds were found on 46 birds and 10 bird species were identified as vectors. The most important bird vectors were the gray jay, Steller's jay, gray-headed junco, Audubon's warbler, and the mountain chickadee. A total of 301 mammals (IRT) of four species were trapped. All four mammal species were identified as vectors with the least chipmunk being the most important. Twenty-nine seeds were found on 29 trapped mammals (IRT). Results show that establishment of dwarf mistletoe on lodgepole pine beyond the range of its explosive fruits can be explained by vector dissemination of seed.

THOMAS H. NICHOLLS is a Research Plant Pathologist and LEANNE EGELAND is a Forestry Technician at the North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minn. 55108. FRANK G. HAWKSWORTH is a Research Plant Pathologist at the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Ft. Collins, Col. 80526.

Lirula abietis-concoloris is an endemic fungus in Western North America that causes a foliage disease of true firs (Abies). In California, white fir (A. concolor) occasionally becomes severely diseased. And for growers of white fir Christmas trees, losses can be heavy. To control the disease and reduce losses, knowledge of the disease cycle is essential, especially as to timing of preventative fungicidal sprays. Research has clarified the various stages in the disease cycle that helps in diagnosis and control.

Fruiting bodies mature and spores of the fungus are released in spring when the new foliage of white fir emerges. Rain triggers the opening of fruiting bodies along a longitudinal slit, and ascospores are shot out of small tubes called "asci". The sticky spores are deposited on young needles, germinate, and form an appressorium that penetrates and infects the host. After infection, the fungus grows within the needle tissue until the following summer without showing visible disease symptoms. First symptoms appear as a yellowing or chlorosis of the previous years foliage. In late summer, longitudinal, black bands or dark mottling appears in the chlorotic foliage. By winter, a single black hysterothecium develops on the lower surface, and a less conspicuous brown asexual fruiting body develops on the upper surface of infected needles. However, hysterothecia do not mature and release ascospores until spring when warm rains occur and new foliage has developed. Because spring rains do not always coincide with new foliage growth, the disease occurs sporadically. Therefore, knowledge of the disease cycle and the weather conditions that regulate infection is necessary for fungicidal control of L. abietis-concoloris.

ROBERT F. SCHARPF is a plant pathologist at the Pacific Southwest Forest and Range Experiment Station, USDA Forest Service, Berkeley, CA

FIELD TRIP--Glaciers, Spruce Brooms & Flutes

Paul Hennon

September 10, 1986: 1pm - 5pm:

Some 80 WIFDWCers and spouses were treated to an uncharacteristically dry day in September during the field trip to view local sites and disease situations. Transportation consisted of two buses, generously supplied by R-10 Forest Pest Management, with local and knowledgeable drivers. Each bus driver briefly described the history of Juneau as they toured through downtown and past the Governor's Mansion.

We then headed north along Egan Expressway towards the Mendenhall Valley. Paul Hennon and Terry Shaw pointed out some rather large Sitka spruce trees in an newly constructed industrial park that were dying from apparent damage to their root systems. Spruce trees are shallow rooted and do not tolerate anaerobic soil conditions that result from soil compaction or the piling of soil around their root collars.

The next stop was Mendenhall Glacier, where field trippers got up close and personal with a quietly receding glacier. While not the largest glacier in Alaska, Mendenhall is the most visited and photographed; it is one of two "drive-in" glaciers in the state.

Spruce needle rust was the topic of the next stop. The rust was sporulating both on spruce and the alternate host, Labrador-tea, in a muskeg. Paul Hennon explained the biology and apparent impact that this rust has on spruce

trees. Paul, however, had no explanation for how participants were supposed to navigate the one-way, dead-end boardwalk trail he had constructed. Rhytisma sp. and Melampsora epitea also were viewed on willow leaves.

The next stop was at Terry Shaw's former house in Juneau. After a brief, albeit unsuccessful, sales pitch, Terry showed participants hemlock dwarf mistletoe in the heavily infected old-growth forest. Terry was uncharacteristically speechless when he found previously unrecorded "brooms" on spruce in his own front yard!

Participants then piled back in the buses and headed north with panoramic views of Lynn Canal and the distant Chilkat Range. Kent Julin briefly explained hemlock fluting at the next stop near Eagle Beach.

Some participants were then driven to the Eagle River Methodist Camp for relaxation and refreshments; others hiked up a short trail to an area where Bill Farr (PNW Research Silviculturist) described his work with thinning and manipulation of stand density. Porcupine damage and some Fomes annosus stump-inoculations were viewed and the possible effects of this root disease on plans for second-growth management were discussed.

Once all participants had been returned to the Eagle River camp and properly refreshed, most opted for a brief walk on the beach at the Eagle River picnic area--ending the "formal" portion of the field trip.

After returning to Juneau, most WIFDWCers were taken to the Gold Creek Salmon Bake for a feast on king salmon barbequed on an open, alder-wood, fire. Nobody went hungry and few, if any, left thirsty.

BUSINESS MEETING MINUTES

Sally J. Cooley

The business meeting was called to order by Kenelm Russell, Chairman, at 11:00 am on September 12, 1986. Appreciation was expressed to John Laut for the successful program. Thanks were given to the people in Alaska who were responsible for the local arrangements and field trip: Juneau Ranger District, Juneau Forest Pest Management, Centennial Hall people (Dorothy Osborne, in particular). Special thanks were given to Paul Hennon and Elaine Loopstra for the time and effort they gave to making 1986 WIFDWC a very enjoyable and efficiently run meeting.

OLD BUSINESS

The minutes and treasurer's report from the 1985 conference were approved as printed in the 1985 proceedings.

Thanks were given to Walt Thies, 1985 WIFDWC Secretary, for the timely and excellent job of putting out the 1985 Proceedings.

1987 WIFDWC Information. The 1987 meeting will be held in Nanaimo, British Columbia, August 18 to 21, at the Inn at Sea Resort, 25 km south of Nanaimo on the east coast of Vancouver Island. The planning and organizational committee is as follows:

J. Beale:	Vancouver	(604) 660-7646
K. Fink:	Victoria	(604) 727-6639
D. Hudson:	Gold River	(604) 283-7213
J. Kumi:	Nanaimo	(604) 753-1112
P. Morris:	Vancouver	(604) 224-3221

The 1987 APS meeting will be in Cincinnati, Ohio, August 2 to 6, so there will be no conflict with WIFDWC.

1986 APS Meeting Report. Dave Johnson reported on the meeting of the Forest Pathology Committee at 1986 APS meeting in Orlando this August. Art Kehlman has prepared an editorial for Plant Disease concerning the declining state of forest pathology personnel, research and funding in the US and Canada. The question was raised as to whether or not WIFDWC should support or endorse this editorial. Discussion followed. Ed Wood: reductions in numbers of pathologists is much less than reductions in other staff groups at District and Forest levels. Ed Wicker: concurs with Ed Wood; we will need better management to better utilize existing resources and personnel. Jim Stewart: Forest Service Chief is interested in practical research which will benefit the land manager. We should be focusing on the program rather than the budget; i.e., what can we do with what we have? Bart Van der Camp: We should not be comparing current conditions with

personnel and budget levels in the 1970's; the peak in numbers and \$'s occurred in 1979. We should perhaps be comparing current levels with levels in the 1950's; when we do that, 1980's look good. Ed Wicker: not concerned about age class skewing, but he is concerned about what it implies; i.e., we are not bringing in new employees with new ideas, current education, etc. We need to be able to wrap-up projects that have been going on a long time and from which sufficient information has been collected and go on to new, pertinent projects ("leave dead dogs lie"). He feels that plant (forest) pathologists should be paying more attention to some new, less traditional areas such as air pollution problems (since atmospheric, aquatic and terrestrial ecosystems are closely tied) and transport of pests with the transporting of wood products (we need to be responsible for export of high quality products, especially to the European economic community).

New Honorary Life Members. The following 1985-86 retirees were given Honorary Life Member status:

Oscar Dooling, retired from Forest Pest Mgmt, Region 1, Missoula

Jerry Riffle, retired from Rocky Mtn. Exp. Stn., Region 2, Lincoln

Jim Trappe, retired from PNW Exp. Stn., Region 6, Corvallis

John Woo, retired from Intermtn. Exp. Stn., Region 1, Moscow

Committee Reports. Committee reports were made by John Laut, Mistletoe Committee Chairman; Ken Russell, Disease Control Committee Chairman; and Rich Hunt, Rust Committee Chairman. Greg Filip, Root Rot Committee Chairman, was not present to give his report. Written reports from committees appear elsewhere in proceedings as committee reports or as individual papers. John Laut announced his resignation as chairman and appointed John Muir as new chairman (the Mistletoe committee formed in 1956; Frank Hawksworth was chairman 1956 to 1971; John Laut was chairman from 1971 to 1986).

Conference Format. Conference format was discussed. Panels with open discussion were successful and most agreed that they enjoyed this type of format. A suggestion was made that, in the future, handouts containing hard data or pertinent information might accompany these "loose" discussions.

NEW BUSINESS

WIFDWC recognized Jim Stewart and his new position as Director of Forest Insect and Disease Research (formerly Director of Forest Pest Management), USDA, Forest Service, Washington, DC.

1987 Executive Committee. The 1987 executive committee was nominated (by Bob Gilbertson, Reed Miller and Dave Johnson) and unanimously approved: John Muir, Chairman, and Greg DeNitto, Secretary-Treasurer. Chairman Muir subsequently appointed Jerry Beatty as Program Chairman.

1988 WIFDWC Location. Park City (or somewhere in the near vicinity), Utah was proposed by Fred Baker as the location for the 1988 WIFDWC; the Utah location was unanimously approved.

Meeting Announcement. Pritam Singh announced the Joint Meeting of the Canadian Phytopathology Society and the American Mycological Society, June 21 to 25, 1987. There will be two forest pathology sessions: a symposium on June 24 and a session of contributed papers in forest pathology. The announcement for this meeting will be in the Phytopathology Newsletter and CPS Newsletter.

SAF C.E. Credits. A motion was made to have the program chairman responsible for sending the WIFDWC program to SAF in order to obtain

SAF Continuing Education credits for attendance. The motion was carried and approved.

Honorariums and Awards. A motion was made to allow the executive committee, after consulting with a reasonable number of members, to award honorariums to non-member WIFDWC speakers. The amount of the honorarium will depend on the funds available and will be at the discretion of the executive committee. The motion was carried and approved.

A motion was made to consider for further discussion graduate student awards, professional achievement awards and the future of the social achievement award.

Miscellaneous. WIFDWC mementos, such as hats, cups, T-shirts, etc, were generally liked. It was agreed that local arrangement people can use money from the treasury to purchase the items, which will be sold during the conference.

Pete Angwin voiced his appreciation of the reduced graduate student registration fee.

Jerome S. Beatty

The following are topics for panels and papers that were suggested in Juneau for the 1987 WIFDWC in Nanaimo, B.C.

Suggested Topics for Panel Discussions:

1. Root diseases; Have a panel with members representing different geographical areas; it is important to compare and contrast root disease prevalence and management in the West. Information to be covered or questions to be answered:
 - a. What are the major root diseases?
 - b. Species impacted?
 - c. Type of impact: mortality, wind-throw, decay? Include recreation areas.
 - d. Stand conditions under which disease occurs?
 - e. Unique aspects of etiology or epidemiology?
 - f. Controls recommended: experimental or operational?
 - g. Control efficacy?
 - h. How are controls used? ie. standard procedure, special areas only?
2. Impact and control of Annosus root disease (butt rot) in western hemlock forests:
 - a. Impacts-are there any?
 - b. Efficacy of control(s)- any needed?
 - c. Stand risk ratings, environmental influences?
3. Impact and control of Armillaria root disease(s):
 - a. Coastal and inland forests.
 - b. Effects of logging and other disturbances on disease severity.
 - c. Detection and appraisal methods.
 - d. Disease occurrence: ubiquitous stress vs. foci.
4. Pinewood nematode situation: surveys, research, quarantine info.
5. How to improve transfer of research results and how to stimulate research on important practical problems: a panel of regional views including Province, State, Federal, University, and Industry.
6. Damage appraisal (effects on growth and yield, stocking standards) for:
 - a. Dwarf mistletoes-new models?
-substantiation?

- b. Root diseases.
- c. Stem rusts and cankers.

7. How can forest planning models incorporate any pest considerations or impacts? (Reid and Errico, Univ. of Victoria).
8. Use of biotechnology in forest disease research:
 - a. Isozymes.
 - b. Tissue culture.
 - c. Molecular biology.
 1. DNA sequencing.
 2. Protein focusing.
9. Use of "chemicals" in forest disease control.
10. Why is forest disease research in the western U.S. in a state of decline?
11. Why aren't we getting more forest pathology results (publications) from the western USDA-Forest Service Experiment Stations?
12. Explore the use and misuse of analytical tools such as RMYLD and the PROGNOSIS root disease model in integrating forest pathology with silviculture.
13. Atmospheric deposition.
14. International transfers of pest organisms.

Suggested Topic for Workshop:

1. Al Funk should be invited to present a pre-WIFDWC workshop on canker disease fungi found on western conifers. Region 6 USDA FS would be willing to pay tuition.

Suggested Topics for Poster Session:

1. British Columbia regional problems and programs in forest pathology.
2. Textbooks, teaching aids, course packages, modules, etc. for Pacific tree diseases.

Other Suggestions:

1. Repeat/maintain program format as established in Juneau.
2. Streamline institution reports on new and old projects.
3. Enforce "no smoking" rule in the meeting rooms.

TREASURER'S REPORT, THIRTY-FOURTH WIFDWC

Balance on hand at close of thirty-second meeting	\$1140.37
Adjustment for final 1985 (33rd) Proceedings printing estimate (original estimate \$850.00; actual \$1056.00)	(206.00)
Interest paid July 1, 1985 through June 30, 1986	108.12
Miscellaneous proceedings sales (30) 1/1/86 to 12/31/86	181.00
Common Names book sales @ \$1.00 ea. (5) 1/1/86 to 12/31/86	5.00
Exchange charge for discount on Canadian check	<u>(15.50)</u>
Sub-total	1212.99

Thirty-fourth WIFDWC statement from Juneau meeting

Receipts:

Regular participants (61 @ \$33)	
Students (2 @ \$20)	
Honorary life members (4 @ \$0)	
Spouses (13 @ \$5)	
Total registration (80)	\$2118.00
Banquet (76 @ \$20)	1520.00
Refund from Centennial Hall	<u>21.71</u>

Sub-total 3659.71

Expenses:

Rental of Centennial Hall	NC
Field trip transportation	NC
Banquet	1540.00
Banquet entertainment	150.00
Rental of Eagle River Lodge	50.00
Monday night appetizers and drink	343.95
Refreshments during meeting breaks	321.00
Hospitality room drinks	104.44
Award to Peter Schutt	300.00
Proceedings printing estimate	<u>1150.00</u>
(adjustment will be made next year)	

Sub total 3959.39

Balance at close of thirty-fourth meeting 913.31

Continuous account number 936258 held at the Washington State Employee's Credit Union. PO Box WSECU, Olympia, WA 98507. Phone (206) 943-7911.

Official signatures for withdrawing funds are Walt Thies, Ken Russell and Fields Cobb.

Ken Russell, December 31, 1986



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

Western International
Forest Disease Work Conference
Mistletoe Committee Report

1986 Highlights

John G. Laut, Chairman

I. Taxonomy, Hosts, Distribution

- A. The following paper has been published "Exotic pines infected by two dwarf mistletoes in southern California." (Robert F. Scharpf and Frank G. Hawksworth. Plant Disease. February, 1986)
- B. Happenings on the International Arceuthobium front: A new species has been reported from Northern Pakistan on Pinus wallichiana and also an undescribed species has been collected in Pinus herrerae in Sonora, Mexico. The mistletoe on Podocarpus in Cuba described as Arceuthobium cubense has been found to be not a dwarf mistletoe, but Dendrophthora cupressoides. (F. G. Hawksworth, RM Station)
- C. The ponderosa pine dwarf mistletoe, Arceuthobium vaginatum subspecies cryptopodum, was collected for the first time in northwestern Arizona; at Mt. Trumbull and the Virgin Mountains. The gap between this mistletoe and A. campylopodum on ponderosa pine near Las Vegas, Nevada has been narrowed to about 100 miles. (F. G. Hawksworth, C. G. Shaw, B. Geils, RM Station; J. Beatty, SW Region)

D. Studies in isozyme analysis of 6 members of the Arceuthobium campylopodum group are underway to help determine their taxonomic status. Mistletoes being studied are those on hard pines (A. campylopodum, A. occidentale, and a population on knobcone pine in northern California and southern Oregon) and the hemlock mistletoe (western hemlock, mountain hemlock, and shore pine races.) (Dan Nickrent, University of Illinois, F. G. Hawksworth, RM Station)

II. Physiology - Anatomy

- A. Growth readings are being taken this summer on dwarf mistletoe infected, young red firs fertilized with 200 lbs. N per acre in 1983. Effect of N on growth of both host and parasite will be evaluated. (R. F. Scharpf PSW)

III. Life Cycle Studies

- A. A paper on pollination ecology of black spruce dwarf mistletoe was published in the Canadian Journal of Forest Research (Vol. 15:708-714), and a paper on seed dispersal appeared in CJFR Vol. 15:1-5, concluding these studies. (F. Baker and D. W. French. University of Minnesota)

IV. Host - Parasite Relations

- A. A study has been initiated to develop a rapid method for screening Jeffrey pines for resistance to dwarf mistletoe. Objectives are to extend existing greenhouse screening methods to tissue cultured Jeffrey pine material and to streamline and improve determination of dwarf mistletoe resistance. Develop in situ methods of co-cultivation of dwarf mistletoe and Jeffrey pine callus in order to examine cellular mechanisms for resistance. This research will be conducted at the Institute of Forest Genetics, Placerville, California and the disease laboratory, PSW Berkeley. (R. F. Scharpf, PSW; Ann Stamp, North Carolina State University)

V. Effects on Hosts

- A. The manuscript "Infection of Understory Jeffrey Pine Seedlings by Western Dwarf Mistletoe," by Robert F. Scharpf and Detlev Vogler is in print. Research note PSW 386, July 1986.
- B. Five year growth and mortality data are being taken this year on several thinned, dwarf mistletoe infected red fir plots. (R. Scharpf PSW)

C. Arceuthobium americanum appears to stress jack pines to the degree that they become attractive to Cerambycid beetles, which in turn carry the pine wood nematode. The nematode and the Cerambycids were found only in declining or dead trees. The dwarf mistletoe appeared to be the primary cause of mortality. This study was published in Forest Science 31:866-870 (F. Baker, T. Burnes, M. Wingfield, University of Minnesota; and K. Knowles and Y. Beaubien, Manitoba Department of Natural Resources)

D. A set of nonlinear models based on 5 cm diameter (dbh) classes were developed for predicting ten year diameter growth and mortality in unevenaged stands of ponderosa pine infested by Arceuthobium vaginatum subsp. cryptopodum. Growth of uninfected and infected trees was reduced (based on severity infection and intertree competition) from a potential growth based on site. The intertree competition effect was best described by: basal area of the dbh class and larger trees (BASL); size class dbh to average stand dbh ratio; and the level of infection caused over a 50% decrease from potential growth. When trees were heavily infected, their competitive effect was reduced. The best predictors of the percent trees within a dbh class dying over a ten-year period were: percent of severely infected trees in each dbh class, size class dbh, and BASL. (H. M. Maffei, F. G. Hawksworth, W. R. Jacobi, CSU & RMS)

VI. Ecology

A. Abstract of an abstract of a PhD thesis from Portland State University by James L. Wanner entitled "Effects on Infection by Dwarf Mistletoe (Arceuthobium americanum) on the Population Dynamics of Lodgepole Pine (Pinus contorta.)" This study demonstrates that the negative short-term effects of parasitism are offset by long-term adjustments in host population dynamics thereby providing a stable community structure. Arceuthobium americanum promotes a disturbance regime that favors the regeneration of P. contorta. This contributes to the perpetuation of the host which is essential for stable host-parasite coexistence (submitted by F. G. Hawksworth).

VII. Control - Chemical

A. A study was initiated in 1986 to evaluate the impact on growth of aerial applications of an ethylene releasing agent on jack pines

infested with Arceuthobium americanum. Aerial applications were done in August. We are also evaluating treatment effects on the levels of Wallrothiella arceuthobii, as there is a severe infestation in one of the treatment areas. (F. Baker, Utah State University; D. W. French, University of Minnesota; K. Knowles and Y. Beaubien, Manitoba Department of Natural Resources)

B. Dwarf mistletoe shoot abscission rates of 74 to 100 percent on individual infections of Arceuthobium americanum on Pinus contorta and A. vaginatum subsp. cryptopodum on P. ponderosa were consistently achieved with August applications of 2500 ppm ethephon plus surfactant using three methods of application. Most shoots abscised from infection within two to five weeks after ethephon treatment. Ethephon did not kill the parasite's endophytic system in the host tissue. Therefore, new shoots began developing on some infections one to two years after treatment. Based on the lengthy life cycles of these two species of dwarf mistletoe, it is predicted that ethephon control can temporarily prevent or reduce spread of infection for up to four years and possibly provide some degree of control even longer. Ethephon has control potential especially in high value stands, recreation areas, seed orchards, and ornamental plantings around homes, cabins, and business establishments. (T. H. Nicholls, L. Egeland, NC Station; F. G. Hawksworth, RM Station; and D. W. Johnson, FPM-R-2)

VIII. Control - Biological

The following manuscripts have recently been published:

- A. Destruction of shoots, flowers, and fruits of dwarf mistletoe by grasshoppers in California. (R. F. Scharpf and T. W. Koerber. Canadian Journal of Forestry Research, 1986)
- B. Dwarf mistletoe as a host for brown felt blight in California. (R. F. Scharpf. Plant Disease, August 1986)
- C. Spiders of 10 families, 18 genera, and 22 species were associated with A. vaginatum, A. cyanocarpum and A. americanum in northern Colorado. Spider species composition varied among dwarf mistletoe species. Two indices of similarity indicated that spider faunas of A. cyanocarpum and A. vaginatum were dissimilar. None of the spiders are restricted to dwarf mistletoes; habitat associations includes numerous conifers. Spider-mistletoe

relationships are discussed and mistletoe-pollen vector by spiders is recorded for the first time. From manuscript to be submitted to Southwestern Naturalist. (D. Jennings, NE Station; R. Penfield, F. Hawksworth, and R. Stevens, RM Station)

IX. Control - Silvicultural

The following manuscripts are in the publication process:

- A. Pruning dwarf mistletoe brooms reduces stress on Jeffrey pines, Cleveland National Forest, California. (Robert F. Scharpf, Richard S. Smith, and Detlev Vogler. Station Research Paper, PSW)
- B. Management of Western Dwarf Mistletoe in Ponderosa and Jeffrey Pines in Forest Recreation Area. (Robert F. Scharpf, Richard S. Smith, and Detlev Vogler. Station Research Paper, PSW)
- C. An interactive computer model is being developed to aid forest managers in making decisions on how to manage dwarf mistletoe infected, high value ponderosa and Jeffrey pine on recreation sites. (R. F. Scharpf, Dave Azuma, PSW)
- D. Dwarf mistletoe suppression projects were conducted over 3,681 acres on 15 National Forests or Bureau of Land Management Areas in the Intermountain Region during 1986. (Hoffman & Tkacz, USFS, Region 4)
- E. In California: (1) two recreational areas, having a combined total of 264 camping units, on the Lake Tahoe Basin Management Unit were treated using tree removal and pruning to control western dwarf mistletoe of Jeffrey pine, (2) infected residual overstory pines were removed from the periphery of an 81-acre Jeffrey pine plantation. (J. Pronos, R-5)
- F. Re-examinations of 37 plots in young mistletoe-infested lodgepole pine stands sanitized and thinned 21 years ago were made. The results will be summarized this winter. (F. G. Hawksworth and B. Geils, RM Station; D. W. Johnson, Region 2)
- G. A summary manuscript on the biology, ecology, and pathology of lodgepole pine dwarf mistletoe and its silvicultural control is completed and in review. (F. G. Hawksworth, RM Station; D. W. Johnson, Region 2)
- H. At the request of the Mexican government, we spent three weeks in central Mexico discussing survey techniques and silvicultural control

of dwarf mistletoes. More than 350 foresters attended our 15 sessions in the states of Puebla, Tlaxcala, Mexico, Michoacan, Zacatecas, Durango, and Jalisco. (F. G. Hawksworth, RM Station; J. Beatty, FTM, Region 3)

- I. Data have been collected for a 20-year study of the effects of dwarf mistletoe control in a young mixed conifer stand at Gronden, Washington, Colville National Forest. Forty quarter acre quadrants were used in a split plot design of two replications of five thinning levels on four mistletoe eradication levels. The effects measured on cap trees of western land and Douglas-fir were diameter and height growth and mistletoe intensification. Preliminary analysis of diameter and height growth failed to detect a significant treatment effect due to large variation between the replicates. Additional analysis is planned and a report will be written this year. (E. Wicker, and B. W. Geils; RM Station)
- J. The last of a series of plots has been remeasured in a 30-year study on the effects of dwarf mistletoe control in Southwestern ponderosa pine on the Mescalero Indian Reservation, New Mexico. The control strategy examined was pruning or removing injected trees in two or three cleanings. Plots varied by initial stand age, stocking and number of cleanings. Early results emphasize the value of follow-up cleanings in retarding subsequent mistletoe intensification. A summary paper is planned to document the unique development of each study plot. (F. G. Hawksworth, B. W. Geils, RM Station)
- K. An examination has been conducted for a series of dwarf mistletoe infested lodgepole pine stands near Pingree Park, Colorado. One stand was left unthinned; the other stands were thinned in 1939 to a 12-foot, 10-foot, 8-foot, or 6-foot spacing. Data from these plots will be used to validate and improve yield models. (F. G. Hawksworth, B. W. Geils, RM Station)
- L. Plans are to treat 2,410 acres of dwarf mistletoe infested stands on the Arapaho and Roosevelt; Grand Mesa, Uncompahgre, and Gunnison; Medicine Bow; Pike and San Isabel; Rio Grande; Routt; Shoshone, and White River National Forests. (D. Johnson, USFS, R-2)

X. Surveys

- A. Presuppression surveys for Arceuthobium americanum, A. douglasii, and A. campylopodum were conducted on over 65,000 acres of commercial timber land in the Intermountain Region. The data, collected in conjunction with stand examination surveys, will provide disease information for silvicultural prescriptions. In addition, the surveys provide a basis for determining future dwarf mistletoe suppression projects. (Hoffman & Tkacz, USFS, Region 4)
- B. The Plumas National Forest, in northern California, surveyed 2600 acres of mixed conifer type. The objective was to gather data on western dwarf mistletoe that could be used with an eastside pine version (for SE Oregon and NE California) of PROGNOSIS to develop stand specific silvicultural prescriptions. This is new for California. The presuppression survey was completed on ninety acres, that included dispersed recreation areas and two campgrounds on the Angeles National Forest. (J. Pronos, R-5)
- C. A 837 km roadside survey for lodgepole pine dwarf mistletoe was completed in January to March, 1986 at Prince George. Percentage of stands infected, based on 100m road units, ranged from 8 to 88. Growth impact on the net, operable, land-base with susceptible stands was estimated at 174,000 m³ per year. Further work is underway to refine these growth impact estimates. (J. Muir, Victoria and K. Lewis, Prince George)

A stand-specific survey for lodgepole pine dwarf mistletoe in mature stands is being conducted in the Kamloops Forest District under the supervision of H. Merler, Regional Forest Pathologist. Strips are run 100m apart with an estimate of proportion of trees infected at 50m intervals and a tree tally with infection ratings on a circular plot at 200m intervals. Data will be useful to prioritize stands for harvesting. (H. Merler, Kamloops)

- D. Presuppression surveys for dwarf mistletoes are planned for 23,000 acres on the Pike and San Isabel, Rio Grande, and Routt National Forests. (D. Johnson, USFS, R-2)

XI. Miscellaneous

- A. A publication is in press describing the hemlock dwarf mistletoe demonstration area recently established at Thorne Bay, Prince of Wales Island, Alaska. (C. G. Shaw, RM Station; P. Hennon, Region 10, Juneau)
- B. Proceedings on a hemlock dwarf mistletoe workshop held August, 1983 at Burnaby, B.C. are available as Pest Management Report No. 4, 1985, from B.C. Forest Service, Protection Branch. Papers on biology, damage appraisal, surveys, simulation model and discussions are included. (J. Muir, Victoria)
- C. Eleven years is enough. The current chairman of this committee, named by his predecessor, Ed Wicker in 1975, has resigned, and has appointed John Muir to carry on (J. G. Laut, CSFS).



34TH Annual Western International Forest Disease Work Conference

Juneau, Alaska
September 9-12, 1986

DISEASE CONTROL COMMITTEE
1986 INVESTIGATIONS

Kenelm Russell, Chairman

For several years now the nursery pathologists have been having a quiet little conference here and there around the West. About 20 to 30 people have been attending. The mini conference has no proceedings or written papers. Discussions are informal. There is space here to report some of the items of general interest.

In early 1986 we met in Olympia. The noteworthy accomplishment there was to standardize the soil disease assays for Pythiums and Fusariums that many of us have been doing over the years. We took the best parts of everyone's favorite recipe and came up with what we feel is the best. Now propagule counts are more similar no matter where they are done. The recipes are available.

In December 1986 a slightly larger group met in McKinleyville, California at the Humboldt Nursery. We had in-depth discussions on the increasing use of Basamid for disease control. Basamid is effective under some conditions for controlling parasitic nematodes and other diseases. It could be very useful in nurseries where nearby residences could be endangered from an accident with methyl bromide.

Sally Cooley prepared a comprehensive packet of material on the various fungicides and adjuvants used today. It goes into much greater detail than many similar lists. Formulations, target organisms, application methods, activity against organisms, solubility and movement in soil and effect of soil properties are listed. The material will be very useful.

A preliminary table of contents has been prepared for a "Forest Nursery Disease and Insect Management Guide for Pacific Northwest Nurseries." Authors for the various segments have been selected.

There are several papers that you might want to secure that may go unnoticed because they are published in the Western Forest Nursery Council Proceedings from their conference held in Olympia in August, 1986. See Tanaka, Russell and Linderman in the projects listing that follows here on mycorrhizae recovery and disease development after fumigation. We found some significant relationships that dispel some myths about mycorrhizal recovery. Another version of this paper is being published in the Canadian Journal of Forest Research. In the Nursery proceedings check out Phil Hamm's excellent story about the Top Blight Complex. Alan Kanaskie followed with its management.

I came back with an expanded paper on watering to reduce summer Fusarium problems. Everett Hanson and Sally Cooley covered Phytophthora and Bob James the Fusarium problems on tree seed from northern Rockies nurseries.

Don't forget to include your project descriptions here in 1987! Good pest management is undergoing a real awakening on the managers' side. It is up to us to keep them supplied with technology.

SEEDLING DISEASES - NURSERIES

1. Marssonina Leaf Spot

Host: Aspen

Causal Organism: Marssonina populi

Control: Chemical

Development Stage: In Vitro - Greenhouse

We have started in vitro and greenhouse studies to determine what fungicides are effective in preventing the disease. No results are available at this time.

(William R. Jacobi, Colorado State University)

2. Phomopsis Blight

Host: 2-0 Douglas-fir

Causal Organism: Phomopsis occulta

Control: Chemical

Development Stage: Field Trial

Five fungicides gave significantly better control than no treatment. Diniconazole (Spotless^R) and chlorothalonil (Bravo 500^R) were more efficacious (1.9% and 2.1% infection, respectively) than the registered fungicide benomyl (Benlate^R) (4.0% infection).

(J. Kliejunas, A. McCain - Forest Service - FPM PSW Region, U.C., Berkeley)

3. Fusarium hypocotyl rot, upper stem canker
 Host: Douglas-fir seedlings
 Causal Organism: Fusarium oxysporum,
Phana spp.
 Control: Chemical
 Development Stage: Field Trial

Purpose was to compare amount of disease in seedlings fertilized with different forms of N and at different times during first growing season. Data to be collected Fall '86.

(S. Cooley, A. Kanaskie - Forest Service - FPM-Region 6, Portland and Oregon State Department of Forestry, Salem, OR)

4. Damping Off/Hypocotyl Rot
 Host: Conifer seedlings
 Causal Organism: Fusarium spp.,
Pythium spp., weeds
 Control: Chemical
 Development Stage: Field Trial

Test comparing metam-sodium (Baramid^R), Vapam (Soil Prep^R) to methyl bromide-chloropicrin and no treatment at 2 nurseries (Bend Nursery and J. Herbert Stone Nursery). Data collected, report forthcoming.

(Sally Cooley - Forest Service - FPM Portland, OR)

5. Nursery problems
 Host: eastern red cedar
 Causal Organism: Parasitic nematodes
 Control: Chemical
 Development Stage: Field Trial

Comparing Basamid granular, Methyl bromide/chloropicrin, and solar heating for control of nematodes, Pythium and Fusarium spp. at Bessey Nursery. Treatment completed summer 1987 for fall-sown eastern red cedar. Nematode data still being processed. Will observe (seedling) survival data next year.

(Diane Hildebrand, Forest Service - FPM Rocky Mt. Region, Lakewood, CO)

6. Nursery seedlings
 Host: Douglas-fir
 Causal Organism: Mycorrhizal Fungi,
Pythium and Fusarium
 spp.
 Control: Chemical
 Development Stage: Field Trial

Soils were treated with methyl bromide/chloropicrin (MBC) at 360 and 720 lbs/A and Basamid at 350 lbs/A in two bare-root Douglas-fir nurseries near Olympia, Washington in 1984-85. Results showed that fumigation (1) increased fall 1+0 seedling count, (2) caused no 1+0 stunting or growth loss, (3) did not hinder

formation of mycorrhizae, (4) suppressed and maintained low soilborne pathogen populations and (5) suppressed root infections by Fusarium spp. but not Pythium spp. (Complete paper available from Russell.)

(Y. Tanaka, K. Russell, R. Linderman, Weyerhaeuser Co., Washington State DNR, and USDA-Agricultural Research Service)

FOLIAGE

1. Lirula Needle Cast
 Host: Abies concolor
 Causal Organism: Lirula abietis-concoloris
 Control: Chemical
 Development Stage: Field Trial

A number of systemic and contact fungicides were sprayed on the new growth in spring of 1986. The grower sprinkled-irrigated to enhance infection. Monitored spore release was high following irrigation.

(R.F. Scharpf and A.H. McCain, PSW Exp. Sta. and U.C., Berkeley)

2. Elytroderma Disease
 Host: Pinus jeffreyi
 Causal Organism: Elytroderma
deformans
 Control: Chemical
 Development Stage: Field Trial

Trees with infections were pressure-injected with solutions of thiabendazole (Arbotect) and imazali (Fungaflor). Uptake was slow but good using 40-60 psi. Shoots will be sampled and assayed for fungicide.

(R.F. Scharf & A.H. McCain, PSW Exp. Sta. and U.C., Berkeley)

DWARF MISTLETOE

1. Western Dwarf Mistletoe
 Host: Pinus jeffreyi
 Causal Organism: Arceuthobium campylopodum
 Control: Silvicultural
 Development Stage: Full operational

Two campgrounds in California are being silviculturally treated through tree removal and pruning to reduce dwarf mistletoe.

(Gregg DeNitto, Tom Hinds - Forest Service, FPM Region 5, San Francisco and LTBMU)

2. Western Dwarf Mistletoe
Host: Ponderosa Pine and
Douglas-fir
Causal Organism: Arceuthobium
campylopodum
Control: Silvicultural
Development State: Full Operational

Remeasured 30 dwarf mistletoe control plots in eastern Washington that were established in 1969-70. Third remeasurement at 15+ years shows that early dwarf mistletoe control in young stands is very successful if done correctly. A complete report will be ready by 1987 conference.

(K. Russell, DNR Olympia, WA)

4. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Control: Chemical
Development Stage: Pilot Operational

We feel that we know enough about fumigating to recommend treatment of infected stumps to reduce Phellinus weirii inoculum on the site.

(W.G. Thies, E.E. Nelson - USDA Forest Service, PNW Station)

ROOT DISEASES

1. Laminated Root Rot
Host: Coastal Douglas-fir
Causal Organism: Phellinus Weirii
Control: Chemical
Development Stage: Field Trial

Glyphosate applied to healthy and infected 40-year Douglas-fir at two dosages. Variables measured are 1) glyphosate translocation in roots, 2) decomposition in healthy roots, 3) fungus viability in roots in progress.

(W.J. Bloomberg, G. Fraser - Canadian Forestry Service - CIP Ltd)

2. Laminated Root Rot
Host: Douglas-fir
Causal Organism: Phellinus weirii
Control: Silvicultural
Development Stage: Full Operational

After nine growing seasons, 67 Douglas-fir seedlings on four acres with stumps pushed were killed by root rot vs. 118 seedlings on 4 acres without pushing. A short report is available.

(K. Russell, DNR, Olympia, WA)

3. Laminated Root Rot
Host: Coastal Douglas-fir
Causal Organism: Phellinus weirii
Control: Silvicultural
Development Stage: Field Trial

Test of 3 stump extraction machines - large backhoe, small backhoe, D7 Cat. Large backhoe left least root material, caused least soil disturbance; small backhoe caused most.

(W.J. Bloomberg, Canadian Forestry Service)

A. Forest Disease Surveys - General

- 71-A-4 Appraisal of damage caused by forest pests in British Columbia (R. Alfaro).
- 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 access 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).
- 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-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 extent and distribution of black stain root disease on state lands in Oregon (A. Kanaskie).
- 86-A-1 Black stain root disease survey, Oregon and Washington (W. Littke).
- 86-A-2 Surveys of pest incidence and damage in young plantations (J. Muir).

B. Non-infectious Diseases

- 80-B-2 Trend of ozone injury to conifers in the southern Sierra Nevada (J. Pronos).
- 86-B-1 Ozone in Puget Sound forests (R. Edmonds).
- 86-B-2 Acid fog in the Cascades (R. Edmonds).

C. Cone, Seed, and Seedling Diseases

- 76-C-1 Diseases of seeds and cones PC-54-07 (J. Sutherland).
- 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-2 Assessment of new chemicals to control Botrytis blight in nurseries (R. James).
- 83-C-3 Fungi associated with pine seedlings tip blight in Northern Rocky Mountain nurseries (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. Kliejumas, J. Allison, A. McCain).
- 85-C-2 Evaluation of metam-sodium, dazomet, and methyl-bromide-chloropicrin soil treatments for disease and weed control (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-16 Interactions between cover crops, fumigation, nitrogen availability, and soil-borne pathogens in nurseries (E. Hansen).
- 86-C-1 Effect of nitrogen fertilization on disease in bareroot 1-0 Douglas-fir seedlings (S. Cooley, A. Kanaskie).
- 86-C-2 Pathogenicity of Fusarium acuminatum to Russian olive (D. Hildebrand).
- 86-C-3 Comparison of solar heating, basamid with polyethylene seal, Basamid with water seal, and methyl bromide-chloropicrin for control of soil-borne pests in fall-sown Eastern red cedar at Bessey Nursery (D. Hildebrand).
- 86-C-4 Influence of pre-sow phosphorus fertilization on incidence of stunting in bareroot Douglas-fir seedlings (A. Kanaskie).
- 86-C-5 Effect of Douglas-fir cone storage method on seed yield, viability, and occurrence of Fusarium spp. (A. Kanaskie).
- 86-C-6 Impact of seed-borne pathogens on seedling performance (W. Littke).
- 86-C-7 Cone and seed treatments to increase seed extractability, quality, and performance (W. Littke).
- 86-C-8 Impact of Fusarium and other pathogens during cold storage on seedling quality. (W. Littke).
- 86-C-9 Measurement of Fusarium populations over entire crop cycle (W. Littke).

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).
- 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-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 wagneri on pinyon at Mesa Verde National Park: disease spread characteristics (D. Johnson, K. Lister, E. Sharon).
- 79-D-5 Spread of Armillaria spp. 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-13 Systems of organisms causing black stain in pine roots (A. Partridge).
- 81-D-4 Monitoring root diseases in commercially thinned northern Idaho forests (J. Schwandt).
- 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).

- 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-7 Armillaria root rot of young intensively managed lodgepole pine stands of Alberta (Y. Hiratsuka, P. Blenis).
- 82-D-8 Resistance screening of Port-Orford cedar to Phytophthora lateralis root rot (E. Hansen, P. Hamm, L. Roth).
- 83-D-5 Intensification 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-2 Trichoderma species associated with Douglas-fir roots colonized by Phellinus weirii (E. Nelson, B. Goldfarb, W. Thies).
- 84-D-4 Mycorrhizae and soil borne pathogens recover after fumigation of nursery soils (K. Russell, Y. Tanaka).
- 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-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 Incompatibility reactions, cytology, and population biology of Phellinus weirii and Phytophthora species (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).
- 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 (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. Jurgensen, 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-27 Phellinus weirii epidemiology and control (W. Bloomberg).
- 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-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).
- 86-D-1 Genetic variability in Fomes annosus (R. Edmonds).
- 86-D-2 Fomes annosus 20 years after pre-commercial thinning in hemlock (R. Edmonds).
- 86-D-3 Pathogenicity of Armillaria spp. on artificially defoliated grand fir seedlings (G. Filip).
- 86-D-3 Decomposition of logging residues (R. Edmonds, K. Vogt).
- 86-D-4 Annosus root rot in the Northern Region (S. Hagle, et al.).
- 86-D-5 Site and tree risk factors in black stain root disease (E. Hansen).
- 86-D-6 Stump treatments to reduce black stain spread rate/vector attractiveness in high value stands (W. Littke).
- 86-D-7 Long-range effects of precommercial thinning on Fomes annosus in western hemlock stands (W. Littke).
- 86-D-8 Interactions of Armillaria and herbicides that are used to manage forest vegetation (N. Martin).
- 86-D-9 De-stumping trials for tomentosus root disease (J. Muir).
- 86-D-10 Evaluation of root removal by mechanical de-stumping in interior areas (J. Muir).
- 86-D-11 Evaluation of root diseases in interior backlog areas (G. A. Van Sickle, W. Bloomberg).
- 86-D-12 Problem analysis of root diseases in coastal backlog areas (G. A. Van Sickle, W. Bloomberg).
- 86-D-13 Survey of wood chips for pinewood nematode in British Columbia (J. Muir).
- 86-D-14 Lethal effects of chloropicrin on Phellinus weirii in culture tubes in stumps (E. Nelson).
- 86-D-15 Rate of damage by Phellinus weirii in Douglas-fir stands (E. Nelson).
- 86-D-16 Variability in Verticicladiella wagnerii (W. Otrosina).
- 86-D-17 Monitoring root disease in thinned ponderosa pine plantations in northern Idaho (J. Schwandt).
- 86-D-28 Carbohydrate reserves and maintenance respirations: controls of mycorrhizal turnover in ponderosa pine (R. Molina, J. Trappe).
- E. Foliage Diseases
- 74-E-1 Inheritance of resistance 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 applications 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).
- 86-E-1 Effect of fertilization and fungicides on Swiss needlecast (W. Littke).
- 86-E-1 Needlecasts of Scots pine Christmas trees in Montana (S. Hagle).
- 86-E-2 Role of Swiss needlecast in negative fertilizer interaction on coastal soils low in phosphorus (W. Littke).
- F. Stem Diseases: Malformations, Witch's-Brooms, Dwarf Mistletoe, Etc.
- 62-F-4 Taxonomy, hosts, and distribution of Arceuthobium (F. Hawksworth, D. Wiens).
- 63-F-1 Spread and intensification of dwarf mistletoe in ponderosa and Jeffrey pines in California (R. Scharpf, J. Parmeter).
- 69-F-1 Effectiveness of dwarf mistletoe control following special DM-precommercial thinnings in ponderosa pine and Douglas-fir (K. Russell).
- 71-F-1 Growth impact, associated mortality, and spread and intensification of dwarf mistletoe in stands of Douglas-fir, and lodgepole pine (O. Dooling).
- 76-F-4 Inoculation studies to determine the host ranges of Arceuthobium campylopodium and A. occidentale in California (W. Mark, R. Scharpf, F. Hawksworth).
- 78-F-2 Control of dwarf mistletoe-caused losses in young true fir stands by thinning (R. Smith, R. Scharpf, D. Vogler).
- 78-F-3 Population dynamics of dwarf mistletoe on true firs in California (R. Scharpf, J. Parmeter).
- 78-F-4 The effect of dwarf mistletoe on mortality and volume loss in released true fir stands (R. Scharpf).

- 78-F-5 Reduction of dwarf mistletoe-caused mortality of Jeffrey pines by broom pruning (R. Smith, R. Scharpf).
- 79-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-4 Development of hemlock dwarf mistletoe following precommercial thinning of infected young stands in southeast Alaska (T. Shaw, P. Hennon).
- 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 pusillum 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-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).
- 86-F-1 Evaluation of ethephon as a control of dwarf mistletoes in high use recreation forests (T. Nicholls, F. Hawksworth, D. Johnson).
- G. Stem Diseases: Stains and Decays
- 79-G-5 Decays and cavity nesting birds in the Pacific Northwest (A. Partridge, E. Bull).
- 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-4 Sexuality, genetics, and biology of Echinodontium tinctorium (J. Rogers, D. Wilson, O. C. Maloy).
- 85-G-5 Effects of thinning on tree wound response in western conifers attacked by insects (G. Filip).
- 86-G-1 Interactions of pine bark beetles, their fungus associates, and their hosts (D. Wood, J. Parmeter).
- 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).
- 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-3 Guidelines for management of western white pine in the Northern Region (S. Hagle, G. McDonald, G. Norby).

- 82-H-4 Western gull 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-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-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).
- 86-H-1 Blister rust incidence and impact in young sugar pine plantations, central Sierra Nevada (G. DeNitto).
- 86-H-2 Biological and economical feasibility of pruning and canker excision to control white pine blister rust (S. Hagle).
- 86-H-3 Evaluating performance of blister-rust resistant white pine stock in the coast range of Oregon (A. Kanaskie).
- I. Wilt and Blight Diseases
- 71-I-1 Dutch elm disease detection surveys in all municipalities in Colorado (J. Laut, M. Schomaker).
- 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 sources of Juniperus virginiana 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 microflora 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 incidence 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-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-2 Tree diseases and their effects in recreational areas (E. Sharon).
- 83-K-4 Mistletoe and root disease control demonstration areas (J. Muir).
- 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 decomposition by Basidiomycetes (R. Blanchette).
- 85-K-7 Survey of condition and vigor of Rocky Mountain aspen sprout 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).
- 86-K-1 Biocontrol of forest weeds (C. Dorworth).
- 86-K-2 Field guide to forest pests in Montana and Idaho (S. Hagle, S. Tunnock).
- 86-K-2 Development of tree health mgmt. series (THMS) for recreational and urban and community forestry-multivolume slide/video tape (M. Sharon).